Chapter- III

Spatio-temporal Variability of Hydrochemical and Geochemical Parameters of Surface and Sub-surface Water

3.1 Introduction:

The hydrochemical properties of water play a significant role to determine the usage for different purposes (Srivastava & Ramanathan, 2008) and they vary spatially and temporally. Hydrochemical parameters have individual characteristics which are associated with each other. Hence, to understand the general characteristics of surface and sub-surface water quality, various water samples were collected from the entire study area and physicochemical characteristics were measured using standard procedures (BIS). In the present study, five parameters such as pH, total dissolved solids (TDS), calcium (Ca), sodium (Na) and fluoride (F) were taken into consideration for the period of pre-monsoon and monsoon (2016 and 2017) and post-monsoon (2015 and 2016). Spatio-temporal variability of hydrochemical properties and water quality of surface as well as sub-surface water were investigated with the help of these parameters.

3.2 General Characteristics of Water:

3.2.1 Post-monsoon, 2015 (Surface Water)

3.2.1.1 pH Level:

During post-monsoon, the surface water was seen to be between normal to alkaline conditions. The pH value of surface water varied between 6.0 to 10.0 with the mean value being 6.98 and a low standard deviation of 0.6 denoting less spatial variability. Skewness and kurtosis indicated low positive values of +1.27 and +3.18 respectively (Fig. 3.1a & Table 3.5).

Jambusar Taluka, Bharuch District

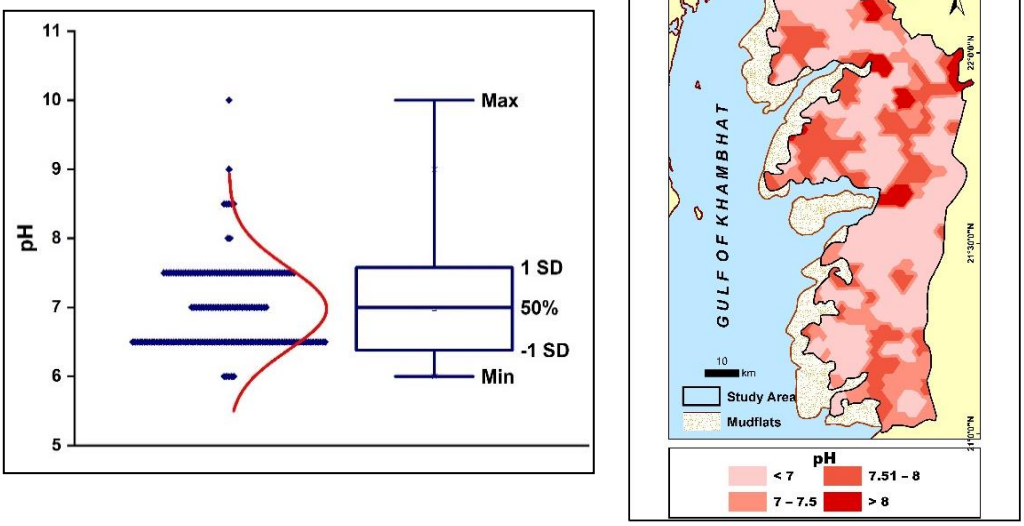


Fig.3.1 (a) Descriptive Statistics *(b) Spatial Distribution*

The average pH level was under the desirable limit (BIS) and only 1.09% of samples exceeded the permissible limit. However, 47.25% of samples spreading over 51.61% of the area had <7 pH (Table 3.1). It was observed over the entire study area but was more pronounced in the southern segment. 7 to 7.5 pH range stretched over 47.08% area covering 48.35% of samples. They were found as isolated patches near Jambusar town, Dahej industrial belt and towards southern bottom. Only 8 samples had>7.51 pH which was found in approximately 55 sq. km of area. This was noticed as patches in the northern part (Fig. 3.1b).

Table 3.1 pH during Post-monsoon Season, 2015 (Surface Water)

Range	**Samples**		**Area**	
	No	**(%)**	**sq. km**	**(%)**
<7	86	47.25	2580.15	51.61
7-7.5	88	48.35	1552.98	47.08
7.51-8	1	1.21	19.25	0.46
>8	7	4.4	35.43	0.86
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.1.2. Total Dissolve Solids (TDS):

During post-monsoon, the minimum and maximum TDS value was 120 mg/l and 10500 mg/l with a considerably higher mean (1114.59 mg/l). Standard deviation and skewness values were 1793.32 and +3.45 respectively (Fig. 3.2a). The kurtosis value

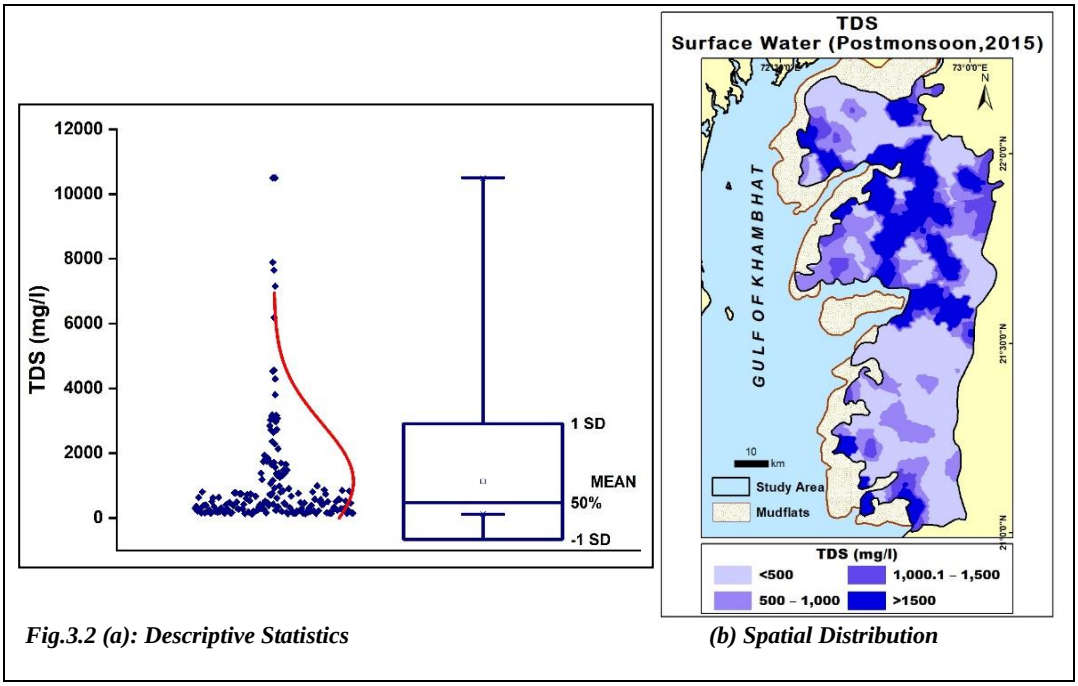


Fig.3.2 (a): Descriptive Statistics *(b) Spatial Distribution*

(+13.42) was also high and positive, indicating the leptokurtic data distribution (Table 3.5).

44.04% of the area with 52.75% of samples had TDS of <500 mg/l. It was observed at Hansot, Olpad, Kamrej talukas in Surat district and the northern part of Jambusar taluka in Bharuch District (Fig. 3.2b). 500 to 1000 mg/l range had 20.88% samples that covered 21.98% of the area. This range was broadly found in the western part of Amod and Vagra talukas. Only 6.59% of samples had 1000.1 to 1500 mg/l and acquired 11.90% of the area. This was largely witnessed in a few pockets in the central part of the study region. >1500 mg/l TDS was noted in 19.78% of samples and it extended over 22.08% of the area. This range was observed in the eastern part of Vagra and the western part of Amod taluka in the Bharuch

Amod Taluka, Bharuch District

district (Table 3.2).

Table 3.2 TDS during Post-monsoon Season, 2015 (Surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	96	52.75	1844.52	44.04
500-1000	38	20.88	920.54	21.98
1000.1-1500	12	6.59	498.38	11.9
>1500	36	19.78	924.71	22.08
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.1.3. Calcium (Ca):

Calcium in the study area was between 2.2 to 166 mg/l. Table 3.5 shows that the average value was 33.79 mg/l and the standard deviation was 21.17 denoting a moderate deviation from the average (Fig. 3.3a). Skewness (+2.14) and kurtosis (+8.94) were positive during this post-monsoon period.

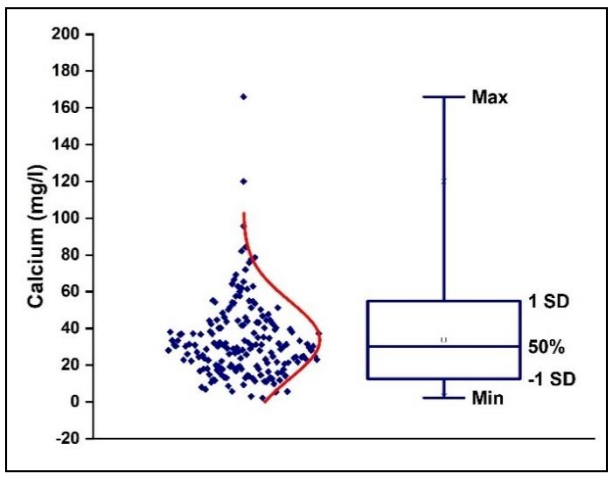
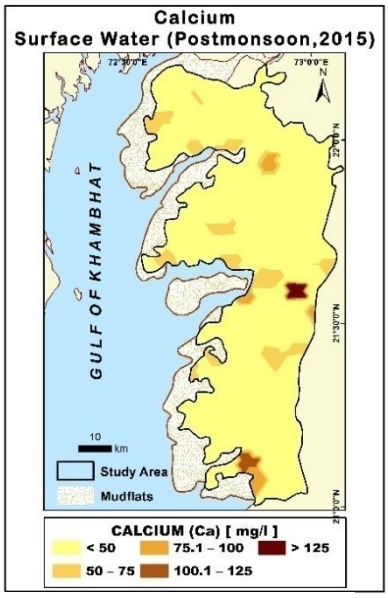


Fig.3.3 (a)Descriptive Statistics



(b) Spatial Distribution

Out of the total 182 calcium samples, 7 samples were above the permissible limit of 75 mg/l. The remaining 95.61% of samples were under the desirable limit set by BIS. The higher

calcium was observed in the central part of the study region in a small pocket (Fig. 3.3b and Table 3.3).

Table 3.3 Calcium (Ca) during Post-monsoon Season, 2015 (Surface Water)

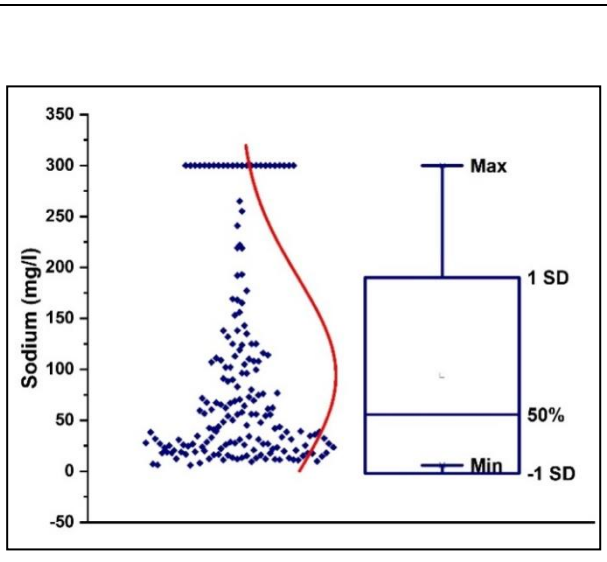
Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	154	84.62	4093.18	86.74
50-75	20	10.99	84.52	10.02
75.1-100	6	3.3	10.11	3.24
100.1-125	1	0.55	0	0
>125	1	0.55	0	0
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.1.4. Sodium (Na):

The concentration of sodium (Na) ranged between 5.9 to 300 mg/l with a mean value of 94.06 mg/l and a standard deviation of 96.17 indicating lower variability in the space which is represented in Fig. 3.4a. Kurtosis of +0.20 depicted a considerably normal distribution whereas skewness was +1.25 (Table 3.5).

During the post-monsoon season, 66.98% area with the approximately same percentage of samples had <100 mg/l of sodium. They were spread over the entire study



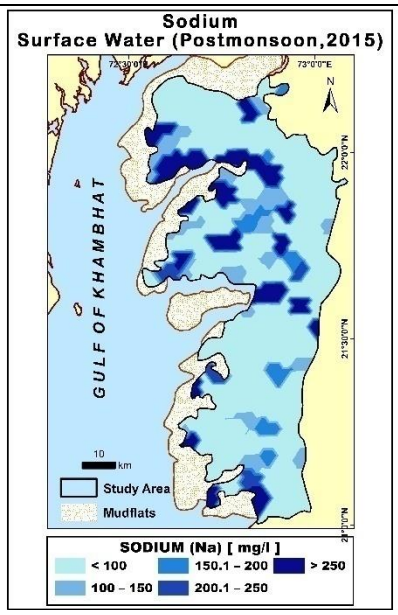


Fig.3.4 *(a)Descriptive Statistics* *(b) Spatial Distribution*

region except for a few pockets (Fig. 3.4b). 12.45% area, as well as samples, had sodium concentrations of 100 to 150 mg/l. Higher sodium concentration (>250 mg/l) had 27 samples and was observed along the seacoast. The remaining ranges of 150.1 to 200 mg/l and 200.1 to 250 mg/l both had 4.40% and 2.20% of samples respectively (Table 3.4).

Table 3.4 Sodium (Na) during Post-monsoon Season, 2015 (Surface Water)

Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	120	65.93	2805.14	66.98
100-150	23	12.64	521.24	12.45
150.1-200	8	4.4	272.25	6.5
200.1-250	4	2.2	176.18	4.21
>250	27	14.84	413.34	9.87
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

Table 3.5 Descriptive Statistics of the Surface Water Samples (Post-monsoon Season, 2015)

Parameters in mg/l, except pH	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
pH	6.00	10.00	6.92	0.60	1.27	3.18
TDS	120.0	10500.0	1114.59	1793.32	3.45	13.42
Calcium (Ca)	2.2	166.0	33.79	21.17	2.14	8.94
Sodium (Na)	5.9	300.0	94.06	96.17	1.25	.20

Source- Computed

3.2.2 Post-monsoon, 2015 (Sub-surface Water)

3.2.2.1 pH Level:

The pH level in sub-surface water ranged from 6.0 to 8.50; with an average of 7.08 indicating considerably natural condition. The standard deviation was 0.48 (Table 3.10). Both skewness and kurtosis recorded low negative values at -0.02 and -1.01 respectively (Fig. 3.5a).

Amod Taluka, Bharuch District

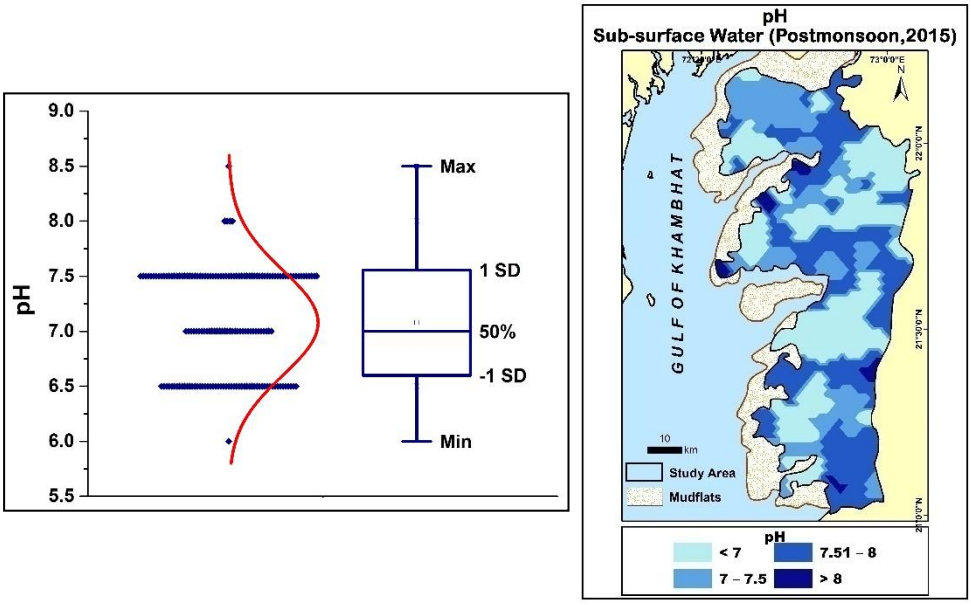


Fig.3.5 *(a)Descriptive Statistics* *(b) Spatial Distribution*

In the post-monsoon season, the pH value was within the desirable limit (6.5 to 8.5) but spatial analysis variations were observed within this range. <7 pH was observed in 33.13% samples covering 33.39% area (Table 3.6). This range of pH value was spread over the entire study area. 20.86% samples covering 28.23% area was noted in the range of 7 to 7.5 pH category. They were more prominent at northern part of Jambusar and Olpad talukas. 7.51 to 8 of pH value was noted in 42.94% samples which stretched over an area of 36.39% which was in the form of continuous patches at northern, central and southern segments. pH of >8 was noted in 1.99% area had 3.07% samples and depicted the alkaline nature which was observed in the villages of Vaiipore, Ambhel (Vagra taluka) and Dahej industrial belt (Fig. 3.5b).

Table 3.6 pH during Post-monsoon Season, 2015 (Sub-surface Water)

Range	**Samples**		**Area**	
	No	**(%)**	**sq. km**	**(%)**
<7	54	33.13	1398.36	33.39
7-7.5	34	20.86	1182.28	28.23
7.51-8	70	42.94	1523.91	36.39
>8	5	3.07	83.52	1.99
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.2.2 Total Dissolved Solids (TDS):

TDS ranged between 50 mg/l and 8490 mg/l with an average value of 1353.53 mg/l and a deviation from the mean being 1224.78 (Table 3.10). The skewness value (+2.54) indicated that TDS in the study area was asymmetric and the kurtosis value of +9.42 denoted the leptokurtic condition (Fig. 3.6a).

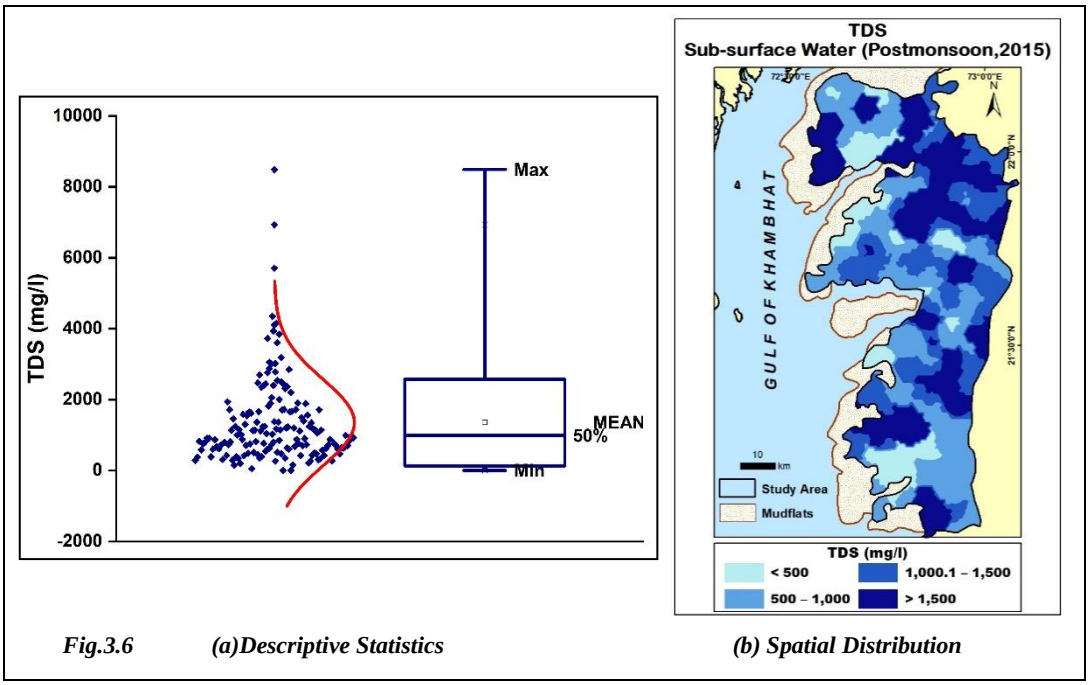


Fig.3.6 *(a)Descriptive Statistics* *(b) Spatial Distribution*

TDS <500 mg/l in the sub-surface water spread over 19.92% area with 20.25% of samples. This level was noted at Vilayat, Bhersam villages of Bharuch taluka and Digas and Mangrol villages of Ankleshwar taluka. 30.06% of samples spreading over 31.53% of the area had 500 to 1000 mg/l of TDS. They were found as a continuous patch over entire the study area except for in a few patches (Fig. 3.6b). A higher range of TDS (1000.1 mg/l to 1500 mg/l) was noted in the 17.33% area with 19.02% of samples. It was mainly concentrated in the north-eastern part of Amod taluka. Isolated patches were found in Ankleshwar and Hansot talukas. TDS of >1500 mg/l was noted in 30.67% of samples which were spread over a 31.23% area. This range was found in the form of isolated pockets in the northwestern part of Jambusar taluka, Amod taluka, the central part of Olpad taluka and the southern part of Pardi Kanade. Other pockets were observed in the Ankleshwar taluka (Table 3.7).

Table 3.7 TDS during Post-monsoon Season, 2015 (Sub-surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	33	20.25	474.53	19.92
500-1000	49	30.06	1320.36	31.53
1000.1-1500	31	19.02	1085.43	17.33
>1500	50	30.67	1307.76	31.23
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.2.3 Calcium (Ca):

In this region, calcium concentration varied between 9.80 mg/l and 220 mg/l. Mean value of calcium was 49.45 mg/l and standard deviation was 32.82 showing a moderate deviation. Skewness (+2.52) and kurtosis (+8.91), both recorded positive values during this post monsoon season (Fig. 3.7a and Table 3.10).

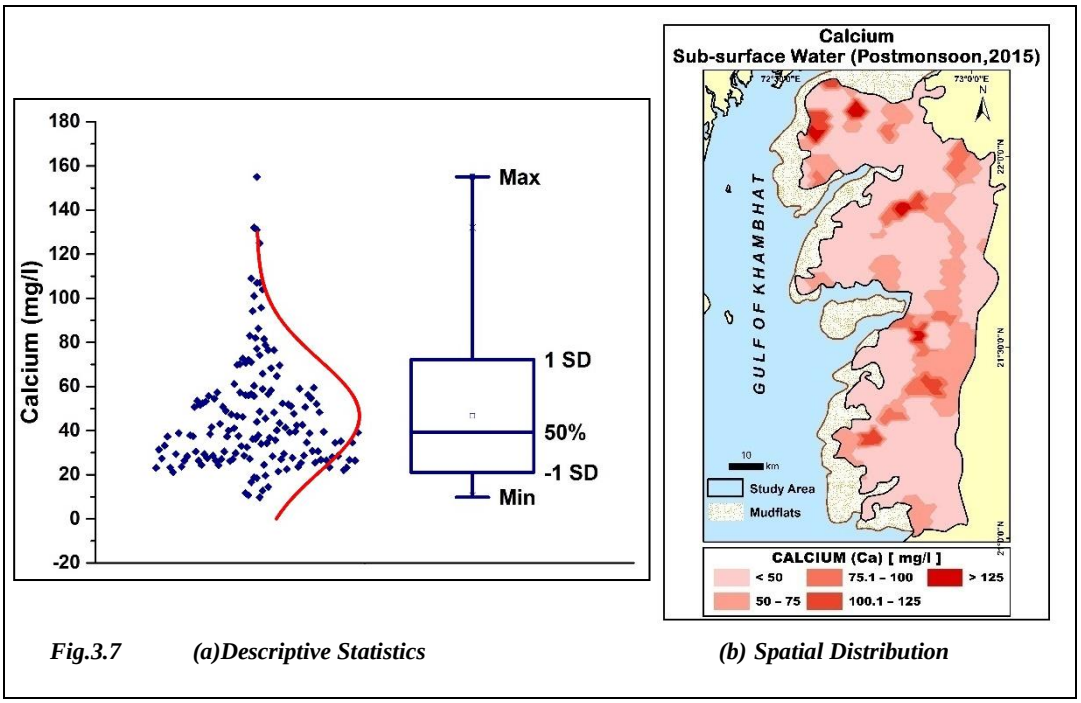


Fig.3.7 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Low calcium content of <50 mg/l was observed in 64.42% samples and covered 63.85% area. 50 to 75 mg/l range of calcium was noted in 24.25% area and 23.93% samples. Both these ranges were under the desirable limit set by BIS (75 mg/l). However, this range was observed in entire the study area (Fig. 3.7b). 6.13% samples spreading over

5.86% area had 75.1 to 100 mg/l calcium concentration. This range was noted near the industrial belt such as Jambusar, Vagra, Palej, Panoli and Olpad. Further, 100.1 to 125 mg/l was noticed in 3.68% of samples covering 3.23% area. It was observed in small patches at Malpore, Bhadkodra, Mosam and Ryma (Bharuch district) and Ambeta, Kareli villages (Surat district). High concentration of calcium (>125 mg/l) in sub-surface water was noted in 2.81% of area and 1.84% of samples (Table 3.8).

Table 3.8 Calcium (Ca) during Post-monsoon Season, 2015 (Sub-Surface Water)

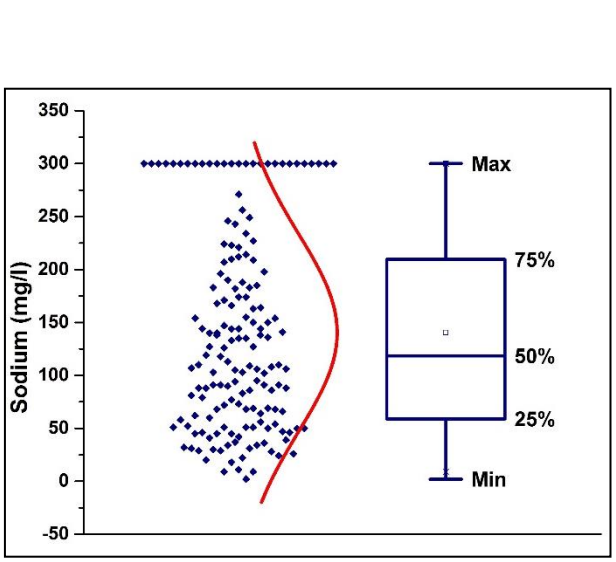
Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	105	64.42	3052.56	63.85
50-75	39	23.93	1051.97	24.25
75.1-100	10	6.13	74.64	5.86
100.1-125	6	3.68	8.33	3.23
>125	3	1.84	0.64	2.81
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

3.2.2.4 Sodium (Na):

Sodium (Na) absorption ranged between 2.0 to 300 mg/l with mean value of 141.19 mg/l and standard deviation of 94.09 denoting moderate variability in the distribution (Fig. 3.8a). Kurtosis value was lower positive (+0.51) and skewness was negative (-1.02) (Table 10).

During the post monsoon season, 41.97% of area had <100 mg/l with 42.94% of samples. It was largely observed over the entire region but was more noticeable towards the northern part. Approximately 14.11% samples covering 22.32% of area had 100 to 150 mg/l of sodium content in sub-surface water. Of the remaining, (150.1 to 200 mg/l and 200.1 to 250 mg/l) ranges, 12.27% and 12.88% samples spread over 12.09% and 10.25% area respectively was noted. >250 mg/l concentration was found in 17.79% samples and it was spread over approximately 14% area (Fig. 3.8b). This concentration level was more prominent in the northern-eastern part, on the north of the Surat city (Table 3.9).



