Chapter 4

RESULTS AND DISCUSSIONS

Detailed discussions of our research findings have been included in this chapter.

4.1 Soil Quality

Little public information is available on soil quality in the tea garden belt of Darrang district of Assam, India. Given the current state of knowledge, a descriptive study was undertaken to monitor various soil quality parameters in the area. In this study, the tools for data analysis are mainly experimental, aimed at defining possible relationships, trends, or interactions among the measured variables of interest. To look into the trend and distribution patterns of the studied soil quality parameters, data were exposed to several statistical treatments like Mean, Variance (V), Standard Deviation (SD), Standard Error (SE), Median, Range, Confidential Limit (CL) at 95%, and Percentile at 25%, 50%, and 75%. One population t-test (t) is performed for all soil quality parameters under the null hypothesis (H_0) by taking assumption that the experimental chemical soil quality data are consistent with the standard rating given by the chemical ranking chart of Indian Council of Agricultural Research (I.C.A.R., 2005).

4.1.1 Soil Texture

Soil texture refers to the relative proportion of sand, silt and clay size particles in a sample of soil. Of soil characteristics, texture is one of the most important and effects many properties like structure, chemistry, and most notably, soil porosity, and permeability. It also influences many other properties of great significance to land use and management. Soils in and around the tea gardens of Darrang district, Assam are found to be hard setting and often characterized by fine-textured, tough subsoil with high clay contents. By use of textural triangle classification of U.S. Department of Agriculture's Soil Survey Staff, 1960, the soil texture in the study area is classified as clay. With the increase in the relative percentages of clay particles, the properties of soils in our study area are increasingly affected. Soil hydraulic property (bulk density) for selected textural classes is calculated by using standard equations (Saxton *et al.*, 1986). Bulk density decreases with clay content and is considered as a measure of the porosity and compaction of a soil. Sandy soils have relatively high bulk density since total pore space in sands is less than that of silt or clay soils. Ideally, medium textured soil with about 50 percent pore space will have bulk density of $1.33g/cm^3$. The bulk density of soil inside and outside the tea gardens of our study area is $1.097gm/cm^3$ and $1.027gm/cm^3$ respectively. Root development is generally decreased in soils with bulk density greater than 1.2 $gmcm^{-3}$ (Webb and Wilson, 1995). The soils of our study area, thus, have low permeability and the decrease in soil porosity mean plant roots are often physically impeded by compact subsoil layers and lack of available nutrients and/or water. When soils are as fine-textured as clayey as in our study area, they are likely to exhibit properties which are somewhat difficult to manage or overcome. Soils in and around the tea gardens of our study area are often too sticky when wet and too hard when dry to cultivate.

The experimental results of soil texture are presented in Tables 4.1 and 4.2.

Table 4.1: Soil Texture inside the tea gardens of Darrang district, Assam

Sample No.	Sand %	Silt %	Clay %	Sample No	Sand %	Silt %	Clay %
A1	25.00	7.00	67.00	D1	36.00	13.00	50.00
A2	26.50	6.00	65.50	D2	39.50	11.50	47.00
A3	29.50	8.00	61.50	D3	34.50	12.50	53.50
B1	32.50	8.00	58.00	E1	36.00	10.00	53.50
B2	29.50	7.50	62.00	E2	38.50	13.00	48.50
B3	28.50	6.00	64.50	E3	32.50	15.00	50.50
C1	28.00	11.00	60.00	F1	31.50	11.00	57.50
C2	22.50	12.50	63.00	F2	40.50	12.00	46.50
C3	32.50	10.00	56.50	F3	35.50	12.50	51.50

Table 4.2: Soil Texture outside the tea gardens of Darrang district, Assam

Sample No.	Sand %	Silt %	Clay %	Sample No	Sand %	Silt %	Clay %
A11	26.50	6.50	66.50	D11	22.50	6.50	66.50
A12	28.50	9.00	62.00	D12	23.00	9.00	65.00
B11	35.50	10.00	52.00	E11	25.00	10.00	58.50
B12	37.00	7.50	53.50	E12	26.50	7.50	59.50
C11	31.00	7.50	59.50	F11	31.50	7.50	61.00
C12	25.00	11.50	62.50	F12	41.50	11.50	49.50

4.1.2 Electrical Conductance (EC)

Measurement of soil electrical conductivity gives an indication of the total concentration of soluble salts in the soil. The term soluble salts refer to the inorganic soil constituents that are dissolved in the soil water. The soluble salts found in soil predominantly consist of calcium, magnesium, sodium, chloride and sulphate. The experimental results of EC in the study area are presented in Tables 4.3 and 4.4. Various statistical estimates derived from NDA are summarized in Table 4.5. Figure 4.1 gives the variation of EC among different sampling stations in the area.

Table 4.3: Electrical Conductance of the soil samples inside the tea gardens.

Sample No.	EC (mmho cm^{-1})	Sample No.	EC (mmho cm^{-1})
A1	1.600	D1	0.560
A2	1.201	D2	0.580
A3	1.00	D3	1.55
B1	1.200	E1	0.440
B2	0.094	E2	0.480
B3	0.991	E3	0.346
C1	6.600	F1	0.332
C2	4.690	F2	0.112
C3	3.271	F3	0.212

Table 4.4: Electrical Conductance of the soil samples outside the tea gardens

Sample No.	EC (mmho cm^{-1})	Sample No.	EC (mmho cm^{-1})
A11	0.364	D11	0.412
A12	0.802	D12	1.121
B11	1.601	E11	0.402
B12	0.132	E12	0.781
C11	1.402	F11	0.362
C12	0.904	F12	0.222

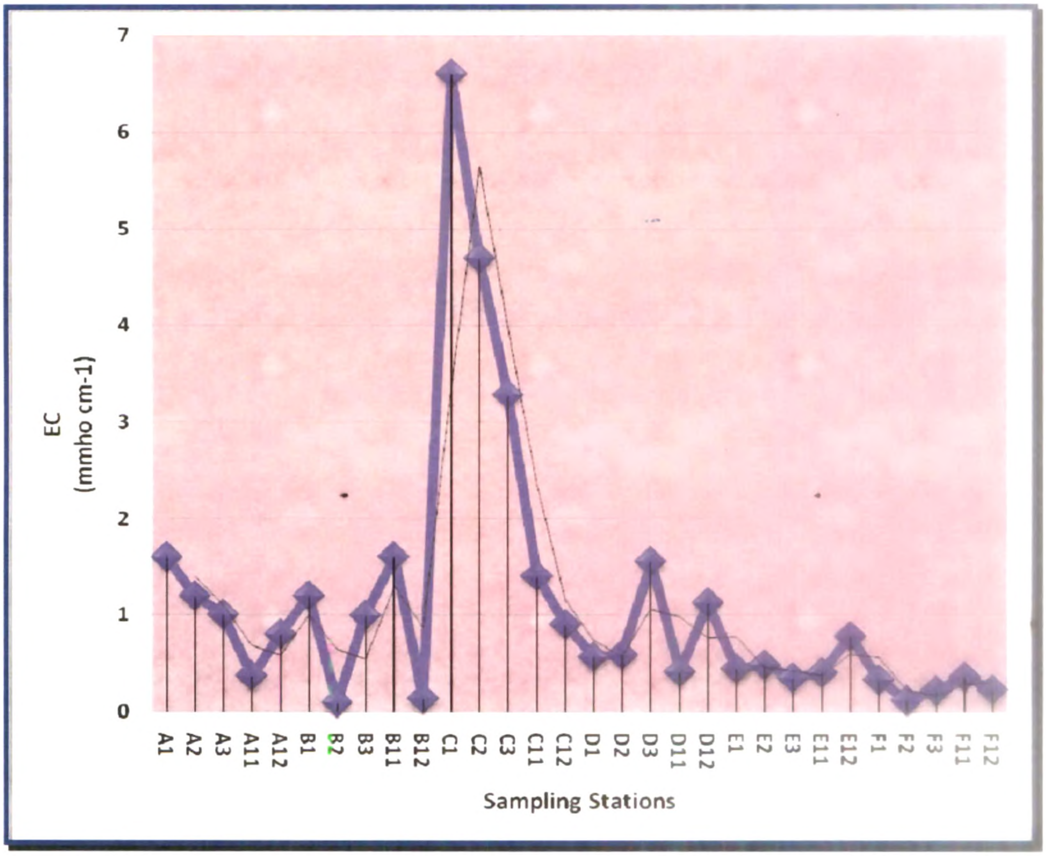

Figure 4.1: Variation of EC among soil sampling stations

Table 4.5: Statistical analysis for Electrical Conductance of soil

Descriptive Statistics		Inside	Outside
Mean		1.403	0.709
Std. Error of Mean		0.412	0.137
Median		0.786	0.597
Mode		0.094	0.132
Std. Deviation		1.749	0.476
Variance		3.059	0.226
Skewness		2.113	0.686
Std. Error of Skewness		0.536	0.637
Kurtosis		4.189	-0.627
Std. Error of Kurtosis		1.038	1.232
Range		6.506	1.469
Minimum		0.094	0.132
Maximum		6.600	1.601
Sum		25.259	8.505
Confidence Limit	Lower Bound	0.713	0.406
	Upper Bound	3.177	1.011
Percentiles	25	0.343	0.363
	50	0.786	0.597
	75	1.563	1.067
Inter Quartile Range		2.171	0.704
ICAR Rating		>0.1 (mmho cm^{-1}) (low)	
t		3.161	4.433
Comment		Significant	Significant

It has also been noticed that EC of our study area has potential to cause specific ion toxicity or upset the nutritional balance in soil. The highest E.C, recorded 6.600 mmho/cm at sampling point, C1. The width of the third quartile is consistently greater than twice the second quartile inside as well as outside soil samples, which for a symmetric distribution should be equal. The width of quartiles for EC in the study zone represents a long asymmetric tail. The t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area. However, one way ANOVA analysis at 0.05 level ($F = 1.78442$, $p = 0.19236$) suggests that the mean pH inside and outside tea gardens are not significantly different.

4.1.3 Soil pH

Soil pH is a good indicator for possible nutrient problems. Acid soils have a pH of less than 5.6 and usually below pH 5.0. Soils in the range 5.6 to 6.0 are moderately acidic and below 5.5 are strongly acidic in nature (ICAR, 2005). The experimental results of pH distribution in the study area are presented in Tables 4.6 and 4.7 Various statistical estimates derived from NDA are summarized in Table 4.8. Figure 4.2 gives the variation of pH among different sampling stations in the area.

Table 4.6: Values for pH of the soil samples outside the tea gardens.

Sample No.	pH	Sample No.	pH
A11	5.13	D11	5.15
A12	5.40	D12	5.20
B11	4.79	E11	5.05
B12	4.88	E12	5.20
C11	5.03	F11	4.89
C12	5.70	F12	5.11

Table 4.7: Values for pH of the soil samples inside the tea gardens

Sample No.	pH	Sample No.	pH
A1	4.01	D1	4.55
A2	4.00	D2	4.38
A3	4.5	D3	4.36
B1	4.99	E1	4.77
B2	4.98	E2	4.72
B3	5.1	E3	4.12
C1	4.55	F1	5.1
C2	4.9	F2	4.91
C3	4.8	F3	5.3

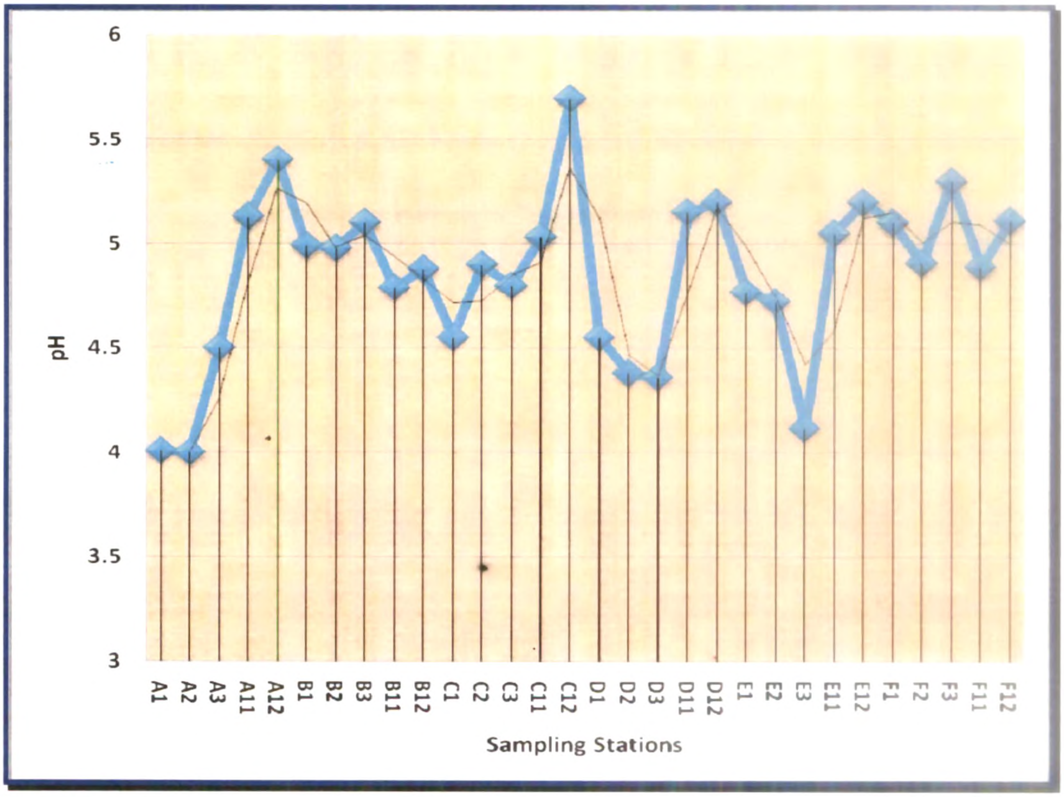

Figure 4.2 Variation of pH among different soil sampling stations

Table 4.8: Statistical analysis for pH of soil

Descriptive Statistics		Inside	Outside
Mean		4.67	5.13
Std. Error of Mean		0.09	0.07
Median		4.75	5.12
Mode		4.55	5.20
Std. Deviation		0.39	0.25
Variance		0.15	0.06
Skewness		-0.36	1.04
Std. Error of Skewness		0.54	0.64
Kurtosis		-0.77	1.78
Std. Error of Kurtosis		1.04	1.23
Range		1.30	0.91
Minimum		4.00	4.79
Maximum		5.30	5.70
Sum		84.04	61.53
Confidence Limit	Lower Bound	4.36	4.97
	Upper Bound	4.83	5.28
Percentiles	25	4.38	4.93
	50	4.75	5.12
	75	4.98	5.20
Inter Quartile Range		0.60	0.28
ICAR Rating		6.0-8.5 (Normal)	
t		-14.639	-12.335
Comment		Significant	Significant

Significant negative skewness and kurtosis value for pH inside tea gardens indicates a flat distribution with a long tail on the left of the median. However, the distribution pattern of pH outside the tea gardens is sharp with a long right tail. The soil in the area was found to be significantly acidic in nature with a mean value of 4.67 inside the tea gardens. The lowest pH recorded 4.00 at A2 and 4.79 at B11, inside and outside the tea gardens respectively. The factors like constant addition of chemicals to the soil along with excessive rainfall results in severe acidity build up in the soil system and affect the nutrient uptake of the tea plantation. Since soil is biodynamic, variation of soil pH in the study area may either result in non availability of nutrients in the available form to the plant or excessive availability of a particular nutrient, resulting in unbalanced growth of the plant or starvation of a particular nutrient. t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area. One way ANOVA analysis at 0.05 level ($F = 13.29028$, $p = 0.00108$) also suggests that the mean pH inside and outside tea gardens are significantly different.

4.1.4 Organic Carbon

Total carbon provides a measure of the organic matter content of soil. The concept of "soil quality" has recognized soil organic matter as an important attribute that has a great deal of control on many of the key soil functions (Doran, J.W., Parkin, T.B., 1994.). The soil samples of the area are found to contain high percentage of soil carbon. The highest organic carbon recorded to be 3.520 at F3 inside tea garden and 2.80 at sampling point F11 outside tea garden. The experimental results of % C distribution in the study area are presented in Tables 4.9 and 4.10. Various statistical estimates derived from NDA are summarized in Table 4.11. Figure 4.3 gives the variation of % C among different sampling stations in the area.

Table 4.9: Values for % Organic carbon of the soil samples inside the tea gardens.

Sample No.	%C	Sample No.	%C
A1	0.86	D1	3.52
A2	1.17	D2	2.04
A3	2.02	D3	1.52
B1	2.43	E1	2.26
B2	1.92	E2	1.88
B3	0.87	E3	1.77
C1	2.9	F1	1.92
C2	1.77	F2	1.77
C3	1.62	F3	3.52

Table 4.10: Values for % Organic carbon of the soil samples outside the tea gardens.

Sample No.	%C	Sample No.	%C
A11	2.03	D11	0.78
A12	1.92	D12	2.39
B11	1.89	E11	1.71
B12	2.39	E12	1.16
C11	1.21	F11	2.80
C12	0.98	F12	1.17

Table 4.11: Statistical analysis for % Organic carbon of soil

Descriptive Statistics		Inside	Outside
Mean		1.987	1.703
Std. Error of Mean		0.176	0.185
Median		1.900	1.800
Mode		1.770	2.390
Std. Deviation		0.748	0.642
Variance		0.560	0.412
Skewness		0.714	0.178
Std. Error of Skewness		0.536	0.637
Kurtosis		0.536	-1.124
Std. Error of Kurtosis		1.038	1.232
Range		2.660	2.020
Minimum		0.860	0.780
Maximum		3.520	2.80
Sum		35.759	20.430
Confidence Limit	Lower Bound	1.385	1.295
	Upper Bound	2.388	2.110
Percentiles	25	1.60	1.16
	50	1.90	1.80
	75	2.30	2.30
Inter Quartile Range		1.074	1.137
ICAR Rating		0.75	
t		7.0156	5.140
Comment		Significant	Significant

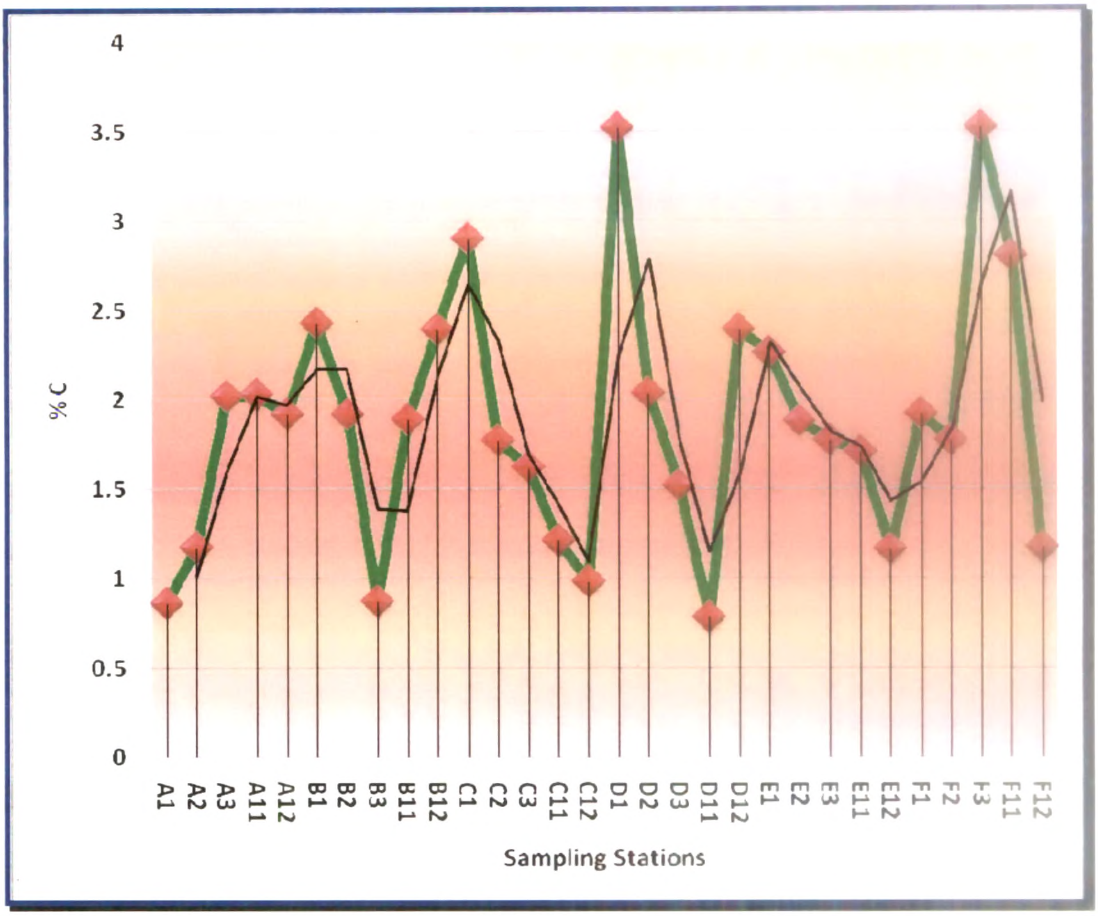

Figure 4.3: Variation of % organic carbon among soil sampling stations.

Positive kurtosis and skewness value for soil carbon inside the tea gardens is indicative of its sharp asymmetric distribution with a long right tail from its median. The scenario is, however, completely opposite for the soil samples taken outside the tea gardens. It is also observed that the width of the third quartile is significantly greater than the second quartile, which for a symmetric distribution should be equal. ANOVA (F = 1.1594, p = 0.29078) shows that the means for soil carbon do not vary significantly inside and outside tea gardens. t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area.