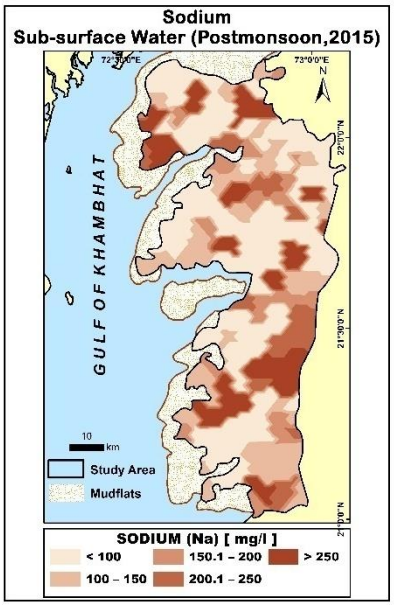


Fig.3.8 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.9 Sodium (Na) during Post-monsoon Season, 2015 (Sub-surface Water)

Range		**Samples**	**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	70	42.94	1758.12	41.98
100-150	23	14.11	934.95	22.32
150.1-200	20	12.27	506.48	12.09
200.1-250	21	12.88	429.48	10.25
>250	29	17.79	559.04	13.35
Total	**182**	**100**	**4188.15**	**100**

Source- Computed

Table 3.10. Descriptive Statistics of the Sub-surface Water Samples (Post-monsoon Season, 2015)

Parameters in mg/l, except pH	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Skewness**	**Kurtosis**
pH	6.00	8.50	7.08	.48	-.02	-1.01
TDS	50.0	8490.0	1353.53	1224.78	2.54	9.42
Calcium (Ca)	9.8	220.0	49.45	32.82	2.52	8.91
Sodium (Na)	2.0	300.0	141.19	94.09	-1.02	.51

Source- Computed

3.2.3 Pre-monsoon, 2016 (Surface Water)

3.2.3.1 pH Level:

In the study area, the level of pH varied between 6.38 to 9.94. The level ranged from slightly acidic to alkaline natures. The mean denoted a slightly alkaline condition (7.65) with low spatial variability of concentration (0.60) (Table 3.16). Skewness and kurtosis depicted low and positive values of (+1.04) and (+1.74) respectively (Fig. 3.9a).

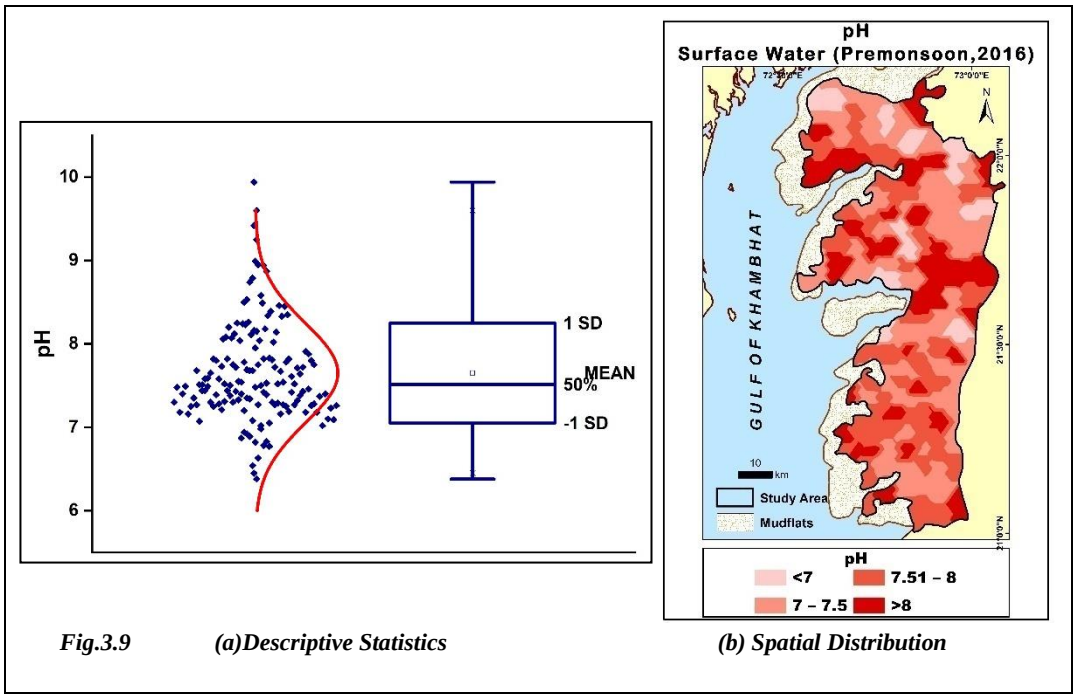


Fig.3.9 *(a)Descriptive Statistics* *(b) Spatial Distribution*

91% of the samples above 7 pH value was observed in the pre-monsoon season. Only 13 samples which spread over 333.30 sq. km in isolated pockets had <7 pH and were more pronounced in the northern half of the region (Fig. 3.9b). pH concentration of 7 to 7.5 was observed in 36.73% area and 40.13% samples. The range category 7.51 to 8 was spread over 32.80% area and 26.97% samples. This was noted in the north-western part covering Vagra, Palej industrial area, central and southern parts in isolated patches (Table 3.11). pH of >7.51 was observed in small patches which were more pronounced in the north-western and central parts covering Jambusar and Ankleshwar talukas and Bharuch industrial area. pH value within the desirable limit (6.5 to 8.5) was noted in 92% area and in the remaining 8% area it crossed the desirable limits.

Table 3.11 pH during Pre-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
	No	**(%)**	**sq. km**	**(%)**
<7	13	8.55	333.295	7.96
7-7.5	61	40.13	1538.45	36.73
7.51-8	41	26.97	1373.63	32.8
>8	37	24.34	942.71	22.51
Total	**152**	**100**	**4188.15**	**100**

Source- Computed

3.2.3.2 Total Dissolved Solids (TDS):

The concentration of TDS ranged from 100 to 12500 mg/l (Table 3.16). The mean concentration was 1386.74 mg/l and the standard deviation was 2324.04 indicating slight variation. Skewness and kurtosis showed high and positive values (+2.96) and (+09) respectively (Fig. 3.10a).

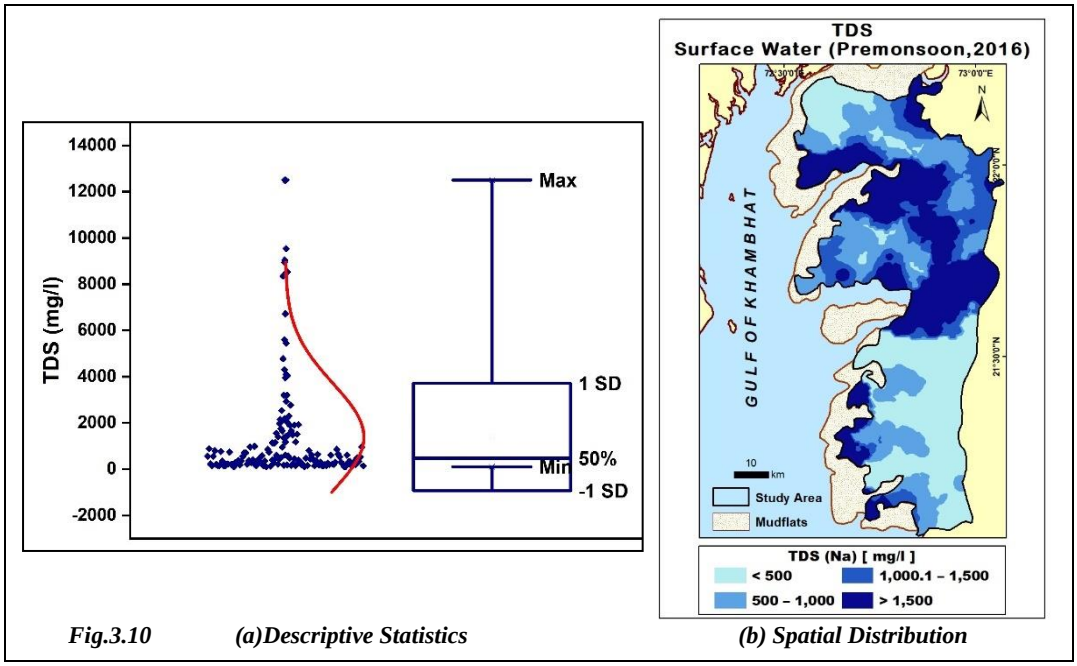


Fig.3.10 *(a)Descriptive Statistics* *(b) Spatial Distribution*

TDS in the surface water was <500 mg/l and was spread over 51.47% area and 51.32% samples (Table 3.12). This category range was found over the entire study region but it was more conspicuous towards southern part. 500-1000 mg/l of TDS was noted in approximately 18.42% of samples covering 841.20 sq. km area. It was broadly observed in Vagra, Amod and Jambusar talukas. Few isolated patches were seen along the coastline in

the study area. Only 11 samples had TDS concentrations between 1000.1 to 1500 mg/l range. It was spread over 5.14% of the total area which was mainly localized in the eastern part of Bharuch taluka and the southern part of Amod taluka, Bharuch district. Concentration of >1500 mg/l was observed in 23.03% of samples which stretched over 23.30% of the total area (Fig. 3.10b).

Table 3.12 TDS during Pre-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	78	51.32	2155.47	51.47
500-1000	28	18.42	841.2	20.09
1000.1-1500	11	7.24	215.31	5.14
>1500	35	23.03	975.98	23.3
Total	**152**	**100**	**4188.15**	**100**

Source- Computed

3.2.3.3 Calcium (Ca):

The concentration of calcium varied between BDL to 250 mg/l (Table 3.16). The average and standard deviation values were 58.99 mg/l and 54.84 respectively denoting little variation in the space. Skewness and kurtosis values had shown considerably moderate positive values of +2.25 and +5.24 respectively (Fig. 3.11a).

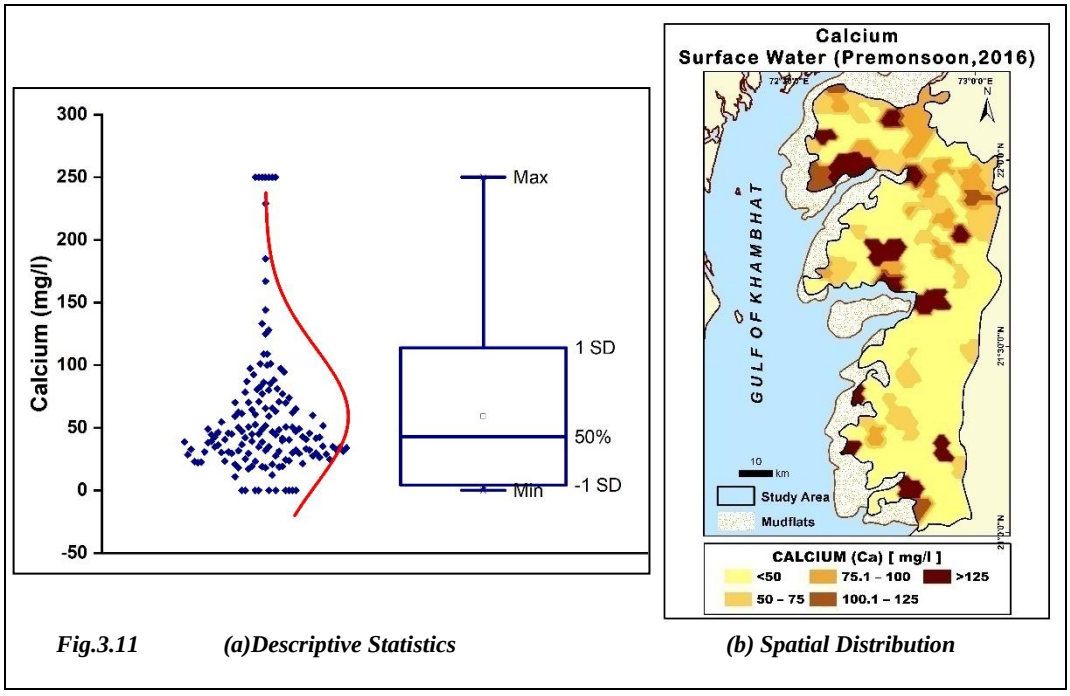


Fig.3.11 *(a)Descriptive Statistics* *(b) Spatial Distribution*

The concentration of calcium in 56.24% area which encompassed 57.75% samples had a content of <50 mg/l. It was observed in the southern half and north-western part of the region. 50 to 75 mg/l calcium content was found in 18.31% samples and stretched over 19.77% of the area (Table 3.13). This was noted in patches spread over north-eastern part and along the sea coast. In the next category, percentage of samples and area covered reduced. 75.1 to 100 mg/l was noted in 11.27% of samples as well as the area. They are also found in isolated patches in the northern half. The number of samples with 100.1 to 125 mg/l was only 3.52% and they were spread over 175 sq. km. area. >125 mg/l was noted in 9% samples and extended over 8.48% area (Fig. 3.11b).

Table 3.13 Calcium (Ca) during Pre-monsoon Season, 2016 (Surface Water)

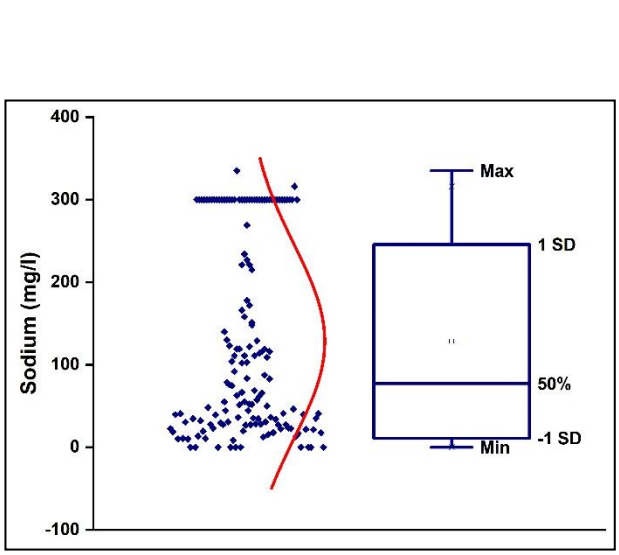
Range		**Samples**	**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	82	57.75	2355.47	56.24
50-75	26	18.31	828.04	19.77
75.1-100	16	11.27	474.11	11.32
100.1-125	5	3.52	175.25	4.18
>125	13	9.15	355.29	8.48
Total	**142**	**100**	**4188.15**	**100**

Source- Computed

3.2.3.4 Sodium (Na):

In the study area, the mean sodium in the surface water was 128.29 mg/l and the deviation from the mean was 117.39 (Table 3.16). The concentration of sodium content varied between BDL to 335 mg/l. Skewness and kurtosis was (-1.37) and (+0.58) respectively (Fig. 3.12a).

In the pre-monsoon season, the maximum concentration of sodium was of <100 mg/l and was observed in 50% samples covering 46.48% area. This range was largely observed in the southern half and in fragmented patches towards north. 100-150 mg/l was witnessed in 13.38% samples stretched over 14.60% area. This category was found over the entire region in scattered form. 150 to 200 mg/l and 200.1 to 250 mg/l had same percentage of area and samples.



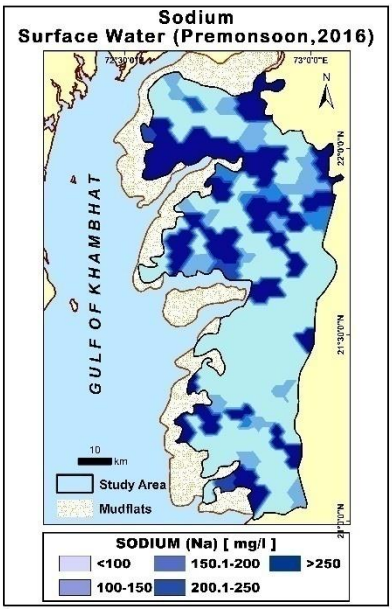


Fig.3.12 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.14 Sodium (Na) during Pre-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	71	50	1946.61	46.48
100-150	19	13.38	611.5	14.6
150.1-200	5	3.52	318.39	7.6
200.1-250	5	3.52	301.28	7.19
>250	42	29.58	1010.36	24.12
Total	**142**	**100**	**4188.15**	**100**

Source- Computed

>250 mg/l was witnessed in 30% of samples and extended over 24.2% of area (Table 3.14). It was more pronounced in the north-western part and in few isolated pockets over the entire region (Fig. 3.12b).

3.2.3.5 Fluoride (F):

Fluoride (F) ranged between 0.01 to 1.51 mg/l with a mean value of 0.18 mg/l and standard deviation of 0.17 denoting low variability in the distribution (Table 3.16). Kurtosis value was high positive (+27.94) and skewness was found positive (+4.16) (Fig. 3.13a).

During the pre-monsoon season, 60.75% of area had <0.20 mg/l with 57.75% of samples. It was largely observed over the entire region but was more noticeable towards the northern part (Fig. 3.13b). Approximately 18.31% samples covering 19.31% of area had 0.20 to 0.40 mg/l of fluoride content in surface water. In the next category, 0.41 to 0.60 mg/l concentration range had 11.27% of samples spread over 9.54% area. This belt was observed in Vagra, Amod and Olpad talukas. 0.61 to 0.80 mg/l of fluoride concentration was noted in

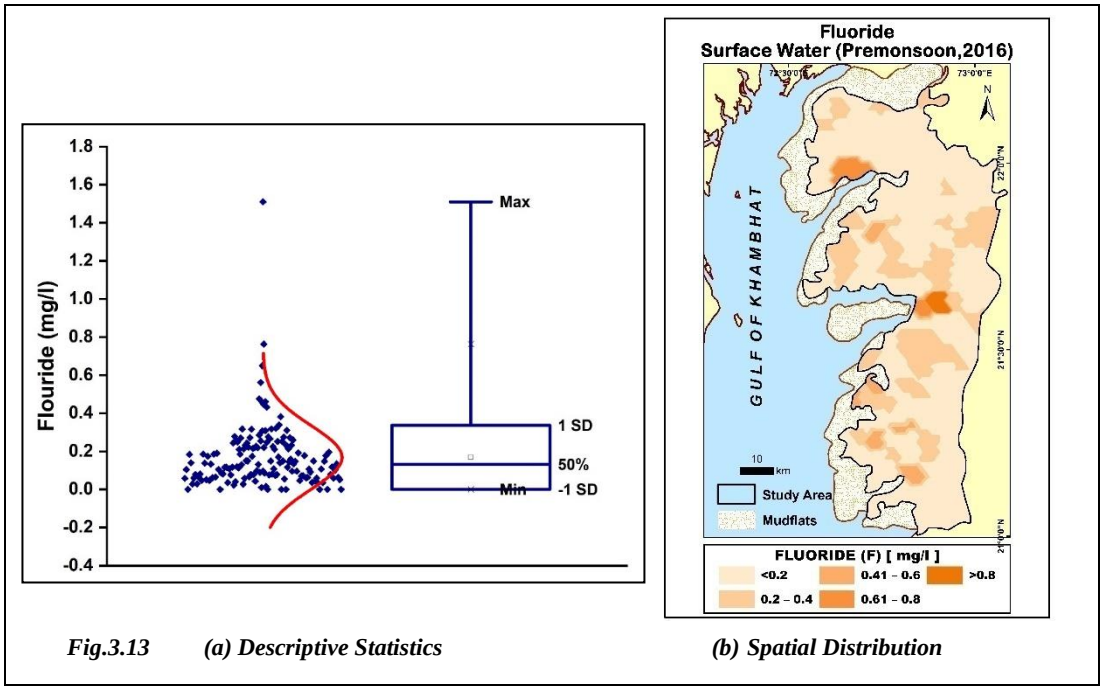


Fig.3.13 ***(a) Descriptive Statistics*** ***(b) Spatial Distribution***

3.52% samples which covered 2.64% of the total area. >0.80 mg/l concentration was found in 9.15% of samples and it was spread over approximately 8% area. This concentration level was found in patches at Hansot industrial zone (Table 3.15).

Table 3.15 Fluoride (F) during Pre-monsoon Season, 2016 (Surface Water)

Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	82	57.75	2950	60.75
0.20-0.40	26	18.31	1019	19.31
0.41-0.60	16	11.27	116	9.54
0.61-0.80	5	3.52	75	2.64
>0.80	13	9.15	28	7.76
Total	**142**	**100**	**4188.15**	**100**

Source- Computed

Table 3.16 Descriptive Statistics of the Surface Water Samples (Pre-monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.38	9.94	7.65	.60	1.04	1.74
TDS	100.0	12500.0	1386.74	2324.04	2.96	9.00
Calcium (Ca)	BDL	250.0	58.99	54.84	2.25	5.24
Sodium (Na)	BDL	335.0	128.29	117.39	.58	-1.37
Fluoride (F)	.01	1.51	.18	.17	4.16	27.94

Source- Computed

3.2.4 Pre-monsoon, 2016 (Sub-surface Water)

3.2.4.1 pH Level:

The mean value of the distribution of the data set was 7.53 which was within the BIS standard. The variation of the data set was low while the standard value was 0.34. The skewness was also near to the normal value of 0 (-0.10), depicting a neutral case (Table 3.22). The kurtosis curve also depicted a fair distribution of pH over space (Fig. 3.14a).

pH value in the study area varied between 6.11 and 8.49, but in most of the samples (>80%), this value was between 7.5 and 8 (Table 3.17). The highest pH value was 8.49 and it was centred in the southern part of the study area. This location was near Surat city. Only 3.87% of samples had a pH value of <7 and 10.97% had >8. The BIS standard for pH varied from 6.5 to 8.5. Hence, it can be said that in most of the samples the pH values were within the range.

The spatial distribution of pH depicted that in 0.27% of the area the pH value was <7 while in 40.63% area it ranged between 7 and 7.5. A continuous patch was noted in the northern segment, while in the east of the study area it was in patches. In totality, it covered 5.16% of samples. A large area of the study region had pH values varying between 7.51 and 8, which was 59% of the total area. This pH value was noted in the entire region and was only broken by segments with a value between 7 and 7.5 (Fig. 3.14b).

Vagra Taluka, Bharuch District

Table 3.17 pH during Pre-monsoon Season, 2016 (Sub-surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<7	6	3.87	11.5	0.27
7-7.5	72	46.45	1701.67	40.63
7.51-8	61	39.35	2470.82	59
>8	16	10.97	4.15	0.1
Total	**155**	**100**	**4188.15**	**100**

Source- Computed

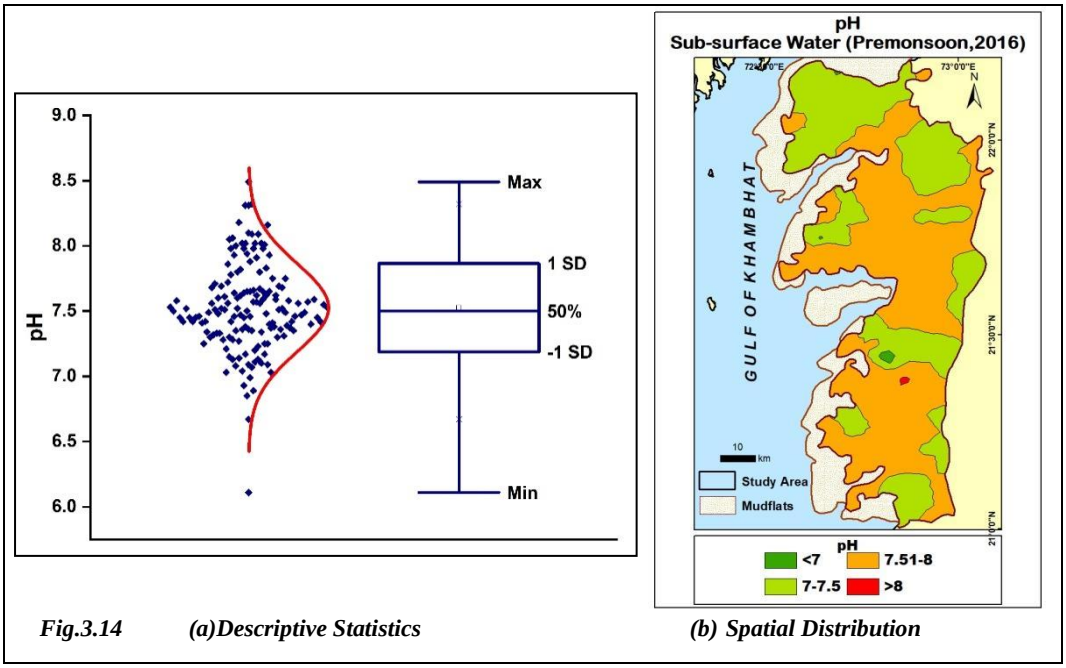


Fig.3.14 *(a)Descriptive Statistics* *(b) Spatial Distribution*

3.2.4.2 Total Dissolved Solids (TDS):

In this distribution, the mean value of the data was 1344.42 mg/l with a standard deviation value of 1451.32 (Fig. 3.15a). The skewness and kurtosis values of the curves were 3.29 and 14.01 respectively (Table 3.22).

In the present study, TDS varied from 100 mg/l to 9555 mg/l. 20.56% of samples had (<500 mg/l) which covered 21.94% of the total area and were observed in the areas adjoining Tapi river and Surat City (Fig. 3.15b). 36.42% area had 500 mg/l to 1000 mg/l. TDS values in this range were noted in 34.19% of samples. This belt was observed over the entire study area. 18.06% samples had TDS concentration between 1000.1 mg/l to 1500 mg/l.

It covered 18.57% area, mostly as patches in Amod, Bharuch and Ankleshwar talukas (Bharuch district). A higher concentration (>1500 mg/l) was seen in the southwestern part of Jambusar and the western part of Amod taluka in Bharuch district. Isolated patches were observed in the Olpad and Surat talukas in Surat district. It covered 24.45% of the area (Table 3.18).

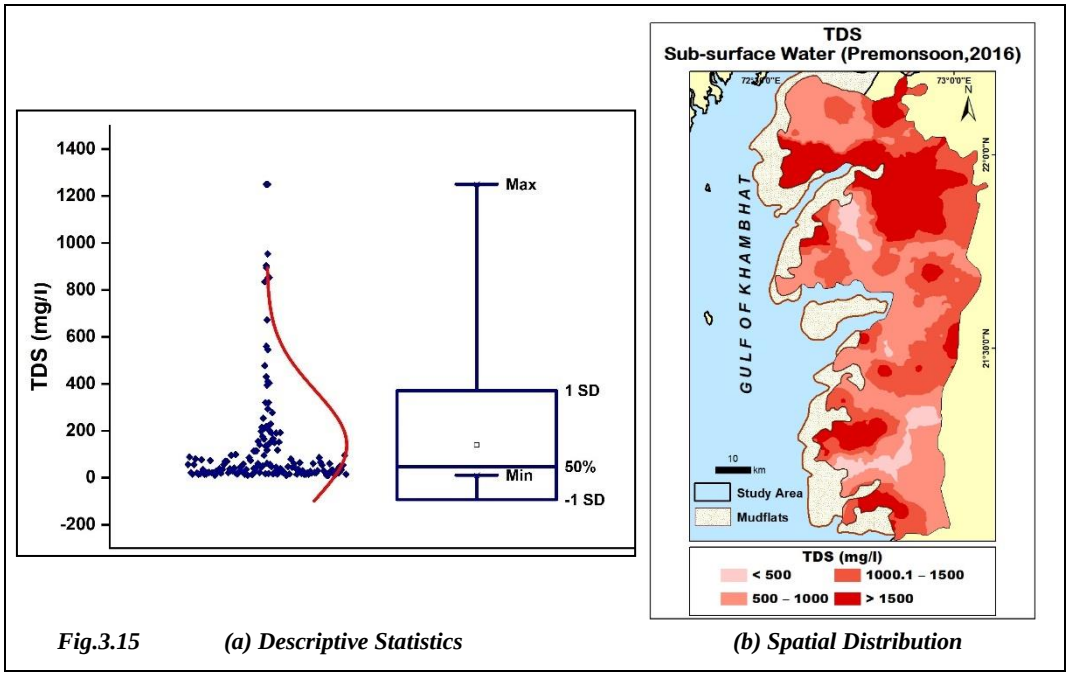


Fig.3.15 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.18 TDS during Pre-monsoon Season, 2016 (Sub-surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	34	21.94	861.08	20.56
500-1000	53	34.19	1525.32	36.42
1000.1-1500	28	18.06	777.74	18.57
>1500	40	25.81	1024	24.45
Total	**155**	**100**	**4188.15**	**100**

Source- Computed

3.2.4.3 Calcium (Ca):

In the study area, the mean of calcium in sub-surface water was 68.45 mg/l. The variation of the data was high with a standard deviation value of 44.37. This distribution had

a positive skewness value of 2.41 (Table 3.22). The kurtosis value of this distribution was 7.38 (Fig. 3.16a).