Monitoring soil organic carbon levels provides a good measure of the fertility of the soil. The term soil organic matter (SOM) has been used in different ways to describe the organic constituents of soil. Baldock and Skjemstad defined the term as "all organic materials found in soils irrespective of origin or state of decomposition" (Baldock, J. A; Skjemstad, J. O, 1999). Loss of organic matter from soil is a cause for concern because organic matter contributes to soil quality in many ways. Because of the many useful effects on soil quality, retention of soil organic matter is a high priority in sustainable soil management. The benefits of increasing soil organic matter include carbon sequestration and an increase in the capacity of the soil to store water and nutrients. % Soil organic matter was calculated by using the equation:

% soil organic matter = % organic Carbon x 1.724 (Allison, 1965)

Good soils are generally understood to be sandy loom soils high in organic matter (4-10%). The soil samples in and around the tea gardens of Darrang district, Assam are found to contain low organic matter and are, therefore, difficult for plant root penetration. Within the study area there is a wide variety of soils. Some are highly productive and extremely important for agriculture, while others are thin and infertile with low agricultural potential. It may be due to sewage containing toxic metals, precipitation of acidic and other airborne contaminants as well as persistent use of fertilizers and pesticides in the tea gardens. Typically soil organic carbon varies as a function of climate and land use. It generally follows continental rainfall and temperature patterns. The climate is also not conducive to production and retention of high levels of organic matter. Some statistical estimates for SOM are presented below in Table 4. 12

Table 4.12: Statistical analysis for % soil organic matter

Descriptive Statistics	SOM (%)	
	Inside tea gardens	Outside teagardens
Mean	3.244	2.936
Standard error	0.263	0.319
95% Confidence Interval for Mean	[2.670-3.798]	[2.234-3.640]
5% Trimmed mean	3.185	2.920
Median	3.145	3.105
Variance	1.242	1.224
Standard deviation	1.114	1.107
Minimum	1.480	1.340
Maximum	6.070	4.830
Range	4.590	3.490
Inter quartile range	0.865	1.958
Skewness	0.766	0.176
Kurtosis	1.603	-1.113

The distribution of SOM in the study area is found to be highly unsymmetrical. Positive skew obtained for SOM indicates an asymmetric tail extending towards higher values. Positive kurtosis data inside the tea garden indicates a sharp distribution while negative kurtosis outside the tea gardens indicates a flat distribution pattern of SOM.

4.1.5 Total Nitrogen (N)

Nitrogen (N) is essential for plants and usually has a larger effect on crop growth, yield and crop quality than any other nutrient. However, too much available N may lower yields and lessen crop quality. The quantity of N in soils is intimately associated with organic matter levels. Over 90 percent of soil N is associated with soil organic matter. Soil nitrogen distribution profiles can be used as a diagnostic tool for evaluating the impact of N fertilization on the accumulation of NO_3–N in soil and the risk of NO_3^- leaching.

Table 4.13: Values for Total Nitrogen of the soil samples inside the tea gardens

Sample No.	N (kg/ha)	Sample No.	N (kg/ha)
A1	380.09	D1	873.90
A2	425.72	D2	403.32
A3	491.53	D3	227.23
B1	582.59	E1	829.08
B2	492.96	E2	649.8
B3	400.4	E3	345.43
C1	784.27	F1	860.11
C2	492.96	F2	749.76
C3	406.00	F3	890.56

Table 4.14: Values for Total Nitrogen of the soil samples outside the tea gardens.

Sample No.	N (kg/ha)	Sample No.	N (kg/ha)
A11	448.15	D11	380.92
A12	313.69	D12	582.59
B11	224.07	E11	515.36
B12	672.23	E12	627.40
C11	268.88	F11	563.13
C12	201.67	F12	501.9

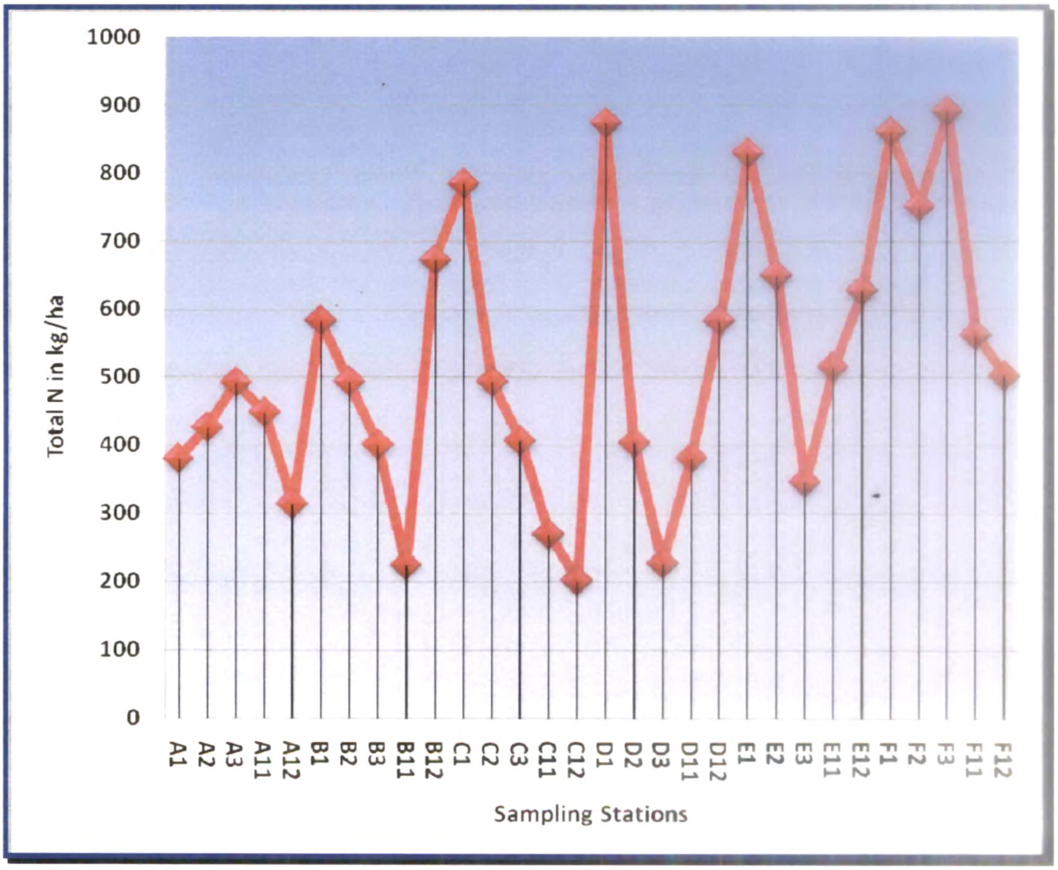

Figure 4.4: Variation of total nitrogen among soil sampling stations

Table 4.15: Statistical analysis for total Nitrogen in soil

Descriptive Statistics		Inside	Outside
Mean		571.43	441.67
Std. Error of Mean		49.75	46.57
Median		492.96	475.03
Mode		492.96	201.67
Std. Deviation		211.07	161.31
Variance		44552.41	26021.82
Skewness		0.27	-0.20
Std. Error of Skewness		0.54	0.64
Kurtosis		-1.33	-1.38
Std. Error of Kurtosis		1.04	1.23
Range		663.33	470.56
Minimum		227.23	201.67
Maximum		890.56	672.23
Sum		10285.71	5299.99
Confidence Limit	Lower Bound	383.43	339.17
	Upper Bound	610.06	544.16
Percentiles	25	402.59	280.08
	50	492.96	475.03
	75	795.47	577.73
Inter Quartile Range		159.05	297.64
ICAR Rating		280-560 (Medium)	
t		5.86	3.47
Comment		Significant	Significant

The experimental results of total nitrogen distribution in the study area are presented in Tables 4.13 and 4.14. The highest nitrogen recorded to be 890.56kg/ha at F3 inside tea garden and 672.23kg/ha at sampling point B12 outside tea garden. The mean values of nitrogen fall within the normal range of ICAR both outside and inside of the tea gardens. Various statistical estimates derived from NDA are summarized in Table 4.15. Figure 4.4 gives the variation of nitrogen among different sampling stations in the area.

Positive skewness and negative kurtosis values for N inside tea gardens indicate flat distribution with a long right tail. The distributions for N in soil also appear to be asymmetric with the common feature of third quartile being wider than the second in the area. Difference between mean, median, mood and significantly high range for N in soil indicate the presence of outliers. It is also noticed from one way ANOVA analysis at 0.05 level ($F = 3.25268$, $p = 0.08208$) that the mean values of N inside and outside tea gardens are significantly not different. t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area.

4.1.6 Phosphorus (P)

Phosphorus (P) is an essential element classified as a macronutrient because of the relatively large amounts of P required by plants. It plays an essential role in agriculture and for all forms of life: respiration, photosynthesis in green leaves, microbial turnover and decomposing litter (Cole, C. V *et al.,* 1977). In acid soils, there is a tendency toward lower P levels over time.

The experimental results of phosphorous distribution in the study area are presented in Tables 4.16 and 4.17. The highest phosphorous recorded to be 134.0kg/acre at F1 inside tea garden and 127.28kg/acre at sampling point E11 outside tea garden.

Various statistical estimates derived from NDA are summarized in Table 4.18. Figure 4.5 gives the variation of phosphorous among different sampling stations in the area.

Table 4.16 Values for Phosphorous of the soil samples inside the tea gardens

Sample No.	P (kg/acre)	Sample No.	P (kg/acre)
A1	16.54	D1	12.61
A2	24.60	D2	6.30
A3	27.09	D3	56.3
B1	19.47	E1	128.09
B2	14.13	E2	123.74
B3	37.89	E3	94.8
C1	11.92	F1	134
C2	16.13	F2	74.8
C3	78.9	F3	56.9

Table 4.17: Values for Phosphorous of the soil samples outside the tea gardens

Sample No.	P (kg/acre)	Sample No.	P (kg/acre)
A11	92.47	D11	14.78
A12	58.24	D12	123.28
B11	47.01	E11	127.28
B12	16.78	E12	61.23
C11	14.31	F11	99.03
C12	10.32	F12	78.6

Table 4.18: Statistical analysis for Phosphorous in soil

Descriptive Statistics		Inside	Outside
Mean		51.90	61.94
Std. Error of Mean		10.33	12.32
Median		32.49	59.74
Mode		6.30	10.32
Std. Deviation		43.81	42.69
Variance		1919.48	1822.82
Skewness		0.82	0.21
Std. Error of Skewness		0.54	0.64
Kurtosis		-0.73	-1.35
Std. Error of Kurtosis		1.04	1.23
Range		127.70	116.96
Minimum		6.30	10.32
Maximum		134.00	127.28
Sum		934.21	743.33
Confidence Limit	Lower Bound	13.29	34.82
	Upper Bound	40.36	89.07
Percentiles	25	15.63	15.28
	50	32.49	59.74
	75	82.88	97.39
Inter Quartile Range		22.20	82.11
ICAR Rating		25-62 Medium	
t		2.60	3.00
Comment		Significant	Significant

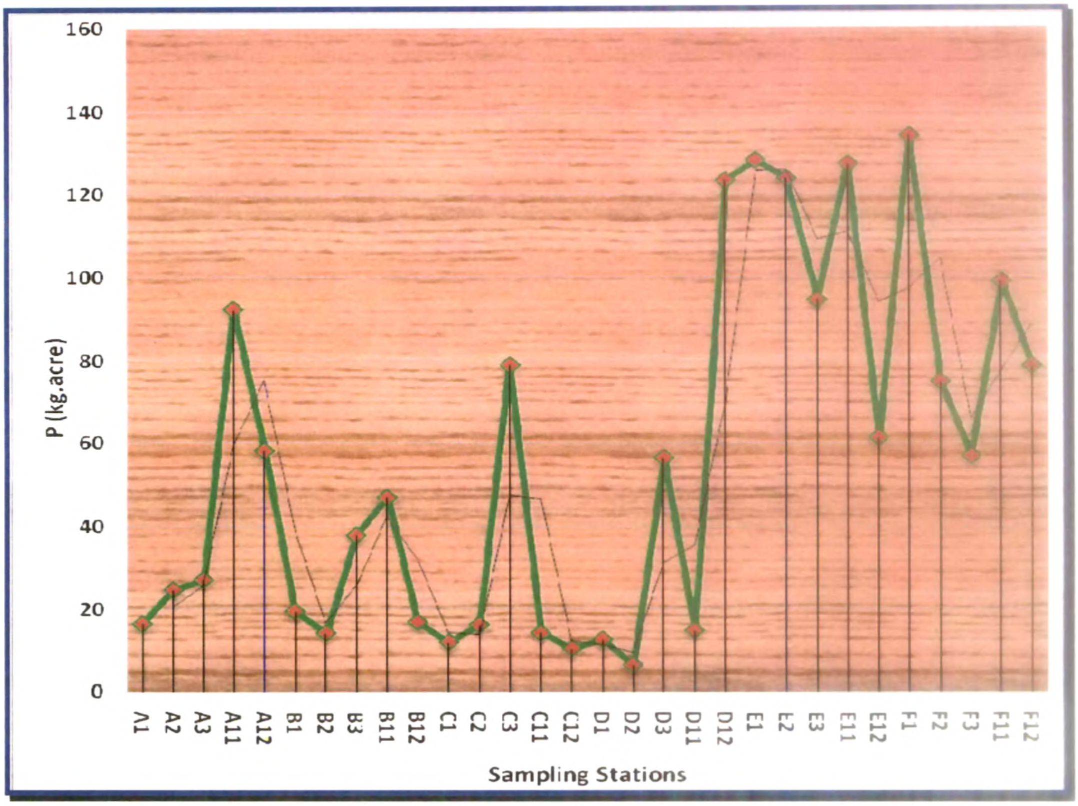

Figure 4.5: Variation of phosphorous among soil sampling stations.

Significant skewness and kurtosis values for P indicate that its distribution in the study area is not uniform. Significant differences among mean, median and mode along with significant skewness and kurtosis values observed for P inside and outside tea gardens are indicative of departure of sample frequency distribution curve from normal. The ANOVA test (F = 0.38602, p = 0.53943) at 0.05 level suggests that the means inside and outside tea gardens are not significantly different. t-test analysis of the data suggests that means are significant with reference to the mean rating of ICAR in both outside and inside the tea gardens of the area.

4.1.7 Potassium (K)

Potassium is very important in maintaining soil health, plant growth and animal nutrition. The consequences of low potassium levels are apparent in a variety of symptoms - restricted growth, reduced flowering, lower yields and lower quality produce.

The experimental results of potassium distribution in the study area are presented in Tables 4.19and 4.20. The mean value of K inside and outside are 101.79 and 100.17 respectively which are less than the ICAR medium range of 272-690. The low potassium availability may be due to low pH of the soil in the region. Various statistical estimates derived from NDA are summarized in Table 4.21. Figure 4.6 gives the variation of potassium among different sampling stations in the area.

Table 4.19 Values for Potassium of the soil samples inside the tea gardens

Sample No.	K (kg/acre)	Sample No.	K (kg/acre)
A1	50.13	D1	54.67
A2	45.57	D2	82.1
A3	94.12	D3	150.5
B1	91.12	E1	62.0
B2	72.9	E2	71.0
B3	33.13	E3	187.0
C1	33.13	F1	246.87
C2	45.57	F2	278.01
C3	47.0	F3	187.34

Table 4.20: Values for Potassium of the soil samples outside the tea gardens

Sample No.	K (kg/acre)	Sample No.	K (kg/acre)
A11	113	D11	68.4
A12	100.3	D12	95.7
B11	86.58	E11	99
B12	95.5	E12	120
C11	68.4	F11	201.79
C12	63.8	F12	89.60

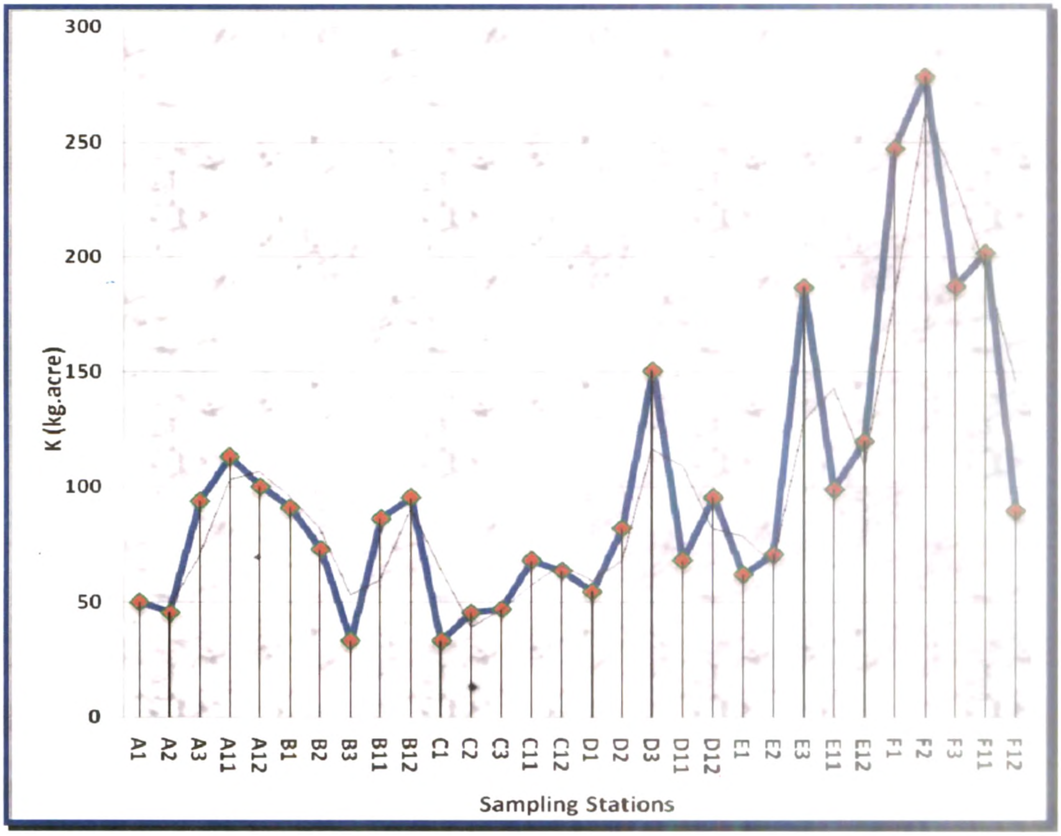

Figure 4.6: Variation of potassium among soil sampling stations.

Table 4.21: Statistical analysis for Potassium in soil

Descriptive Statistics		Inside	Outside
Mean		101.79	100.17
Std. Error of Mean		17.77	10.50
Median		71.95	95.60
Mode		33.13	68.40
Std. Deviation		75.39	36.39
Variance		5683.58	1324.14
Skewness		1.29	2.14
Std. Error of Skewness		0.54	0.64
Kurtosis		0.56	5.91
Std. Error of Kurtosis		1.04	1.23
Range		244.88	137.99
Minimum		33.13	63.80
Maximum		278.01	201.79
Sum		1832.16	1202.07
Confidence Limit	Lower Bound	45.16	77.05
	Upper Bound	88.17	123.29
Percentiles	25	46.64	72.95
	50	71.95	95.60
	75	159.63	109.83
Inter Quartile Range		43.30	36.88
ICAR Rating		272-690 (Medium)	
t		-9.57897	-16.3575
Comment		Significant	Significant

The soils in and around the tea gardens of the study area are potassium deficient and is not in accordance with the rating (lower limit 272 kg/acre) given by ICAR' 2005. This observation is also supported by the statistical t-test data. The ANOVA test ($F = 0.00472$, $p = 0.94569$) at 0.05 level suggests that the means inside and outside tea gardens are not significantly different. Positive skewness and kurtosis values obtained for K inside as well as outside tea gardens indicate sharp distribution pattern with a right tail. Asymmetric nature of K distribution is also apparent from the width of the third quartile which is much greater than the first and second quartile in both inside and outside tea gardens. Wide data range and high standard deviation in case of K also bias the normal distribution statistic in the area.

4.1.8 Bulk Density (ρ_b)

Bulk density (ρ_b) is a measure of the mass of particles that are packed into a volume of soil. It is useful in estimating, evaluating, and calculating many physical soil properties. The measurement of ρ_b provides a relative value of the porosity and compaction of a soil. Thus, ρ_b is an important soil structure attribute. Saxton *et al.*, estimated generalized bulk densities and soil-water characteristics from texture and developed a set of equations from which soil-water characteristic equations for a number of soil textural classes can be derived (Saxton *et al.*, 1986). One of the dominating **factors changing** ρ_b is the soil's organic matter (SOM) concentration that alters the soil's compressibility (Ruehlmann, J.,Körschens, M., 2009). The experimental results of bulk density distribution in the study area are presented in Tables 4.22 and 4.23. Various statistical estimates derived from NDA are summarized in Table 4.24. Figure 4.7 gives the variation of bulk density among different sampling stations in the area.

Table 4.22 Values for Bulk density of the soil samples inside the tea gardens

Sample No	ρ_b (g/cm^3)	Sample No	ρ_b (g/cm^3)
A1	0.775	D1	1.300
A2	0.791	D2	1.450
A3	0.991	D3	1.110
B1	1.033	E1	1.230
B2	0.994	E2	1.360
B3	0.876	E3	1.320
C1	0.921	F1	1.020
C2	0.689	F2	1.480
C3	1.090	F3	1.320

Table 4.23: Values for bulk density of the Soil samples outside the tea gardens

Sample No	ρ_b (g/cm^3)	Sample No	ρ_b (g/cm^3)
A11	1.480	D11	0.791
A12	1.320	D12	0.871
B11	0.866	E11	0.987
B12	0.956	E12	0.998
C11	1.130	F11	1.010
C12	1.240	F12	1.580

Table: 4.24 Statistical analysis for bulk density of soil

Descriptive Statistics	ρ_b (g/cm^3)	
	Inside tea gardens	Outside teagardens
Mean	1.097	1.027
Standard error	0.056	0.061
95% Confidence Interval for Mean	[0.98- 1.22]	[0.893-0.162]
5% Trimmed mean	1.099	1.010
Median	1.062	0.993
Variance	0.057	0.045
Standard deviation	0.239	0.212
Minimum	0.689	0.790
Maximum	1.480	1.580
Range	0.791	0.790
Inter quartile range	0.410	0.224
Skewness	0.007	1.776
Kurtosis	-1.071	3.780

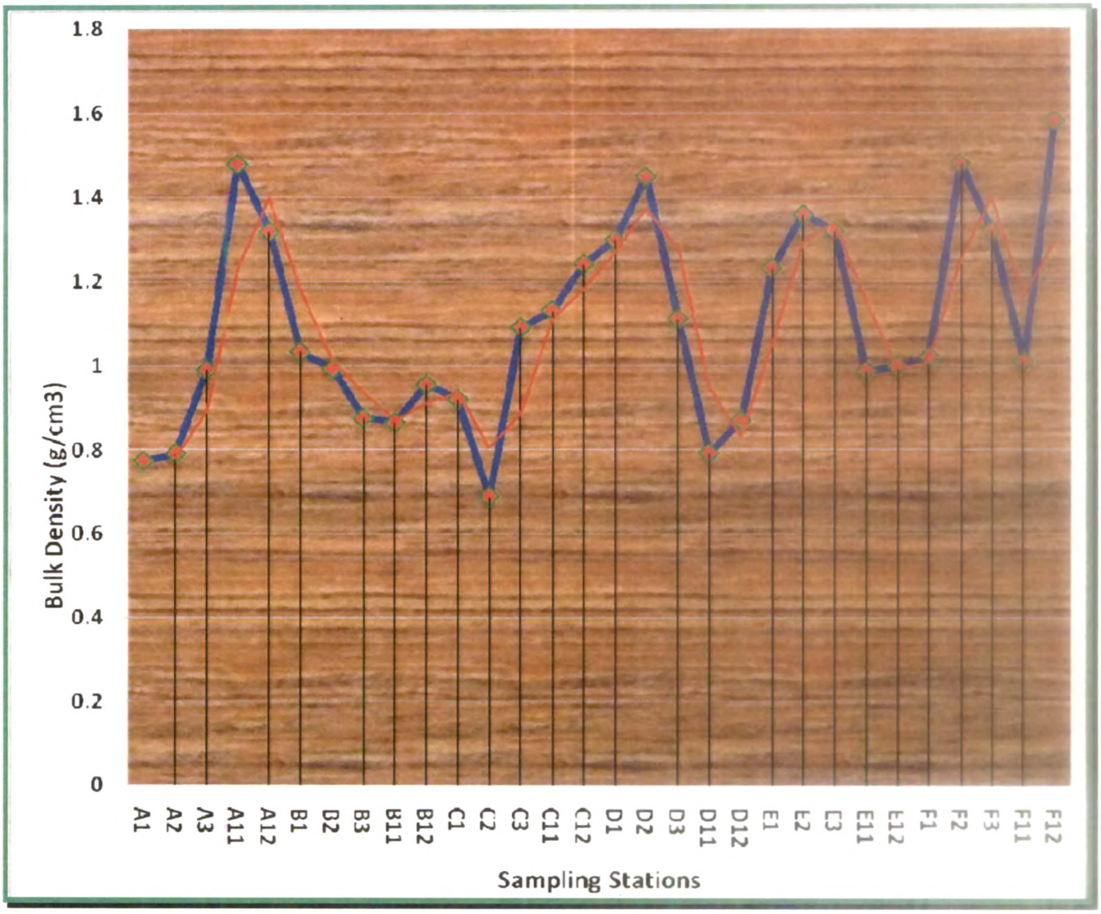

Figure 4.7: Variation of bulk density among soil sampling stations.

The bulk density of soil is inversely related to the porosity of the same soil. High bulk density is an indicator of low soil porosity and soil compaction. At the same time, bulk density also decreases with clay content. The soil texture in the study area is classified as clay. The mean bulk density of soil inside and outside the tea gardens of the study area was found to be 1.097gm/cm^3 and 1.027gm/cm^3 respectively. The soils of the study area, thus, have low permeability and the decrease in soil porosity means that plant roots are often physically impeded by compact subsoil layers. This also implies that the subsoil of the area can not held sufficient amount of available nutrients and water. The soils in the area are likely to exhibit properties which are somewhat difficult to manage or overcome. For example, soils in the area are often too sticky when wet and too hard when dry to cultivate. Subsoil in most of the sampling stations is found to be never wet up properly and others can have high mechanical impedance or poor aeration resulting in poorly developed root systems. The skewness and kurtosis values for bulk density inside and outside the tea gardens indicate that its distribution in the study area is not uniform with a long right tail with respect to the mean. Wide data range and high standard deviation obtained for bulk density in both inside and outside the tea gardens also likely to bias the normal distribution statistic in the area.

4.1.9 Zinc (Zn)

Zn is an essential micronutrient for plants (Sadiq, 1991; Tiller *et al.,* 1972). In contrast, Zn in high concentrations can be toxic to plants and animals (Barbarick *et al.*, 1997; Lerch *et al.,* 1990). Zinc availability in soils is at its minimum at pH values between 5.5-7.0 and the situation becomes more complex when pH increases to more than 7.0 (Rai, 1995). Zn in soil solution exists as Zn^{2+}. As a positive ion, it is quite immobile in soil. Above pH 7.7 it becomes $Zn(OH)^{+}$ and at pH 9.7 it is precipitated as $Zn(OH)_2$. At lower pH, the yield is reduced. The experimental results after comparing with the critical ratings given for zinc (Baruah T.C.C & Borthakur, H.P, 1997) show that the soils inside as well as outside tea gardens of Darrang district, Assam have medium zinc content.

The experimental results of zinc distribution in the study area are presented in Tables 4.25 and 4.26. Various statistical estimates derived from NDA are summarized in Table 4.27. Figure 4.8 gives the variation of zinc among different sampling stations in the area.

Table 4.25 Values for Zinc of the soil samples inside the tea gardens

Sample No	Zn (mg/kg)	Sample No	Zn (mg/kg)
A1	98.6	D1	164.9
A2	38.3	D2	101.5
A3	21.9	D3	100.9
B1	35.7	E1	25.5
B2	112.5	E2	31.9
B3	13.8	E3	32.1
C1	22.6	F1	21.7
C2	12.5	F2	22.0
C3	25.7	F3	23.9

Table 4.26: Values for Zinc of the soil samples outside the tea gardens

Sample No	Zn (mg/kg)	Sample No	Zn (mg/kg)
A11	30.1	D11	2.3
A12	54.8	D12	22.8
B11	21.7	E11	22.2
B12	78.3	E12	15.6
C11	37.9	F11	23.9
C12	34	F12	13.9

Table: 4.27 Statistical analysis for Zinc in soil

Descriptive Statistics		Inside	Outside
Mean		50.33	29.79
Std. Error of Mean		10.45	5.82
Median		28.80	23.35
Mode		12.50	2.30
Std. Deviation		44.33	20.18
Variance		1965.56	407.13
Skewness		1.41	1.34
Std. Error of Skewness		0.54	0.64
Kurtosis		1.03	2.26
Std. Error of Kurtosis		1.04	1.23
Range		152.40	76.00
Minimum		12.50	2.30
Maximum		164.90	78.30
Sum		906.00	357.50
Confidence Limit	Lower Bound	30.32	16.97
	Upper Bound	94.50	42.61
Percentiles	25	21.98	17.13
	50	28.80	23.35
	75	99.18	36.93
Inter Quartile Range		79.26	19.80

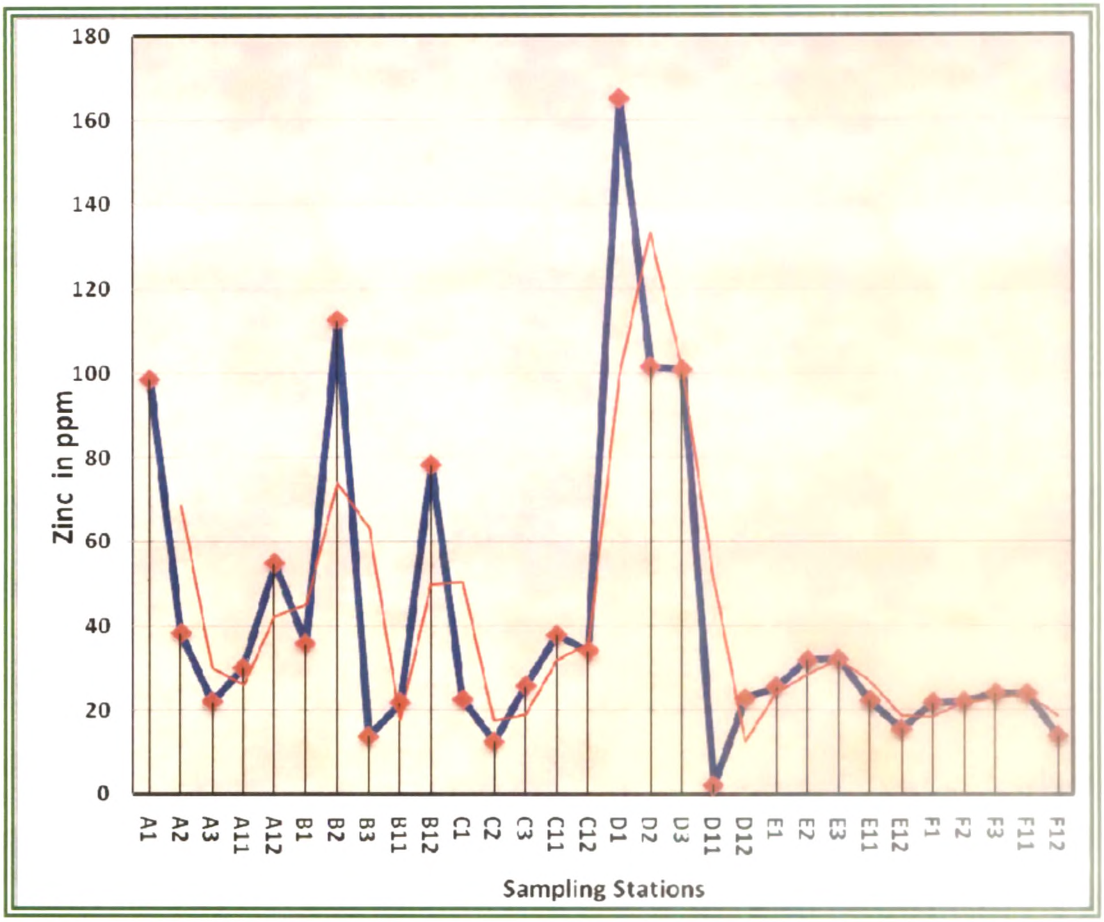

Figure 4.8: Variation of Zinc among soil sampling stations

Significant skewness and kurtosis values for Zn indicate that its distribution in the study area is not uniform. Significant differences among mean, median and mode along with significant skewness and kurtosis values observed for Zn inside and outside tea gardens are indicative of departure of sample frequency distribution curve from normal. The ANOVA test ((F = 2.24493, p = 0.14524)) at 0.05 level suggests that the means inside and outside tea gardens are not significantly different.

4.1.10 Copper (Cu)

Solubility of copper in soil is highly pH dependent. Soils hold copper most securely at pH 7-8, appreciably less securely at pH 6 and as the soil acidity increases further, copper is held very loosely (Rai, 1995). In soil it mainly exists as Cu^{2+} and less frequently as Cu^{+}. The deficiency of copper starts from values as low as 1-3 ppm and toxicity occurs from values as high as 200 ppm and above. Seasonal variation is very narrow in case of Cu and in fact almost steady inside the tea gardens. However, in pre monsoon season the distribution of copper in soil show significant variation than post monsoon season.

The experimental results of copper distribution in the study area are presented in Tables 4.28 and 4.29. Various statistical estimates derived from NDA are summarized in Table 4.30. Figure 4.9 gives the variation of copper among different sampling stations in the area.

Table 4.28 Values for Copper of the soil samples inside tea gardens

Sample No.	Cu (ppm)	Sample No.	Cu (ppm)
A1	97.1	D1	bdl
A2	30.7	D2	7.9
A3	28.9	D3	11.8
B1	14.3	E1	25.5
B2	15.8	E2	21.3
B3	10.1	E3	22.5
C1	8.9	F1	20.3
C2	8.7	F2	17.3
C3	12.6	F3	23.8

Table 4.29: Values for Copper of the soil samples outside tea gardens

Sample No.	Cu (ppm)	Sample No.	Cu (ppm)
A11	14.9	D11	17.3
A12	13.7	D12	14.7
B11	12.0	E11	29.5
B12	25.2	E12	26.3
C11	10.2	F11	11.3
C12	7.9	F12	23.6

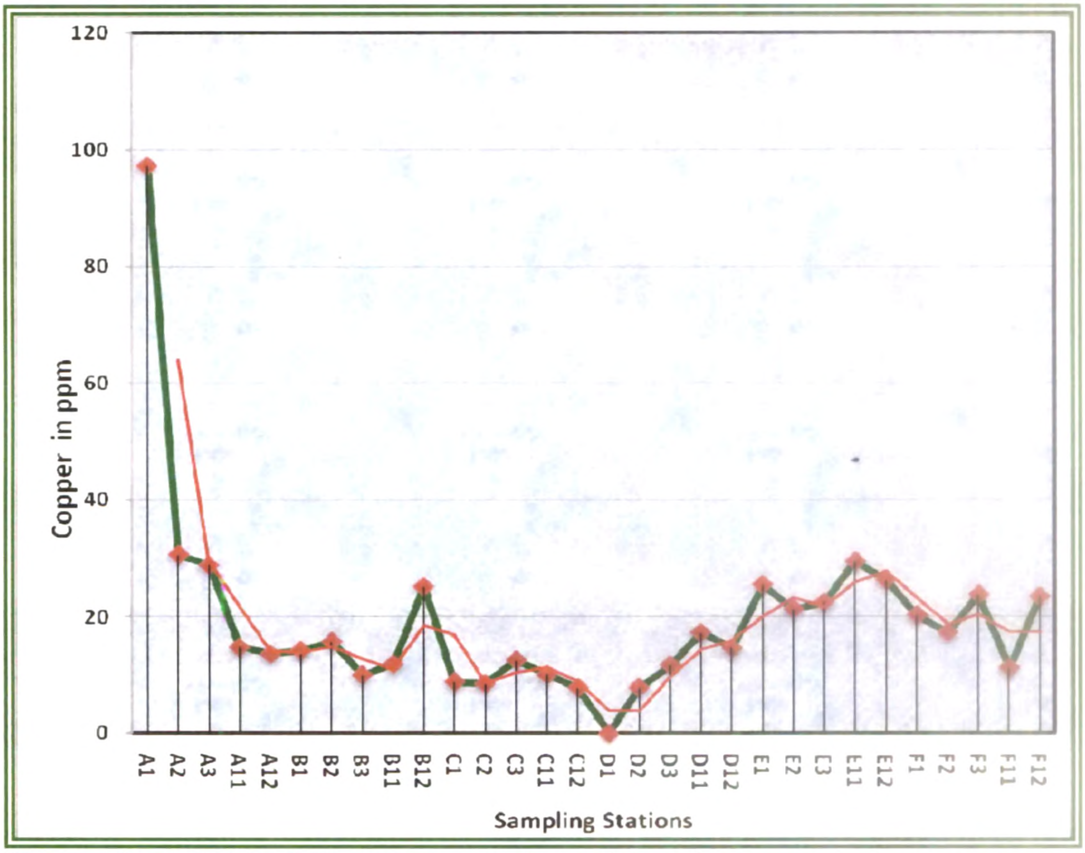

Figure 4.9: Variation of Copper among soil sampling stations

Table: 4.30 Statistical analysis for Copper in soil

Descriptive Statistics		Inside	Outside
Mean		20.97	17.22
Std. Error of Mean		4.87	2.06
Median		16.55	14.80
Mode		0.00	7.90
Std. Deviation		20.65	7.14
Variance		426.39	50.93
Skewness		3.19	0.54
Std. Error of Skewness		0.54	0.64
Kurtosis		12.02	-1.15
Std. Error of Kurtosis		1.04	1.23
Range		97.10	21.60
Minimum		bdl	7.90
Maximum		97.10	29.50
Sum		377.50	206.60
Confidence Limit	Lower Bound	4.31	12.68
	Upper Bound	36.82	21.75
Percentiles	25	9.80	11.48
	50	16.55	14.80
	75	24.23	24.80
Inter Quartile Range		16.88	13.33

Significant positive skew and kurt values for Cu indicate that its distribution in the study area is not uniform This is also evident from the width of the third quartile, which is much greater than the first and second quartile. Significant differences among mean, median and mode along with significant skewness and kurtosis values also observed for Cu inside and outside the tea gardens. A broad third quartile and positive skewness in case of Cu represents a long asymmetric tail on the right of the median. The ANOVA test ($F = 0.36413$, $p = 0.55108$) at 0.05 level suggests that the means inside and outside tea gardens are not significantly different.

4.1.11 Manganese (Mn)

Soil manganese exists in equilibrium between plant available 2+ manganous manganese (Mn^{2+}) and unavailable forms of manganic manganese (Mn^{3+}). Plants take up manganese as Mn^{2+} from the soil solution. It is fairly mobile in the soil and can be leached, particularly on acid soils. Soil Mn^{2+} concentrations decrease as the pH increases. At low pH levels (less than 5.5), manganese becomes very soluble, and manganese toxicity may occur. Toxicity is usually associated with other acid soil infertility problems such as aluminium toxicity and deficiencies of calcium and magnesium. Manganese is required for healthy growth of plants and animals Plants suffer from toxicity when they absorb too much Mn^{2+}. The low pH values favour reduction of Mn^{3+} to Mn^{2+}. Environmental conditions cause a peak or pulse of Mn^{2+} which often lasts for about three weeks. The longer the pulse of high soil Mn^{2+}, the greater the chance of toxicity effects developing. At pH 4.6 and below, toxicity can be a continuing problem. Where high soil Mn^{2+} is primarily caused by low pH, liming to pH 5.6 will usually reduce soil Mn^{2+} to non-toxic levels. However, where Mn^{2+} toxicity is primarily the consequence of environmental conditions liming will only reduce the peak and duration of the pulse. Phytotoxicity from manganese may also occur in soil containing low humus and low pH (Gauthreaux *et al.,* 2001).

The experimental results of manganese distribution in the study area are presented in Tables 4.31 and 4.32. Various statistical estimates derived from NDA are summarized in Table 4.33. Figure 4.10 gives the variation of manganese among different sampling stations in the area.

Table 4.31 Values for manganese of the soil samples inside the tea gardens

Sample No.	Mn (ppm)	Sample No.	Mn (ppm)
A1	58.2	D1	240.4
A2	100.1	D2	97.8
A3	93.9	D3	41.6
B1	150.2	E1	157.3
B2	153.7	E2	140
B3	157	E3	71.8
C1	80.3	F1	148.6
C2	81.1	F2	155.9
C3	91.0	F3	140.7

Table 4.32: Values for Manganese of the soil samples outside tea gardens

Sample No.	Mn (ppm)	Sample No.	Mn (ppm)
A11	256.6	D11	158.6
A12	204.5	D12	140.1
B11	245.1	E11	217.5
B12	197.3	E12	105.8
C11	111.3	F11	135.6
C12	120.3	F12	140.5

Table: 4.33 Statistical analysis for Manganese in soil

Descriptive Statistics		Inside	Outside
Mean		119.98	169.43
Std. Error of Mean		11.44	15.19
Median		120.05	149.55
Mode		41.60	105.80
Std. Deviation		48.52	52.61
Variance		2354.64	2767.50
Skewness		0.57	0.46
Std. Error of Skewness		0.54	0.64
Kurtosis		0.67	-1.27
Std. Error of Kurtosis		1.04	1.23
Range		198.80	150.80
Minimum		41.60	105.80
Maximum		240.40	256.60
Sum		2159.60	2033.20
Confidence Limit	Lower Bound	77.50	136.01
	Upper Bound	146.71	202.86
Percentiles	25	80.90	124.13
	50	120.05	149.55
	75	154.25	214.25
Inter Quartile Range		72.33	90.13

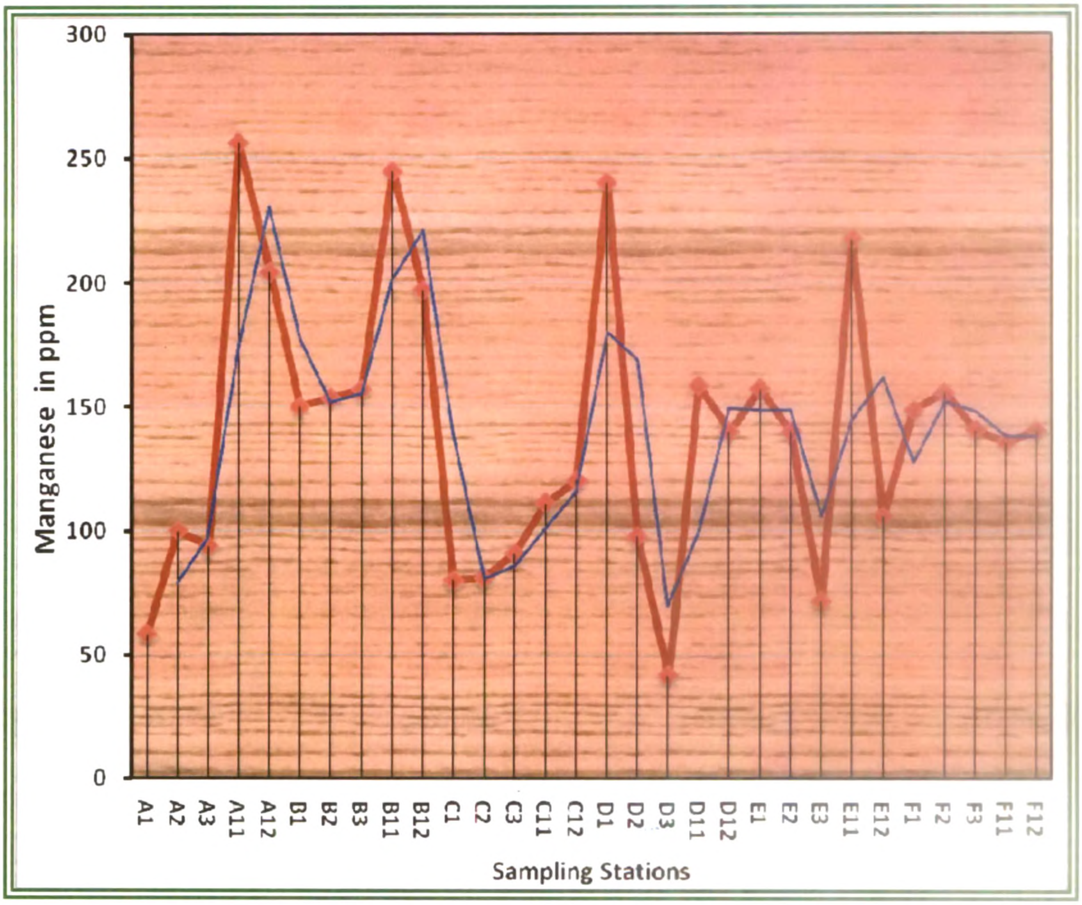

Figure 4.10: Variation of Manganese among soil sampling stations

Mn content of the soil in the area was found to be very high. The average amount of manganese (Mn) in the soil samples is 119.98 mg kg^{-1} and 169.43 mg/kg inside and outside the tea gardens of the study area respectively. The distribution of Mn in the study area is not normal as observed from the various statistical estimates. Negative kurt and positive skew values for Mn out side the tea gardens indicate flat distribution with long asymmetric tail extending towards the right of the median.