Calcium is an important required element that is commonly present in water. According to BIS standard, the permissible value of calcium in water is 75 mg/l and the acceptable range is 200 mg/l. In the study region, the calcium concentration varied from 19.1 mg/l to 250 mg/l. A small number (1.29%) of samples had calcium concentrations above the BIS standard. <50 mg/l of calcium concentration was found in 35.48% samples and it covered 15.09% of the area. It was mostly localized in the south-eastern part of the region. 50 mg/l to 75 mg/l of calcium concentration was noted in 30.97% samples which covered 61.23% of the total area. This concentration was noted over the entire region. 75 mg/l to 100 mg/l calcium concentration was observed in 19.34% area and 18.06% samples. This range of calcium was more pronounced in the northern region (Fig. 3.16b). Calcium concentration from 100 mg/l to 125 mg/l was found in 10.32% samples and 2.35% of the area. Some small patches of higher concentration >125 mg/l were found in just 1.97% of the total area and 5.16% of total samples of the Bara tract (Table 3.19).

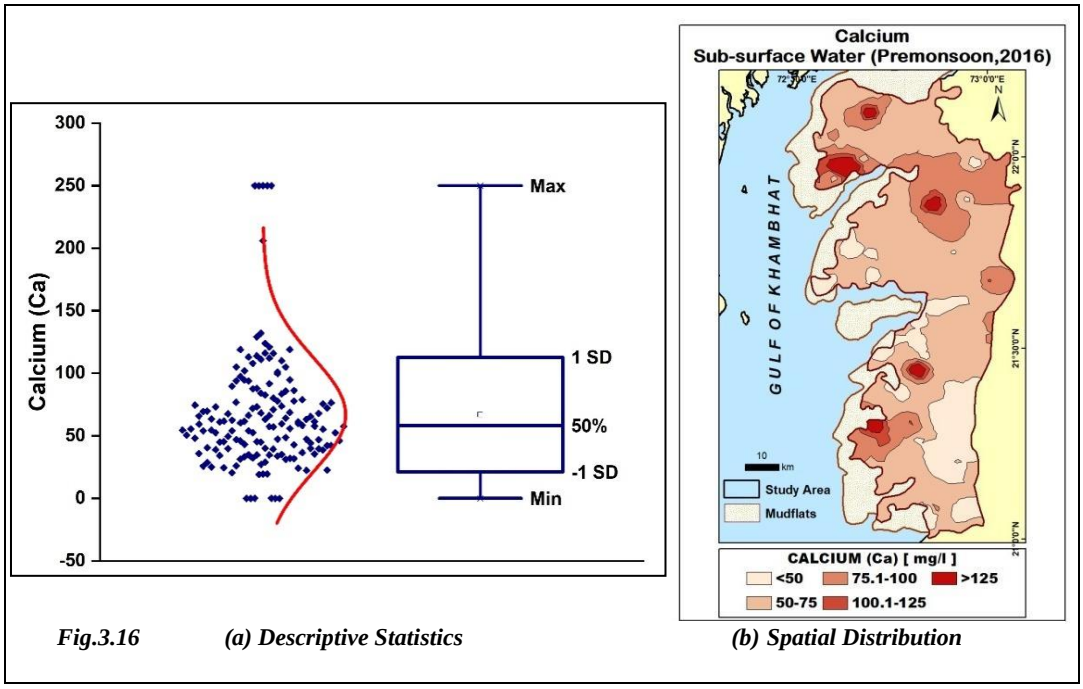


Fig.3.16 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.19 Calcium (Ca) during Pre-monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	61	35.48	1589.61	15.09
50-75	48	30.97	1434.15	61.23
75.1-100	22	18.06	651.66	19.34
100.1-125	16	10.32	349.55	2.35
>125	8	5.16	163.18	1.97
Total	**155**	**100**	**4188.15**	**100**

Source- Computed

3.2.4.4 Sodium (Na):

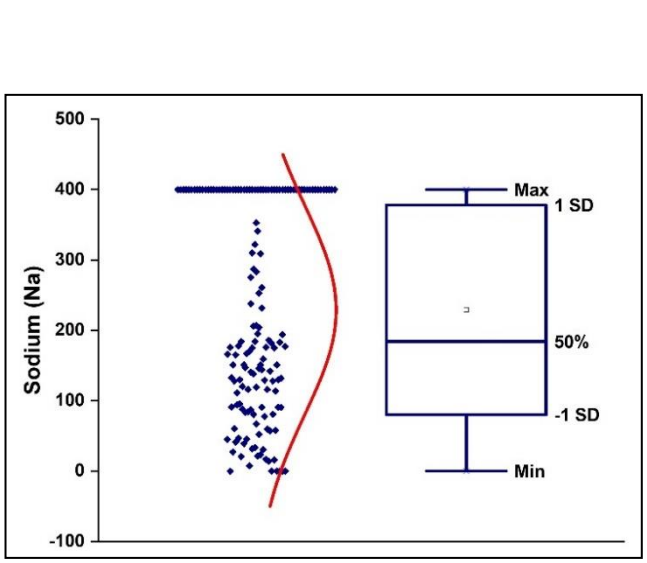
The mean value of sodium in sub-surface water was 229.31 mg/l. It was slightly higher than the WHO standard (200 mg/l). A very high standard deviation value (148.38) showed that the variation in the data was very high (Table 3.22). The skewness of the distribution was normal with a value of 0.02. The kurtosis value of the distribution was less than 3 (-1.62) so that the peak of the curve was flat (Fig. 3.17a).

The presence of sodium in water is because of the higher solubility of sodium in water. The concentration of sodium in this region was high. It ranged from 55 mg/l to 400 mg/l whereas the WHO standard value for sodium is 200 mg/l. 37.3% of sub-surface water samples were below this standard. The concentration of <100 mg/l was noted in 22.58% of samples but it covered only 1.67% of the total area. It was distributed as small patches throughout the region. 12.25% samples had sodium from 100 mg/l and 150 mg/l. It covered 9.48% of the total area and was also found in patches in the entire region except for the north-eastern part. 16.12% samples had a concentration between 150 mg/l and 200 mg/l (Table 3.20). It covered 26.3% area, mostly as patches. Slightly high sodium concentration (200 mg/l to 250 mg/l) was noticed in 4.51% of samples and was spread over 22.6% of the area. A very high concentration (>250 mg/l) was observed in 44.51% of samples which stretched over 39.87% of the total area. It was mainly concentrated in the northern part of the Bara tract (Fig. 3.17 b).

Table 3.20 Sodium (Na) during Pre-monsoon Season, 2016 (Sub-surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	40	22.58	881.49	1.67
100-150	19	12.25	662.86	9.48
150.1-200	22	16.12	538.91	12.87
200.1-250	5	4.51	298.64	22.6
>250	69	44.51	1806.25	39.87
Total	**155**	**100**	**4188.15**	**100**

Source- Computed



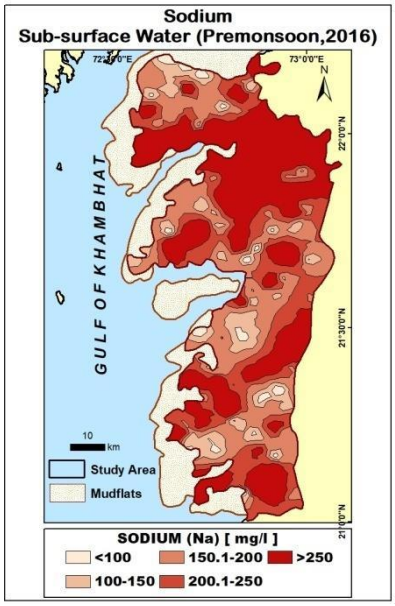


Fig.3.17 *(a)Descriptive Statistics* *(b) Spatial Distribution*

3.2.4.5 Fluoride (F):

The mean of the fluoride distribution was 0.18 mg/l. It was lower than the BIS range (1-1.5). The standard deviation value of the distribution was 0.16 showing that the range of the data was low. Skewness value (4.14) depicted positive skewness (Table 3.22). Kurtosis value (28.10) indicated the peakedness of the curve (Fig. 3.18a).

Fluoride concentration in the study area ranged from 0.2 mg/l to 1.51 mg/l. The BIS standard for fluoride was 1 mg/l to 1.5 mg/l. The fluoride concentration in all the sample sites was within the BIS standards. 63.23% samples had fluoride concentration of <0.20 mg/l. It

was spread over 73.46% of the total area, both in the northern and southern parts of the study area. 0.20 mg/l to 0.40 mg/l concentration was found in 30.23% samples which covered 25.70% of the total area. It was mainly localized in the central parts and in some segments south of the study area. 0.41 mg/l to 0.60 mg/l fluoride concentration covered 0.46% of the total area and 3.87% of the total samples (Table 3.21). 1.29% of samples had fluoride concentration between 0.61 mg/l and 0.80 mg/l with 0.21% area. 0.15% of total area and 1.29% samples had > 0.80 mg/l concentration (Fig. 3.18b).

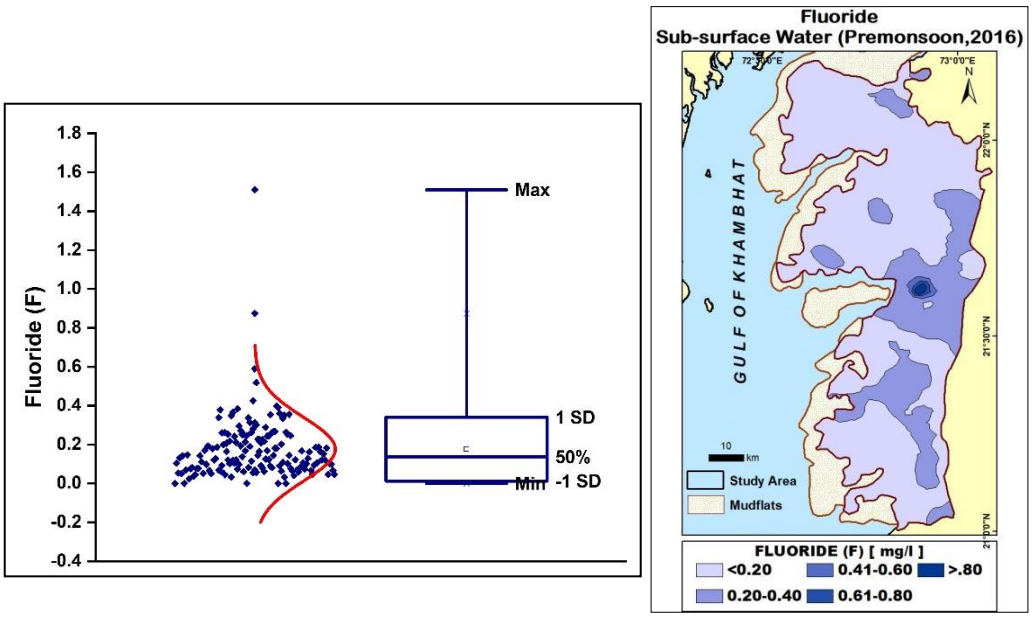


Fig.3.18 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.21 Fluoride (F) during Pre-monsoon Season, 2016 (Sub-surface Water)

Range		**Samples**	**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	98	63.23	2844.99	73.46
0.20-0.40	47	30.23	1224.16	25.7
0.41-0.60	2	3.87	66.34	0.46
0.61-0.80	3	1.29	15.48	0.21
>0.80	2	1.29	37.17	0.15
Total	**155**	**100**	**4188.15**	**100**

Source- Computed

Table 3.22 Descriptive Statistics of the Sub-surface Water Samples (Pre-monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.11	8.49	7.53	.34	-.10	1.67
TDS	100.0	9555.0	1344.42	1451.32	3.29	14.01
Calcium (Ca)	19.1	250.0	68.45	44.37	2.41	7.80
Sodium (Na)	55.0	400.0	229.31	148.38	.02	-1.64
Fluoride (F)	.20	1.51	.18	.16	4.14	28.10

Source- Computed

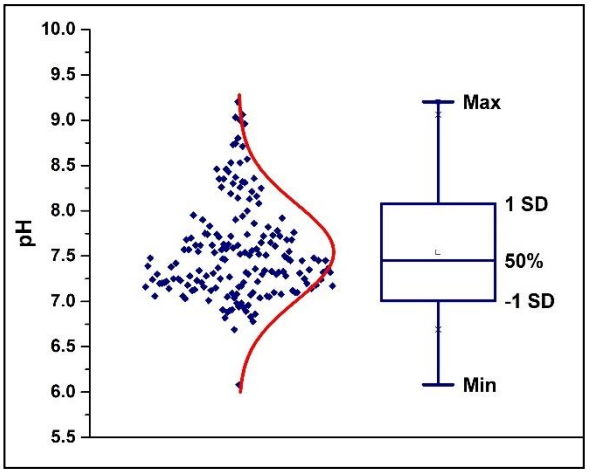
3.2.5 Monsoon, 2016 (Surface Water)

3.2.5.1 pH Level:

During monsoon 2016, pH values in the study area varied from 6.08 to 9.20, depicting a slightly acidic to alkaline nature (Table 3.28). The standard deviation was 0.53 and the mean value was 7.54 which indicated the neutral condition. Both skewness (+0.94) and kurtosis (+0.80) were low with positive values. Skewness denoted a moderate flatter distribution of data (Fig. 3.19a).

pH of >8 was noted in 614 sq. km area and in 17.51% of samples depicting the alkaline nature (Table 3.23). It was observed in the north of the Narmada River and was more prominent in the industrial belt. On the other hand, the basic nature of surface water (<7.5) was found in the southern segment of the region. 48 samples had 7.51 to 8 of pH value which stretched over an area of 27.51% of the area and was noted in continuous patches towards the northern part. 46.33% samples were spread over 51.90% area and were noted in the range of 7 to 7.5 pH category (Fig. 3.19b). pH of <7 was observed in <9.04% samples covering a small area (5.93%).

Tapi River, Surat District



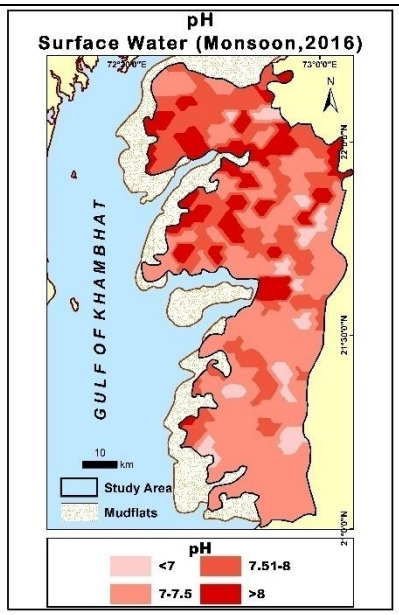


Fig.3.19 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.23 pH during Monsoon Season, 2016 (Surface Water)

Range	**Samples**		**Area**	
	No	**(%)**	**sq. km**	**(%)**
<7	16	9.04	248.183	5.93
7-7.5	82	46.33	2173.54	51.9
7.51-8	48	27.12	1152.06	27.51
>8	31	17.51	614.365	14.67
Total	**177**	**100**	**4188.15**	**100**

Source- Computed

3.2.5.2 Total Dissolved Solids (TDS):

TDS varied from 50 to 7700 mg/l with a mean and standard deviation of 720.06 mg/l and 1083.53 correspondingly (Table 3.28). Both skewness and kurtosis were positive (+3.50 and +14.66 respectively) which explained positively skewed with a steep slope and leptokurtic distribution (Fig. 3.20a).

In terms of spatial pattern, <500 mg/l TDS comprised the maximum area (62.60%) observed in 144 samples that were spread over the entire study area. 16.95% of samples had

TDS from 500 to 1000 mg/l. It covered 18.76% of the total area and was also found in patches at Nondhana, Uber, Amonpur Mota villages in Jambusar taluka, southwestern part of Vagra taluka, Derol, Saladara, Kasad, Tham villages (Amod taluka) and few patches were also observed in Olpad taluka. A slightly high TDS concentration of 1000.1 mg/l to 1500 mg/l was noticed in 6.78% of samples and was spread over 7.86% of the area. >1500 mg/l TDS was observed in a few small patches in the central and western parts along the coastline (Table 3.24 and Fig. 3.20b).

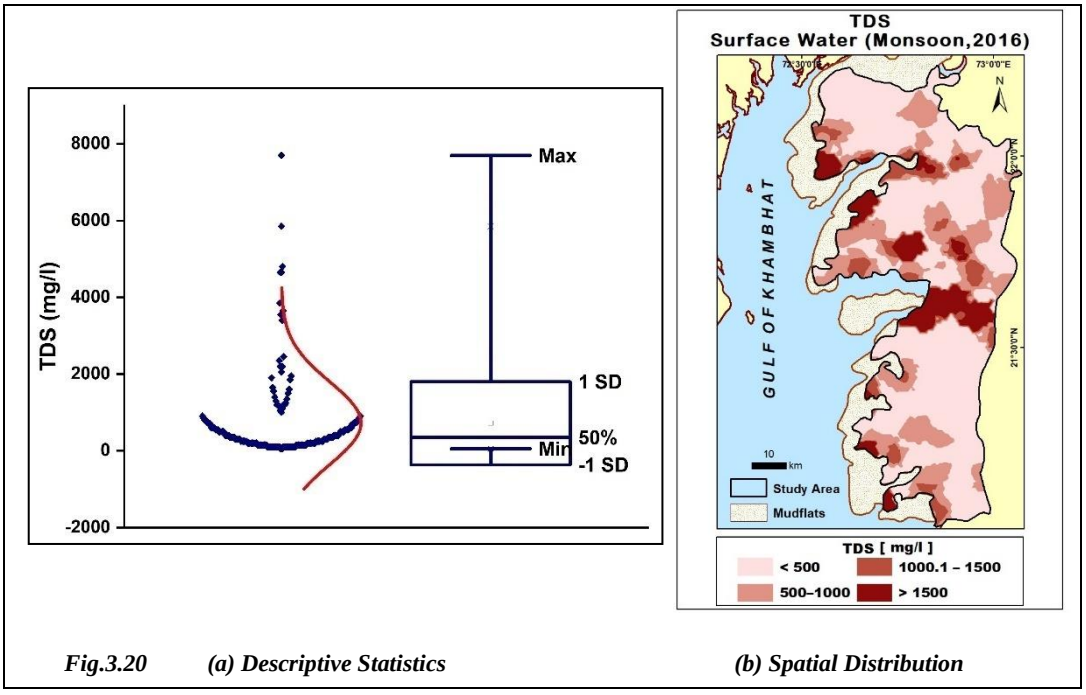


Fig.3.20 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.24 TDS during Monsoon Season, 2016 (Surface Water)

Range		Samples	Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	114	64.41	2621.94	62.6
500-1000	30	16.95	785.54	18.76
1000.1-1500	12	6.78	329.18	7.86
>1500	21	11.86	450.72	10.76
Total	**177**	**100**	**4188.15**	**100**

Source- Computed

3.2.5.3 Calcium (Ca):

In the monsoon season, the concentration of calcium ranged between 9.30 to 250 mg/l. The average concentration of calcium in surface water was 90.47 mg/l while the standard deviation was 50.66 (Table 3.28). Calcium distribution depicted low positive skewness (+1.65) and kurtosis (+2.85) (Fig. 3.21a).

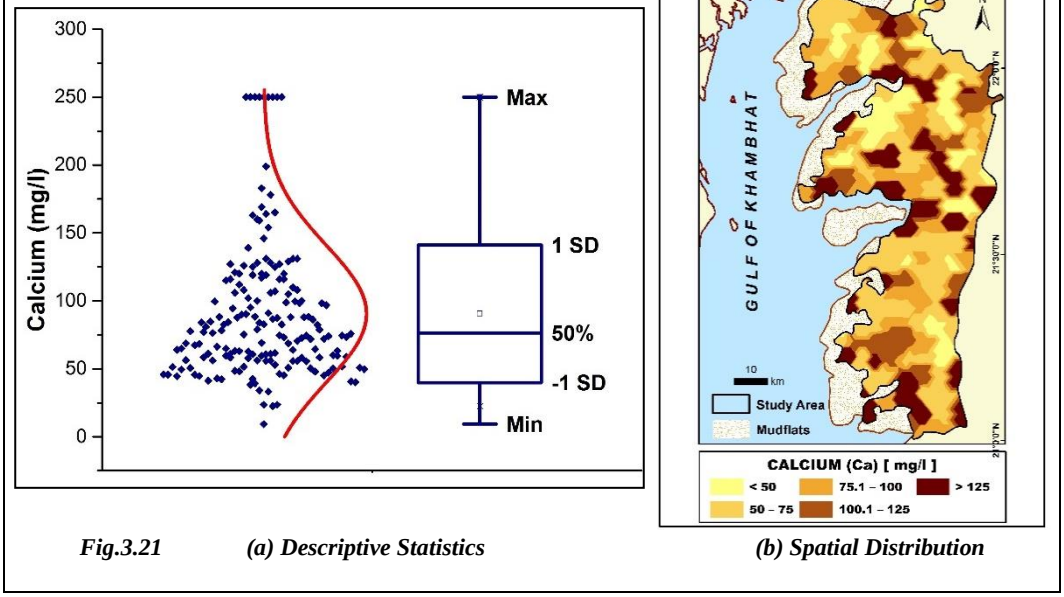


Fig.3.21 *(a) Descriptive Statistics* *(b) Spatial Distribution*

A high concentration of calcium in surface water was found in pockets over the entire region (Table 3.25). 15.60% area had a concentration of >125 mg/l which was noted in 30 samples. Further, 100.1 to125 mg/l was noticed in 13.56% samples covering 15.26% area. It was observed in small patches over the region. 20.90% samples spread over 22.90% area had 75.1-100 mg/l. 50-75 mg/l of calcium. It was noticed in the entire study area except for the central portion. It was spread over 33.95% area and had 32.77% samples. Low calcium content of <50 mg/l was observed in 15.82% samples spread over a 12.29% area (Fig. 3.21b).

Hansot Taluka, Bharuch District

Table 3.25 Calcium (Ca) during Monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	28	15.82	514.87	12.29
50-75	58	32.77	1422.04	33.95
75.1-100	37	20.9	959.01	22.9
100.1-125	24	13.56	639.05	15.26
>125	30	16.95	653.18	15.6
Total	**177**	**100**	**4188.15**	**100**

Source- Computed

3.2.5.4 Sodium (Na):

Sodium concentration ranged between 9.10 mg/1 and 300 mg/1. The mean value was 135.76 mg/1 and the standard deviation was 108.59, explaining relatively low variation in the level of concentration. Skewness and kurtosis both were low (+0.56 and -1.30 respectively). Kurtosis value indicated a platykurtic distribution (Fig. 3.22a and Table 3.28).

During the monsoon season, half of the total area had <100 mg/l with 50.28% of samples noted in small patches covered the entire region but was more noticeable towards the southern part. Approximately 13% of samples covering the same percentage of the area had 100 to 150 mg/l of sodium content (Fig. 3.22b). The remaining 150.1 to 200 mg/l and 200.1 to 250 mg/l sodium concentration ranges had 9.04% and 2.82% samples spread over 11.23% and 6.45% area respectively. >250 mg/l was found in 25.42% samples and it was spread over approximately 19% area. This concentration level was more prominent in the northern-western, as well as in the south-western segment which was adjacent to the coast (Table 3.26).

Table 3.26 Sodium (Na) during Monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	89	50.28	2109	50.36
100-150	22	12.43	543	12.97
150.1-200	16	9.04	470	11.22
200.1-250	5	2.82	270	6.45
>250	45	25.42	795	18.98
Total	**177**	**100**	**4188.15**	**100**

Source- Computed

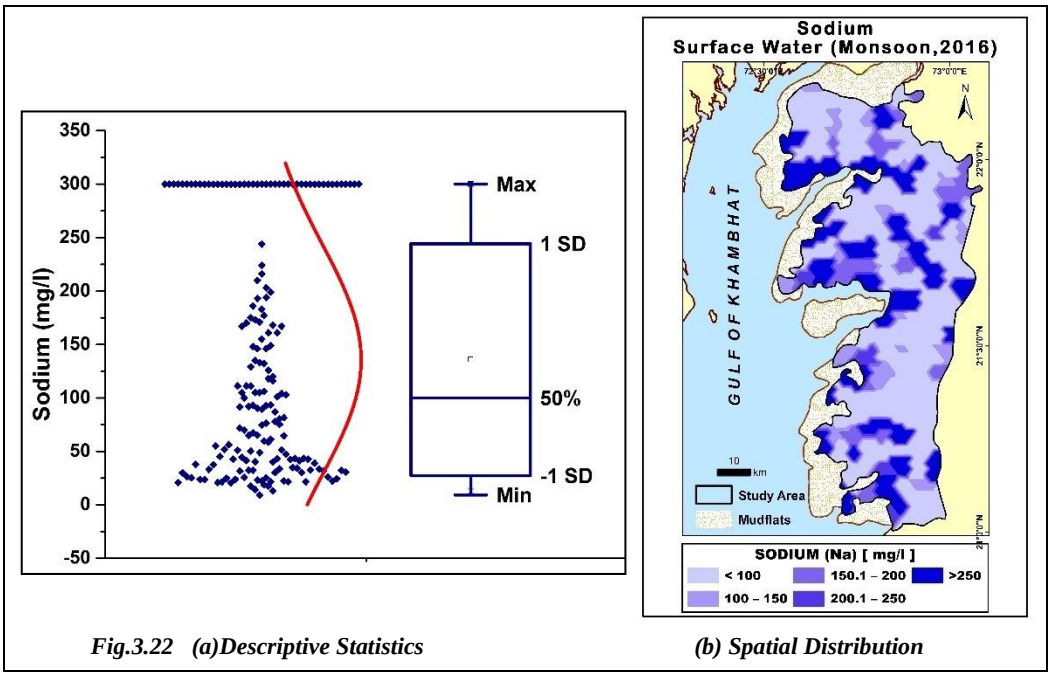


Fig.3.22 (a)Descriptive Statistics *(b) Spatial Distribution*

3.2.5.5 Fluoride (F):

Fluoride concentration varied between Below Detection Level (BDL) to 1.06 mg/l with an average value of 0.36 mg/l and a standard deviation of 0.26 (Table 3.28). Skewness and kurtosis were low in the dataset, the former being 0.57 while later was -0.23 (Fig. 3.23a).