4.1.12 Iron (Fe)

Iron is the fourth most common element in soil, comprising 5% of the earth's crust. The Fe in soil is usually found in the soluble cationic form (Fe^{2+}). All the soil samples of our study area have high iron contents and cross the critical limit as suggested by Olson and Carlson (1950). The high iron content of soils in the study area also contributes towards rusting hazard.

The experimental results of iron distribution in the study area are presented in Tables 4.34 and 4.35. Various statistical estimates derived from NDA are summarized in Table 4.36. Figure 4.11 gives the variation of iron among different sampling stations in the area.

Table 4.34 Values for Iron in the soil samples inside the tea gardens

Sample No.	Fe (ppm)	Sample No.	Fe (ppm)
A1	826.7	D1	970.2
A2	730.2	D2	607.1
A3	570.6	D3	277.0
B1	930.7	E1	955.7
B2	969.2	E2	879.4
B3	958.8	E3	455.7
C1	524.5	F1	896
C2	539.7	F2	930.8
C3	589.7	F3	867.1

Table 4.35: Values for Iron in the soil samples outside the tea gardens

Sample No.	Fe (ppm)	Sample No.	Fe (ppm)
A11	969.3	D11	962.5
A12	867.0	D12	868.3
B11	960.7	E11	957.9
B12	896.0	E12	955.9
C11	668.4	F11	844.1
C12	768.0	F12	897.4

Table: 4.36 Statistical analysis for Iron in soil

Descriptive Statistics		Inside	Outside
Mean		748.84	884.63
Std. Error of Mean		50.80	26.45
Median		846.90	896.70
Mode		277.00	668.40
Std. Deviation		215.51	91.62
Variance		46442.93	8394.34
Skewness		-0.69	-1.35
Std. Error of Skewness		0.54	0.64
Kurtosis		-0.69	1.67
Std. Error of Kurtosis		1.04	1.23
Range		693.20	300.90
Minimum		277.00	668.40
Maximum		970.2	969.30
Sum		13479.10	10615.50
Confidence Limit	Lower Bound	565.17	826.41
	Upper Bound	850.57	942.84
Percentiles	25	562.88	849.83
	50	846.90	896.70
	75	937.03	960.00
Inter Quartile Range		404.35	110.18

In the study area the variation of Fe is large and statistical observation shows that the distribution of Fe is not even. However, negative skewness value of the data is indicative of the asymmetric nature of arsenic distribution in the study area with a sharp long left tail outside and right tail inside the tea gardens with respect to the median.

ANNOVA study reveals that at the 0.05 level, the means are significantly different (F = 4.215, p = 0.04952) inside and outside teagardens.

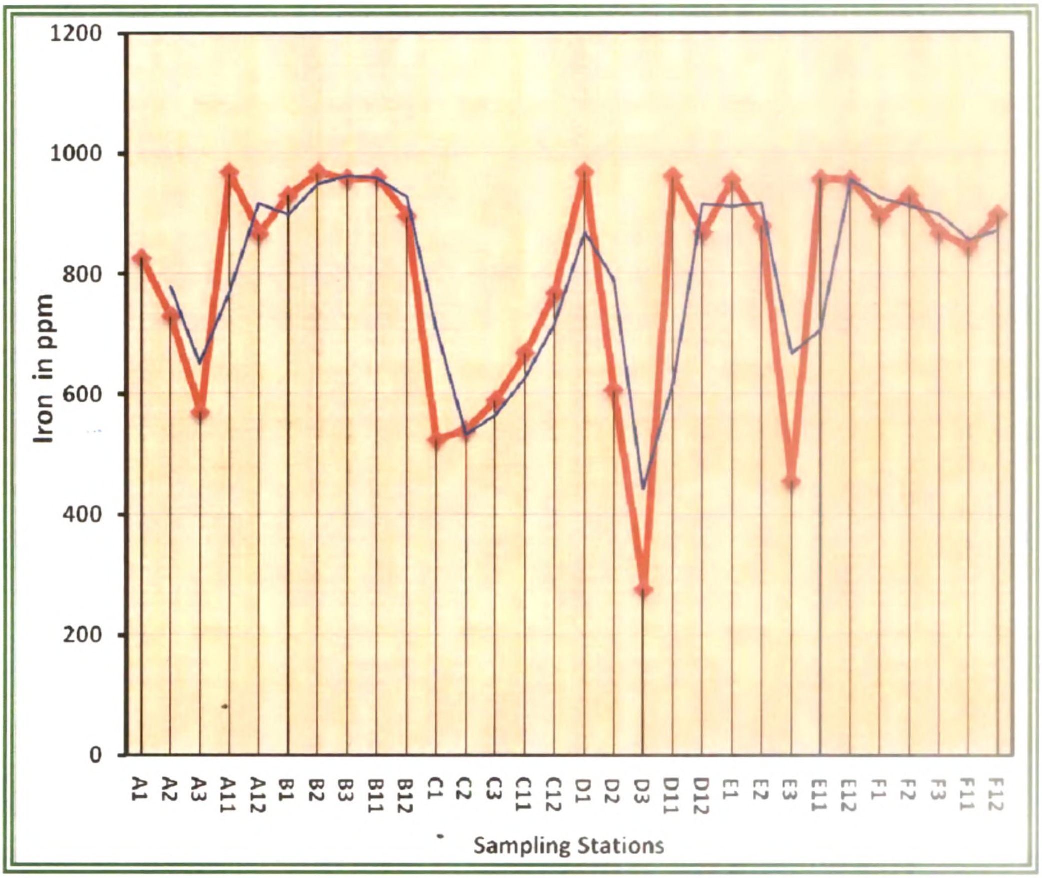

Figure 4.11: Variation of iron among soil sampling stations

4.1.13 Lead (Pb)

Lead occurs naturally in soils, typically at concentrations that range from 10 to 50 mg/kg. However, Because of the widespread use of leaded paint before the mid 1970s and leaded gasoline before the mid 1980s, as well as contamination from various industrial sources, urban soils often have lead concentrations much greater than normal background levels. These concentrations frequently range from 150 mg/kg to as high as 10,000 mg/kg at the base of a home painted with lead based paint. Lead does not biodegrade, or disappears over time, but remains in soils for thousands of years. Lead contamination of soil level is categorised as very low, low, medium, high and very high depending on the lead level in soil (Stehouwer, 1999).

Soil Lead Level (in mg/kg)	Contamination Level of lead
Less than 150	very low
From 150 to 400	Low
From 400 to 1,000	Medium
From 1,000 to 2,000	High
Greater than 2,000	Very high

The experimental results of lead distribution in the study area are presented in Tables 4.37 and 4.38. From the results it is clear that level of lead contamination can be categorized as very low in the study area as per the above rating. Various statistical estimates derived from NDA are summarized in Table 4.39. Figure 4.12 gives the variation of lead among different sampling stations in the area.

Table 4.37 Values for Lead in the soil samples inside the tea gardens

Sample No.	Pb (mg/kg)	Sample No.	Pb (mg/kg)
A1	9.8	D1	40.8
A2	11.4	D2	51.8
A3	8.6	D3	43.7
B1	21.6	E1	24.5
B2	22.6	E2	22.4
B3	23.1	E3	20.8
C1	10.1	F1	8.6
C2	12.8	F2	6.8
C3	11.3	F3	4.8

Table 4.38: Values for Lead in the soil samples outside tea gardens

Sample No.	Pb (mg/kg)	Sample No.	Pb (mg/kg)
A11	20.4	D11	64.5
A12	15.9	D12	30.4
B11	24.4	E11	20.8
B12	20.6	E12	11.8
C11	16.7	F11	13.7
C12	30.4	F12	10.5

Table: 4.39 Statistical analysis for Lead in soil

Descriptive Statistics		Inside	Outside
Mean		19.75	23.34
Std. Error of Mean		3.19	4.18
Median		16.80	20.50
Mode		8.60	30.40
Std. Deviation		13.54	14.49
Variance		183.46	209.82
Skewness		1.18	2.34
Std. Error of Skewness		0.54	0.64
Kurtosis		0.67	6.47
Std. Error of Kurtosis		1.04	1.23
Range		47.00	54.00
Minimum		4.80	10.50
Maximum		51.80	64.50
Sum		355.50	280.10
Confidence Limit	Lower Bound	13.01	14.14
	Upper Bound	26.48	32.54
Percentiles	25	9.50	14.25
	50	16.80	20.50
	75	23.45	28.90
Inter Quartile Range		13.3	8.5

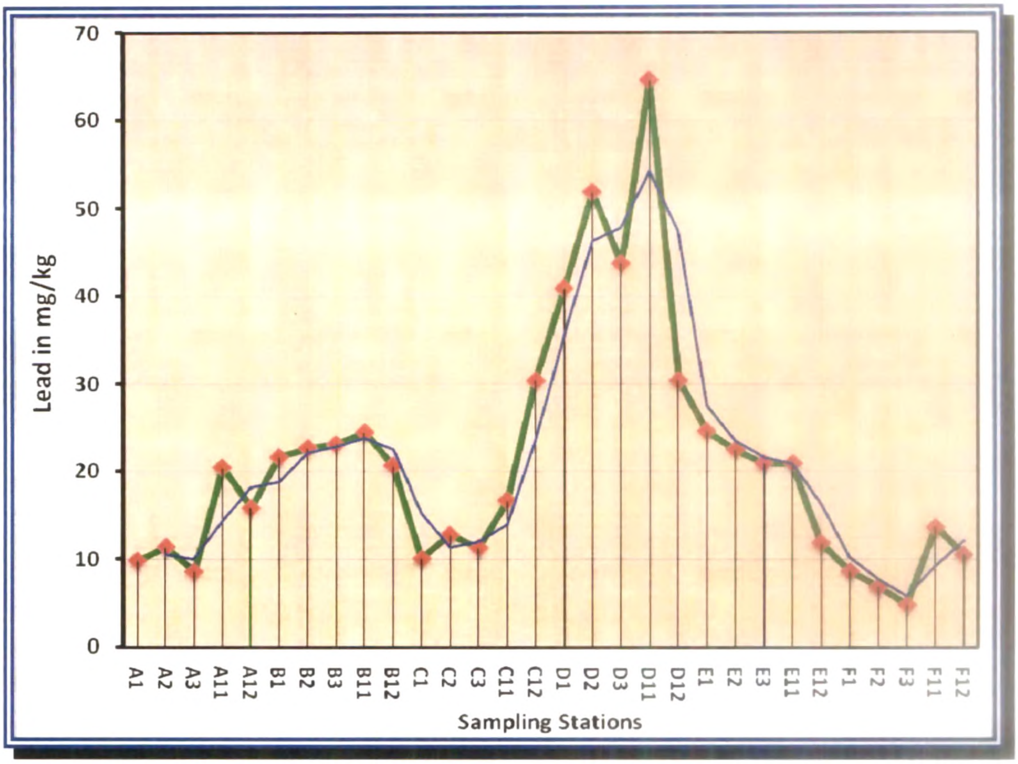

Figure 4.12: Variation of lead among soil sampling stations

In most of the samples under investigation, the lead contents were not very high to cause any environmental concern. Positive skewness of the data is indicative of the asymmetric nature of lead distribution in the study area. The distribution is also found to be sharp with positive kurtosis values. Defference between mean, median and mode, significant standard deviation and error value indicate that the distribution of arsenic in the study area is not symmetric. ANOVA analysis also suggests that the means are not significantly different ($F = 0.47923$, $p = 0.49447$) inside and outside teagardens at the 0.05 level.

4.1.14 Calcium and Magnesium (Ca & Mg)

Ca and Mg are classified as secondary nutrients. They are secondary only in the probability of deficiencies and are taken up by plants in quantities similar to phosphorus. We have measured the amounts of exchangeable Ca and Mg since this is the plant available form. The experimental results of calcium distribution in the study area are presented in Tables 4.40 and 4.41. Various statistical estimates derived from NDA are summarized in Table 4.42. Figure 4.13 gives the variation of calcium among different sampling stations in the area.

Table 4.40 Values for Calcium in the soil samples inside the tea gardens

Sample No.	Ca (meq/100g)	Sample No.	Ca (meq/100g)
A1	1.68	D1	1.64
A2	1.73	D2	2.60
A3	3.00	D3	0.36
B1	2.40	E1	0.881
B2	0.72	E2	0.88
B3	1.50	E3	1.13
C1	1.80	F1	2.16
C2	2.40	F2	2.24
C3	2.30	F3	1.68

Table 4.41: Values for Calcium in the soil samples outside the tea gardens

Sample No.	Ca (meq/100g)	Sample No.	Ca (meq/100g)
A11	2.88	D11	1.76
A12	1.20	D12	1.20
B11	2.48	E11	1.60
B12	1.30	E12	1.40
C11	2.12	F11	2.40
C12	2.60	F12	2.36

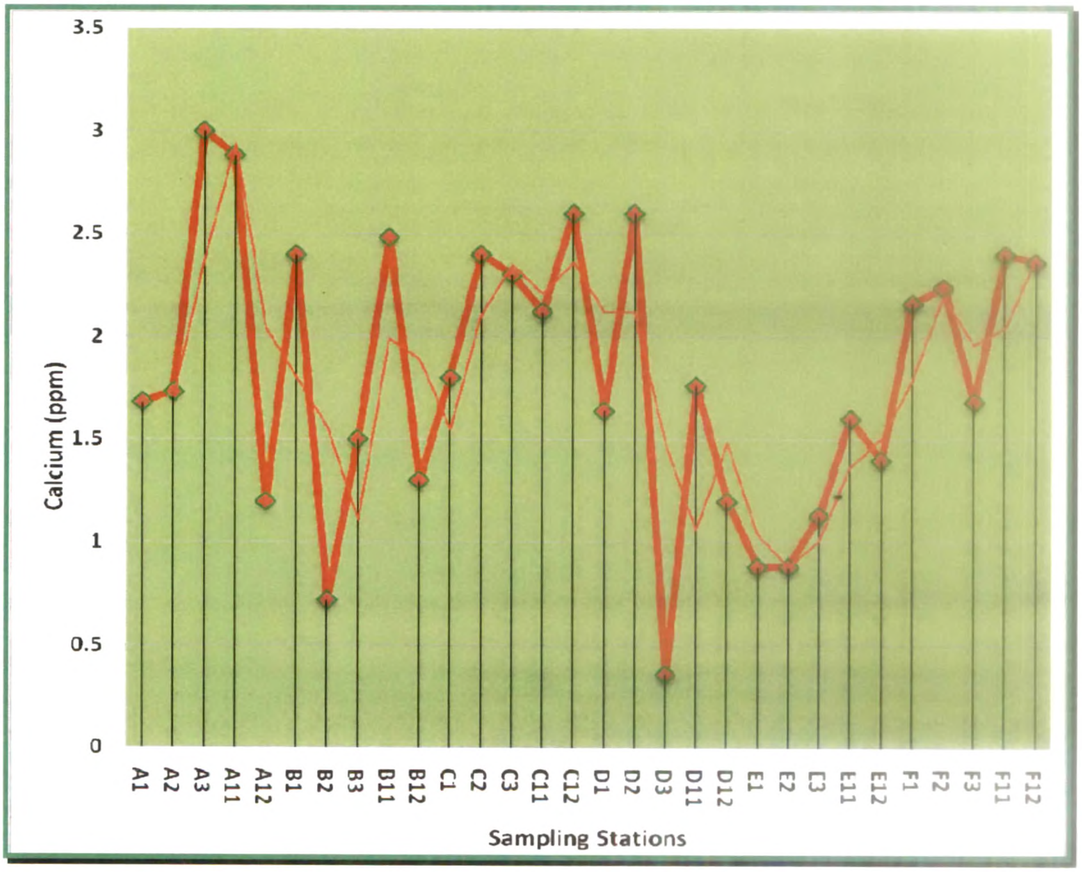

Figure 4.13: Variation of calcium among soil sampling stations

Table: 4.42 Statistical analysis for Calcium in soil

Descriptive Statistics		Inside	Outside
Mean		1.73	1.94
Std. Error of Mean		0.17	0.17
Median		1.71	1.94
Mode		1.68	1.20
Std. Deviation		0.72	0.60
Variance		0.52	0.36
Skewness		-0.23	0.08
Std. Error of Skewness		0.54	0.64
Kurtosis		-0.64	-1.62
Std. Error of Kurtosis		1.04	1.23
Range		2.64	1.68
Minimum		0.36	1.20
Maximum		3.00	2.88
Sum		31.10	23.30
Confidence Limit	Lower Bound	1.36	1.56
	Upper Bound	2.33	2.32
Percentiles	25	1.07	1.33
	50	1.71	1.94
	75	2.33	2.46
Inter Quartile Range		0.87	1.14

The experimental results of magnesium distribution in the study area are presented in Tables 4.43and 4.44. Various statistical estimates derived from NDA are summarized in Table 4.45. Figure 4.14 gives the variation of magnesium among different sampling stations in the area.

Table 4.43 Values for Magnesium of the soil samples inside the tea gardens

Sample No.	Mg (meq/100g)	Sample No.	Mg (meq/100g)
A1	0.30	D1	0.40
A2	0.70	D2	0.30
A3	1.68	D3	0.16
B1	0.37	E1	0.60
B2	0.20	E2	0.08
B3	0.30	E3	0.07
C1	0.12	F1	0.32
C2	0.50	F2	0.32
C3	0.56	F3	0.48

Table 4.44: Values for Magnesium of the soil samples outside the tea gardens

Sample No.	Mg (meq/100g)	Sample No.	Mg (meq/100g)
A11	0.80	D11	0.15
A12	0.20	D12	0.40
B11	0.40	E11	0.51
B12	0.40	E12	0.48
C11	0.18	F11	0.56
C12	0.80	F12	0.48

Table: 4.45 Statistical analysis for Magnesium in soil

Descriptive Statistics		Inside	Outside
Mean		0.41	0.45
Std. Error of Mean		0.09	0.06
Median		0.32	0.44
Mode		0.30	0.40
Std. Deviation		0.36	0.21
Variance		0.13	0.05
Skewness		2.67	0.34
Std. Error of Skewness		0.54	0.64
Kurtosis		9.04	-0.31
Std. Error of Kurtosis		1.04	1.23
Range		1.61	0.65
Minimum		0.07	0.15
Maximum		1.68	0.80
Sum		7.46	5.36
Confidence Limit	Lower Bound	0.20	0.31
	Upper Bound	0.73	0.58
Percentiles	25	0.19	0.25
	50	0.32	0.44
	75	0.52	0.55
Inter Quartile Range		0.32	0.30

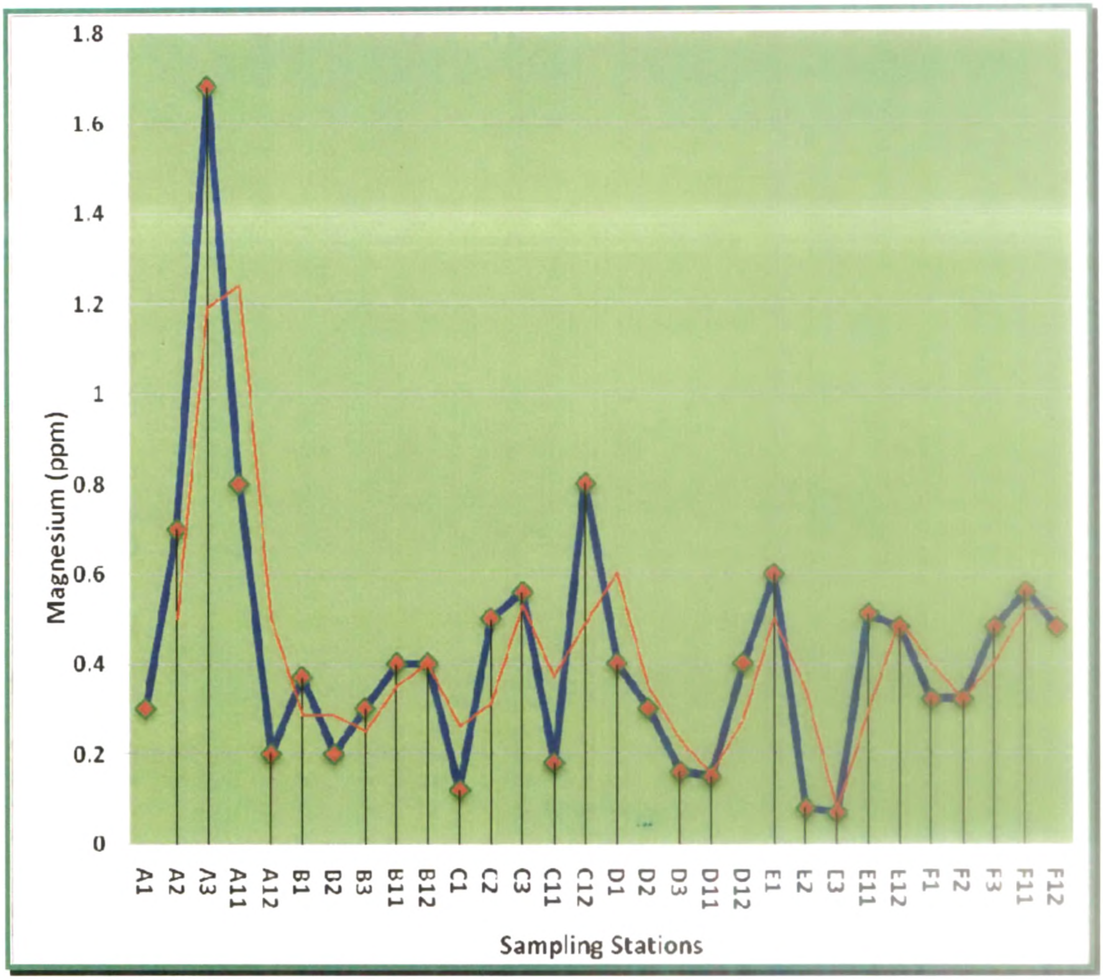

Figure 4.14: Variation of magnesium among soil sampling stations

Calcium and magnesium deficiency symptoms can be rather vague since the situation often is accompanied by a low soil pH. The high acidity of soils limits the availability of Ca and Mg to the plant. It is also observed that Ca and Mg share a significant correlation with pH at the 0.05 level in the study area which have been observed in I (a) and I (b) Pearson's Two-tailed Correlations. Statistical differences between mean, median, mode, quartiles and significant standard deviation implies that the distribution of arsenic in the study area is highly asymmetric. This is also supported by positive skew and kurtosis values.