In this season, all fluoride samples were below the desirable limits. However, 52 samples covering 26.31% of the area had <0.20 mg/l fluoride concentration which was observed over the entire region (Fig. 3.23b). 0.20 mg/l to 0.40 mg/l was relatively more prominent towards the northern side. This concentration had 29.38% of samples and was spread over 33.73% area. In the next category, (0.41 to 0.60 mg/l) 43 samples covered 24.35% area, whereas 0.61-0.80 mg/l was noted in 9.60% samples and was noted in the same percentage of area. Further, 7.34% of samples had >0.80 mg/l fluoride content which was spread over 6.57% area. This concentration was more pronounced towards the southern part (Table 3.27).

Jambusar Taluka, Bharuch District

Table 3.27 Fluoride (F) during Monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	52	29.38	1101.89	26.31
0.20-0.40	52	29.38	1412.72	33.73
0.41-0.60	43	24.29	1019.64	24.35
0.61-0.80	17	9.6	378.7	9.04
>0.80	13	7.34	275.2	6.57
Total	**177**	**100**	**4188.15**	**100**

Source- Computed

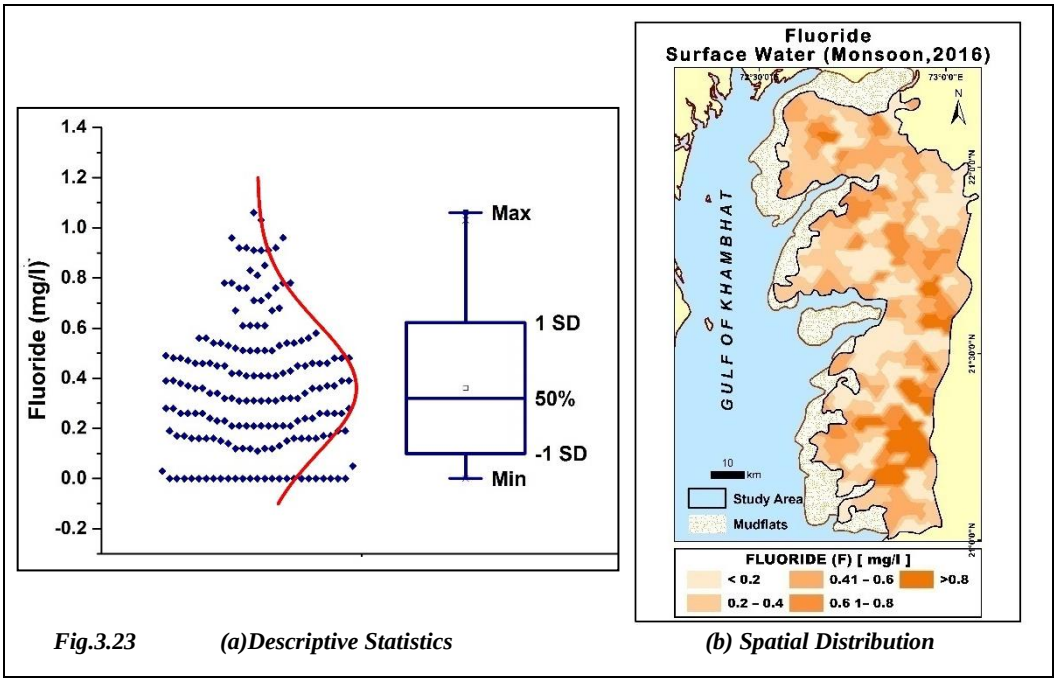


Fig.3.23 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.28 Descriptive Statistics of the Surface Water Samples (Monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.08	9.20	7.54	.53	.94	.80
TDS	50.0	7700.0	720.06	1083.53	3.50	14.66
Calcium (Ca)	9.3	250.0	90.47	50.66	1.65	2.85
Sodium (Na)	9.1	300.0	135.76	108.59	.56	-1.30
Fluoride (F)	BDL	1.06	.36	.26	.57	-.23

Source- Computed

3.2.6 Monsoon, 2016 (Sub-surface Water)

3.2.6.1 pH Level:

In the Monsoon season, the concentration of pH varied from 6.89 to 8.47, indicating a slightly acidic to an alkaline condition (Table 3.34). The average pH in sub-surface water was 7.52 denoting the normal condition and low deviation of 0.31. Skewness and kurtosis too showed low and positive values of +0.43 and +0.08 respectively (Fig. 3.24a).

In terms of spatial pattern, the acidic nature (<7) was noted in just 2.63% samples covering 1.96% area. 7 to 7.5 values were observed in 58.55% samples and it stretched over 48.95% area indicating the normal range of sub-surface water (Fig. 3.24b). 32.89% samples spreading over 43.42% area had a value between 7.51 to 8. In this season, extremes of the values were not observed. Thus, >8 pH value was restricted to 5.68% area as well as samples. Almost >90% of sub-surface water samples had a content between 7 to 8. A higher pH concentration was observed in the northern half. River Narmada can be considered as the dividing line between the northern and southern half of the study region (Table 3.29).

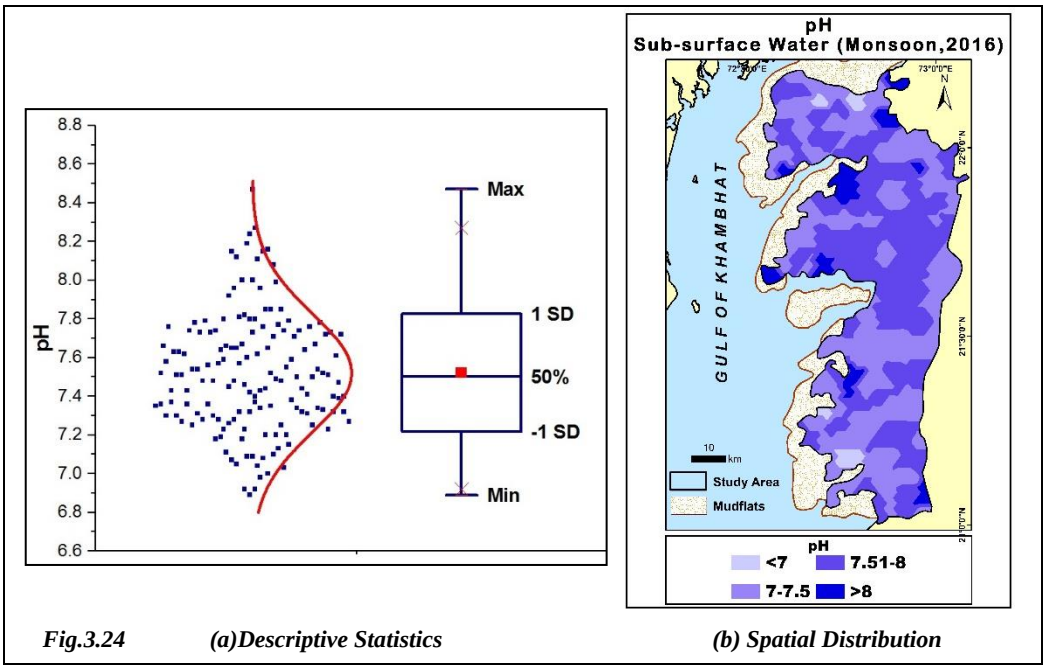


Fig.3.24 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.29 pH during Monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
	No	**(%)**	**sq. km**	**(%)**
<7	4	2.63	81.91	1.96
7-7.5	89	58.55	2049.94	48.95
7.51-8	50	32.89	1818.3	43.42
>8	9	5.92	237.99	5.68
Total	**152**	**100**	**4188.15**	**100**

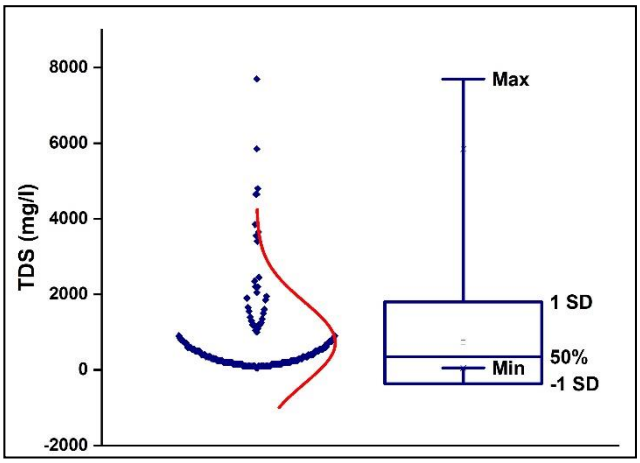
Source- Computed

3.2.6.2 Total Dissolved Solids (TDS):

The minimum TDS value was 100 mg/l and the maximum was 8500 mg/l. The average value of TDS was 1119.08 mg/l and the standard deviation was 1252.88. Skewness and kurtosis showed very high and positive values of +3.44 and +14.91 respectively (Table 3.34). The value of kurtosis showed high peakedness, explaining high standard deviation and positive skewness with a steep slope (Fig. 3.25a).

TDS of <500 mg/l was observed in 30.26% of samples that covered 29.06% area. This range was found in small patches in the north-western part of Jambusar taluka and the western part of Vagra, Hansot and Olpad talukas. 500 to 1000 mg/l range of TDS was observed in 55 samples covering 35.51% of the area. This belt was seen over entire the study region except for a few small patches (Fig. 3.25b). 1000.1 to 1500 mg/l range was noted in 16.24% area and 13.16% samples. This patch was found in the southern part of Jambusar taluka and north-eastern part of Amod, north western part of Vagra taluka and few segments in Ankleshwar and Olpad talukas (Surat district). The next highest TDS category (>1500 mg/l) was observed in small patches in the northern part and in Narthan and Dihen villages of Olpad taluka (Table 3.30).

Olpad Taluka, Surat District



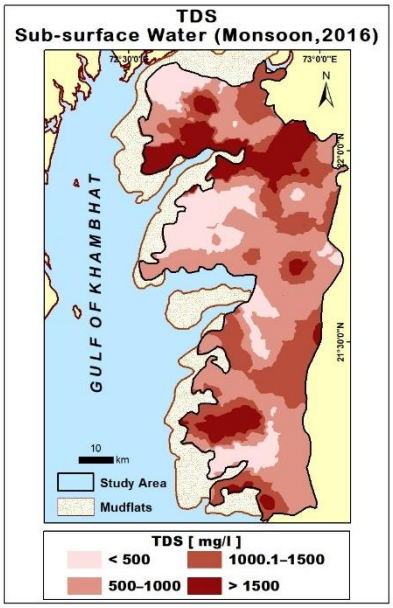


Fig.3.25 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.30 TDS during Monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
(mg/l)	**No**	**(%)**	**sq. km**	**(%)**
<500	46	30.26	1217.01	29.06
500-1000	55	36.18	1487.34	35.51
1000.1-1500	20	13.16	680.11	16.24
>1500	31	20.39	800.91	19.12
Total	**152**	**100**	**4188.15**	**100**

Source- Computed

3.2.6.3 Calcium (Ca):

In the study area, the mean of calcium in sub-surface water was 124.51 mg/l. The standard deviation value was 58.04, indicating a wide range of concentration throughout the space (Table 3.34). The concentration of calcium varied from 37.0 to 250.0 mg/l. This distribution had a positive skewness value of +1.09 representing an asymmetric tail on the right of the median (Fig. 3.26a). Kurtosis showed a low value (+0.38) of this distribution.

In terms of spatial patterns in the monsoon season, the amount of calcium in sub-surface water was quite high. >85% samples had the element above the desirable limit set by BIS and it was spread over in approximately the same percentage of the area and also

samples (Fig. 3.26b). A higher concentration was observed in the entire region in isolated form. 100.1 to 125 mg/l of calcium was noted in the 26.71% area which was more pronounced near Tapi and Narmada rivers. The same pattern was observed in the range of 75.1 to 100 mg/l (Table 3.31).

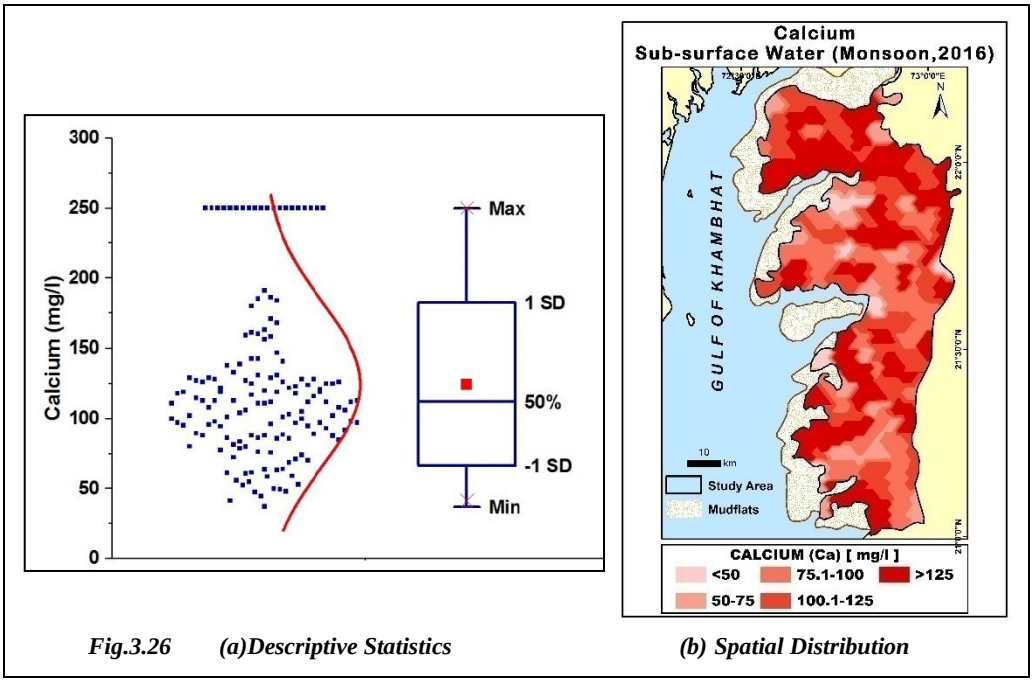


Fig.3.26 (a)Descriptive Statistics (b) Spatial Distribution

Table 3.31 Calcium (Ca) during Monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	7	4.61	119.14	2.84
50-75	17	11.18	406.99	9.72
75.1-100	35	23.03	998.3	23.84
100.1-125	40	26.32	1118.78	26.71
>125	53	34.87	1544.93	36.89
Total	**152**	**100**	**4188.15**	**100**

Source- Computed

3.2.6.4 Sodium (Na):

The concentration of sodium (Na) ranged from 9.8 mg/l to 400 mg/l and was slightly higher than WHO standard (200 mg/l). The mean concentration was 211.95 mg/l and the deviation from the mean was very high (104.45). Skewness and kurtosis showed negative and low values (-0.44 and -1.12 respectively). Therefore, kurtosis indicated that the

distribution had lighter tail and a flatter peak than the normal distribution while skewness denoted an extended tail towards the left (Fig. 3.27a and Table 3.34).

During the rains, 21% of samples covering 16.82% area had a sodium content of <100 mg/l in sub-surface water (Fig. 3.27b). This was largely observed closer to the main rivers ie., Tapi and Narmada. 48% samples with 43% area had content of >250 mg/l. This range was more evenly spread in the entire region. The continuity was broken at many segments – one in the Jambusar industrial belt, Dahej, near Surat city was a bigger one. 21% had <100 mg/l and the remaining 12% were with 100 to 150 mg/l content (Table 3.32).

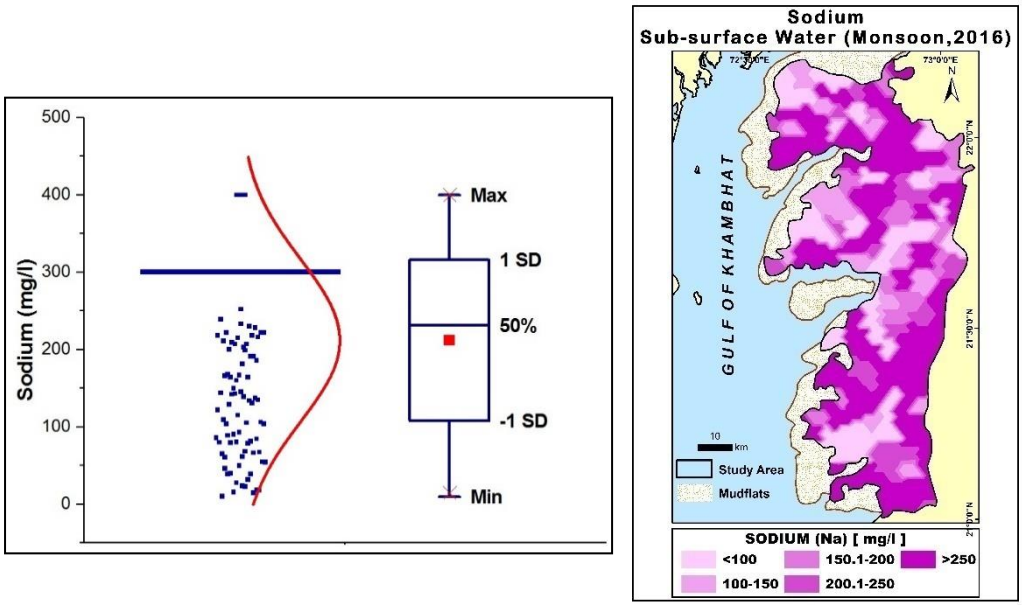


Fig.3.27 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.32 Sodium (Na) during Monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	32	21.05	704.28	16.82
100-150	18	11.84	528.26	12.61
150.1-200	12	7.89	527.23	12.59
200.1-250	16	10.53	611.68	14.6
>250	74	48.68	1816.7	43.38
Total	**152**	**100**	**4188.15**	**100**

Source- Computed

3.2.6.5 Fluoride (F):

The average of the fluoride distribution was 0.36 mg/l and it varied between Below Detectable Limit (BDL) to 1.50 mg/l (Table 3.34). The standard deviation value of the distribution was 0.25 showing the low range of concentration throughout the space. The skewness value (+0.96) depicted positive skewness. Kurtosis value was (+1.65) denoting the peakedness of the curve (Fig. 3.28a).

In terms of the spatial pattern, 27% of samples had fluoride concentration of <0.20 mg/l. It was spread over the same amount of area covering the entire region. 0.20 mg/l to 0.40 mg/l fluoride concentration was found in 49 samples which covered 36.62% of the total area.

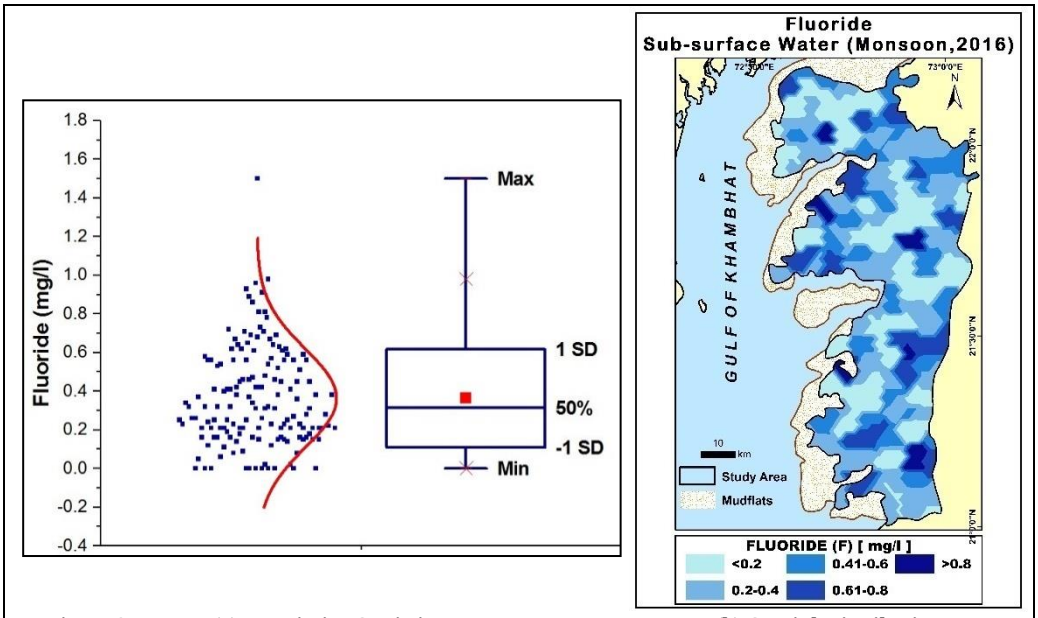


Fig.3.28 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.33 Fluoride (F) during Monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	29	21.17	1144.27	27.32
0.20-0.40	49	35.77	1533.53	36.62
0.41-0.60	33	24.09	897.57	21.43
0.61-0.80	19	13.87	499.91	11.94
>0.80	7	5.11	112.87	2.69
Total		**100**	**4188.15**	**100**

Source- Computed

>0.60 mg/l fluoride concentration covered 15% of the total area (Fig. 3.28b). Only in 1 (one) sample the concentration was more than the BIS standard. Spatially, higher fluoride concentration was observed as clusters in the entire study area (Table 3.33).

Table 3.34 Descriptive Statistics of the Sub-surface Water Samples (Monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.89	8.47	7.52	.31	.43	.08
TDS	100.0	8500.0	1119.08	1252.88	3.44	14.91
Calcium (Ca)	37.0	250.0	124.51	58.04	1.09	.38
Sodium (Na)	9.8	400.0	211.95	104.45	-.44	-1.12
Fluoride (F)	BDL	1.50	.36	.25	.96	1.65

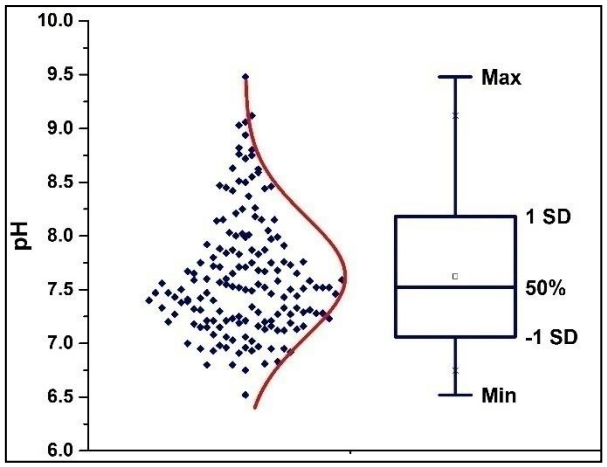
Source-Computed

3.2.7 Post-monsoon, 2016 (Surface Water)

3.2.7.1 pH Level:

In the post-monsoon season, the concentration of pH varied from 6.5 to 9.5, indicating a slightly acidic to an alkaline condition (Table 3.40). The average pH in surface water was 7.6 and a low deviation of 0.56. Skewness and kurtosis also indicated low and positive values of (+0.88) and (+0.45) respectively (Fig.3.29a). Kurtosis values denoted a low degree of peakedness (platykurtic distribution).

In terms of spatial pattern, the acidic nature (<7) was found in 10.56% of samples covering 8.29% of the total area. They were concentrated at Olpad taluka in a clustered form (Fig. 3.29b). pH of 7 to 7.5 values was observed in 38.51% samples and it stretched over 39.37% area. It was spatially seen in a major segment of central to southern portion covering Bharuch, Hansot, Olpad, Kamrej and Surat talukas in both the districts of Bharuch and Surat. 29.81% samples spreading over 32.04% area had values of 7.51 to 8 pH. In this season, >8 pH value was restricted to 20.30% area as well as samples. The higher pH level concentration was mostly confined in the northern segment as well in the north-western part of the study area (Table 3.35).



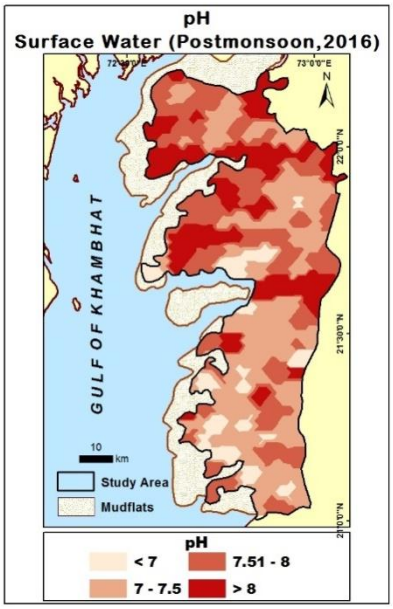


Fig.3.29 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.35 pH during Post-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
	No	**(%)**	**sq. km**	**(%)**
<7	17	10.56	347	8.29
7-7.5	62	38.51	1649	39.37
7.51-8	48	29.81	1342	32.04
>8	34	21.12	850	20.3
Total	**161**	**100**	**4188.15**	**100**

Source- Computed

3.2.7.2 Total Dissolved Solids (TDS):

The TDS ranged between 100 mg/l and 12500 mg/l. The mean was 888.55 mg/l. The diversification of data was high with a standard deviation value of 1591.98. Skewness and kurtosis showed very high and positive values of +5.28 and +34.05 respectively. The value of kurtosis showed a high degree of peakedness, depicting leptokurtic distribution, explaining high standard deviation and positive skewness with a steep slope (Fig. 3.30a and Table 3.40).

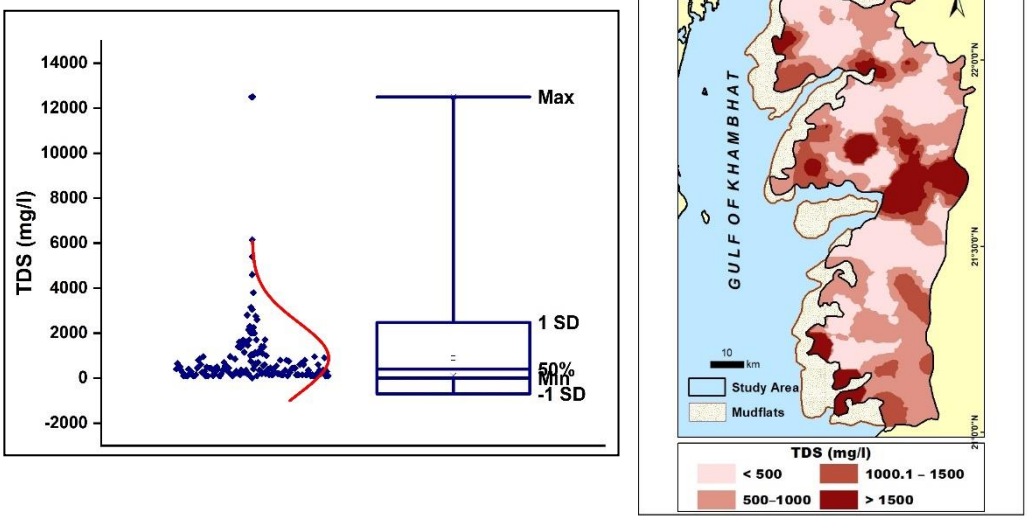


Fig.3.30 *(a)Descriptive Statistics* *(b) Spatial Distribution*

TDS of (<500 mg/l) was observed in 60.87% of samples which covered 61.16% area. This range was noted in the entire study region. Another 17.39% of samples had 500 to 1000 mg/l of TDS which was spread over 17.20% of the area. This belt was observed near Surat city and in the western part of Kamrej taluka. Between 1000.1 to 1500 mg/l of TDS was noted in 9.21% of samples which covered 9.32% of the area. It was found in small patches in the western part of Vagra, Jambusar and Ankleshwar of Bharuch district and Kamrej taluka (Surat district). >1500 mg/l TDS was observed in just 12.42% of samples covering a 12.43% area. This category was observed along the Narmada River (Fig. 3.30b and Table 3.36).

Table 3.36 TDS during Post-monsoon Season, 2016 (Surface Water)

Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	98	60.87	2562	61.16
500-1000	28	17.39	720.45	17.2
1000.1-1500	15	9.32	385.7	9.21
>1500	20	12.42	520.55	12.43
Total	**161**	**100**	**4188.15**	**100**

Source- Computed

3.2.7.3 Calcium (Ca):

In the study area, the mean of calcium in surface water was 81.48 mg/l. The standard deviation value was 68.83, showing little variation in the dataset. The concentration of calcium varied between 2.6 mg/l to 312.0 mg/l (Table 3.40). This distribution had a positive skewness value of +2.14 representing an asymmetric tail on the right of the median. The kurtosis value of this distribution was +4.09 (Fig. 3.31a).

In the post-monsoon season of 2016, the content of <50 mg/l in surface water was found in 39.13% samples and it was spread over 35.69% of the area (Table 3.37). This lowest range of concentration was observed in the entire region. 50 to 75 mg/l category had 25.47% samples spread over 28.01% of the area. The spatial pattern is reflected in northern as well as southern segments of the study area. The talukas of Jambusar, Vagra and Amod in Bharuch district and Olpad (Surat district) are mostly associated with this range. 15% of the samples spread over 14% area had the concentration of 75.1 to 100 mg/l. The concentration between 100.1 to 125 mg/l was noted in just 7.45% samples spread over 300 sq. km area. The high concentration of >125 mg/l was spread over 15% area and in 13% samples. The talukas of Jambusar and Bharuch were associated with the higher range covering the northern and central segments of the Bharuch district (Fig. 3.31b).

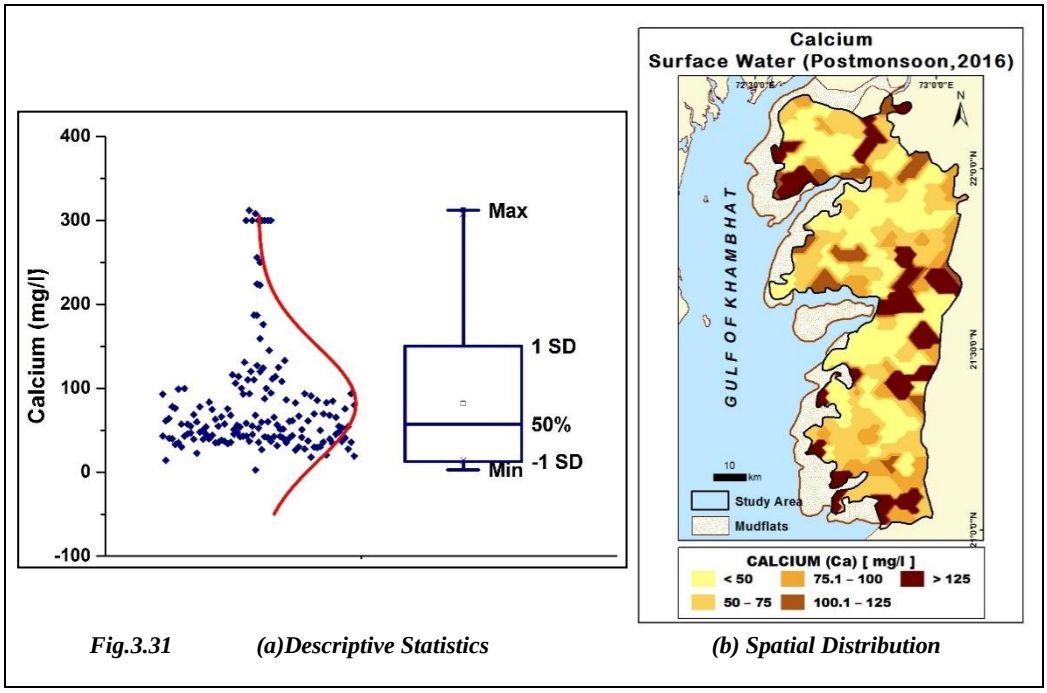


Fig.3.31 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.37 Calcium (Ca) during Post-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	63	39.13	1494.73	35.69
50-75	41	25.47	1172.84	28.01
75.1-100	24	14.91	593.68	14.18
100.1-125	12	7.45	300.74	7.18
>125	21	13.04	625.83	14.94
Total	**161**	**100**	**4188.15**	**100**

Source- Computed

3.2.7.4 Sodium (Na):

The concentration of sodium ranged from 11.3 mg/l to 300.0 mg/l with the mean concentration being 143.81 mg/l. The deviation from the mean was very high (112.33 mg/l). Skewness value was +0.50 and kurtosis showed negative and low values (-1.45). Therefore, kurtosis indicated platykurtic type distribution and skewness denoted as a normal distribution (Fig. 3.32a and Table 3.40).

After the rains, 47.20% of samples covering 44.31% area had a sodium content of <100 mg/l in surface water. This was largely observed in the northern half of the study area. 18.63% of sodium samples with the same percentage of the area had the content between 100 mg/l to 150 mg/l. Another 6.41% of the area and 2.48% of samples had calcium concentrations between 150.1 to 200 mg/l (Table 3.38). Sodium was absent in the range of 200.1 to 250 mg/l. 31.68% samples with 30.66% area had content of >250 mg/l. This range was more evenly spread over the entire region (Fig. 3.32b).

Jambusar Taluka, Bharuch District

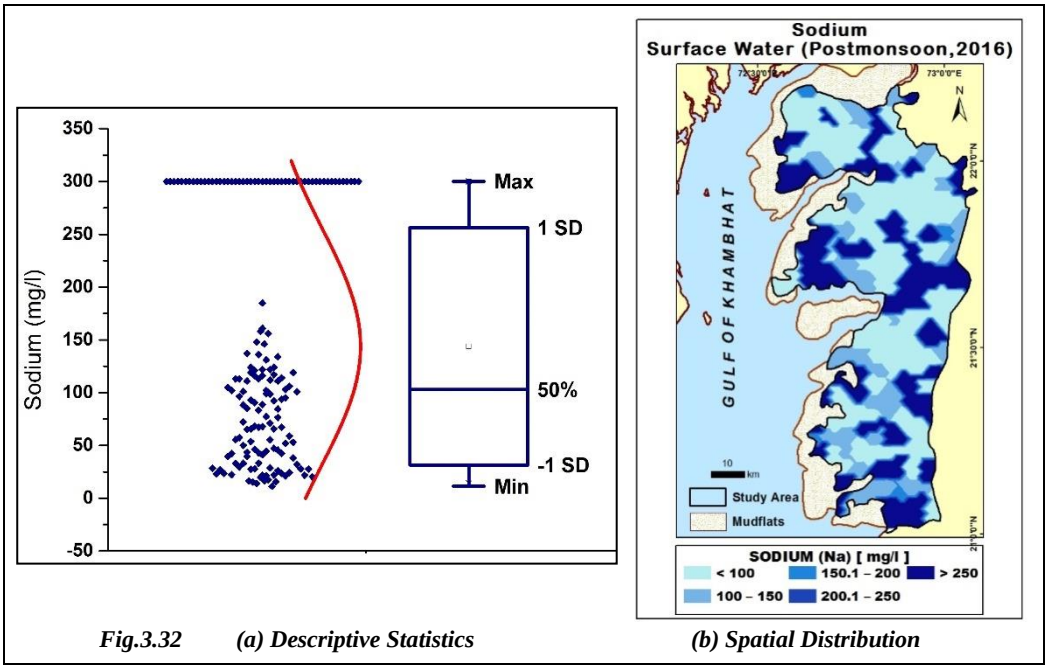


Fig.3.32 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.38 Sodium (Na) during Post-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	76	47.2	1855.45	44.31
100-150	30	18.63	783.79	18.72
150.1-200	4	2.48	268.62	6.41
200.1-250	0	0	214.51	5.12
>250	51	31.68	1065.45	25.44
Total	**161**	**100**	**4188.15**	**100**

Source- Computed

3.2.7.5 Fluoride (F):

The average of the fluoride distribution was 0.28 mg/l and it varied between Below Detectable Limit (BDL) to 1.52 mg/l. The standard deviation value of the distribution was 0.233 showing a low range of concentration throughout the space (Table 3.40). The skewness value of +2.43 depicted positive skewness. Kurtosis value was +9.17, denoting the peakedness of the curve with a steep slope (Fig. 3.33a).

In terms of spatial pattern, 38.56% samples had fluoride concentration of <0.20 mg/l. It was spread over 39.58% of an area covering the northern, central and few patches in the southern part of the study area. 0.20 mg/l to 0.40 mg/l fluoride concentration was found in

39.87% of samples which covered 41.76% of the total area. This level was is in patches spread over the entire region. In the next category, 13.73% of samples covering 12.31% of the study area had 0.41 to 0.6 mg/l of fluoride (Table 3.39). They were observed as isolated scattered pockets at Vagra, the north-eastern part of Jambusar and a few in the southern part of the study area near Tapi River. In the remaining categories viz., in 0.61 to 0.80 mg/l and >0.81 mg/l, the percentage of samples was <5% and 4% respectively with approximately 8% of the area each. This was observed in Ankleshwar taluka and in the villages of Ikhar, Pariej, Aldar and Kapuria in Jambusar and Bharuch talukas (Fig. 3.33b).

Table 3.39 Fluoride (F) during Post-monsoon Season, 2016 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	59	38.56	1656.61	39.58
0.20-0.40	61	39.87	1747.96	41.76
0.41-0.60	21	13.73	515.42	12.31
0.61-0.80	7	4.58	162.52	3.88
>0.80	5	3.27	103.2	2.47
Total	**153**	**100**	**4188.15**	**100**

Source- Computed

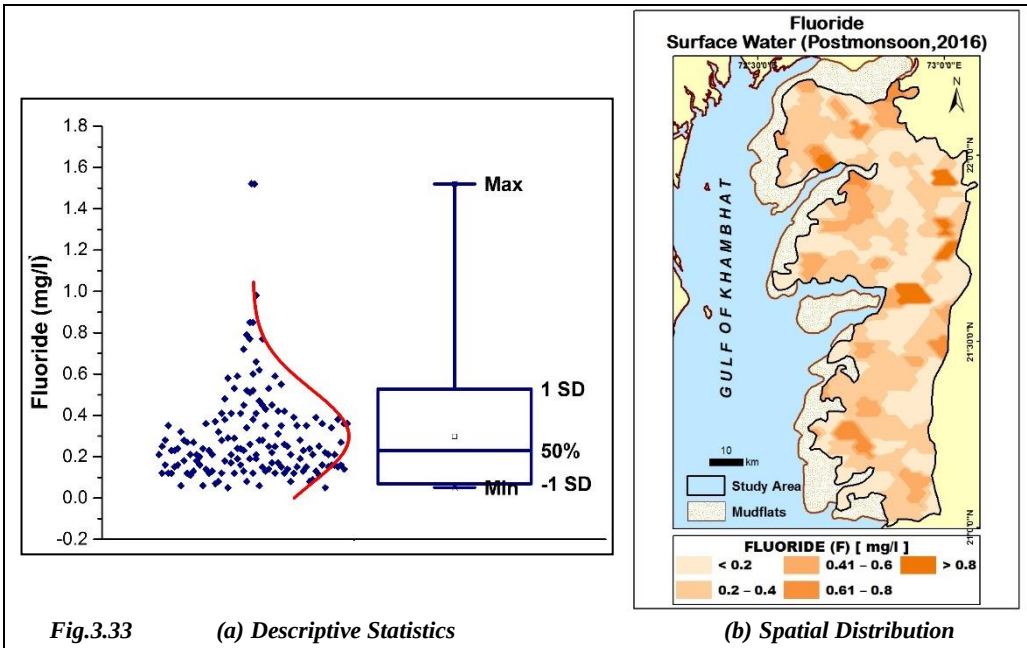


Fig.3.33 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.40 Descriptive Statistics of the Surface Water Samples (Post-monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.50	9.50	7.60	.56	.88	.45
TDS	100.0	12500.0	888.55	1591.98	5.28	34.05
Calcium (Ca)	2.6	312.0	81.48	68.83	2.14	4.09
Sodium (Na)	11.3	300.0	143.81	112.33	.50	-1.45
Fluoride (F)	BDL	1.52	.28	.23	2.43	9.17

Source- Computed

3.2.8 Post-monsoon, 2016 (Sub-surface Water)

3.2.8.1 pH Level:

In the post-monsoon season, the concentration of pH varied from 6.67 to 8.55, ranging from slightly acidic to an alkaline condition (Table 3.46). The average pH in sub-surface water was 7.51 denoting the normal condition and less deviation of 0.34. Skewness and kurtosis showed small and positive values of +0. 30 and +0.38 respectively (Fig. 3.34a).

The recommended value of pH for drinking purposes was between 6.5-8.5 (BIS, 1998). In the post-monsoon season, a sub-surface water level of <7 pH was noticed in the southern section of the region. 9 out of 147 samples were in this category and covered 4.58% area. 7 to 7.5 value was observed in 44.22% samples and it stretched over 48.83% area indicating the normal condition of sub-surface water. 42.86% samples spreading over 41.81% area had a value between 7.51 to 8. In this season, a higher degree of pH was not observed. Thus, >8 pH value was restricted to 4.78% area and only had 6.80% of samples. The north-eastern part of the study area observed a higher concentration of pH and small pockets were also found in the central part. In this season all the sub-surface water samples had pH within the permissible limits (Fig. 3.34b and Table 3.41).

Chourasiya Taluka, Surat District

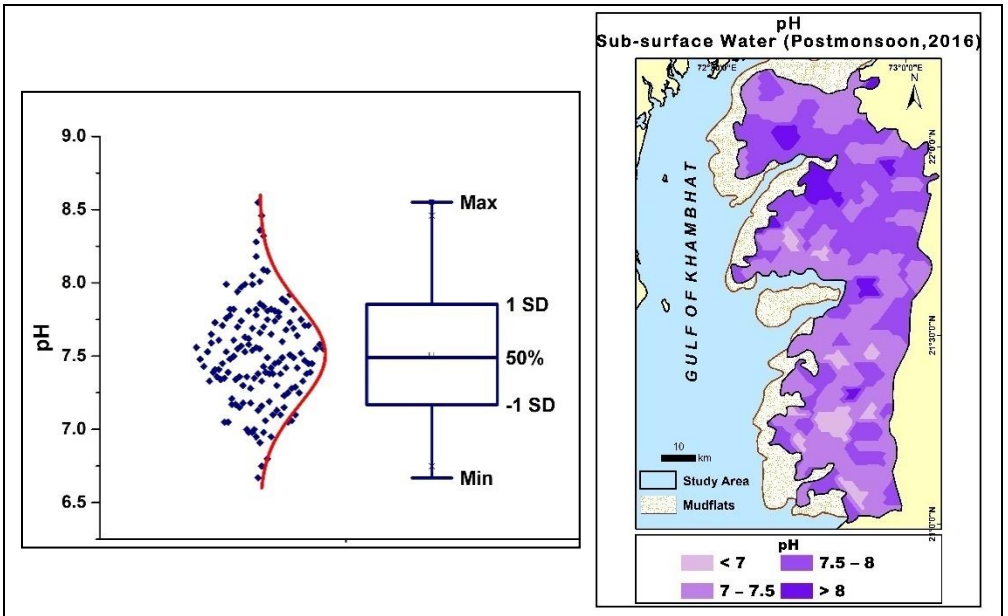


Fig.3.34 (a) Descriptive Statistics *(b) Spatial Distribution*

Table 3.41 pH during Post-monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
	No	(%)	sq. km	(%)
<7	9	6.12	191.66	4.58
7-7.5	65	44.22	2044.92	48.83
7.51-8	63	42.86	1751.19	41.81
>8	10	6.8	200.38	4.78
Total	**147**	**100**	**4188.15**	**100**

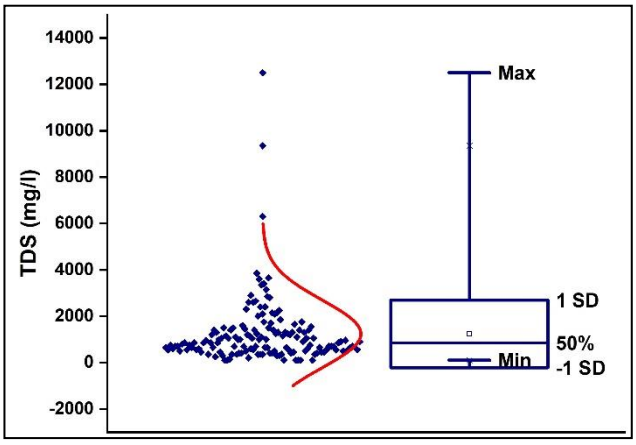
Source- Computed

3.2.8.2 Total Dissolved Solids (TDS):

The values of TDS ranged from a minimum of 100 mg/l to a maximum of 12500 mg/l. In this distribution, the mean value of the data was 1268.37 mg/l with a standard deviation value of 1465.92 (Fig. 3.35a). The skewness and kurtosis values of the curves were 4.70 and 29.46 respectively. The curve had a positive skewness with a steep slope (Table 3.46).

A low amount of TDS (<500 mg/l) was observed in 20.68% of the area and >19.05% of sub-surface water samples. This range of TDS was found mainly in Vagra taluka and a few small pockets were also observed in Jambusar, Hansot and Bharuch talukas. 34.69% of samples had a little higher range of 500 to 1000 mg/l which covered 33.38% area which was spread in the entire the study area (Table 3.42). In the next category (1000.1 to 1500 mg/l),

23.13% of samples and 25.25% area was noted. This belt was distributed in the northern part of Amod, Olapd and Ankleshwar talukas. The higher TDS (>500 mg/l) was noted in isolated segments in north-western part of Vagra, north-eastern part of Amod, southern part of Jambusar taluka and few patches were also observed in the Olpad taluka. (Fig. 3.35b).



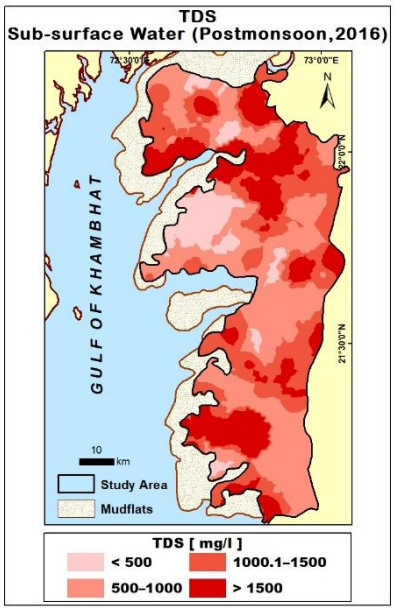


Fig.3.35 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.42 TDS during Post-monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	28	19.05	866.09	20.68
500-1000	51	34.69	1397.88	33.38
1000.1-1500	34	23.13	1057.56	25.25
>1500	34	23.13	865.85	20.67
Total	**147**	**100**	**4188.15**	**100**

Source- Computed

3.2.8.3 Calcium (Ca):

In the study area, the concentration of calcium ranged from 24.60 to 300 mg/l whereas the mean in sub-surface water was 100.44 mg/l. The deviation from the mean was considerably high (79.12). This distribution had a positive skewness value of (+1.58), depicting a relatively normal distribution of data (Table 3.46). The kurtosis value of this distribution was (+1.46) indicating the leptokurtic distribution of the data (Fig. 3.36a).

After the rainfall, the maximum concentration (>125 mg/l) of calcium was observed over the entire region in isolated form. It was noted in 23.13% of samples and was spread over 24.54% of the area (Table 3.43). 53.06% samples had the element lower than the desirable limit set by BIS and it was spread over in approximately the same percentage of area. 100.1 to 125 mg/l of calcium was noted in the 10.78% area which was noted near the Jambusar industrial region and in a few patches in the central part. 13.61% samples spread over 14.98% area had content between 75.1 to 100 mg/l (Fig. 3.36b).

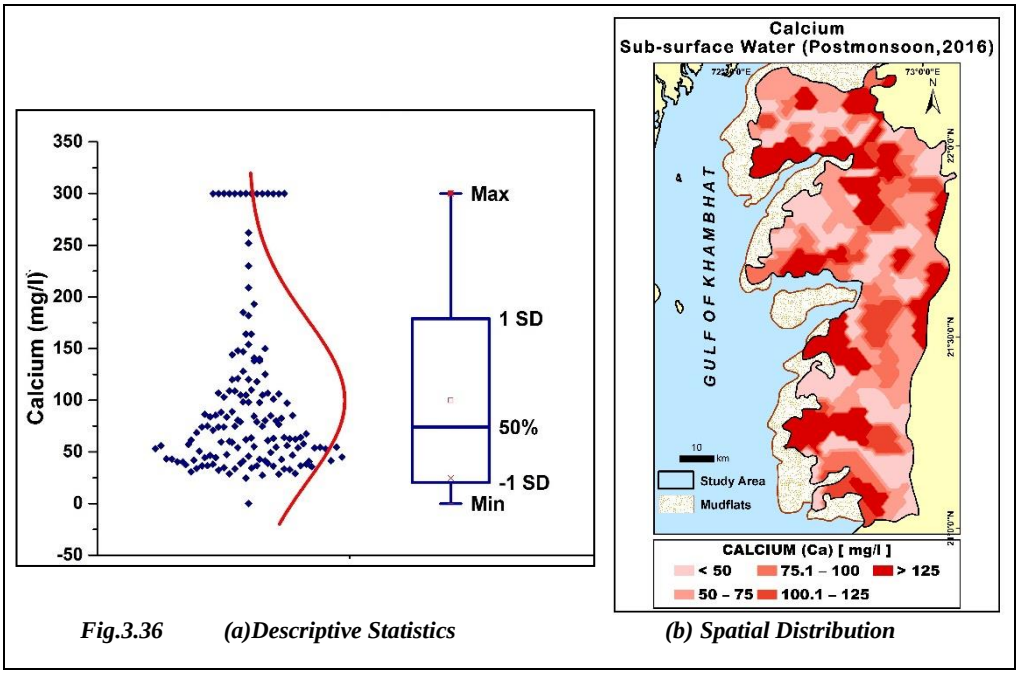


Fig.3.36 ***(a)Descriptive Statistics*** ***(b) Spatial Distribution***

Table 3.43 Calcium (Ca) during Post-monsoon Season, 2016 (Sub-surface Water)

Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	43	29.25	1003.76	23.97
50-75	35	23.81	1077.77	25.73
75.1-100	20	13.61	627.19	14.98
100.1-125	15	10.2	451.65	10.78
>125	34	23.13	1027.78	24.54
Total	**147**	**100**	**4188.15**	**100**

Source- Computed

3.2.8.4 Sodium (Na):

The level of sodium varied between 15.20 and 300 mg/l with a higher mean (205.10 mg/l) and standard deviation (100.92). A very high standard deviation value explained that the variation in the data was high (Table 3.46). Both skewness and kurtosis values were negative and small (-0.27 and -1.63 respectively) (Fig. 3.37a).

In the post-monsoon season, the sodium content of <100 mg/l was noted in 14.29% of samples which was spread over approximately the same percentage of area. This range was observed in the central part of the region. In continuation to the upper range, 30% of samples covering 28.08% of the area witnessed 100 to 150 mg/l (Fig. 3.37b). The next category range (150.1 to 200 mg/l), was spread over 11% of the area and this content was noted in only 4.76% samples. 6.80% samples which was spread over 291.83 sq. km of the area had a concentration of 200.1 to 250 mg/l. Patches of >250 mg/l of this element were noted in the entire region in the form of isolated pockets. 44% of samples covered 43.50% of the area. The continuity was broken at many segments – one in the Jambusar industrial belt, Dahej, near Surat city (Table 3.44).

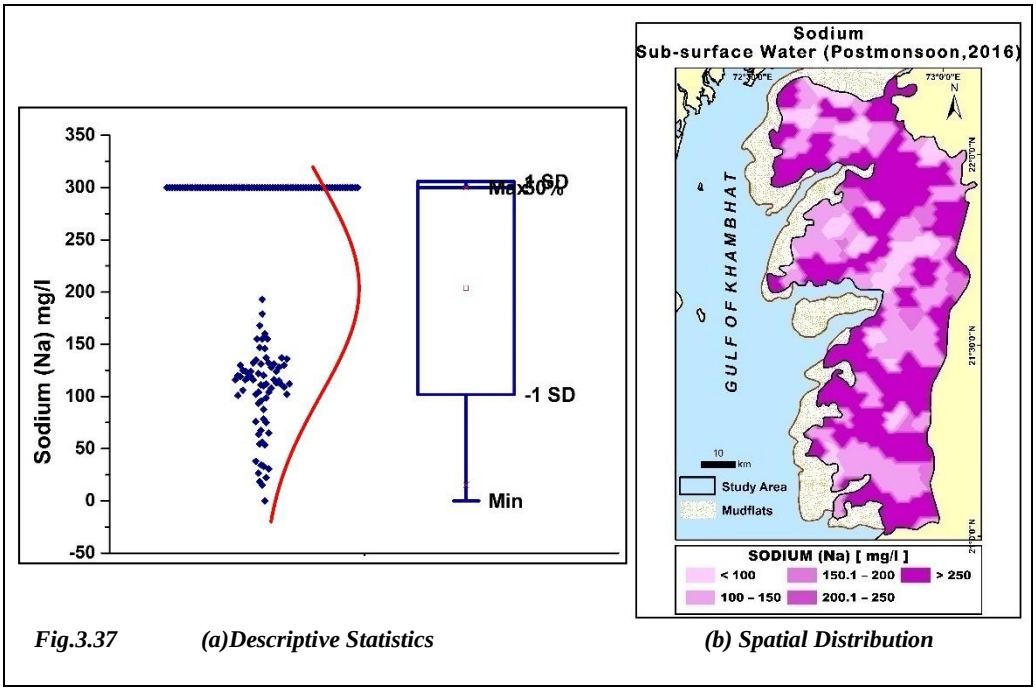


Fig.3.37 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.44 Sodium (Na) during Post-monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	20	14.29	461.76	11.03
100-150	44	30	1176.32	28.09
150.1-200	7	4.76	436.72	10.43
200.1-250	10	6.8	291.83	6.97
>250	66	44	1821.52	43.49
Total	**147**	**100**	**4188.15**	**100**

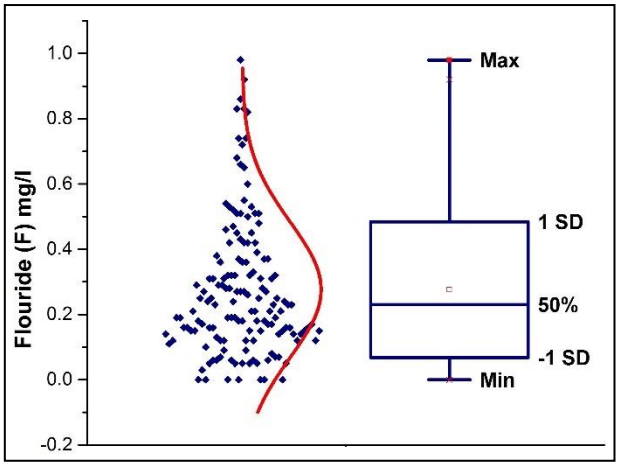
Source- Computed

3.2.8.5 Fluoride (F):

The range of fluoride in post monsoon season varied from BDL to 0.98 mg/l. Mean and standard deviation at this time was 0.28 and 0.21 with positive skewness (+1.21) and kurtosis (+1.26) (Table 3.46). Standard deviation of the dataset depicted that the range of the data was low. Kurtosis value indicated the peakedness of the curve (Fig. 3.38a).

46% samples had fluoride concentration of <0.20 mg/l. It stretched over 41.46% of area spreading over the entire region. 0.20 mg/l to 0.40 mg/l fluoride concentration was found in 45 samples which covered 36.99% of the area. 0.41 to 0.60 mg/l of absorption was observed in 15.36% of the total area. 4.02% area with 4.76% samples had the content of 0.61 to 0.80 mg/l (Table 3.45). Spatially, higher fluoride concentration was observed as clusters in the entire study area. The concentration of >0.8 mg/l was noted in 6 samples spread over 2.16% of the total area. All water samples were under the permissible limit (1.5) set by BIS (1998) (Fig. 3.38b).