4.1.15 Chloride and Sulphate

Chlorine is one of the most abundant elements on the surface of the Earth. In soil, it is mainly present as chloride ions (Cl–) and as an integrated part of the organic matter, that is organically bound (Cl org). Chloride is the most recent addition to the list of essential elements. Although chloride (Cl) is classified as a micronutrient, plants may take up as much chloride as they do secondary elements such as sulfur. Chloride is important in the opening and closing of stomata. Chloride also functions in photosynthesis, specifically in the water splitting system. Chloride functions in cation balance and transport within the plant. Chloride diminishes the effects of fungal infections in an as yet undefined way. Chloride suppresses diseases by lowering the nitrate uptake by plant.

Sulphur is required for all biological systems. Sulphate (SO_4^{2-}) is the main form absorbed by plants but it is not the predominant form in most soils, which explains why S-deficiencies are a common phenomenon (Pierzynski *et al.,* 2000). The primary source of sulphur in tea garden soils is organic matter, several other soil minerals, artificial fertilization of land and irrigation water. The total sulphur in Indian soils has been summarized by Takkar (1988). The soils inside the tea gardens have mean Sulphate-sulphur contents 10.9mg/kg. The paddy field around the tea gardens has a mean sulphur content of 12.1 mg/kg. This comparatively high value of soil sulphur in our study area is ascribable to the fact that the soil texture is heavy clay along with modest organic matter content. The experimental results of chloride distribution in the study area are presented in Tables 4.46 and 4.47. Various statistical estimates derived from NDA are summarized in Table 4.48. Figure 4.15 gives the variation of chloride among different sampling stations in the area.

Table 4.46 Values for Chloride of the soil samples inside the tea gardens

Sample No.	chloride (mg/100g)	Sample No.	chloride (mg/100g)
A1	15.60	D1	28.03
A2	15.40	D2	27.20
A3	14.2	D3	24.85
B1	11.36	E1	22.01
B2	11.20	E2	26.60
B3	13.49	E3	27.69
C1	14.91	F1	14.91
C2	14.20	F2	18.46
C3	18.45	F3	22.01

Table 4.47: Values for Chloride of the soil samples outside the tea gardens

Sample No.	chloride (mg/100g)	Sample No.	chloride (mg/100g)
A11	22.01	D11	25.24
A12	29.04	D12	22.43
B11	12.07	E11	24.85
B12	12.60	E12	25.66
C11	30.53	F11	18.46
C12	23.80	F12	10.65

Table: 4.48 Statistical analysis for Chloride in soil

Descriptive Statistics		Inside	Outside
Mean		18.92	21.45
Std. Error of Mean		1.39	1.91
Median		17.03	23.12
Mode		14.20	10.65
Std. Deviation		5.88	6.62
Variance		34.62	43.85
Skewness		0.40	-0.54
Std. Error of Skewness		0.54	0.64
Kurtosis		-1.38	-0.89
Std. Error of Kurtosis		1.04	1.23
Range		16.83	19.88
Minimum		11.20	10.65
Maximum		28.03	30.53
Sum		340.57	257.34
Confidence Limit	Lower Bound	13.63	17.24
	Upper Bound	21.19	25.65
Percentiles	25	14.20	14.07
	50	17.03	23.12
	75	25.29	25.56
Inter Quartile Range		9.58	11.49

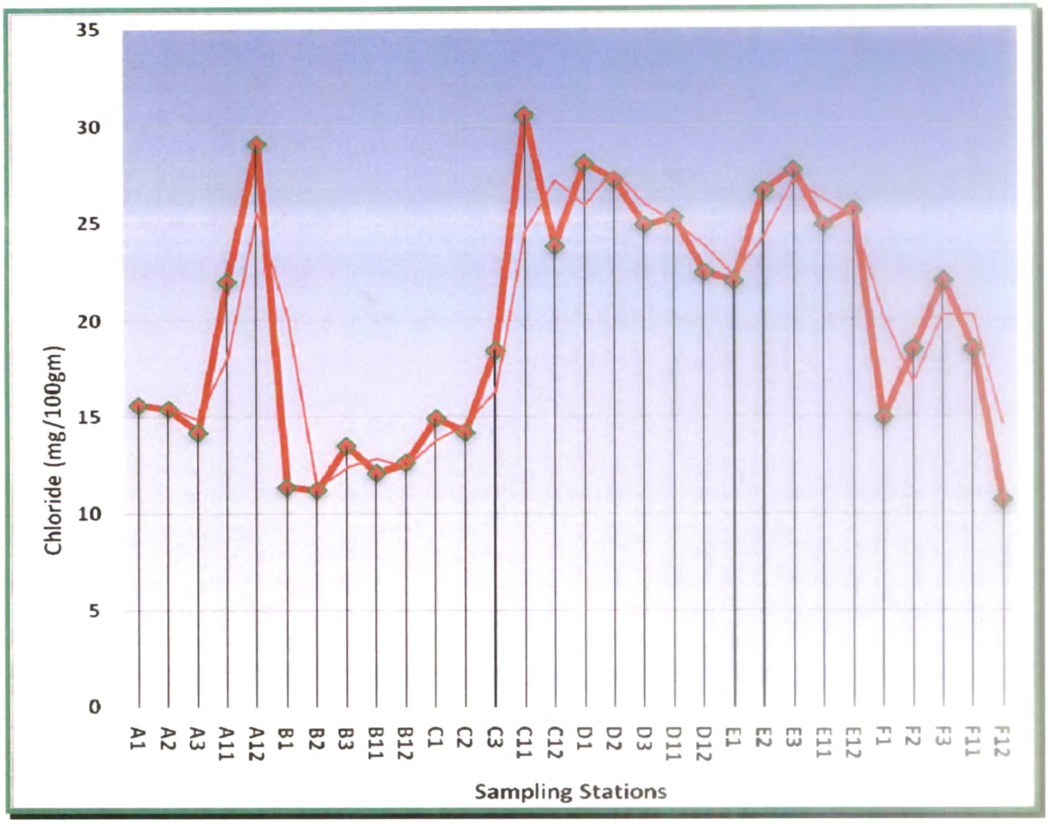

Figure 4.15: Variation of chloride among soil sampling stations

Table 4.49 Values for Sulphate –S of the soil samples inside the tea gardens

Sample No.	Sulphate-sulphur in mg/kg	Sample No.	sulphate -sulphur in mg/kg
A1	10.4	D1	9.9
A2	14.7	D2	12.5
A3	7.4	D3	10.5
B1	6.4	E1	14.0
B2	5.2	E2	15.5
B3	5.4	E3	12.8
C1	7.3	F1	11.5
C2	13.1	F2	7.7
C3	7.3	F3	3.7

Table 4.50: Values for Sulphate –S of soil samples outside the tea gardens

Sample No.	Sulphate-sulphur in mg/kg	Sample No.	Sulphate-sulphur in mg/kg
A11	14.7	D11	1.8
A12	14.6	D12	4.3
B11	13.0	E11	12.2
B12	1.9	E12	14.1
C11	15.4	F11	17.8
C12	17.9	F12	17.4

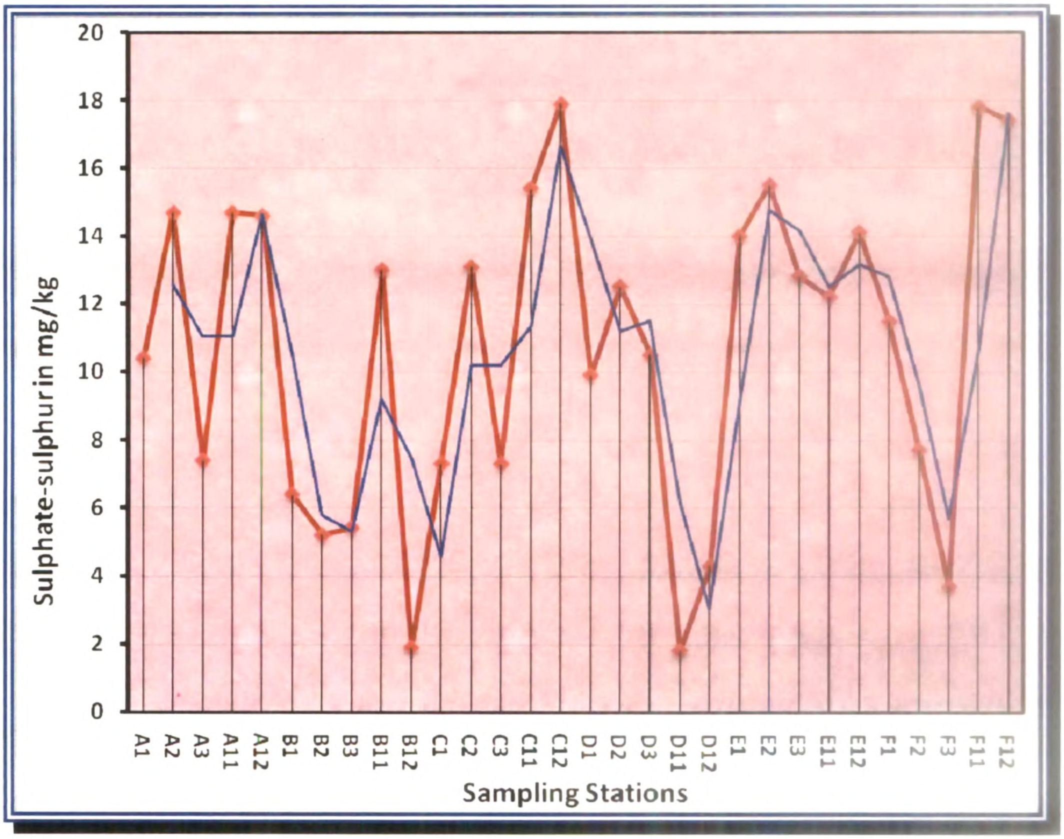

Figure 4.15: Variation of sulphate-sulphur among soil sampling stations

Table: 4.51 Statistical analysis for Sulphate –S in soil

Descriptive Statistics		Inside	Outside
Mean		9.739	12.092
Std. Error of Mean		0.842	1.727
Median		10.150	14.350
Mode		7.300	1.800
Std. Deviation		3.572	5.984
Variance		12.763	35.810
Skewness		0.002	-1.024
Std. Error of Skewness		0.536	0.637
Kurtosis		-1.208	-0.481
Std. Error of Kurtosis		1.038	1.232
Range		11.800	16.100
Minimum		3.700	1.800
Maximum		15.500	17.900
Sum		175.300	145.100
Confidence Limit	Lower Bound	7.178	8.290
	Upper Bound	11.172	15.894

Differences between mean, median and mode, significant standard deviation and error value indicate that the distribution of iron in the study area is highly asymmetric. This is also evident from the width of the third quartile, which is much greater than the first and second quartile. Wide data range in each case indicates the presence of extreme values, which are likely to bias the normal distribution statistic. ANOVA analysis suggests that the means are not significantly different ($F = 1.82685$, $p = 0.18732$) inside and outside teagardens.

4.2 Water Quality

The results of physic-chemical and aesthetic parameters of water quality in the tea garden belt of Darrang district, Assam are discussed one by one below.

4.2.1 Temperature

Human activities should not change water temperatures beyond natural seasonal fluctuations. To do so could disrupt aquatic ecosystems. Good temperatures are dependent on the type of stream. In general water temperatures should be between 20 °C to 32 °C. Temperature varies at different sampling stations in the study area. The variation is mainly due to the locations of the sampling stations and their exposure to sun. It ranges between 19^0C to 27^0C in the pre monsoon and 25°C to 30°C in the post monsoon season and listed in Table 4.52

4.2.2 Colour

Colour is monitored through visual observation only. Colour of water may be indicative of large quantities of organic chemicals and inadequate treatment. Colour from iron is referred to as "apparent colour" rather than "true colour". True colour is distinguished from apparent colour by filtering the sample. While colour itself is not usually objectionable from the standpoint of health, its presence is aesthetically objectionable and suggests that the water samples in the present study may need additional treatment since seven samples have colours that are not suitable for drinking. It may be due to oxidation of dissolved iron particles in water that changes the iron to white, then yellow and finally to red-brown solid particles that settle out of the water. Iron that does not form particles large enough to settle out and that remains suspended (colloidal iron) leaves the water with a red tint. The colour of the water samples has been summarised below in the Table 4.53

Table 4.52: Values for temperature of the water samples in the study area

Inside Tea Garden			Outside Tea Garden		
Sample No.	**Pre monsoon**	**Post monsoon**	**Sample No.**	**Premonsoon**	**Post monsoon**
A1	23	28	B1	24	27
A2	25	28	B2	23	28
A3	26	27	B3	24	27
A4	23	26	B4	19	25
A5	21	28	B5	27	28
A6	23	29	B6	27	27
A7	26	27	B7	25	28
A8	25	27	B8	24	26
A9	27	26	B9	25	27
A10	25	25	B10	25	29
A11	19	26	B11	27	28
A12	20	26	A12	26	29
A13	19	28	A13	24	28
A14	20	30	A14	23	27

Table 4.53: Colour of the water samples in the study area

Colour			
Sample No.	**Inside Tea Garden**	**Sample No.**	**Outside Tea Garden**
A1	Colourless	B1	Colourless
A2	Colourless	B2	Colourless
A3	Light Brown	B3	Reddish
A4	Light Brown	B4	Reddish olour
A5	Colourless	B5	Reddish
A6	colourless	B6	Colourless
A7	Reddish Tint	B7	Reddish Tint
A8	Colourless	B8	colourless
A9	Reddish colour	B9	Colourless
A10	Reddish Brown	B10	Light brown
A11	colourless	B11	Light brown
A12	colourless	B12	Light brown
A13	Light Brown	B13	Light brown
A14	Light Brown	B14	Light brown

4.2.3 Odour

Assessment of odour is usually not included in the water quality evaluation. If a change in odour is detected, it might indicate a water quality problem that requires further investigation. So, odour is an important quality factor affecting the drinkability of water. Odours for certain substances in water may be detected at extremely low concentrations. This may be indicative of the presence of organic and inorganic pollutants that may originate from municipal and industrial waste discharges or from natural sources. Seven samples of the present study have objectionable odour.

4.2.4 Taste

It is not recommended to taste water of unknown source as it might cause some health problems. This is usually not included in water quality assessment, but if a change is noticed, it might indicate a water quality problem that requires further analysis. It has been found that seven samples of the present research have unpleasant taste.

Table 4.54: Odour and Taste of the water samples in the study area

Inside Tea Garden			Outside Tea Garden		
Sample No.	**Odour**	**Taste**	**Sample No.**	**Odour**	**Taste**
A1	Odourless	Tasteless	B1	Odourless	Tasteless
A2	Odourless	Tasteless	B2	Odourless	Tasteless
A3	Odourless	Tasteless	B3	Odourless	Tasteless
A4	Chemical Smell	Metallic Taste	B4	Odourless	Tasteless
A5	Odourless	Tasteless	B5	Odourless	Tasteless
A6	Earthy Smell	Mild	B6	Odourless	Tasteless
A7	Odourless	Tasteless	B7	Earthy Smell	Salty
A8	Grassy Smell	Salty	B8	Oily Smell	Salty-brackish
A9	Odourless	Tasteless	B9	Odourless	Tasteless
A10	Oily Smell	Salty-brackish	B10	Grassy Smell	Mild
A11	Odourless	Tasteless	B11	Earthy Smell	No characteristic taste
A12	Odourless	Tasteless	B12	Grassy Smell	Mild
A13	Earthy Smell	Mild	B13	Earthy Smell	Mild
A14	Oily Smell	Salty-brackish	B14	Earthy Smell	Mild

4.2.5 Solids

Water is a good solvent and picks up impurities easily. Water normally contains solid material, both in dissolved and suspended forms. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulphates) and some small amounts of organic matter that are dissolved in water. In general, the total dissolved solids concentration is the sum of the cations (positively charged ions) and anions (negatively charged ions) in the water. Total dissolved solids, consequently, (W.H.O limit: 500 mg/L) may have an influence on the acceptability of the water in general. TSS constitutes particles of different sizes ranging from coarse to fine colloidal particles and impart turbidity of water. Results indicate water samples inside tea gardens are more turbid. TSS concentrations in the study area exceed the maximum permissible limit (5 mg/L) of United States Public Health (USPH) Standard. The variation in TDS, TS and TSS are mainly due to ionic composition of water and the factors like rainfall and biota cause changes in their concentrations.

Total dissolved solids (TDS) are the term used to describe the inorganic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulphate, and nitrate anions (W.H.O, 1996). No data on health effects associated with the ingestion of TDS in drinking-water has been reported, however, the presence of dissolved solids in water may affect its taste (Bruvold WH, Ongerth HJ, 1969). Tables 4.55 and 4.56 show different values of TS, TSS, TDS in the post monsoon and pre monsoon respectively.

Table 4. 55: Values for solids of the water samples in post-monsoon in the study area

Inside Tea Garden				Outside Tea Garden			
Sample No.	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	Sample No.	TS (mg/L)	TSS (mg/L)	TDS (mg/L)
A1	561	26	535	B1	589	35	554
A2	282	2	280	B2	141	31	110
A3	588	32	556	B3	341	05	336
A4	222	10	210	B4	542	02	540
A5	183	11	172	B5	279	23	256
A6	198	9	189	B6	299	19	280
A7	343	20	223	B7	556	28	528
A8	350	07	343	B8	339	19	320
A9	678	32	646	B9	446	23	423
A10	410	21	389	B10	559	28	538
A11	555	23	532	B11	132	19	113
A12	543	16	527	B12	119	08	111
A13	423	31	392		102	09	93
A14	134	04	130	B14	546	18	528

Table 4.56: Values for solids of the water samples in pre-monsoon in the study area

Sample No.	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	Sample No.	TS (mg/L)	TSS (mg/L)	TDS (mg/L)
A1	530	19	511	B1	480	29	554
A2	198	4	194	B2	126	25	101
A3	530	28	502	B3	304	19	385
A4	217	11	206	B4	360	21	339
A5	183	11	172	B5	189	14	175
A6	298	9	286	B6	282	13	269
A7	350	25	325	B7	515	27	488
A8	219	3	216	B8	327	17	310
A9	599	14	585	B9	329	19	310
A10	411	20	391	B10	459	26	433
A11	555	15	525	B11	122	12	110
A12	521	16	505	B12	121	8	113
A13	423	30	393	B13	93	05	88
A14	110	19	110	B14	502	14	488

4.2.6 Turbidity

Turbidity is an expression of the optical property that causes light to scatter. Suspended particles in the form of clay, slit, organic matter, plankton and other microorganism contributes to the turbidity. Generally ground water is less turbid than surface water because water gets filtered through layers of sand and soil. The degree of turbidity of water is the measure of intensity of pollution. So, EPA drinking water standards specify a maximum turbidity value of 1NTU and WHO specify a maximum turbidity value of 5 NTU. The experimental results of turbidity in the study area are presented in Table 4.57. Various statistical estimates derived from NDA are summarized in Table 4.58. Figures 4.17 and 4.18 gives the variation of turbidity among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.57: Values for turbidity of the water samples in the study area

Turbidity NTU					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.2	0.3	B1	1.1	2.7
A2	0.2	0.1	B2	0.9	2.1
A3	0.4	0.7	B3	0.2	0.3
A4	0.2	0.2	B4	0.7	1.3
A5	0.1	0.1	B5	0.8	2.2
A6	0.3	0.2	B6	0.7	1.2
A7	0.3	0.5	B7	0.9	2.9
A8	0.1	0.4	B8	0.7	1.1
A9	0.7	1.5	B9	0.4	0.7
A10	0.5	0.8	B10	0.3	0.8
A11	0.9	1.3	B11	0.3	0.4
A12	0.9	1.2	B12	0.2	0.1
A13	3.1	5.6	B13	0.3	0.2
A14	0.3	0.7	B14	1.2	1.3

Table 4.58: Statistical analysis for turbidity of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.585	0.971	0.621	1.235
Std. Error of Mean		0.206	0.376	0.090	0.246
Median		0.3	0.5	0.7	1.1
Mode		0.20	0.10	0.30	1.30
Std. Deviation		0.771	1.407	0.337	0.921
Variance		0.595	1.980	0.114	0.848
Skewness		3.03	3.11	0.22	0.58
Kurtosis		10.041	10.549	-1.254	-0.802
Range		3	5.5	1	2.8
Minimum		0.1	0.1	0.2	0.1
Maximum		3.1	5.6	1.2	2.9
Sum		8.2	13.6	8.7	17.3
Confidence Limit	Lower	0.140	0.158	0.426	0.703
	Upper Bound	1.031	1.784	0.816	1.767
Percentiles	25	0.2	0.2	0.3	0.4
	50	0.3	0.6	0.7	1.15
	75	0.7	1.2	0.9	2.1
Inter Quartile Range		0.5	1	0.6	1.7
WHO Rating		5NTU			
t		-21.409	-10.710	-48.496	-15.289
Comment		Significant	Significant	Significant	Significant