Amod Taluka, Bharuch District



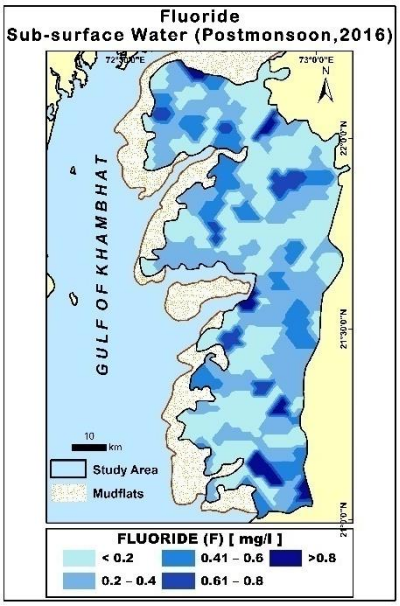


Fig.3.38 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.45 Fluoride (F) during Post-monsoon Season, 2016 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	69	46.94	1736.26	41.46
0.20-0.40	45	30.61	1549.31	36.99
0.41-0.60	20	13.61	643.25	15.36
0.61-0.80	7	4.76	168.44	4.02
>0.80	6	4.08	90.87	2.17
Total	**147**	**100**	**4188.15**	**100**

Source- Computed

Table 3.46 Descriptive Statistics of the Sub-surface Water Samples (Post-monsoon Season, 2016)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.67	8.55	7.51	.34	.30	.38
TDS	100.0	12500.0	1268.37	1465.92	4.70	29.46
Calcium (Ca)	24.6	300.0	100.44	79.12	1.58	1.46
Sodium (Na)	15.2	300.0	205.10	100.92	-.27	-1.63
Fluoride (F)	BDL	.98	.28	.21	1.21	1.26

Source- Computed

3.2.9 Pre-monsoon, 2017 (Surface Water)

3.2.9.1 pH Level:

The pH value of surface water ranged from 7.25 to 10.49 with an average of 8.61 indicating a considerably alkaline nature (Table 3.52). The standard deviation value was low (0.59). Both skewness and kurtosis recorded low positive values +0.14 and +0.04 respectively (Fig. 3.39a).

The spatial distribution of pH in surface water in the Bharuch-Surat industrial region is shown in Fig. 3.39b. pH in surface water was very high in the pre-monsoon season. >8 pH was noted in 87.17% area and in 83.20% samples depicting the alkaline nature which was largely observed in the northern half of the study area. Another alkaline belt was found towards the south-west of the region. Further south-central, there were several small patches noticed in the range of 7.51 to 8 value. This category had 13.74% of samples and was spread over 11.33% of the area. 7 to 7.5 pH was noted at Olpad and near the Hazira port. It was noted in 3% samples and 1.49% of the area. pH <7 was absent in this season (Table 3.47).

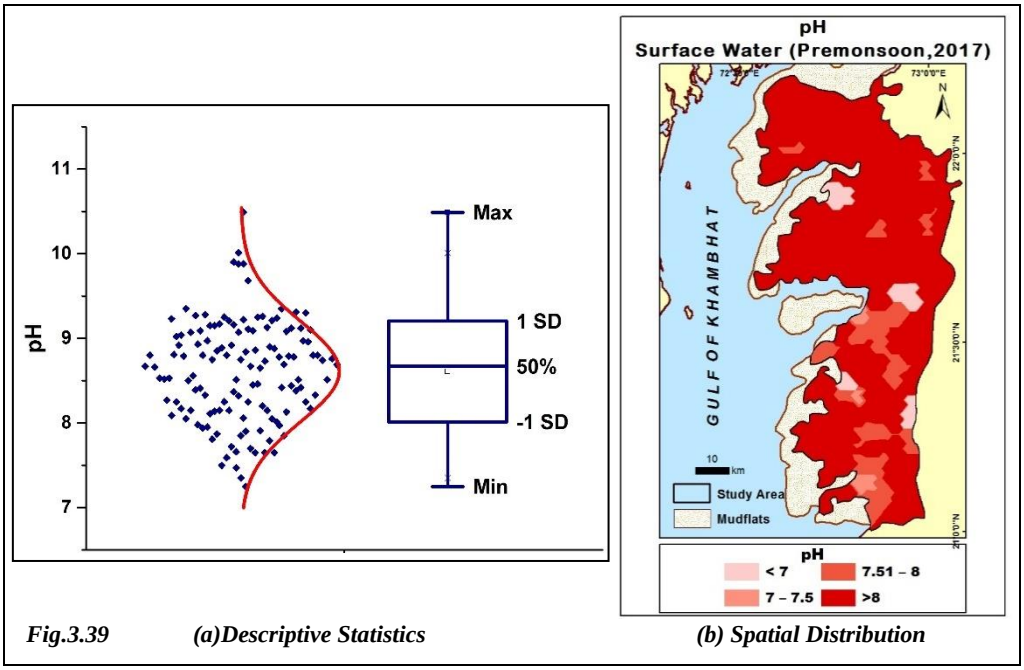


Fig.3.39 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.47 pH during Pre-monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
	No	**(%)**	**sq. km**	**(%)**
<7	0	0	0	0
7-7.5	4	3.05	62.53	1.49
7.51-8	18	13.74	474.71	11.34
>8	109	83.21	3650.58	87.17
Total	**131**	**100**	**4188.15**	**100**

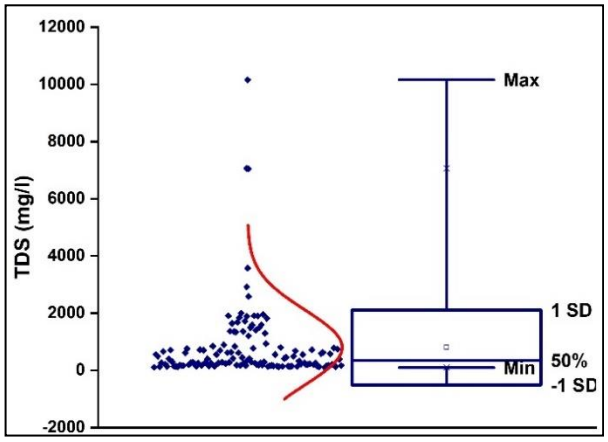
Source- Computed

3.2.9.2 Total Dissolved Solids (TDS):

TDS ranged from 95 mg/l to 7059.40 mg/l with a mean value being 734.56 mg/l and standard deviation being 1009.59 (Table 3.52). Skewness (+4.09) indicated asymmetric distribution and kurtosis (+21.99) denoted a high degree of peakedness with a steep slope (Fig. 3.40a).

In pre-monsoon season, <500 mg/l in the surface water covered the maximum area (60.18%) and samples (57.81%) distributed over entire the region. 24.22% of samples spread over 21.38% of the area had 500 mg/l to 1000 mg/l of TDS. Several patches were observed in the north-western and north-eastern parts (Fig. 3.40b). TDS between 1000.1 mg/l to 1500 mg/l was noted in 6.25% of samples and stretched over 8.20% of the area. The higher range of TDS (>1500 mg/l), was noted in 11.72% of samples and 10.25% area. They were observed at the villages of Ranada, Kurchan, Karela in Amod taluka and a few pockets of Vagra taluka (Table 3.48).

Ankleshwar Taluka, Bharuch District



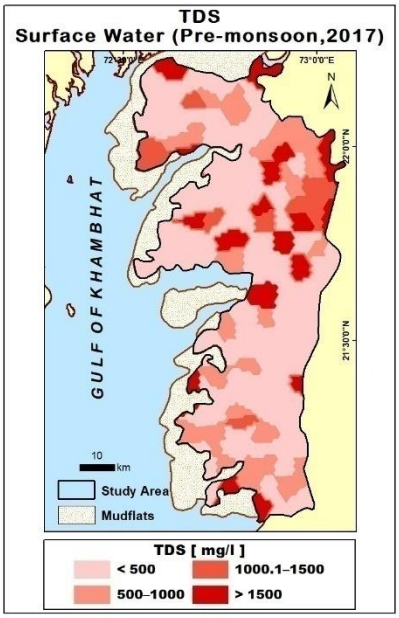


Fig.3.40 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.48 TDS during Pre-monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	74	57.81	2502.6	60.18
500-1000	31	24.22	888.99	21.38
1000.1-1500	8	6.25	340.92	8.2
>1500	15	11.72	426.24	10.25
Total	**131**	**100**	**4188.15**	**100**

Source- Computed

3.2.9.3 Calcium (Ca):

In this study, calcium concentration varied between 3.66 mg/l and 400 mg/l. The mean value of calcium was 58.19 mg/l and the standard deviation was 70.95 showing moderate deviation (Table 3.52). Skewness (+3.54) and kurtosis (+13.25) were positive during this pre-monsoon season in surface water (Fig. 3.41a).

Lowest calcium range <50 mg/l was observed in 64.84% samples and 65.85% area. 50 to 75 mg/l calcium content was spread over 15.61% area and the same percentage of samples. Both these ranges were under the desirable limit set by BIS (75 mg/l). However,

these categories were more prominent in the southern half (Table 3.49). The next category of 75.1 to 100 mg/l approximately had 11% of samples and covered 9%, particularly in the north-eastern part. 100.1 to 125 mg/l was noticed in 2.22% area and 2.34% of samples. A high concentration of calcium range (>125 mg/l) in surface water was seen in several pockets at the extreme western part of Jambusar, the center portion of Vagra and the western part of Ankleshwar talukas (Fig. 3.41a).

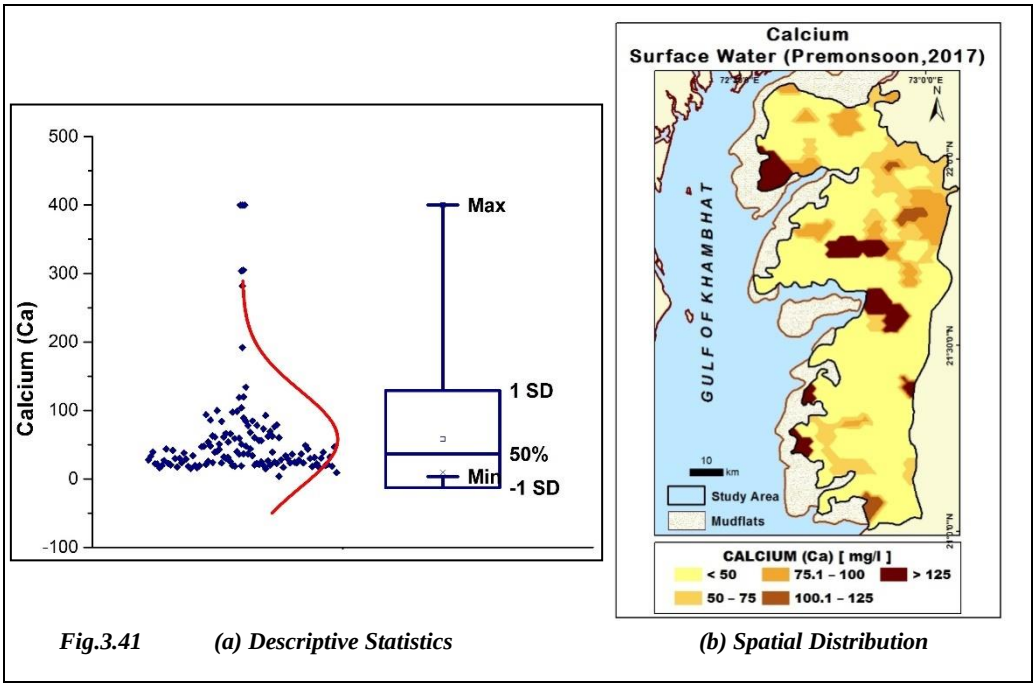


Fig.3.41 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.49 Calcium (Ca) during Pre-monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	83	64.84	2758	65.85
50-75	20	15.63	654	15.62
75.1-100	14	10.94	382	9.12
100.1-125	3	2.34	93	2.22
>125	8	6.25	301	7.19
Total	**128**	**100**	**4188.15**	**100**

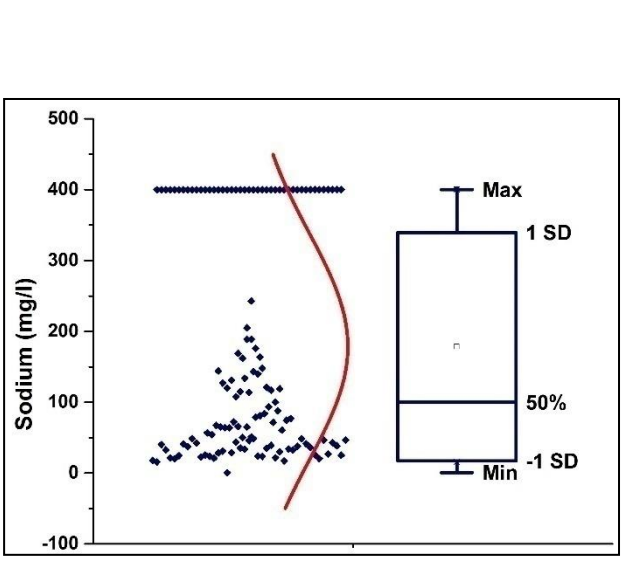
Source- Computed

3.2.9.4 Sodium (Na):

The range of Sodium absorption was 0.60 mg/l to 400 mg/l with a mean value of 178.53 mg/l and a standard deviation of 161.18 (Table 3.52). It indicated moderate variability

in the distribution. Kurtosis value was +0.55, while skewness was -1.54. It depicted the platykurtic distribution of the dataset (Fig. 3.42a).

The spatial distribution of sodium in surface water during the post-monsoon season is shown in Fig. 3.42b. 49.22% of the area had <100 mg/l with 45.27% of samples. It was more noticeable in the southern part. 10.93% samples covering 14.12% of the area had 100 to 150 mg/l of sodium content in surface water. This belt was found roughly parallel to the upper Narmada River basin. Of the remaining, 150.1 to 200 mg/l and 200.1 to 250 mg/l sodium concentrations had 4.69% and 1.56% samples spread over 6.65% and 4.06% area respectively.



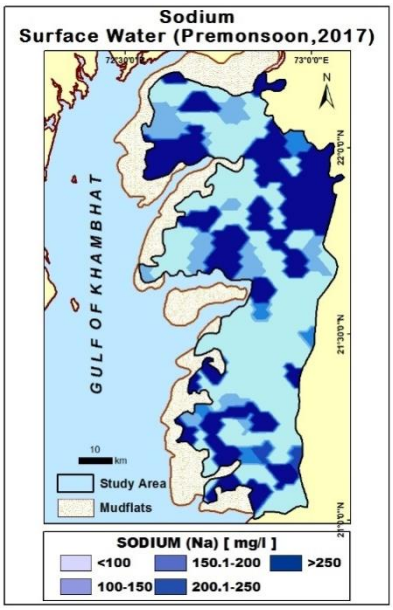


Fig.3.42 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.50 Sodium (Na) during Pre-monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	63	49.22	1896.02	45.27
100-150	14	10.94	591.64	14.13
150.1-200	6	4.69	278.84	6.66
200.1-250	2	1.56	170.07	4.06
>250	43	33.59	1251.25	29.88
Total	**128**	**100**	**4188.15**	**100**

Source- Computed

>250 mg/l concentration was found in 33.53% samples and it was spread over approximately 30% area. This concentration level was observed towards the central to north-western and north-eastern parts of the study area (Table 3.50).

3.2.9.5 Fluoride (F):

The average of the fluoride in this period was 0.87 mg/l and varied between Below Detectable Limit (BDL) to 2.81 mg/l (Fig. 3.43a). The standard deviation was 0.60 depicting a low range of variation in the dataset. Both skewness (+0.86) and kurtosis (+0.43) indicated positive values (Table 3.52).

Before the rains, the fluoride distribution map of the study area demonstrated that 81.68% of samples were under the permissible limit (1.5 mg/l) set by BIS whereas 18.32% of samples were in the non-permissible range (Fig. 3.43b). 0.78% samples had fluoride concentration of <0.20 mg/l. It was seen in several small pockets at the villages of Vasna, Cholad, Bhadbhut in Bharuch district and a few were in the south-eastern part of the study area. 0.20 mg/l to 0.40 mg/l fluoride concentration was found in 18% of samples which covered 13% of the total area. 14% samples covering 16% of the area had 0.41 to 0.6 mg/l of fluoride. 0.61 to 0.80 mg/l covered 18% of the area with 13.28% samples and was observed in the central part. 52% of samples had >0.81 mg/l spread over 50.24% of the area. This was observed over the entire study area in isolated patches (Table 3.51).

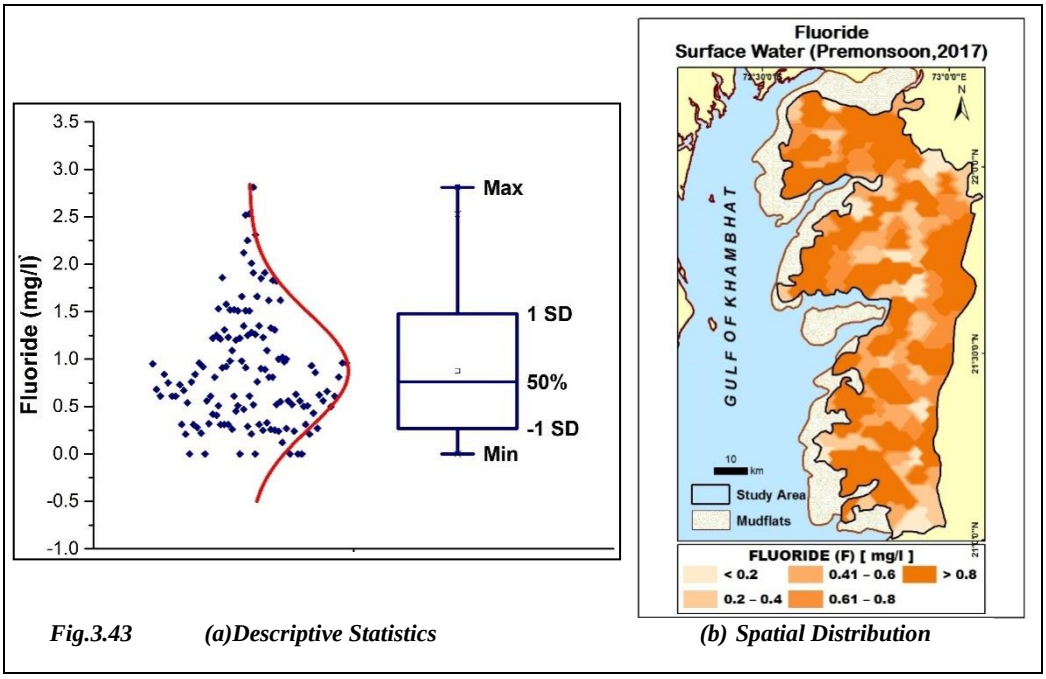


Fig.3.43 (a)Descriptive Statistics (b) Spatial Distribution

Table 3.51 Fluoride (F) during Pre-monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	1	0.78	239.25	5.71
0.20-0.40	23	17.97	543.47	12.98
0.41-0.60	20	15.63	581.65	13.89
0.61-0.80	17	13.28	719.44	17.18
>0.80	66	51.56	2104.33	50.25
Total		**100**	**4188.15**	**100**

Source- Computed

Table 3.52 Descriptive Statistics of the Surface Water Samples (Pre-monsoon Season, 2017)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	7.25	10.49	8.61	.59	.14	.04
TDS	95.0	7095.4	734.56	1009.59	4.09	21.99
Calcium (Ca)	3.7	400.0	58.19	70.95	3.54	13.25
Sodium (Na)	.6	400.0	178.53	161.18	-1.54	.55
Fluoride (F)	BDL	2.81	.87	.60	.86	.43

Source- Computed

3.2.10 Pre-monsoon, 2017 (Sub-surface Water)

3.2.10.1 pH Level:

In the pre-monsoon season, the level of pH varied between 6.05 to 9.45, indicating an acidic to alkaline nature (Table 3.58). The mean pH in sub-surface water was 7.92 depicting a normal condition and the standard deviation was 0.46. Skewness was negative (-0.16) and kurtosis showed a positive value (+2. 31) (Fig. 3.44a).

38.64% of samples had pH of >8 which covered 1517.4 sq. km of the total area. The western part of the region largely had >8 of the concentration and Vagra taluka in the Bharuch district specifically, had maximum level. 7.51 to 8 pH was observed in 46.21% samples which was spread over 48.78% area covering the entire study area. 12.88% samples had a concentration between 7 to 7.5 and it was spread over 12.14% area. It was observed in the southern part in the form of isolated pockets. pH of <7.5 was noted in 3 out of 132 samples. The lowest pH (6.05) value was noted in Amod taluka (Fig. 3.44b) (Table 3.53).

Table3.53 pH during Pre-monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
	No	(%)	sq. km	(%)
<7	3	2.27	119.12	2.84
7-7.5	17	12.88	508.59	12.14
7.51-8	61	46.21	2042.71	48.78
>8	51	38.64	1517.4	36.23
Total	**132**	**100**	**4188.15**	**100**

Source- Computed

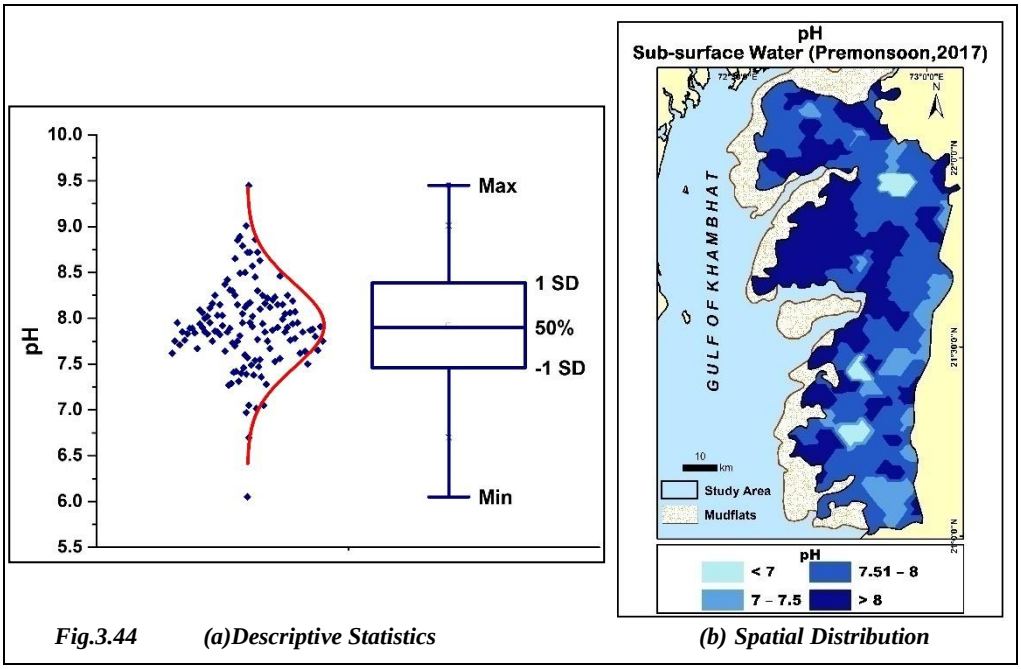


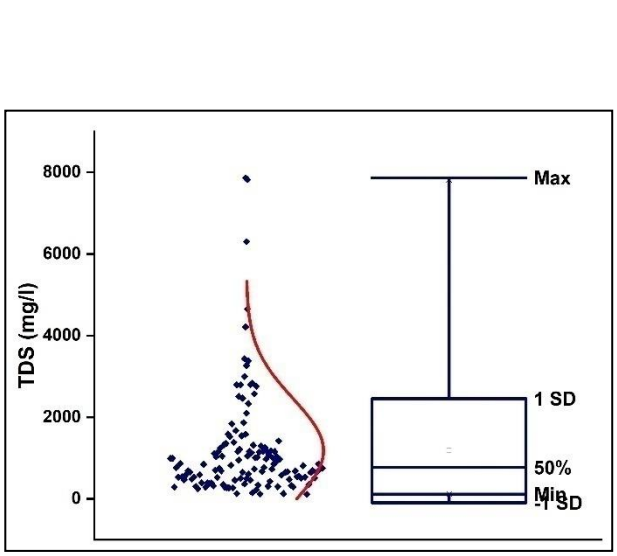
Fig.3.44 *(a)Descriptive Statistics* *(b) Spatial Distribution*

3.2.10.2 Total Dissolved Solids (TDS):

The values of TDS ranged from a minimum of 112.50 mg/l to a maximum of 7865.40 mg/l in the pre-monsoon season (Table 3.58). The mean value of the data was 1155.56 mg/l with the standard deviation value of 1263.02. The skewness and kurtosis values were +3.17 and +12.44 respectively, indicating positive skewness and leptokurtic characteristics of data (Fig. 3.45a).

TDS of >1500 mg/l was noted as a patch in the north-western part. This range of TDS was spread over Tankaria, Nada, Islampur, Devla, Khanpur and Kalak villages in Jambusar taluka. 20.45% of samples spread over 20.67% of area observed the concentration of 1000.1 to 1500 mg/l (Table 3.54). 34.09% of samples stretched over 34.13% of area observed 500 to

1000 mg/l TDS. They were observed in northern and southern parts as a small pocket. 25.76% samples covering the 26.23% of area had <500 mg/l of TDS in sub-surface water. This lower range was observed over the entire region except for in few pockets (Fig. 3.45b).



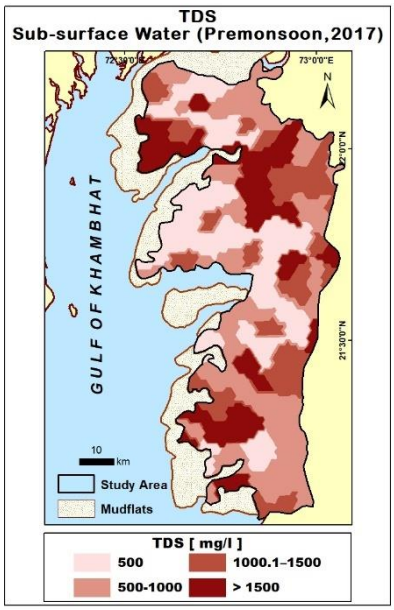


Fig.3.45 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.54 TDS during Pre-monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	34	25.76	1095.4	26.23
500-1000	45	34.09	1425.13	34.13
1000.1-1500	27	20.45	863.14	20.67
>1500	26	19.7	792.5	18.98
Total	**132**	**100**	**4188.15**	**100**

Source- Computed

3.2.10.3 Calcium (Ca):

In the study area, the concentration of calcium ranged from 15.50 to 420 mg/l. The mean was 74.31 mg/l (Table 3.58). Before the rains, the standard deviation was considerably high (85.37). Skewness and kurtosis both depicted positive and leptokurtic characteristics (+3.13 and +9.44 respectively) (Fig. 3.46a).

78.79% of samples had calcium concentrations above the BIS standard. 56.06% of samples had <50 mg/l calcium content which was spread over 51.77% of the area. They were distributed over the entire region. A slightly higher range of 50 to 75 mg/l was observed in a few segments which were more pronounced in Amod taluka (Bharuch district) and a long narrow tail was noted along the National Highway. 75.1 to 100 mg/l of calcium was observed in 6.06% of samples spreading over 4.20% of the area (Table 3.55). This range was noted in Dahej industrial region. In the remaining 16% of samples and area, both of them decreased with the increase in the range. In 6.06% samples and 12% samples, 100.1 to 125 mg/l and >125 mg/l of calcium was detected. Both ranges were observed in the form of patches in Jambusar, Amod, Vagra and Hansot talukas (Fig. 3.46a).