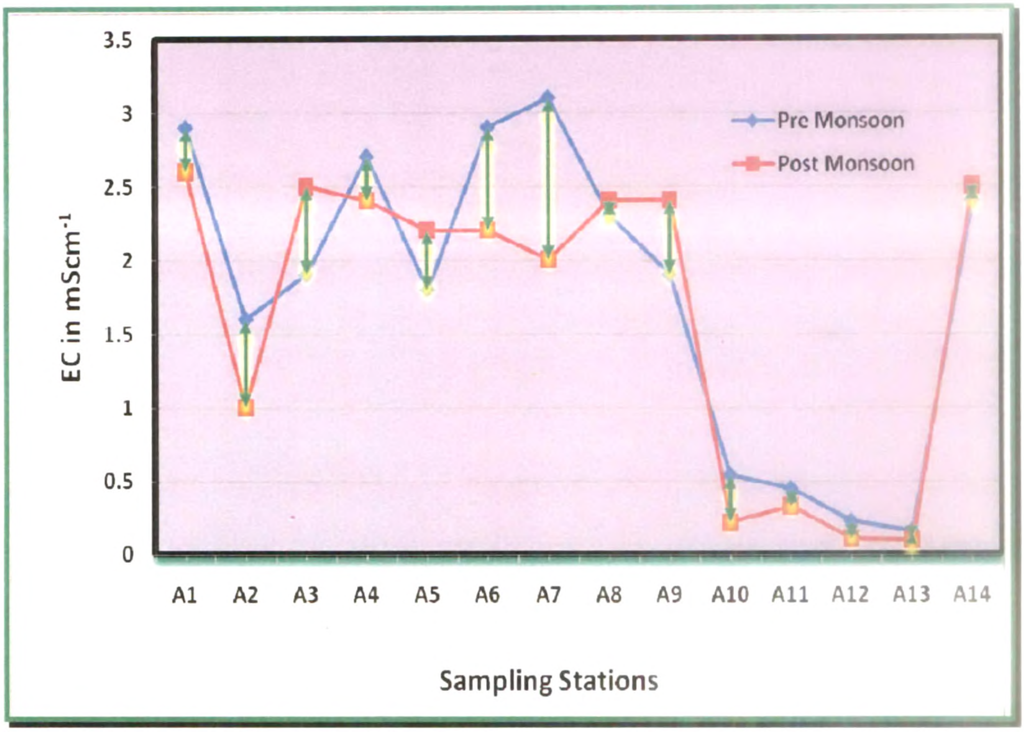

Figure 4.17: Seasonal variations of turbidity of water inside the tea gardens

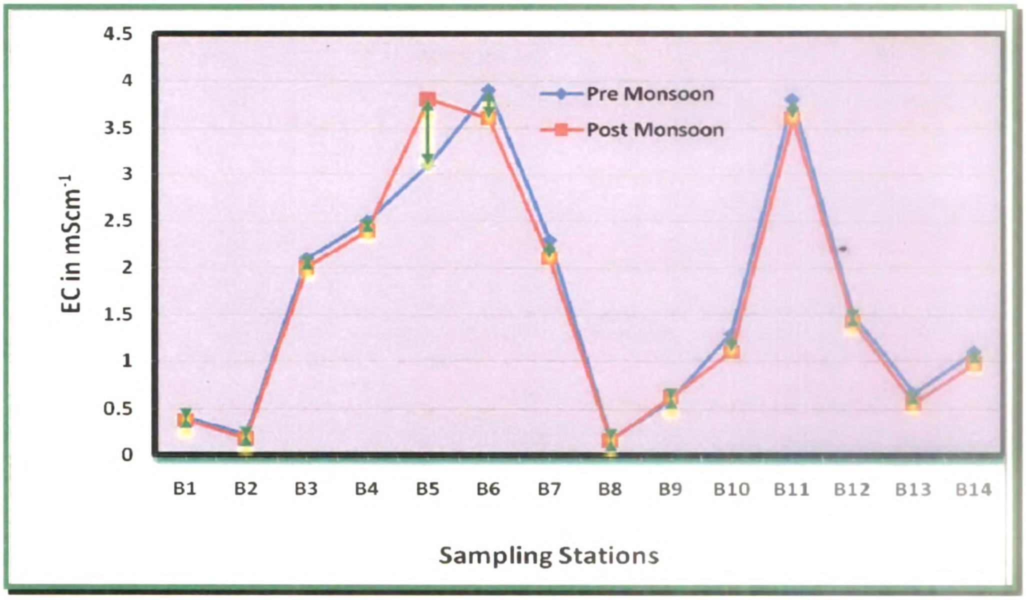

Figure 4.18: Seasonal variations of turbidity of water outside the tea gardens

Turbidity showed remarkable seasonal variation inside the tea gardens. However, the variation is somewhat lower in the outside tea gardens. Highest value of turbidity was recorded at sampling point A13 (Singrimari tubewell , Inside tea garden) in post monsoon season and it exceeds WHO maximum permissible limit of 5 NTU. High turbidity value of the sampling point A13 may be due to age-old iron pipe used. Rusting of this iron pipe adds excess iron to the water and this may also create some leakage in the pipe and makes the water turbid.

ANNOVA analysis ($F = 0.80862$, $p = 0.37678$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. But ANNOVA analysis ($F = 5.48727$, $p = 0.02709$) at the 0.05 level, suggests that the means are significantly different during the pre and post monsoon season outside the tea gardens.

4.2.7 Electrical Conductance (EC)

Conductance is not a pollution indicator; in fact, it reflects the degree of mineralization of water. Conductivity is a good and rapid measure of total dissolved solids. Total dissolved solid can be obtained roughly by multiplying the conductivity with a factor of 0.55 to 0.909(APHA, 1985). Freshly prepared distilled water has conductivity value of 0.5 μScm^{-1} to 2.0 μScm^{-1} which may change to 2 μScm^{-1} to 4 μScm^{-1} on standing due to absorption of CO_2 from the atmosphere.

The experimental results of EC in the study area are presented in Table 4.59. Various statistical estimates derived from NDA are summarized in Table 4.60. Figures 4.19 and 4.20 gives the variation of EC among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. The conductance values shown in the tables range from

0.16 $mScm^{-1}$ to 3.10 $mScm^{-1}$ (Inside tea gardens, Pre monsoon season)

0.10 $mScm^{-1}$ to 2.6 $mScm^{-1}$ (Inside tea gardens, Post monsoon season)

0.17$mScm^{-1}$ to 3.90 $mScm^{-1}$ (Outside tea gardens, Pre monsoon season)

0.16$mScm^{-1}$ to 3.80 $mScm^{-1}$ (Outside tea gardens, Post monsoon season)

Table 4.59: Values for electrical conductance of the water samples in the study

EC in $mScm^{-1}$					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	2.9	2.6	B1	0.41	0.38
A2	1.6	1.0	B2	0.22	0.18
A3	1.9	2.5	B3	2.1	2.0
A4	2.7	2.4	B4	2.5	2.4
A5	1.8	2.2	B5	3.1	3.8
A6	2.9	2.2	B6	3.9	3.6
A7	3.1	2.0	B7	2.3	2.1
A8	2.3	2.4	B8	0.17	0.16
A9	1.9	2.4	B9	0.60	0.63
A10	0.54	0.22	B10	1.3	1.1
A11	0.45	0.33	B11	3.8	3.6
A12	0.23	0.11	B12	1.5	1.43
A13	0.16	0.10	B13	0.67	0.56
A14	2.4	2.5	B14	1.1	0.98

Table 4.60: Statistical analysis for electrical conductance of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		1.78	1.64	1.69	1.64
Std. Error of Mean		0.28	0.27	0.34	0.35
Median		1.90	2.20	1.40	1.27
Mode		1.90	2.40	0.17	3.60
Std. Deviation		1.04	1.03	1.28	1.30
Variance		1.09	1.06	1.65	1.70
Skewness		-0.46	-0.72	0.53	0.60
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-1.24	-1.49	-0.97	-1.04
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		2.94	2.50	3.73	3.64
Minimum		0.16	0.10	0.17	0.16
Maximum		3.10	2.60	3.90	3.80
Sum		24.88	22.96	23.67	22.92
Confidence Limit	Lower	1.17	1.05	0.95	0.88
	Upper Bound	2.38	2.23	2.43	2.39
Percentiles	25	0.52	0.30	0.55	0.52
	50	1.90	2.20	1.40	1.27
	75	2.75	2.43	2.65	2.70
Inter Quartile Range		2.23	2.12	2.10	2.19
USPH Rating		0.3 mmho cm^{-1}			
t		54.12	45.69	43.64	39.50
Comment		Significant	Significant	Significant	Significant

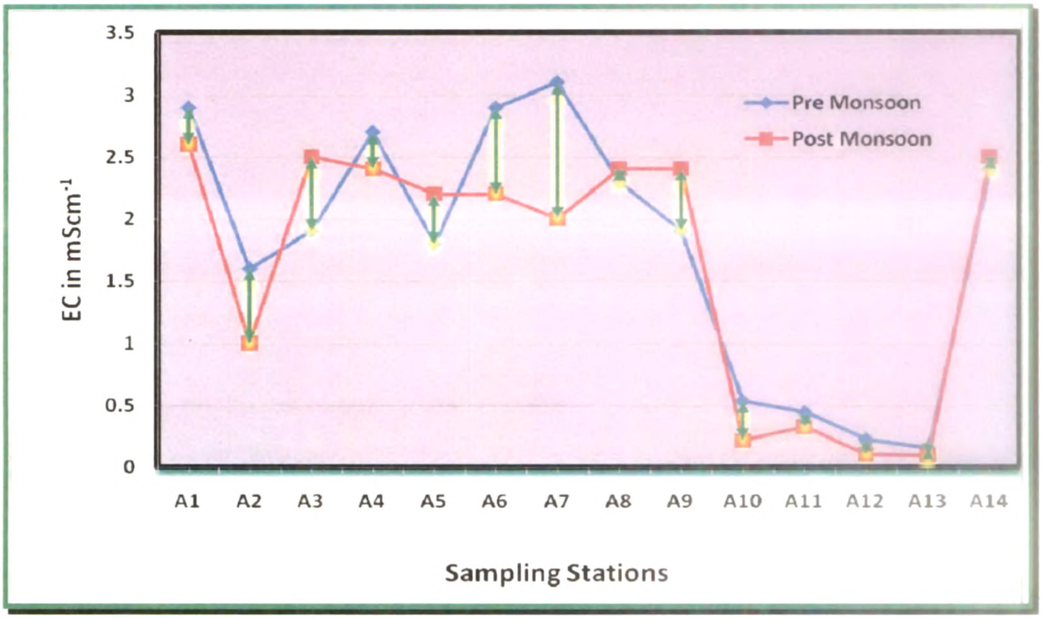

Figure 4.19: Seasonal variations of electrical conductance of water inside the tea gardens

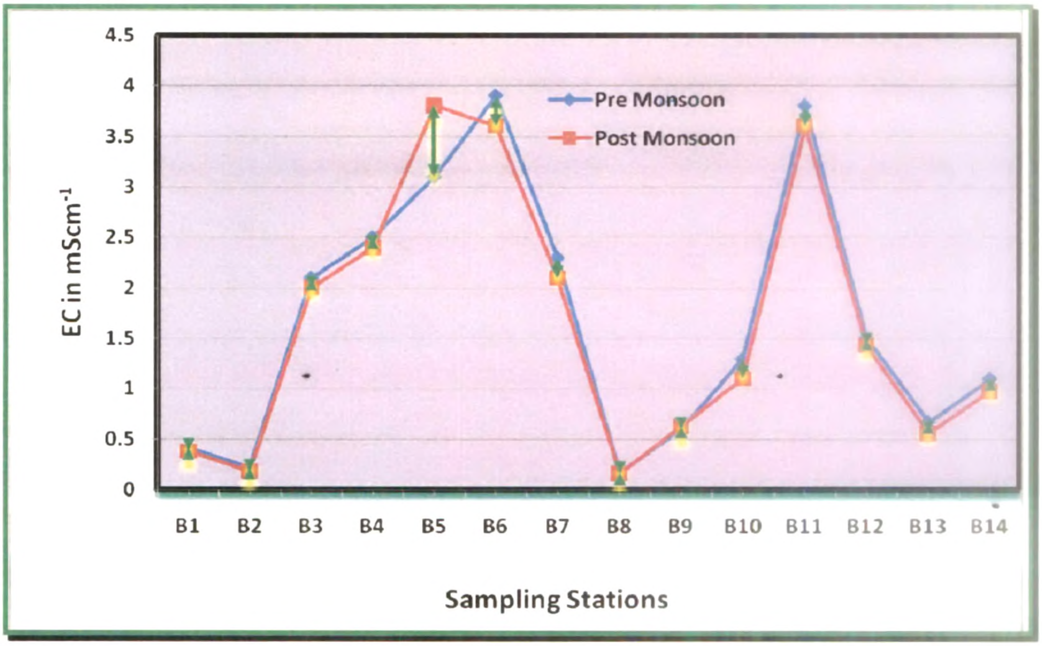

Figure 4.20: Seasonal variations of electrical conductance of water outside the tea gardens

The conductance of water in the study area has values greater than the maximum permissible limit (0.3 mmho cm^{-1}) of USPH and indicates that water is markedly polluted with its reference. The maximum value of EC recorded to be 3.9 $mScm^{-1}$ in the pre monsoon season in outside tea gardens. ANNOVA analysis ($F = 0.52228$, $p = 0.47632$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.05447$, $p = 0.81729$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.8 pH

pH is a numerical expression that indicates the degree to which a water is acidic or alkaline and is an operational parameter. Natural waters usually have pH values in the range of 4 to 9 and most are slightly basic (i.e. greater than7) because of the presence of bicarbonates and carbonates. Corrosion effects may become significant at a pH below 6.5 and scaling may become a problem at a pH above 8.5. For this reason an acceptable range for drinking water pH is from 6.5 to 8.5 (WHO, 2005). High pH levels are undesirable since they may impart a bitter taste to water and also depress the effectiveness of disinfection by chlorination. However, pH alone does not provide a full picture of the characteristics or limitations with the water supply. The experimental results of pH in the study area are presented in Table 4.61 Various statistical estimates derived from NDA are summarized in Table 4.62. Figures 4.21 and 4.22 gives the variation of pH among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.61: Values for pH of the water samples in the study area

pH					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	7.01	7.39	B1	7.01	7.07
A2	7.32	7.72	B2	7.56	7.31
A3	7.11	7.52	B3	6.18	6.39
A4	7.23	7.51	B4	6.55	6.53
A5	6.98	6.92	B5	6.14	6.49
A6	6.77	6.73	B6	6.11	6.17
A7	7.01	6.92	B7	5.98	5.9
A8	6.51	6.60	B8	5.57	5.35
A9	6.43	6.40	B9	6.32	5.90
A10	6.27	6.45	B10	5.95	6.1
A11	6.11	6.09	B11	7.01	7.4
A12	6.02	6.29	B12	6.50	6.8
A13	6.17	6.31	B13	6.84	7.01
A14	6.50	6.46	B14	6.68	6.67

Table 4.62: Statistical analysis for pH of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		6.67	6.81	6.46	6.51
Std. Error of Mean		0.12	0.14	0.14	0.16
Median		6.64	6.67	6.41	6.51
Mode		7.01	6.92	7.01	5.90
Std. Deviation		0.44	0.53	0.53	0.59
Variance		0.19	0.28	0.28	0.35
Skewness		-0.05	0.52	0.43	-0.23
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-1.50	-1.16	0.03	-0.43
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		1.30	1.63	1.99	2.05
Minimum		6.02	6.09	5.57	5.35
Maximum		7.32	7.72	7.56	7.40
Sum		93.44	95.31	90.40	91.09
Confidence Limit	Lower Bound	6.42	6.50	6.15	6.17
	Upper Bound	6.93	7.12	6.76	6.85
Percentiles	25	6.25	6.38	6.08	6.05
	50	6.64	6.67	6.41	6.51
	75	7.04	7.42	6.88	7.03
Inter Quartile Range		0.79	1.04	0.81	0.98
WHO Rating		6.5-8.5			
t		1.48	2.16	-0.30	0.04091
Comment		Non Significant	Significant	Non Significant	Non Significant

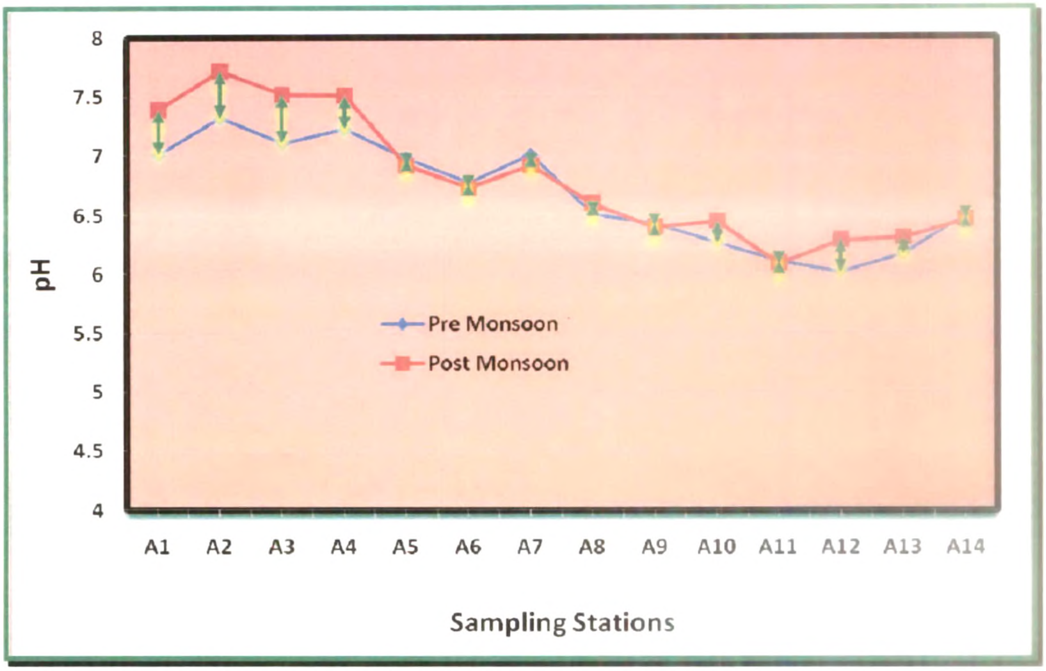

Figure 4.21: Seasonal variations of pH of water inside the tea gardens

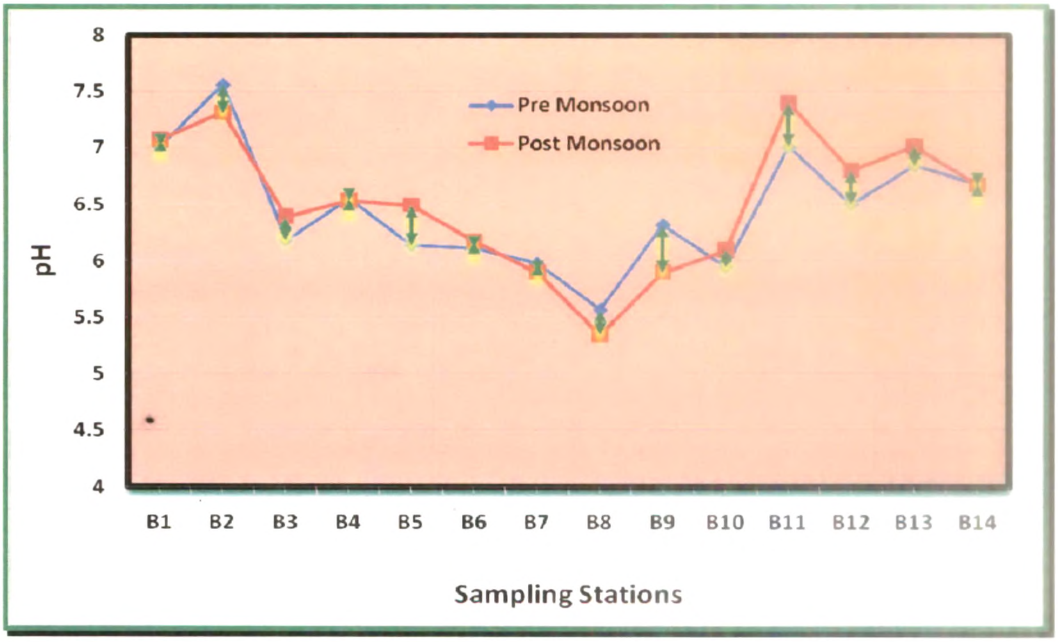

Figure 4.22: Seasonal variations of pH of water outside the tea gardens

In all the sampling stations studied pH are within the W.H.O guide lines values for safe drinking water. In the study area the variation of pH is narrow and in general the pH is towards alkaline side. ANNOVA analysis ($F = 0.52228$, $p = 0.47632$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.05447$, $p = 0.81729$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.9 Dissolve Oxygen (D.O.)

Dissolved oxygen analysis measures the amount of gaseous oxygen (O_2) dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. Very low DO is an indicator of organic pollution, particularly when pollution is contributed by sewage outfall. Adequate dissolved oxygen is necessary for good water quality. Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/l, aquatic life is put under stress. The lower the concentration, the greater the stress. Depletion of dissolved oxygen in water supplies can encourage microbial reduction of nitrate to nitrite and sulphate to sulphide, giving rise to odour problem (Park, K., 2005). Oxygen levels that remain below 1-2 mg/l for a few hours can result in large fish kills. In the present study DO values of different sampling sources are in the following ranges

The highest DO value 8.78 mg/L observed at sampling points A11 and B9 in pre monsoon and post monsoon respectively. DO has less importance to drinking water, however its complete absence or very low concentration may affect the test of water and fish life becomes impossible (Camp T. R., 1963). Survival of most aquatic life is just impossible if DO goes below 5 mg/L (Hodges L., 1973). Present study reveals that in most cases, DO content relatively higher in winter season compared to the summer season. The reason probably due to difference in atmospheric temperature (Sunil Kumar *et al.*, 2004)

The experimental results of dissolved oxygen in the study area are presented in Table 4.72. Various statistical estimates derived from NDA are summarized in Table 4.73. Figures 4.27 and 4.28 gives the variation of dissolved oxygen among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. Mean DO's in the pre monsoon is relatively higher than that of postmonsoon both inside and iutside of the tea gardens. The higher value in the premonsoon may be due to lower temperature in the season.