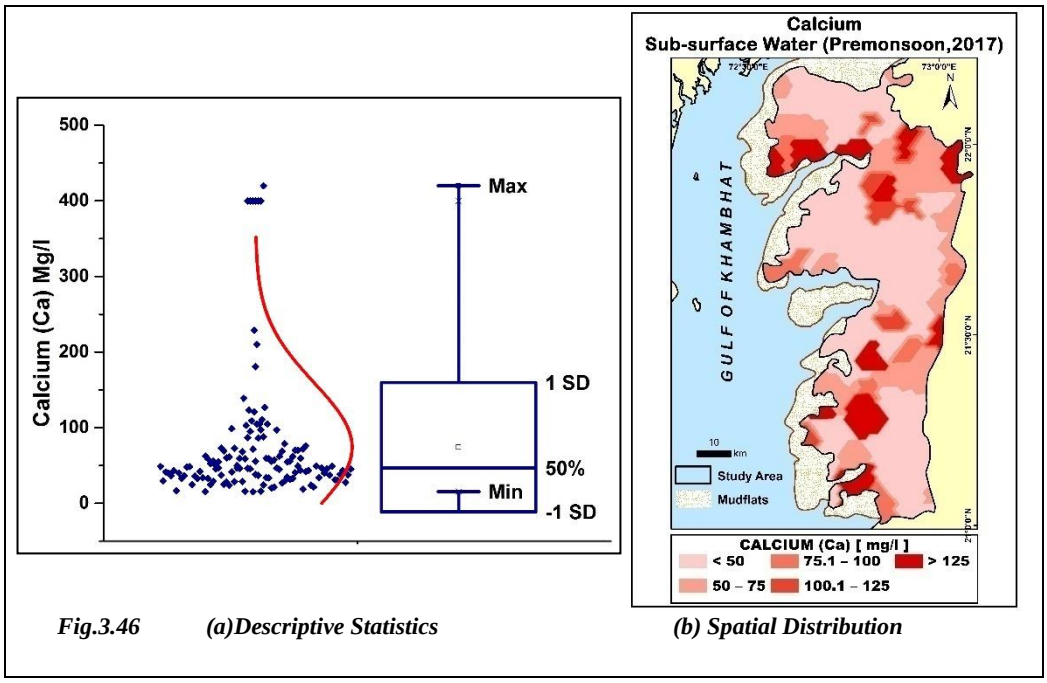


Fig.3.46 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.55 Calcium (Ca) during Pre-monsoon Season, 2017 (Sub-surface Water)

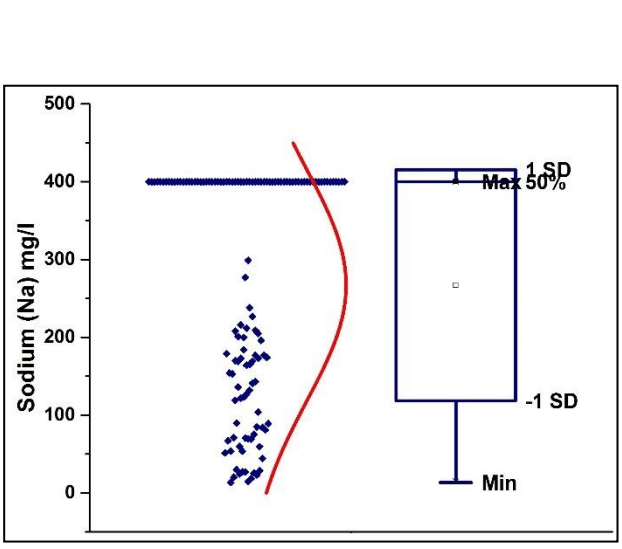
Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	74	56.06	2168.16	51.77
50-75	30	22.73	1061.65	25.35
75.1-100	8	6.06	352.42	8.42
100.1-125	8	6.06	175.73	4.2
>125	12	9.09	429.85	10.26
Total	**132**	**100**	**4188.15**	**100**

Source- Computed

3.2.10.4 Sodium (Na):

The range of sodium in pre-monsoon season varied between 13.40 and 400 mg/l with higher mean (267.00 mg/l) and standard deviation (148.47). Both skewness and kurtosis values were negative (-0.41 and -1.55 respectively) (Fig. 3.47a and Table 3.58).

The concentration of sodium in the sub-surface water was <100 mg/l in approximately 19% of the area and 21.37% of samples. They were observed in the Vagra, Bharuch and Ankelshwar talukas (Bharuch District) and Surat city. Basically, it was more prominent towards central to northern part. Sodium content of 100 to 150 mg/l was noted in 9 samples which were spread over 8.76% of area. This range was observed over entire the study area in isolated pockets. Higher concentration of sodium 150.1 to 200 mg/l was found in 15 samples covering 434.05 sq. km of area. The next category range (150.1 to 200 mg/l) was spread over 10.36% of area and this content was observed in only 15 samples (Fig.3.47b). 6.11% samples which were spread in 7.17% sq. km of area had the concentration of 200.1 to 250 mg/l. In 54.20% sub-surface water samples the sodium was >250 mg/l. They were spread over 55.13% area. This concentration was observed in two segments: one is northern part and southern part and another in central part in small pocket near the Dahej industrial belt (Table 3.56).



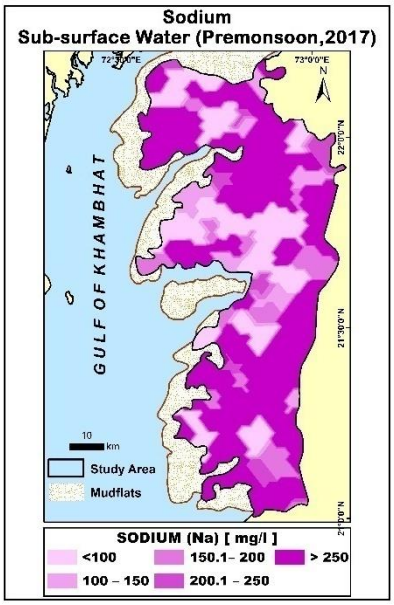


Fig.3.47 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.56 Sodium (Na) during Pre-monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	28	21.37	777.84	18.57
100-150	9	6.87	366.92	8.76
150.1-200	15	11.45	434.05	10.36
200.1-250	8	6.11	300.38	7.17
>250	71	54.2	2308.62	55.13
Total	**132**	**100**	**4188.15**	**100**

Source- Computed

3.2.10.5. Fluoride (F):

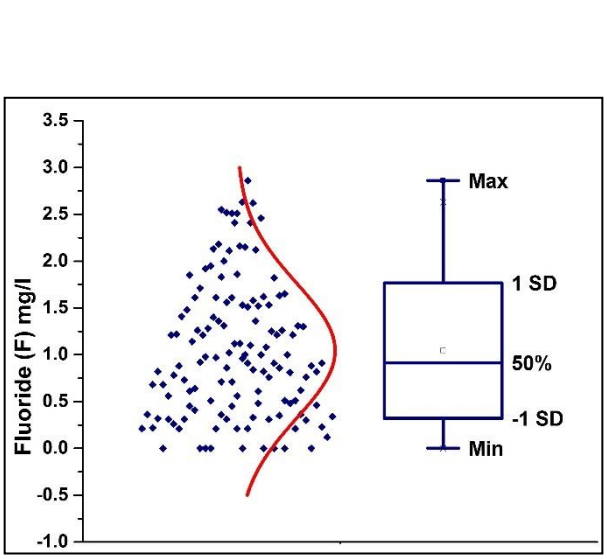
The concentration of fluoride varied between BDL to 2.86 mg/l. The average of fluoride was 1.04 mg/l and the standard deviation was 0.72. Skewness (+0.55) indicated a positively skewed distribution whereas kurtosis (-0.52) depicted a low degree of peakedness (Fig. 3.48a and Table 3.58).

8.40% samples had fluoride concentration of <0.20 mg/l. It was spread over the 6.76% area covering the entire region. 0.20 to 0.40 mg/l fluoride concentration was found in 20 samples which covered 13% of the total area. It was observed in northeastern part of the study area. 439 sq. km area with 11 samples had fluoride content between 0.41 to 0.60 mg/l. 9.16% samples which spread over 10.73% area had 0.61 to 0.80 mg/l of fluoride (Table 3.57). They were observed in isolated scattered pockets near Jambusar, Bharbhut, and Mangrol villages (Bharuch District). The element with >0.8 mg/l was observed in 60% samples and they were spread over almost the same percentage of area in industrial areas of Dahej, Vagra, Bharuch, Ankleshwar and Surat (Fig. 3.48b).

Table 3.57 Fluoride (F) during Pre-monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	11	8.33	283.06	6.76
0.20-0.40	20	15.15	544.57	13
0.41-0.60	11	8.33	438.98	10.48
0.61-0.80	12	9.16	449.39	10.73
>0.80	78	59.09	2472.15	59.03
Total	**132**	**100**	**4188.15**	**100**

Source- Computed



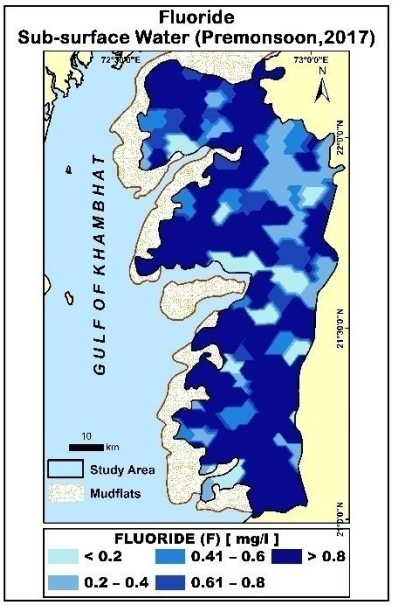


Fig.3.48 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.58 Descriptive Statistics of the Sub-surface Water Samples (Pre-monsoon Season, 2017)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	6.05	9.45	7.92	.46	-.16	2.31
TDS	112.5	7865.4	1155.56	1263.02	3.17	12.44
Calcium (Ca)	15.5	420.0	74.31	85.37	3.13	9.44
Sodium (Na)	13.4	400.0	267.00	148.47	-.41	-1.55
Fluoride (F)	BDL	2.86	1.04	.72	.55	-.52

Source- Computed

3.2.11 Monsoon, 2017 (Surface Water)

3.2.11.1 pH level:

During monsoon, the surface water was seen in normal to an alkaline condition. The pH value varied between 7.32 to 9.85 with a mean value was 8.49 and a low standard deviation of 0.54 indicating low spatial variability (Table 3.64). Skewness value was low (+0.18) and kurtosis indicated low negative value (-0.56) (Fig. 3.49a).

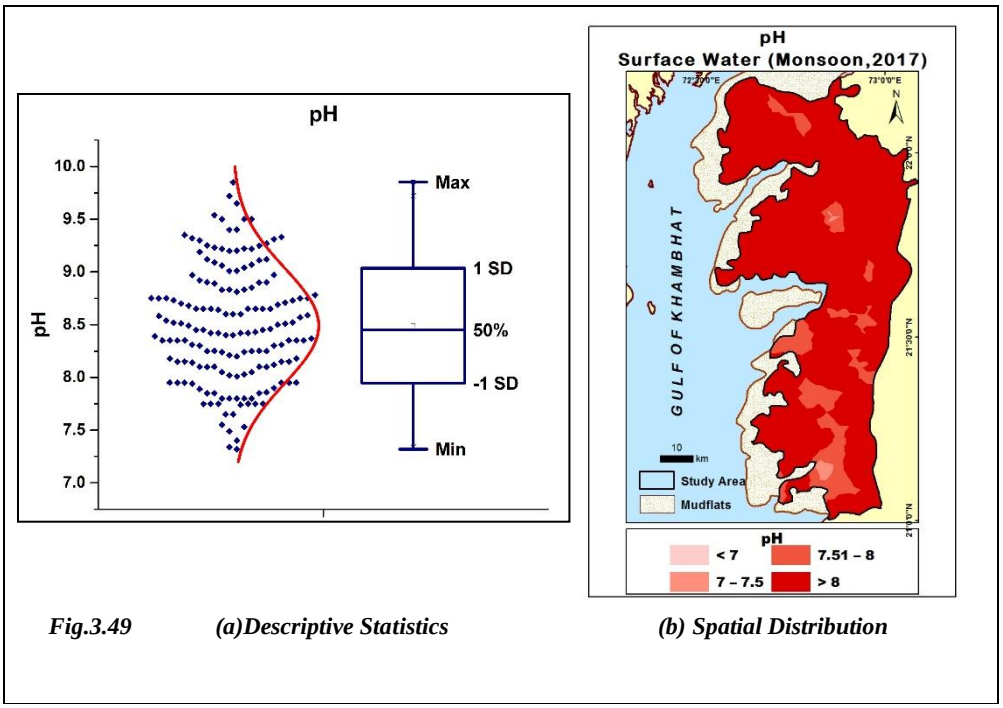


Fig.3.49 *(a)Descriptive Statistics* *(b) Spatial Distribution*

In the study area, the lowest pH value of 7.32 was observed at Pandeshwar industrial area and Obha village in Hansot taluka had the highest value of 9.85 (Fig. 3.49b). Most of the samples fell in the range of >8 pH and covered 85.12% area spread over the entire study area. However, 18.13% samples spread over 13.84% of the area had pH between 7.51 to 8. This was more pronounced in the southern part and in small pockets in the northern segment. 7 to 7.5 pH range stretched in 1.04% area covering 1.25% of samples. <7 pH was absent in this season (Table 3.59).

Table 3.59 pH during Monsoon Season, 2017 (Surface Water)

Range	**Samples**		**Area**	
	No	**(%)**	**sq. km**	**(%)**
<7	0	0	0	0
7-7.5	2	1.25	43.54	1.04
7.51-8	29	18.13	579.43	13.84
>8	129	80.63	3564.84	85.12
Total	**160**	**100**	**4188.15**	**100**

Source- Computed

3.2.11.2 Total Dissolved Solids (TDS):

TDS varied between 8.80 mg/l to 6549.20 mg/l with a mean of 507.13 mg/l and standard deviation of 830.83 (Table 3.64). Skewness and kurtosis values were +4.47 and +24.08 respectively. Both indicated higher values, the former was positively skewed and latter was depicted leptokurtic characteristics (Fig. 3.50a).

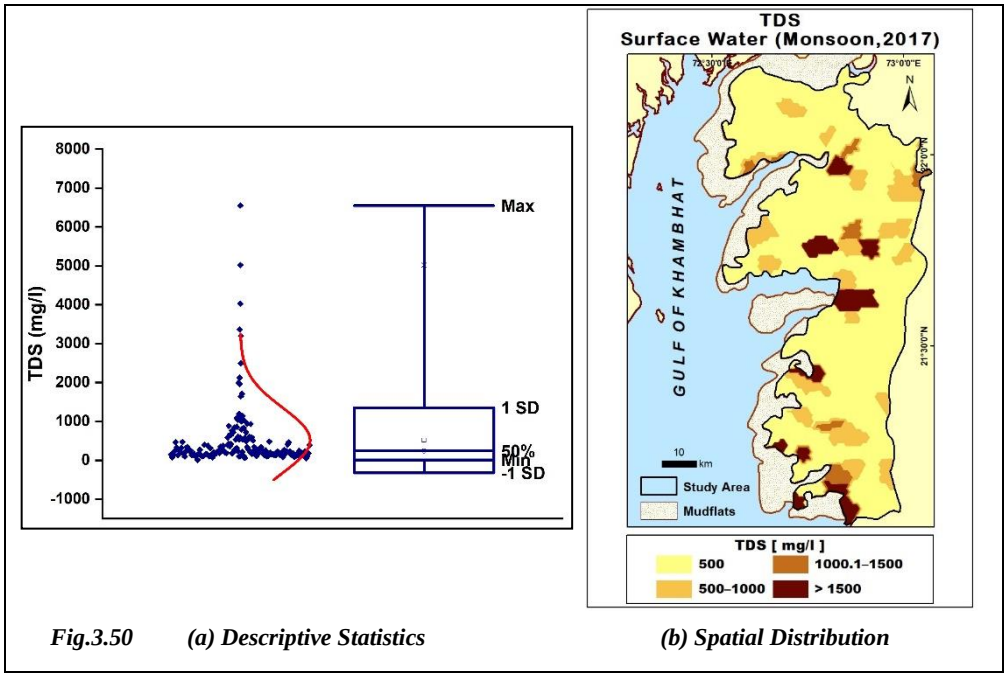


Fig.3.50 *(a) Descriptive Statistics* *(b) Spatial Distribution*

<500 mg/l of TDS was observed in 76.6% of the area and 74.38% of sub-surface water samples. This range of TDS was found over the entire region. 14.38% of samples had a little higher range of 500 to 1000 mg/l which covered 14.34% of the area and was seen in pockets in Amod, Vagra and Olpad talukas. In the next category (1000.1 to 1500 mg/l), only 4.38% of samples and 3.43% of the area was observed (Fig. 3.50b). This range was restricted to only a few talukas such as Bharuch, Vagra, Kamrej and Olpad. The higher TDS (>1500 mg/l) was noted in isolated pockets in the central part of the study area, and also, few patches were seen in the southern portion (Table 3.60).

Table 3.60 TDS during Monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	119	74.38	3207.95	76.6
500-1000	23	14.38	600.59	14.34
1000.1-1500	7	4.38	143.71	3.43
>1500	11	6.88	232.19	5.54
Total	**160**	**100**	**4188.15**	**100**

Source- Computed

3.2.11.3 Calcium (Ca):

Calcium in the study area ranged between 15.80 to 120 mg/l. The average value was 66.60 mg/l and the standard deviation was 23.81. Both skewness (-0.007) and kurtosis (-0.67) recorded low negative values (Table 3.64 and Fig. 3.51a).

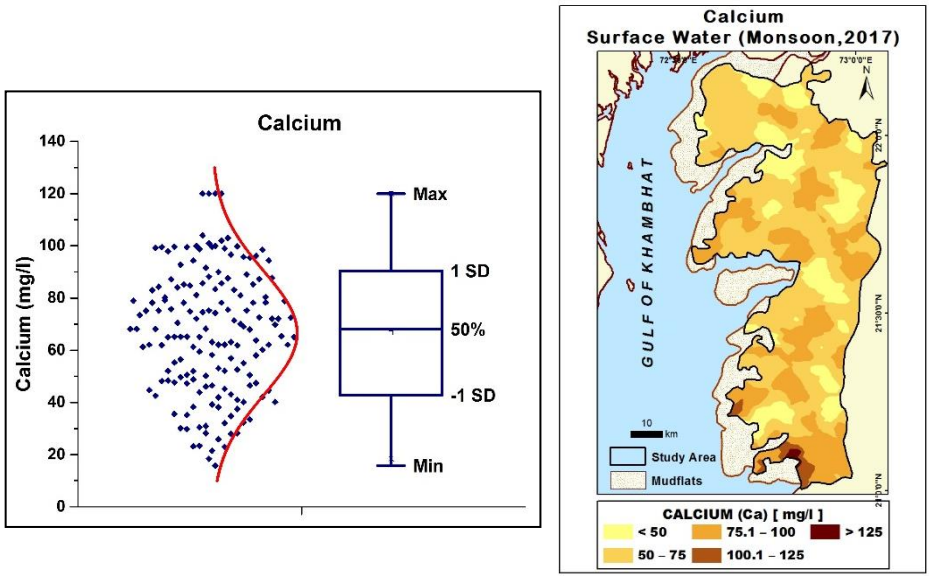


Fig.3.51 *(a)Descriptive Statistics* *(b) Spatial Distribution*

The calcium concentration in the surface water during the monsoon season of 2017 was below the desirable limit (75 mg/l) in 60.37% of the samples. They were noted in the major portion of the study area (63.84%) and remaining samples 39.62% samples covering 36.15% area were under the permissible limit (Table 3.61). It was found in several patches all

over the region. The lowest amount of calcium was noted at Ikhar village in Jambusar taluka and the highest was observed near Sachin industrial belt (Fig. 3.51b).

Table 3.61 Calcium (Ca) during Monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	42	26.42	934.913	22.32
50-75	54	33.96	1738.93	41.52
75.1-100	55	34.59	1312.76	31.35
100.1-125	8	5.03	201.22	4.8
>125	0	0	0	0
Total	**159**	**100**	**4188.15**	**100**

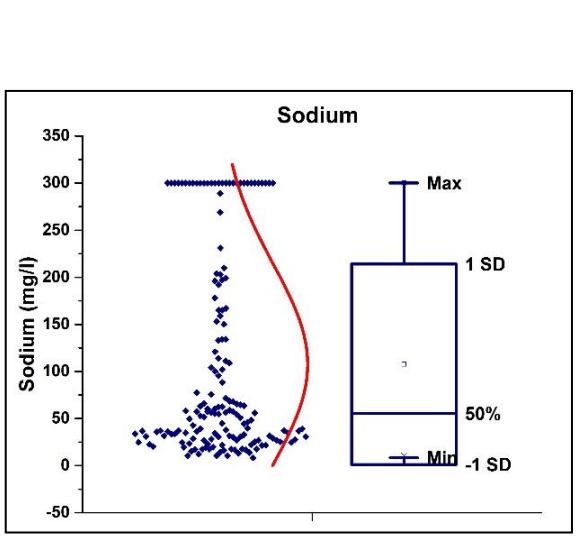
Source- Computed

3.2.11.4 Sodium (Na):

The concentration of sodium ranged between 8.30 to 300 mg/l with a mean value of 107.59 mg/l and standard deviation of 106.37 indicating moderate deviation from the mean. Kurtosis was negative (-0.68) and skewness (+0.99) was positively skewed (Fig. 3.52a and Table 3.64).

<65% samples had the sodium concentration of <100 mg/l. It extended over 63.75% area and was spread over the entire region. 15.09% of the total samples had sodium between 100 to 250 mg/l (Table 3.62). They were found as isolated pockets scattered over the entire region. 20.13% of the samples had concentration of >250 mg/l. The pockets were seen in the northern, central as well as southern segment. The lowest content of sodium was recorded at Sigam villages while Kapuria village had the highest level of sodium (Fig. 3.52b).

Surat City, Surat District



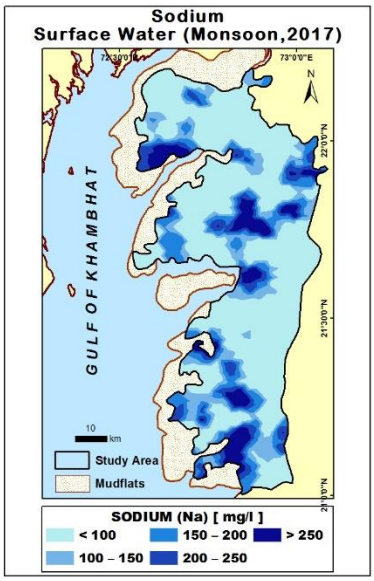


Fig.3.52 (a) Descriptive Statistics *(b) Spatial Distribution*

Table 3.62 Sodium (Na) during Monsoon Season, 2017 (Surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	103	64.78	2669.63	63.75
100-150	10	6.29	364.57	8.71
150.1-200	10	6.29	285.98	6.83
200.1-250	4	2.52	200.42	4.79
>250	32	20.13	667.22	15.93
Total	**159**	**100**	**4188.15**	**100**

Source- Computed

3.2.11.5 Fluoride (F):

The average of fluoride was 0.52 mg/l. It varied from Below Detection Level (BDL) to 1.65 mg/l with a standard deviation of 0.34. Moreover, the low value of standard deviation indicated that data was less spread out. The skewness value was +0.50 indicating asymmetric condition and low kurtosis value of -0.22 indicated platykurtic distribution of the data (Fig. 3.53a and Table 3.64).

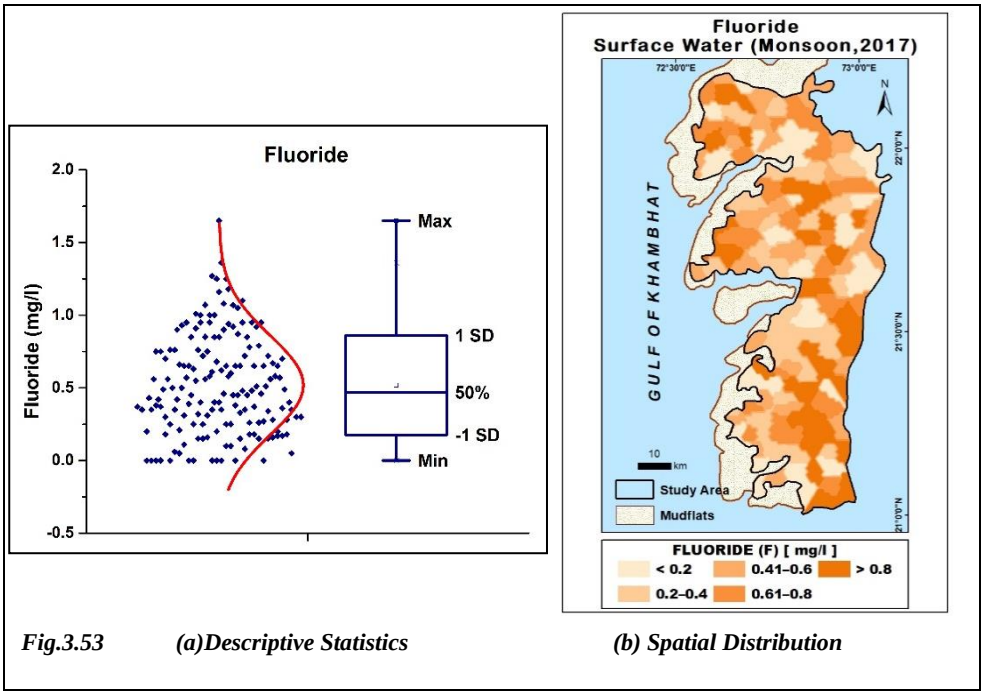


Fig.3.53 *(a)Descriptive Statistics* *(b) Spatial Distribution*

The content of this element during the rains was low. 9.25% of samples were under the permissible limit and 1 sample was over the limit of BIS. In >90% samples that covered the same percentage of area, the concentration was within the permissible limits. The spatial pattern was broken and no long stretches were observed. 22.01% samples spreading over 16.08% area had a content of <0.20 mg/l. 23.27% samples had 0.20 to 0.40 mg/l of fluoride. It was spread over 23.08% area (Table 3.63). The concentration of 0.41 to 0.60 mg/l was noted in 17.61% samples and was spread over 22.29% area. Approximately, 17% samples had a concentration of 0.60 to 0.80 mg/l and 19.24% area had this amount of the element. 20.13% of samples had >0.80 mg/l of fluoride and it was observed in 19.32% area (Fig. 3.53b).