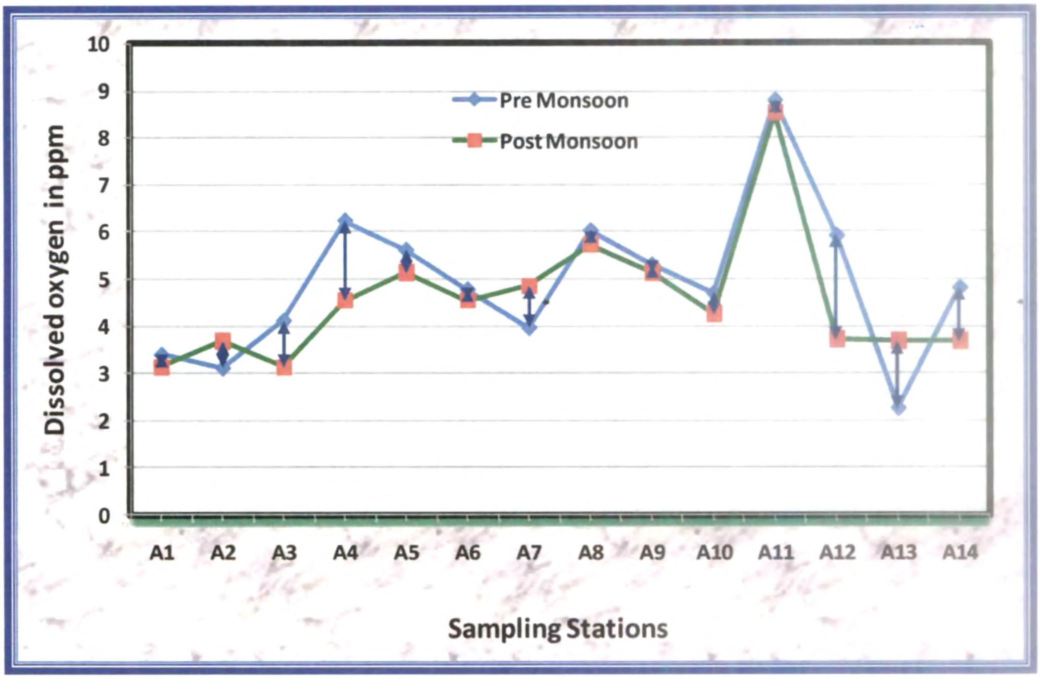

Figure 4.23: Seasonal variations of dissolved oxygen of water inside the tea gardens

Table 4.63: Values for dissolved oxygen of the water samples in the study area

Dissolved oxygen in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	3.40	3.13	B1	5.10	4.25
A2	3.12	3.68	B2	7.11	6.01
A3	4.12	3.13	B3	5.67	4.56
A4	6.23	4.53	B4	4.91	4.28
A5	5.61	5.13	B5	5.40	5.13
A6	4.78	4.53	B6	5.90	5.13
A7	3.97	4.85	B7	6.32	5.90
A8	6.02	5.71	B8	4.52	3.40
A9	5.30	5.13	B9	8.22	8.78
A10	4.70	4.25	B10	6.41	4.28
A11	8.78	8.50	B11	4.73	3.13
A12	5.91	3.71	B12	4.81	3.71
A13	2.27	3.68	B13	3.13	4.24
A14	4.82	3.68	B14	3.12	5.13

Table 4.64: Statistical analysis for dissolved oxygen of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		4.93	4.54	5.38	4.85
Std. Error of Mean		0.43	0.37	0.37	0.37
Median		4.78	4.25	5.10	4.28
Mode		2.27	3.68	3.12	5.13
Std. Deviation		1.61	1.38	1.39	1.41
Variance		2.59	1.91	1.95	1.99
Skewness		0.69	1.90	0.19	1.68
Kurtosis		1.51	4.78	0.31	4.03
Range		6.51	5.37	5.10	5.65
Minimum		2.27	3.13	3.12	3.13
Maximum		8.78	8.50	8.22	8.78
Sum		69.03	63.64	75.35	67.93
Confidence Limit	Lower Bound	4.00	3.75	4.57	4.04
	Upper Bound	5.86	5.34	6.18	5.66
Percentiles	25	3.97	3.68	4.73	4.24
	50	4.80	4.39	5.25	4.42
	75	5.91	5.13	6.32	5.13
Inter Quartile Range		1.94	1.45	1.59	0.89

The distribution of D.O in the area is asymmetric with long right tail about the median which is evident from positive kurtosis and skewness values. The third quartile is more than second quartile and for which we infer that the distribution is off normal in the study area.

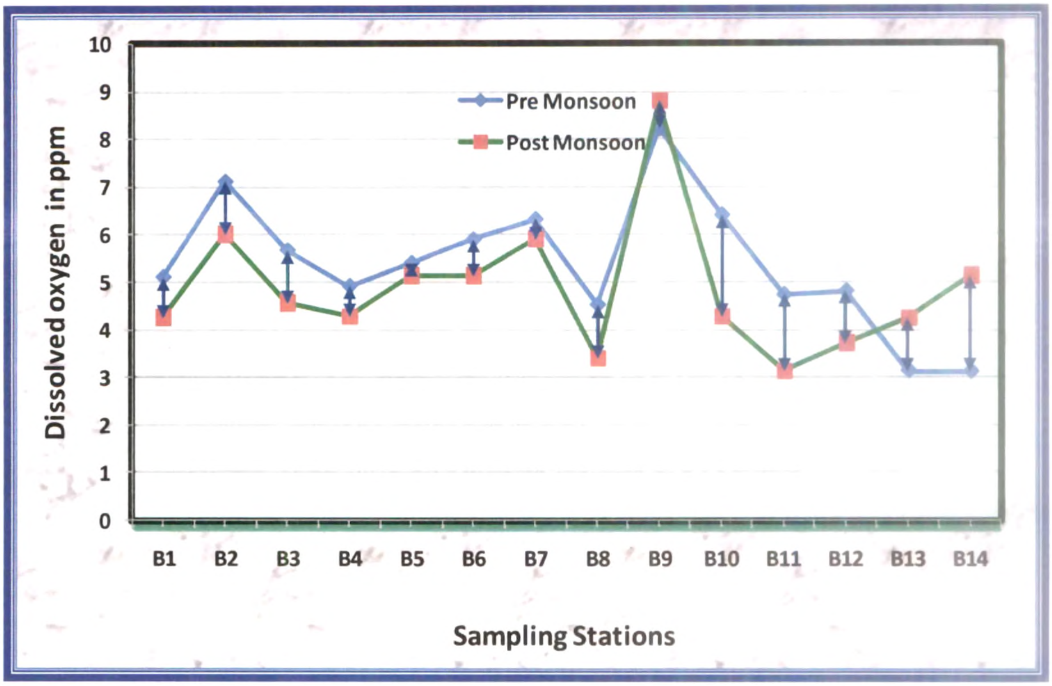

Table 4.24: Seasonal variations of dissolved oxygen of water outside the tea gardens ANNOVA analysis (F = 0.46171, p = 0.50283) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.99717, p = 0.3272) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.10 Total Alkalinity

Total alkalinity of a water body refers to its ability to neutralise a strong acid, ie. its buffering capacity. Although the alkalinity may in theory be caused by any weak acid anion it is usually only carbonate, or more strictly bicarbonate, alkalinity that is important in freshwaters (Wetzel and Likens 1991). Alkalinity itself is not harmful to human being. Still alkalinity 100mg/L is desirable for domestic use (Trivedy, R.K,

Table 4.66: Statistical analysis for alkalinity of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		42.44	47.54	45.75	57.30
Std. Error of Mean		9.39	7.63	10.83	12.84
Median		30.62	40.91	30.66	52.37
Mode		9.88	19.76	29.64	59.28
Std. Deviation		35.15	28.56	40.51	48.03
Variance		1235.57	815.57	1640.76	2306.46
Skewness		1.71	1.31	2.08	1.62
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		2.34	1.60	4.30	3.31
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		118.57	98.82	148.21	177.90
Minimum		9.88	19.76	9.88	9.80
Maximum		128.45	118.58	158.09	187.70
Sum		594.13	665.59	640.45	802.21
Confidence Limit	Lower Bound	22.14	31.05	22.36	29.57
	Upper Bound	62.73	64.03	69.13	85.03
Percentiles	25	19.76	27.07	27.12	18.52
	50	30.62	40.91	30.66	52.37
	75	49.07	64.23	49.07	82.65
Inter Quartile Range		29.31	37.16	21.96	64.13
WHO Rating		500 mg/L			
t		-48.71	-59.28	-41.96	-34.49
Comment		Significant	Significant	Significant	Significant

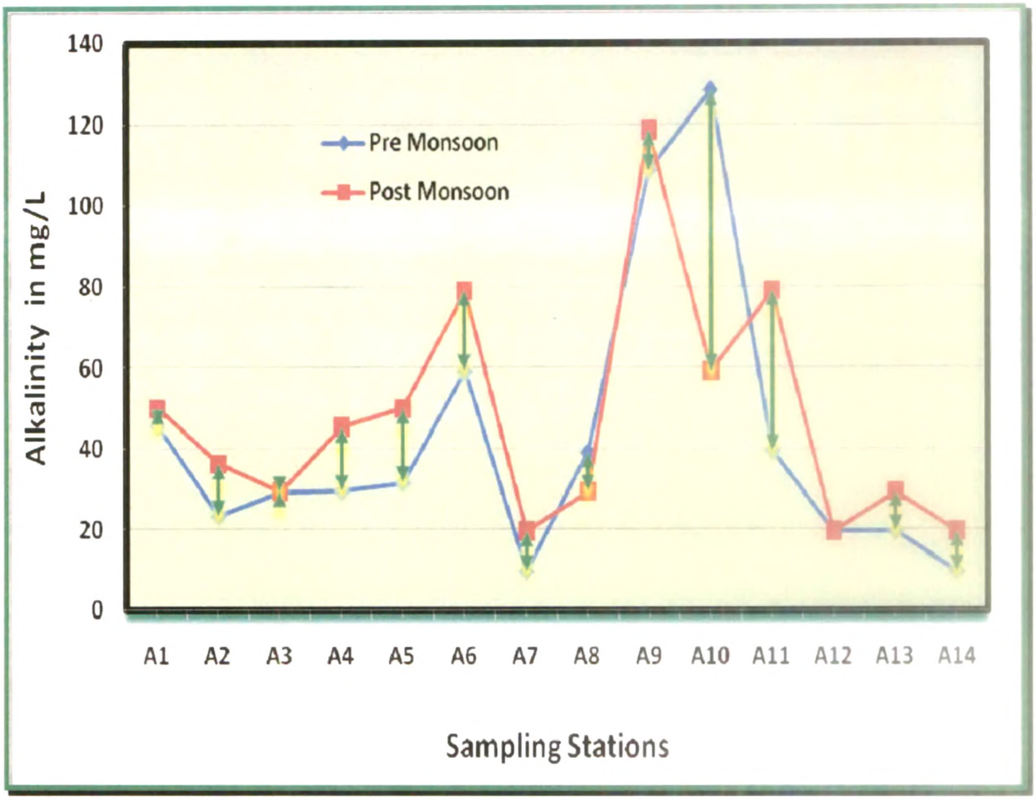

Figure 4.25: Seasonal variations of alkalinity of water inside the tea gardens

The experimental results of alkalinity in the study area are presented in Table 4.65. Various statistical estimates derived from NDA are summarized in Table 4.66 Figures 4.25 and 4.26 gives the variation of alkalinity among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. Significant positive kurtosis and skewness reveals that the distribution of alkalinity is sharp with long right tail about the median in both the seasons for outside and inside the tea gardens. The difference between quartiles also suggests that distribution is off normal.

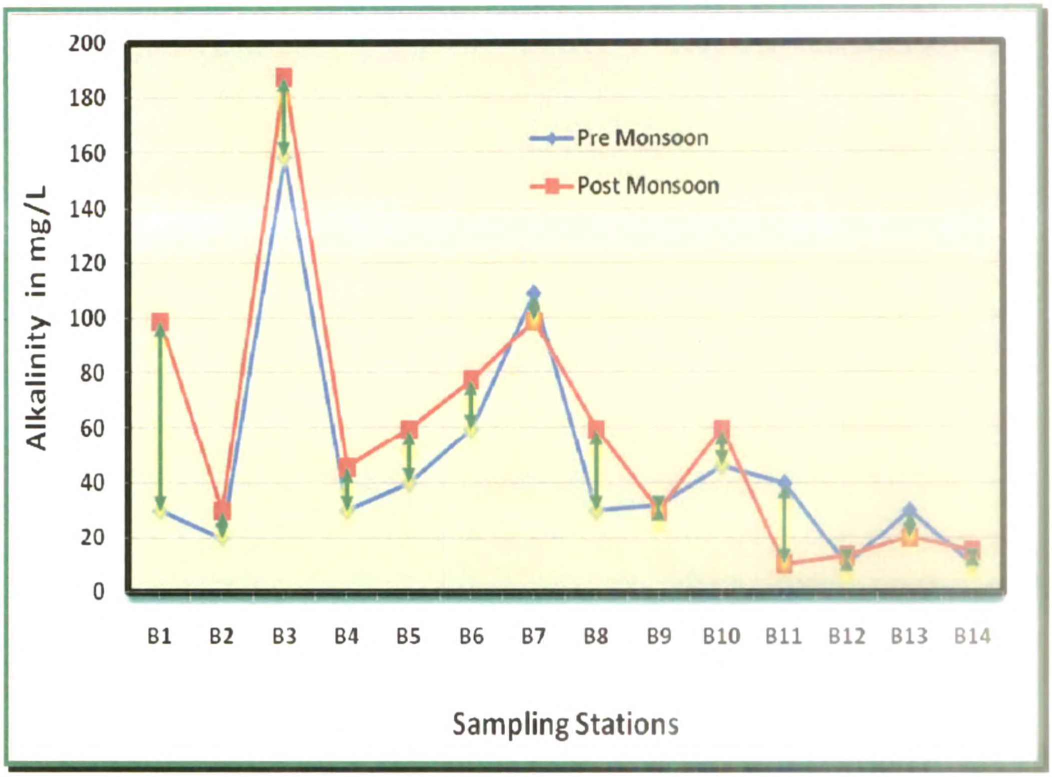

Figure 4.26: Seasonal variations of alkalinity of water outside the tea gardens

ANNOVA analysis (F = 0.17783, p = 0.67671) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.4735, p = 0.49747) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.11 Total hardness (as $CaCO_3$)

Water hardness is the traditional measure of the capacity of water to react with soap, hard water requiring considerably more soap to produce lather. Hardness is most commonly expressed as milligrams of calcium carbonate equivalent per litre. Water containing calcium carbonate at concentrations below 60 mg/l is generally considered as soft; 60–120 mg/l, moderately hard; 120–180 mg/l, hard; and more than 180 mg/l, very hard (McGowan W., 2000).

Table 4.67: Values for hardness of the water samples in the study area

$CaCO_3$ in mg/L					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	27	30	B1	41	48
A2	24	22	B2	30	46
A3	26	30	B3	35	32
A4	48	32	B4	30	33
A5	32	44	B5	54	68
A6	20	32	B6	69	60
A7	21	41	B7	31	40
A8	34	37	B8	11	20
A9	34	38	B9	34	29
A10	22	28	B10	36	45
A11	39	38	B11	20	19
A12	13	10	B12	12	18
A13	23	16	B13	32	23
A14	27	55	B14	30	35

Table 4.68: Statistical analysis for hardness of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		27.86	32.36	33.21	36.86
Std. Error of Mean		2.38	3.07	4.02	4.09
Median		26.50	32.00	31.50	34.00
Mode		27.00	30.00	30.00	18.00
Std. Deviation		8.90	11.48	15.04	15.30
Variance		79.21	131.79	226.18	234.13
Skewness		0.72	-0.15	0.85	0.62
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		0.84	0.55	1.68	-0.26
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		35.00	45.00	58.00	50.00
Minimum		13.00	10.00	11.00	18.00
Maximum		48.00	55.00	69.00	68.00
Sum		390.00	453.00	465.00	516.00
Confidence Limit	Lower Bound	22.72	25.73	24.53	36.86
	Upper Bound	33.00	38.99	41.90	28.02
Percentiles	25	21.75	26.50	27.50	22.25
	50	26.50	32.00	31.50	34.00
	75	34.00	38.75	37.25	46.50
Inter Quartile Range		12.25	12.25	9.75	24.25
WHO Rating		100 mg/l			
t		-30.32	-22.05	-16.62	-15.44
Comment		Significant	Significant	Significant	Significant

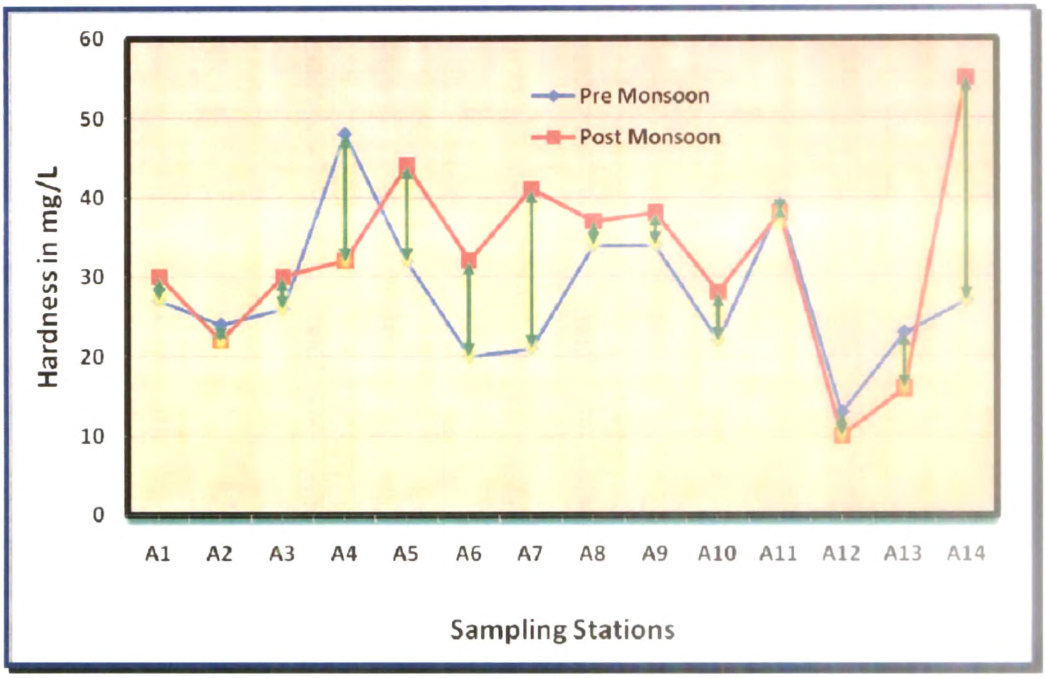

Figure 4.27: Seasonal variations of hardness of water inside the tea gardens

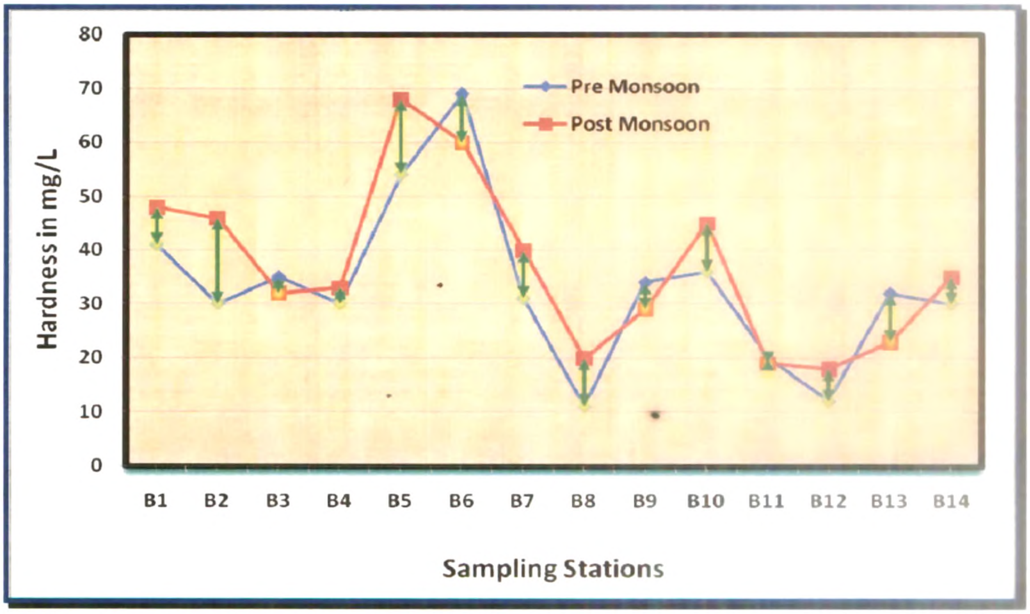

Figure 4.28: Seasonal variations of hardness of water outside the tea gardens

Principal cations imparting hardness such as strontium, iron and manganese also contribute to the hardness. The anions responsible for hardness are bicarbonate, carbonate, sulphate, chloride, nitrate, and silicate. However, the concentration of these ions is very low in natural waters, hence hardness is measured as concentration of only calcium and magnesium (as calcium carbonate), which are far higher in quantities over other hardness producing ions. WHO (1984) limit for hardness of potable water is 100mg/L. It is observed that the water is soft for most of the samples and all the samples in study area are as per the maximum limit prescribed by W.H.O for potability purposes. Highest value 69.0mg/L of hardness was observed at sampling point B6 which may be due to comparatively high amount of calcium content in that sampling point.

ANNOVA analysis ($F = 1.34364$, $p = 0.25693$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.40361$, $p = 0.53078$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.12 Calcium and Magnesium (Ca & Mg)

Calcium and magnesium are abundant substances in natural water. Being present in high quantities in the rocks, they are leached from there to contaminate the water. Apart from rocks, sewage and industrial wastes are also important contributors of calcium and magnesium. Calcium and magnesium are important parts of drinking water and are of both direct and indirect health significance. A certain minimum amount of these elements in drinking water is desirable since their deficiency poses at least comparable health risk as exceedance of the limit for some toxic substances does. Based on the available data, the desirable minimum of magnesium and calcium can be estimated to be > 10 mg/L and > 20-30 mg/L, respectively. Nevertheless, this does not mean that if low levels of these elements were increased to remain below the minimum mentioned above (e.g. if the magnesium level were increased from 2 to 5 mg/L), it would be of no importance. It seems that any increase, even by several mg/L, could have a health effect. Although a certain minimum quantity of these elements is desirable, it definitely does not mean the more the better. Calcium concentrations upto 1800mg/L have been found not impair any significant physiological reaction in man and magnesium content of > 125mg/L can produce some cathartic and diuretic effects (Trivedy & Goel, 1986). While considering higher levels of magnesium and calcium in drinking water, not only the absolute content of these elements but also the fact that higher water Mg and Ca levels are mostly associated with higher levels of the other dissolved solids that may not be beneficial to health, should be taken into account. What can be called the optimum Mg and Ca levels in drinking water ranges from 20 to 30 mg/L (for magnesium) and from 40 to 80 mg/L (for calcium), respectively.