Table 3.63 Fluoride (F) during Monsoon Season, 2017 (Surface Water)

Range	**Samples**		**Area**	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<0.20	35	22.01	673.49	16.08
0.20-0.40	37	23.27	966.45	23.08
0.41-0.60	28	17.61	933.57	22.29
0.61-0.80	27	16.98	805.58	19.24
>0.80	32	20.13	809.05	19.32
Total	**159**	**100**	**4188.15**	**100**

Source- Computed

Table 3.64 Descriptive Statistics of the Surface Water Samples (Monsoon Season, 2017)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	7.32	9.85	8.49	.54	.18	-.56
TDS	8.8	6549.2	507.13	830.83	4.47	24.08
Calcium (Ca)	15.8	120.0	66.60	23.81	-.01	-.67
Sodium (Na)	8.3	300.0	107.59	106.37	.99	-.68
Fluoride (F)	BDL	1.69	.52	.34	.50	-.22

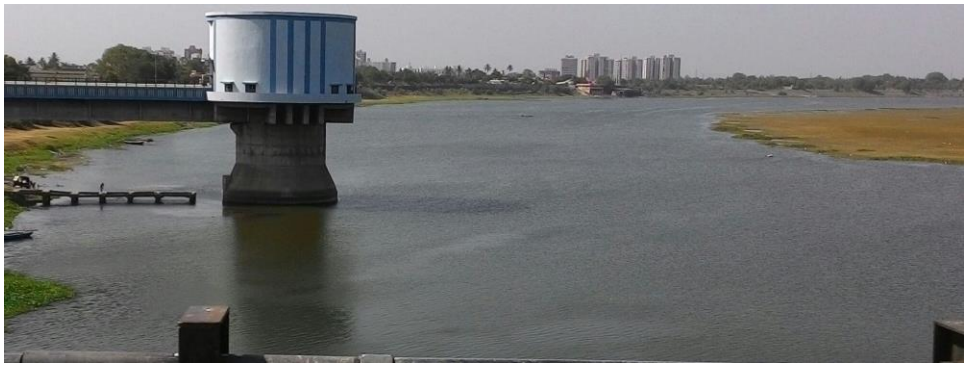
Source- Computed

3.2.12 Monsoon, 2017 (Sub-surface Water)

3.2.12.1 pH Level:

During monsoon 2017, pH values in the study area varied from 7.04 to 9.04 and depicted a normal to alkaline nature. The standard deviation value was 0.39 and the mean value was 7.97, showing the neutral condition. A negative value of kurtosis (-0.02) was noted whereas skewness (+0.44) observed a little positive value. Skewness was denoted normal distribution of the data (Fig. 3.54a and Table 3.70).

The level of pH >8 was noted in 41.54% of the samples and was spread over a 40.51% area. The alkaline nature was more pronounced towards the central to northern portion and the southern part had scattered small pockets (Fig. 3.54b). 7.51 to 8 pH value was noted in 48.46% samples which stretched over 48.70% of the area. 10% samples spread over almost same percentage of the area was witnessed in the range of 7 to 7.5 pH and was found in the Olpad and Ankleshwar talukas, near Bharuch city and near Jambusar town in isolated patches. At no place <7 pH was noted (Table 3.65).



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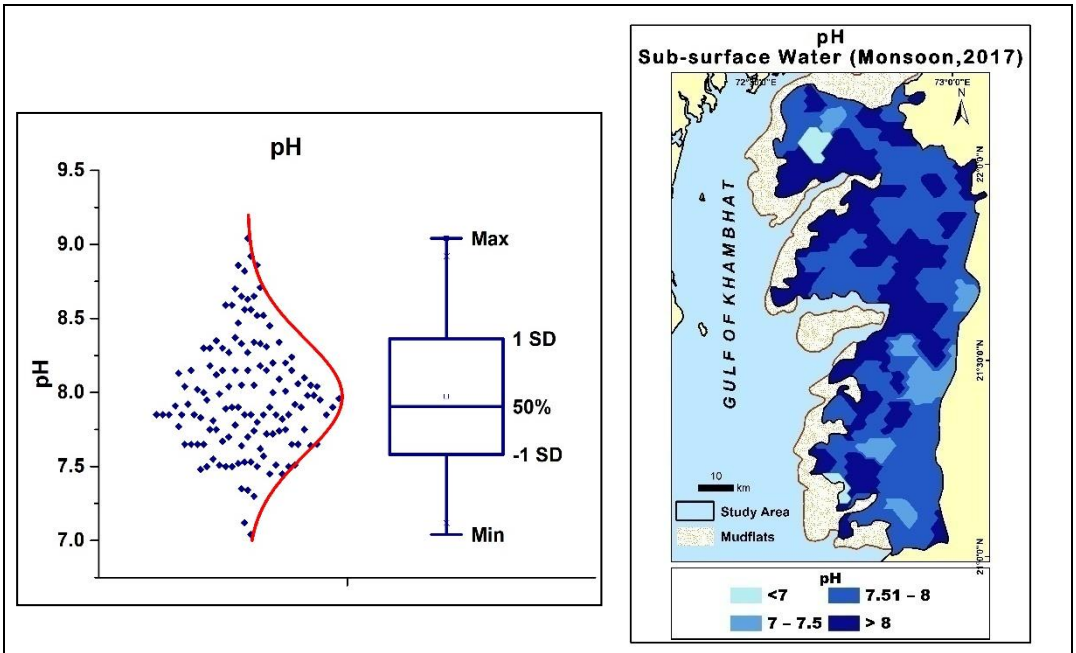


Fig.3.54 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.65 pH during Monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
	No	(%)	sq. km	(%)
<7	0	0	0	0
7-7.5	13	10	451.93	10.79
7.51-8	63	48.46	2039.26	48.7
>8	54	41.54	1696.62	40.51
Total	**130**	**100**	**4188.15**	**100**

Source- Computed

3.2.12.2 Total Dissolved Solids (TDS):

The TDS ranged between 56.50 mg/l and 7211.10 mg/l with a mean and standard deviation of 999.82 mg/l and 909.84 respectively (Table 3.70). Skewness and kurtosis showed very high and positive values of +3.44 and +18.42 respectively. The value of kurtosis showed a high degree of peakedness, depicting leptokurtic distribution, explaining high standard deviation and positive skewness with a steep slope (Fig. 3.55a).

In terms of spatial pattern, the concentration of TDS >1500 mg/l in the sub-surface water comprised of 16.69% area and 17.97% of samples which was prominent in the

northern half of the study area (Table 3.66). 33.59% of samples spread over a 35.06% area witnessed between 500 to 1000 mg/l of TDS. 1000.1 to 1500 mg/l was noted in 22.66% of the samples and they were spread over 20.77% of the area. This range of the element was observed at Rodh, Shrikothi, Badalpura, Pahej and Hinglot villages in Bharuch district and near Jothan and Khajod villages (Surat district). TDS level of <500 mg/l was observed in 25.78% of samples which stretched over 26.62% of the total area. They were found in the western part of Jambusar taluka, central part of Vagra and western part of Olpad taluka. The highest TDS values were recorded at Islampore village in Jambusar taluka (Fig. 3.55b).

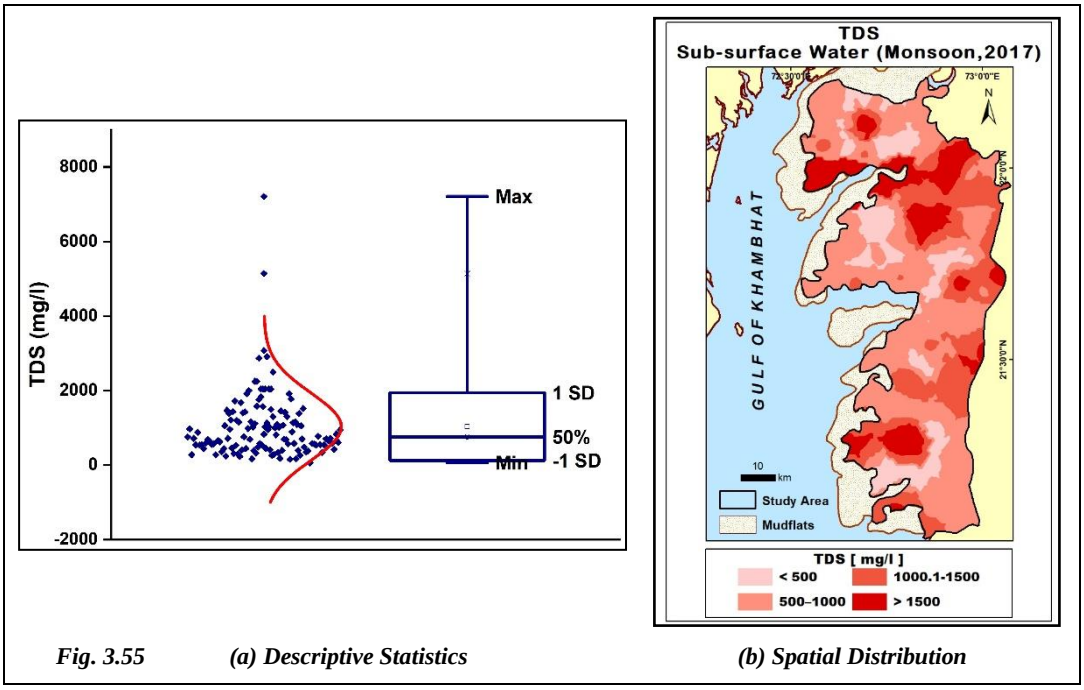


Fig. 3.55 *(a) Descriptive Statistics* *(b) Spatial Distribution*

Table 3.66 TDS during Monsoon Season, 2017 (Sub-surface Water)

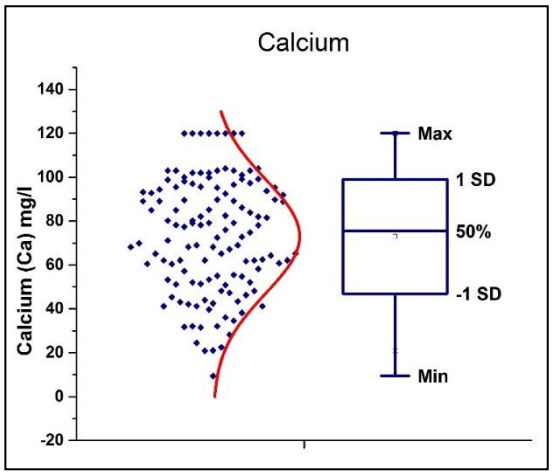
Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<500	33	25.78	1114.91	26.62
500-1000	43	33.59	1468.45	35.06
1000.1-1500	29	22.66	869.84	20.77
>1500	23	17.97	699.07	16.69
Total	**130**	**100**	**4188.15**	**100**

Source- Computed

3.2.12.3 Calcium (Ca):

During monsoon season, the concentration of calcium ranged between 9.40 mg/l to 120 mg/l (Table 3.70). The mean concentration was 73.05 mg/l while the standard deviation was 26.07. Skewness (-0.17) and kurtosis (-0.73) both observed showed low negative values in the dataset (Fig. 3.56a).

17.59% area had calcium concentration of <50 mg/l and 21.09% samples were noted in this category. They were seen at Vagra, Juned, Sayakha, Anor, Vaipor and Tham in (Jambusar and Vagra talukas in Bharuch district) and few pockets near Olpad and along the River Tapi. Further, 50 to 75 mg/l was noticed in 28.91% samples and covered 34.27% area (Table 3.67). Both the categories were under the permissible limit set by BIS. However, they were distributed over entire the study area. 35.16% samples spread over 35.93% area had 75.1 to 100 mg/l of this element. 100.1 to 125 mg/l element was noticed towards the centre to the northern part of the study area. They were spread over 12.21% area and had 14.84% samples. A high content of calcium (>125 mg/l) was not noted in this season (Fig. 3.56b).



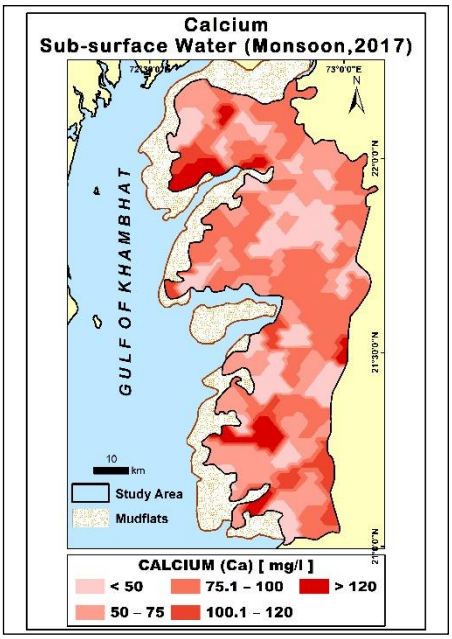


Fig.3.56 (a)Descriptive Statistics *(b) Spatial Distribution*

Table 3.67 Calcium (Ca) during Monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<50	27	21.09	736.5	17.59
50-75	37	28.91	1435.31	34.27
75.1-100	45	35.16	1504.49	35.93
100.1-125	19	14.84	511.49	12.21
>125	0	0	0	0
Total	**128**	**100**	**4188.15**	**100**

Source- Computed

3.2.12.4 Sodium (Na):

In the monsoon season, the concentration of sodium varied between 12.5 to 305 mg/1. The mean value was 220.89 mg/l whereas the standard deviation was 104.14, explaining relatively high variation in the level of concentration. Skewness and kurtosis both were low (-0.84 and -0.99 respectively). The dataset was negatively skewed while the kurtosis value was low, indicating the platykurtic distribution (Fig. 3.a and Table 3.70).

During the monsoon season, 53.41% area had >250 mg/l concentration in 59.38% of samples (Table 3.68). 200.1 to 250 mg/l sodium was noted in 7.03% samples which was spread over 10.71% area. They were seen at villages of Devla, Kavi, Vavli, Kesrol and also at Ankleshwar city (Bharuch district) and Kadarma and Niyol villages in Surat district. 4.69% samples covering 8.06% of the area had 150.1 mg/ to 200 mg/l of sodium content in sub-surface water. 10.21% area with 7.03% samples had sodium content between 100 to 150 mg/l range. This range was found near Muler, Ambhel and Pipalia villages in Jambusar taluka and in a few patches in the southern part of the study area. <100 mg/l category of sodium content was noted in 21.88% samples which was spread over 17.61% of the total area and were observed in isolated (Fig. 3.57b).

Kamrej Taluka, Surat District

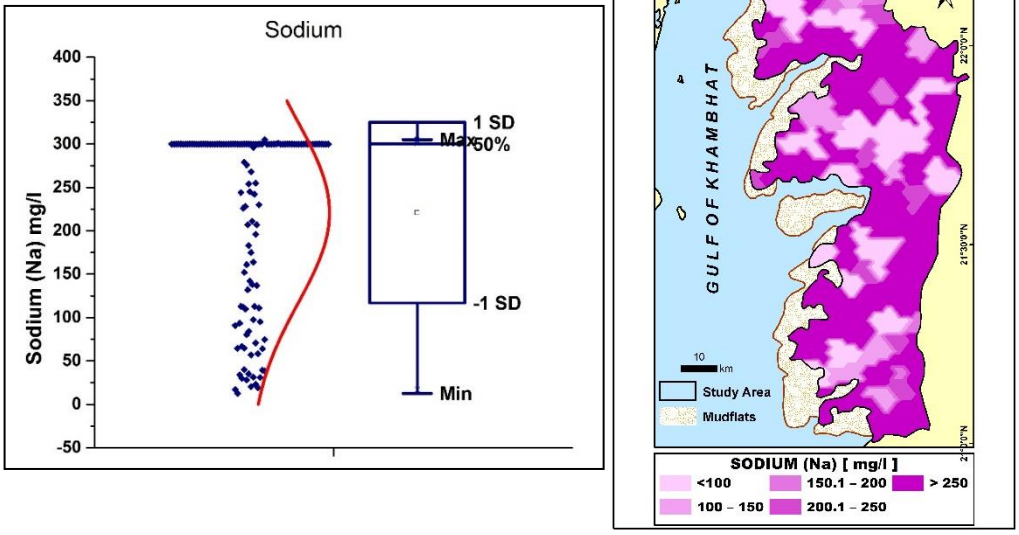


Fig.3.57 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.68 Sodium (Na) during Monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
mg/l	**No**	**(%)**	**sq. km**	**(%)**
<100	28	21.88	737.58	17.61
100-150	9	7.03	427.39	10.21
150.1-200	6	4.69	337.47	8.06
200.1-250	9	7.03	448.48	10.71
>250	76	59.38	2236.89	53.41
Total	**128**	**100**	**4188.15**	**100**

Source- Computed

3.2.12.5 Fluoride (F):

The Fluoride in this period varied between Below Detection Level (BDL) to 2.56 mg/l with the average value of 0.43 mg/l and standard deviation of 0.46 (Table 3.70). Skewness and kurtosis also indicated positive and high values in the dataset. Former was +2.11 while later was +6.28 (Fig. 3.58a).

In sub-surface water during monsoon season, <0.2 mg/l content of fluoride was found in 35.16% samples which covered 31.77% of area. 0.20 to 0.40 mg/l was relatively more

prominent in the central part. This concentration was noted in 21.09% of samples and was spread over 25.97% area. 20.31% of samples covering 20.51% of area had 0.41 to 0.60 mg/l fluoride concentration which was found near river Narmada belt. Other patches were noted in the northern side at Jambusar taluka (Table 3.69). The next category, (0.61 to 0.80 mg/l) was observed in 13.28% samples covering 10.71% area. It was largely observed at the southern portion of the study area. >0.80 mg/l was noted in 12.50% samples and encompassed 11.04% of area. It was found in isolated pockets at Surat city, Ankleshwar city and villages of Antoroli, Northan and Vadod in Kamrej taluka (Surat district) (Fig. 3.58b).

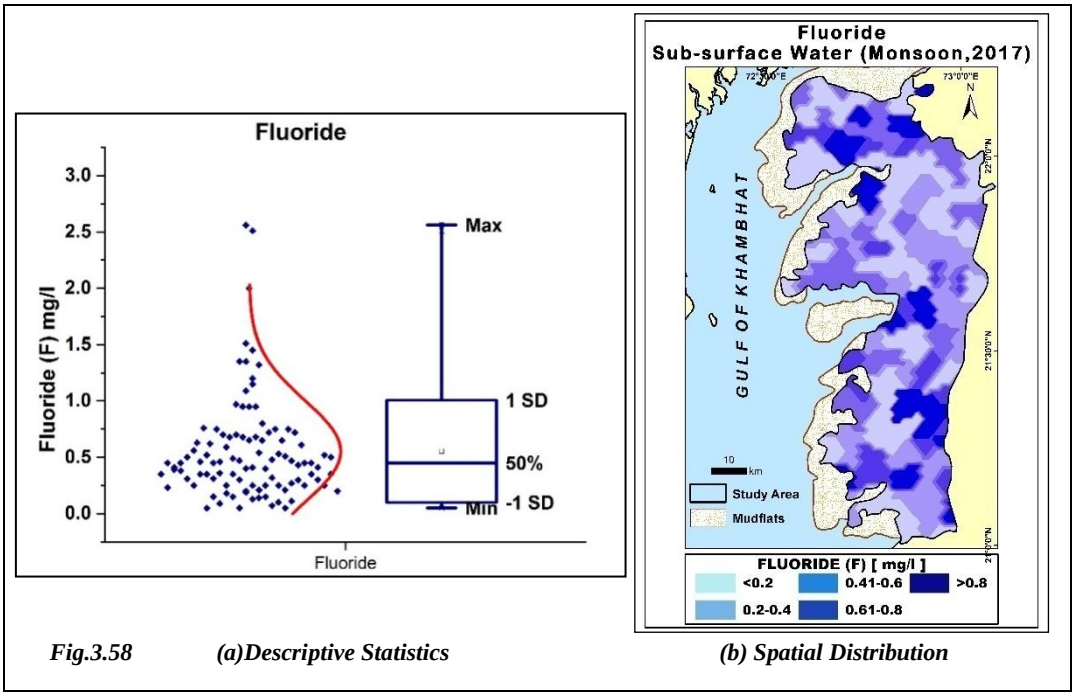


Fig.3.58 *(a)Descriptive Statistics* *(b) Spatial Distribution*

Table 3.69 Fluoride (F) during Monsoon Season, 2017 (Sub-surface Water)

Range	Samples		Area	
	No	(%)	sq. km	(%)
<0.20	45	35.16	1330.53	31.77
0.20-0.40	27	21.09	1087.62	25.97
0.41-0.60	26	20.31	858.96	20.51
0.61-0.80	17	13.28	448.53	10.71
>0.80	16	12.5	462.36	11.04
Total	**128**	**100**	**4188.15**	**100**

Source- Computed

Table 3.70 Descriptive Statistics of the Sub-surface Water Samples (Monsoon Season, 2017)

Parameters in mg/l, except pH	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
pH	7.04	9.04	7.97	.39	.44	-.02
TDS	56.5	7211.1	999.82	909.84	3.44	18.42
Calcium (Ca)	9.4	120.0	73.05	26.07	-.17	-.73
Sodium (Na)	12.5	305.0	220.89	104.14	-.84	-.99
Fluoride (F)	BDL	2.56	.43	.46	2.11	6.28

Source- Computed

3.3 Seasonal Variability:

"t"-test:

A 't-test' is a statistical test that compares two groups of means (Wang & Liu, 2016). In this research, 't-test' was used for hypothesis testing which was performed in SPSS version-22 software.

Hypothesis:

1. There is no significant seasonal variation in the physicochemical parameters of surface and sub-surface water.

2. There is significant seasonal variation in the physicochemical parameters of the surface and sub-surface water.

3.3.1 Surface Water:

On 180 samples, a pair t-test was calculated at a 95% significant level for the pre-monsoon, monsoon, and post-monsoon seasons. The 't-test results indicated a changing trend in the mean of parameters throughout the seasons. To conduct the analysis, three pairs were generated for each parameter.

a) pH:

The computed 't' value was greater than the 't' statistics of pairings 1p, 2p, and 3p, which were 2.18, 4.201, and 3.566, respectively. As a result, the null hypothesis was rejected, whereas the alternative hypothesis was accepted.

b) TDS:

The ‘t’ statistics for TDS was (0.625, and 0.269) and was smaller than the table value which indicated ‘no significant change’ in the seasons of Post-monsoon (2015-16) and Pre-monsoon (2016-17) whereas pair 1p “Monsoon (2016-17) and Post-monsoon (2016-17)” was higher than the table value (-3.312) which denoted that significant variation was observed in this season. Thus, null hypothesis was rejected.

c) Calcium (Ca):

The calculated 't' value (6.44 and 5.7) was greater than the tabulated 't' value for pair 2 and pair 3. As a result, the null hypothesis was rejected. In the instance of pair 1, however, the estimated 't' value (1.51) was less than the table value. It showed no significant difference in calcium concentrations during the post-monsoon (2015-16) and pre-monsoon (2016-17) seasons. As a result, the null hypothesis can be accepted.

d) Sodium (Na):

The estimated 't' value for the pairs was -0.752, 0.413, and 0.382, which was less than the tabulated value, indicating no significant change in sodium concentration between seasons. As a result, the null hypothesis was accepted for all of the seasons.

e) Fluoride (F):

The ‘t’ statistics for “Pre-monsoon (2016-17) and Monsoon (2016-17)” season indicated that the table value (-2.929) was higher than the table value. Thus, null hypothesis was accepted for all the seasons.

3.3.2 Sub-surface Water

On 158 samples, the pair t-test was calculated at 95% significant level for pre-monsoon, monsoon, and post-monsoon seasons.

a) pH:

The ‘t’ statistics of pair 2p and pair 3p wase 3.07 and -3.07, respectively, which exceeded the 't' value. Hence, null hypothesis was rejected and the alternative hypothesis was accepted while pair 1p was 0.298 which indicated that null hypothesis was accepted.

b) TDS:

The calculated ‘t’ value of 1p was higher than the tabulated value 3.07. Thus, null hypothesis was rejected and it can be concluded that there was significant change in the concentration of TDS in “Post-monsoon (2015-16) and Pre-monsoon (2016-170)” seasons. While in case of pair 2p and 3p the calculated ‘t’ value (1.91 and -1.91) was smaller than the table value. It indicated no significant change in the concentration of TDS in “Pre-monsoon (2016-170) and Monsoon (2016-17) seasons”. Thus, null hypothesis can be accepted.

Table 3.71 Paired ‘t’ Statistics

Parameters	Seasons Combination (Surface Water)	t	df	Sig. (2-tailed)
pH	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	2.18	360	0.03
pH	Pre-Monsoon (2016-17) and Monsoon (2016-17)	-4.201	360	.00
pH	Monsoon (2016-17) and Post-monsoon (2015-16)	3.566	360	.00
TDS	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	**0.625**	360	0.180
TDS	Pre-Monsoon (2016-17) and Monsoon (2016-17)	**0.269**	360	0.007
TDS	Monsoon (2016-17) and Post-monsoon (2015-16)	-3.312	360	0.001
Calcium	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	**1.51**	360	0.138
Calcium	Pre-Monsoon (2016-17) and Monsoon (2016-17)	6.44	360	.00
Calcium	Monsoon (2016-17) and Post-monsoon (2015-16)	5.7	360	.00
Sodium	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	**-0.752**	360	0.453
Sodium	Pre-Monsoon (2016-17) and Monsoon (2016-17)	**0.413**	360	0.68
Sodium	Monsoon (2016-17) and Post-monsoon (2015-16)	**0.382**	360	0.702
Fluoride	Pre-Monsoon (2016-17) and Monsoon (2016-17)	-2.929	323	-0.099

Source- Computed

c) Calcium (Ca):

The computed 't' value (-5.063 and 5.333) was larger than the tabulated 't' value for pair 2 and pair 3. As a result, the null hypothesis was rejected. In the instance of pair 1, however, the estimated 't' value (1.27) was less than the table value. It found no significant difference in calcium concentrations during the post-monsoon (2015-16) and pre-monsoon (2016-17) seasons. As a result, the null hypothesis can be accepted.

d) Sodium (Na):

The 't' statistics of all the pairs (-5.08, 2.555 and 2.679) of sodium were greater than the table value denoting the change in the concentration of sodium in the different seasons.

e) Fluoride (F):

The 't' statistics for "Pre-monsoon (2016-17) and Monsoon (2016-17)" season indicated that the 't' value (4.373) was higher than the table value. Thus, null hypothesis was accepted for all the seasons.

Table 3.72 Paired 't' Statistics

Parameters	Seasons Combination (Sub-surface Water)	t	df	Sig. (2-tailed)
pH	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	**0.298**	316	0.766
pH	Pre-Monsoon (2016-17) and Monsoon (2016-17)	3.07	316	0.002
pH	Monsoon (2016-17) and Post-monsoon (2015-16)	-3.07	316	0.002
TDS	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	3.07	316	0.002
TDS	Pre-Monsoon (2016-17) and Monsoon (2016-17)	1.915	316	0.056
TDS	Monsoon (2016-17) and Post-monsoon (2015-16)	-1.915	316	0.056
Calcium	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	**1.27**	316	0.205
Calcium	Pre-Monsoon (2016-17) and Monsoon (2016-17)	-5.063	316	.00
Calcium	Monsoon (2016-17) and Post-monsoon (2015-16)	5.333	316	.00
Sodium	Post-monsoon (2015-16) and Pre-monsoon (2016-17)	-5.08	316	.00
Sodium	Pre-Monsoon (2016-17) and Monsoon (2016-17)	2.555	316	0.011
Sodium	Monsoon (2016-17) and Post-monsoon (2015-16)	2.679	316	0.008
Fluoride	Pre-Monsoon (2016-17) and Monsoon (2016-17)	4.373	316	.00

Source- Computed

Resume:

In the present chapter, various hydrochemical parameters such as pH, TDS, Calcium (Ca), Sodium (Na) and Fluoride (F) were analysed in pre-monsoon, monsoon and post-monsoon seasons of surface and sub-surface water. More concentration of pH, Sodium, TDS and Calcium were noted nearer to industrial belt and adjacent to Tapi and Narmada rivers.

During monsoon period concentration level of all the parameters significantly decreased. The next chapter will focus upon the Water Quality Index (WQI).

Reference:

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Wang, M., & Liu, G. (2016). A Simple Two-Sample Bayesian t-Test for Hypothesis Testing. *American Statistician*, *70*(2), 195–201. https://doi.org/10.1080/00031305.2015.1093027