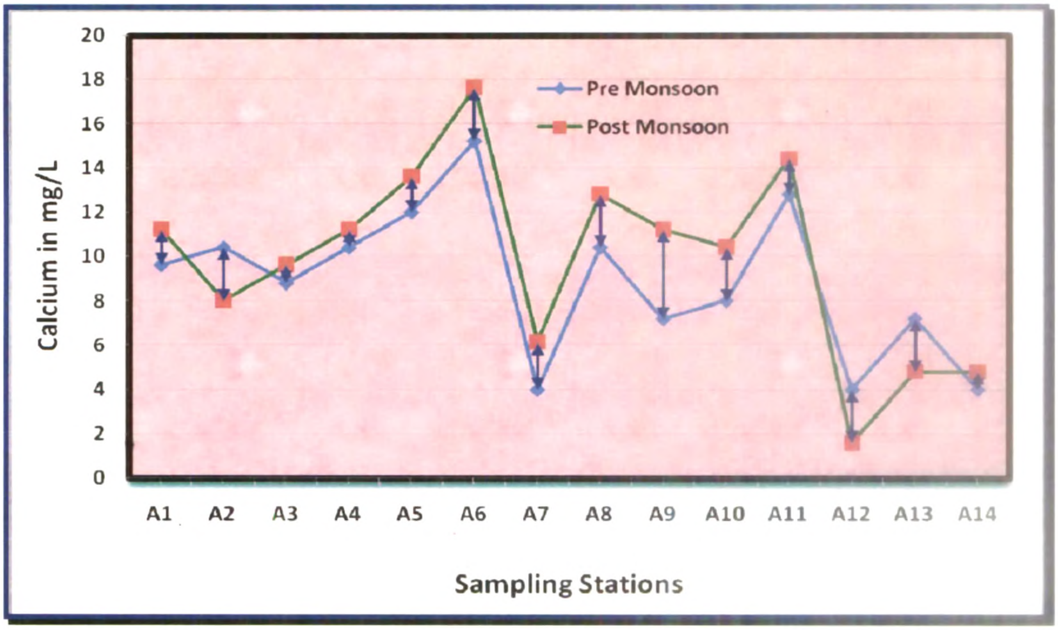

Figure 4.29: Seasonal variations of calcium of water inside the tea gardens

Table 4.69: Values for calcium of the water samples in the study area

Ca in mg/L					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	9.62	11.22	B1	14.42	16.03
A2	10.41	8.01	B2	6.14	4.01
A3	8.81	9.61	B3	11.22	12.02
A4	10.41	11.22	B4	8.01	12.82
A5	12.02	13.62	B5	16.03	19.23
A6	15.23	17.63	B6	24.05	27.25
A7	4.01	6.14	B7	15.23	14.42
A8	10.42	12.82	B8	6.41	7.21
A9	7.21	11.22	B9	4.01	7.21
A10	8.01	10.42	B10	11.22	15.23
A11	12.82	14.42	B11	8.81	11.8
A12	4.01	1.60	B12	13.6	12.02
A13	7.21	4.81	B13	9.62	15.23
A14	4.01	4.81	B14	17.64	24.04

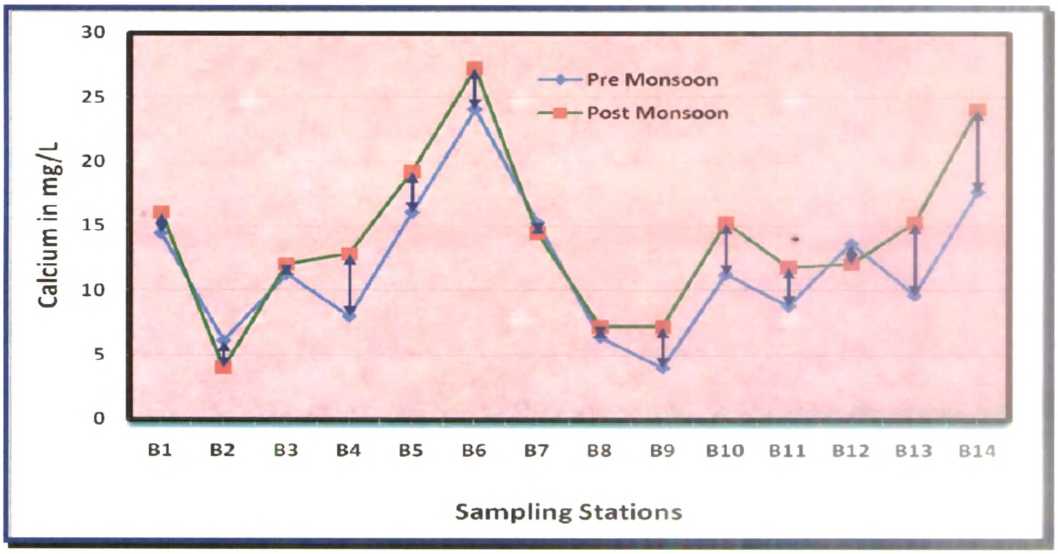

Figure 4.30: Seasonal variations of calcium of water outside the tea gardens

Table 4.70: Statistical analysis for calcium in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		8.87	9.83	11.89	14.18
Std. Error of Mean		0.91	1.16	1.43	1.68
Median		9.22	10.82	11.22	13.62
Mode		4.01	11.22	11.22	7.21
Std. Deviation		3.41	4.35	5.37	6.30
Variance		11.60	18.96	28.79	39.74
Skewness		0.02	-0.22	0.68	0.56
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-0.49	-0.27	0.53	0.40
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		11.22	16.03	20.04	23.24
Minimum		4.01	1.60	4.01	4.01
Maximum		15.23	17.63	24.05	27.25
Sum		124.20	137.55	166.41	198.52
Confidence Limit	Lower Bound	6.90	7.31	8.79	10.54
	Upper Bound	10.84	12.34	14.98	17.82
Percentiles	25	6.41	5.81	7.61	10.65
	50	9.22	10.82	11.22	13.62
	75	10.82	13.02	15.43	16.83
Inter Quartile Range		4.41	7.21	7.82	6.18
ISI Rating		75 mg/l			
t		-72.65	-56.01	-44.01	-36.10
Comment		Significant	Significant	Significant	Significant

ANNOVA analysis (F = 0.41658, p = 0.5243) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 1.07454, p = 0.30947) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens. Negative kurtosis values indicate that distribution of Ca is flat inside the tea gardens and positive kurtosis indicate sharp distribution outside the tea gardens.

In the present study the calcium concentration does not exceed the ISI limit of 75 mg/L (ISI, 1989).

Table 4.71: Values for magnesium of the water samples in the study area

Mg in mg/L					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.97	0.49	B1	2.44	1.95
A2	1.46	0.49	B2	1.95	1.46
A3	0.97	0.97	B3	0.97	0.49
A4	1.95	0.49	B4	2.44	2.28
A5	3.89	2.44	B5	3.89	4.87
A6	0.49	0.49	B6	3.89	4.54
A7	2.43	3.89	B7	2.44	2.06
A8	4.87	3.89	B8	0.97	0.49
A9	1.46	1.95	B9	1.95	1.46
A10	1.46	0.49	B10	2.43	1.95
A11	2.43	0.49	B11	2.28	2.44
A12	2.28	1.46	B12	2.44	1.95
A13	1.46	0.97	B13	3.89	2.43
A14	2.43	1.46	B14	4.54	3.90

Table 4.72: Statistical analysis for magnesium in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		2.04	1.43	2.61	2.31
Std. Error of Mean		0.31	0.32	0.28	0.35
Median		1.46	0.97	2.44	2.01
Mode		0.56	0.49	0.97	1.95
Std. Deviation		1.17	1.21	1.08	1.32
Variance		1.38	1.47	1.16	1.74
Skewness		1.11	1.31	1.34	0.74
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		1.58	0.66	-0.52	0.10
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		4.38	3.40	3.57	4.38
Minimum		0.49	0.49	0.97	0.49
Maximum		4.87	3.89	4.54	4.87
Sum		28.55	19.97	36.52	32.27
Confidence Limit	Lower Bound	1.36	0.73	1.98	1.54
	Upper Bound	2.72	2.13	3.23	3.07
Percentiles	25	1.46	0.49	1.95	1.46
	50	1.46	0.97	1.46	2.01
	75	2.43	2.07	3.89	2.81
Inter Quartile Range		0.97	1.58	1.94	1.35
ISI Rating		30 mg/l			
t		-88.93	-88.16	-94.94	-78.58
Comment		Significant	Significant	Significant	Significant

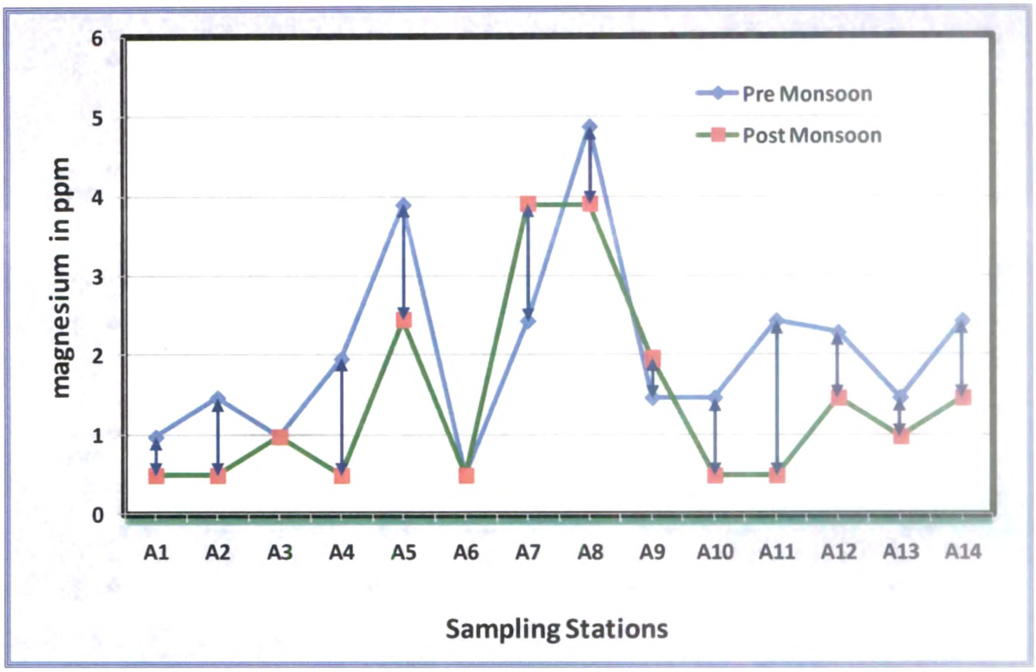

Figure 4.31: Seasonal variations of magnesium of water inside the tea gardens

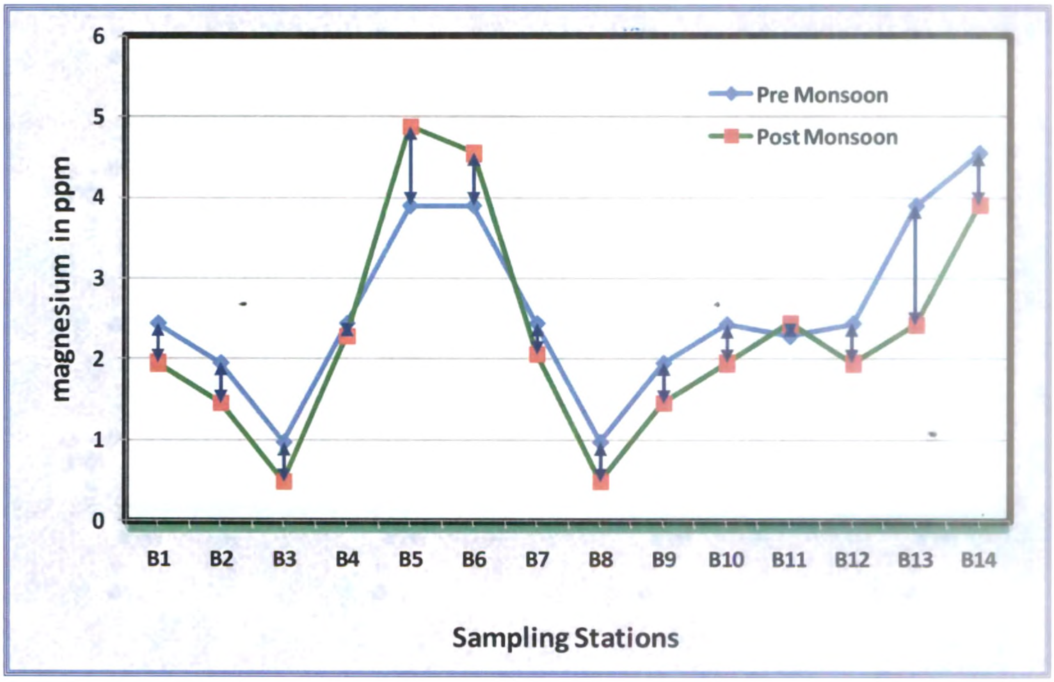

Figure 4.32: Seasonal variations of magnesium of water outside the tea gardens

The experimental results of magnesium in the study area are presented in Table 4.71. Various statistical estimates derived from NDA are summarized in Table 4.72 Figures 4.31 and 4.32 gives the variation of magnesium among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area and values indicate that the distribution is off normal.

ANNOVA analysis ($F = 1.84197$, $p = 0.18639$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.44424$, $p = 0.51095$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens. Lower concentration of magnesium was observed in the post monsoon season in both inside and outside the tea gardens which may be attributed to the dilution during post monsoon season (Saikia, S., 2008)

4.2.13 Chloride (Cl^-)

Chloride content (WHO limit: 250 mg/L) above the permissible limit changes the taste of water which may become objectionable to the consumer. The salty taste imparted by chloride is variable and dependent on the chemical composition of the water. In addition to the adverse taste effects, high chloride concentration levels in the water contribute to the deterioration of domestic plumbing, water heaters, and municipal waterworks equipment. The slight salty taste of eight water samples may be due to the presence of chloride in small concentration, however, it is not harmful in moderate quantity. No fixed trend of variation of chloride among the sampling stations could be ascertained which may be due to precipitation, evaporation, human activity and waste disposal. Chloride is a common to all types of water. Below 250mg/L of chloride in drinking water is regarded as harmless. High concentration of chloride can damage metallic pipes and it may harm agricultural crops. (Sunil Kumar *et al.*, 1998). The probable source of chloride in the water is the discharge of domestic sewage. Contamination of drinking water by sodium chloride and bleaching powder has become an area of much concern (Sarma H.P., 1997). The experimental results of chloride in the study area are presented in Table 4.73. Various statistical estimates derived from NDA are summarized in Table 4.74. Figures 4.33 and 4.34 gives the variation of chloride among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.73: Values for chloride of the water samples in the study area

Chloride in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	56.80	85.20	B1	21.30	49.70
A2	28.40	29.82	B2	24.14	49.70
A3	62.48	84.30	B3	18.46	17.04
A4	46.86	90.88	B4	22.72	24.14
A5	29.82	21.30	B5	15.62	25.56
A6	18.46	20.40	B6	25.56	29.82
A7	15.62	16.03	B7	26.98	30.00
A8	17.04	22.12	B8	49.70	44.02
A9	18.46	23.74	B9	39.76	42.60
A10	44.02	51.12	B10	15.62	22.12
A11	49.70	52.54	B11	11.36	16.03
A12	38.34	42.60	B12	19.88	21.30
A13	29.82	42.60	B13	18.46	42.60
A14	42.60	52.54	B14	17.04	26.98

Table 4.74: Statistical analysis for chloride in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		35.60	45.37	23.33	31.54
Std. Error of Mean		4.11	6.89	2.72	3.16
Median		34.08	42.60	20.59	28.40
Mode		18.46	42.60	15.62	42.60
Std. Deviation		15.38	25.78	10.19	11.84
Variance		236.53	664.48	103.83	140.08
Skewness		0.22	0.71	1.67	0.39
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-1.12	-0.75	2.82	-1.36
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		46.86	74.85	38.34	33.67
Minimum		15.62	16.03	11.36	16.03
Maximum		62.48	90.88	49.70	49.70
Sum		498.42	635.19	326.60	441.61
Confidence Limit	Lower Bound	26.72	30.49	17.45	
	Upper Bound	44.48	60.25	29.21	
Percentiles	25	18.46	21.92	16.69	21.92
	50	34.08	42.60	20.59	28.40
	75	47.57	60.48	25.92	42.96
Inter Quartile Range		29.11	38.57	9.23	21.04
WHO Rating		250 mg/l			
t		-52.16	-29.70	-83.23	-69.06
Comment		Significant	Significant	Significant	Significant

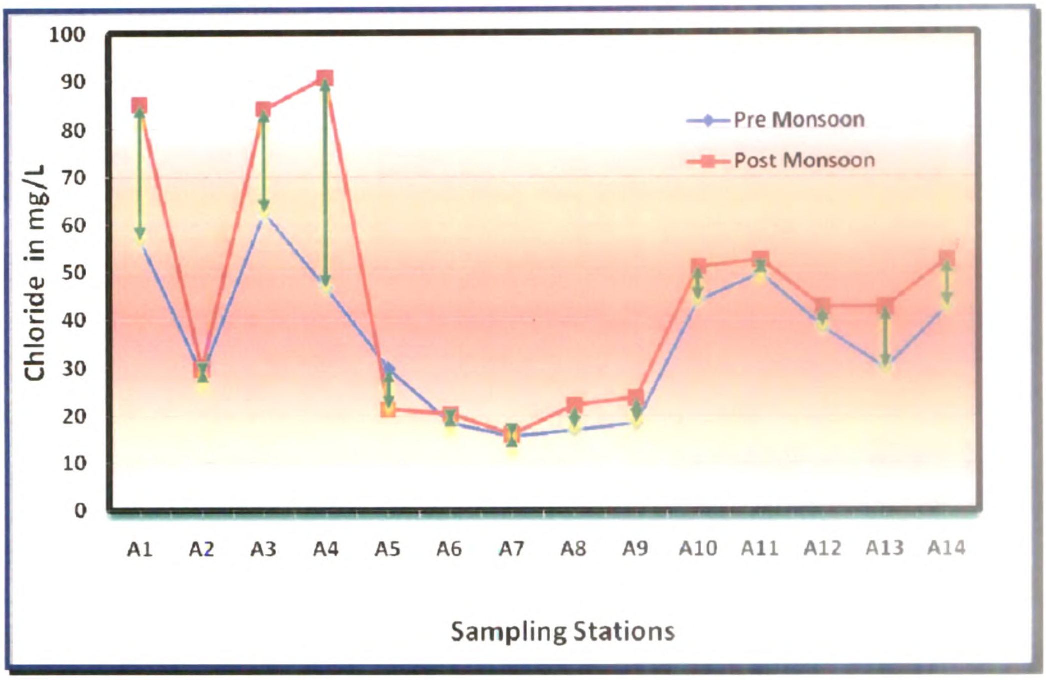

Figure 4.33: Seasonal variations of chloride of water inside the tea gardens

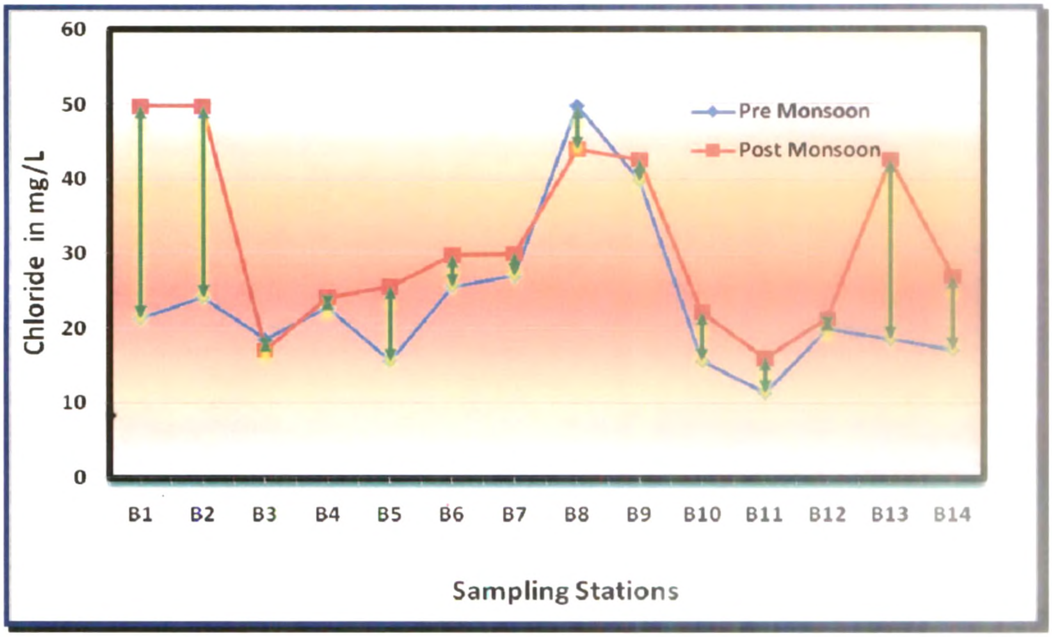

Figure 4.34: Seasonal variations of chloride of water outside the tea gardens

ANNOVA analysis (F = 1.48294, p = 0.23425) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 3.87356, p = 0.0598) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.14 Sulphate (SO_4^{2-})

Sulphate occurs naturally in water and may be present in natural waters in concentrations ranging from a few to several thousand mg/L. Higher concentration of sulphate (W.H.O limit: 250 mg/L) in drinking waters can cause scale formation, taste effects and laxative effects with excessive intake. While sulphate imparts a slightly milder taste to drinking water than chloride, no significant taste effects are detected below 300 mg/L. The sulphate concentrations of water under study are within the approved WHO guideline values for safe drinking water.

The experimental results of sulphate in the study area are presented in Table 4.75. Various statistical estimates derived from NDA are summarized in Table 4.76. Figures 4.35 and 4.46gives the variation of sulphate among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. By comparing calculated | t | value with tabulated t at 5% probability level of significance, it is clear that studied water quality inside and outside for both the seasons with respect to sulphate is significant implying that the null hypothesis may be rejected. The distribution is sharp and positively skewed inside the tea gardens and the distribution is flat with long right asymmetric tail outside the tea gardens as is evident from kurtosis and skewness values.

Table 4.75: Values for sulphate of the water samples in the study area

Sulphate in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	3.10	4.90	B1	0.90	9.16
A2	0.34	0.52	B2	1.45	7.90
A3	4.87	5.90	B3	11.89	17.04
A4	0.54	2.40	B4	0.89	0.53
A5	1.45	0.69	B5	3.89	11.10
A6	0.99	1.40	B6	8.53	10.20
A7	3.63	10.21	B7	17.56	19.90
A8	1.29	1.31	B8	11.20	10.30
A9	11.10	23.60	B9	9.01	12.00
A10	3.68	11.90	B10	18.50	17.90
A11	7.88	8.90	B11	9.45	10.10
A12	8.21	8.80	B12	4.13	3.56
A13	0.69	8.90	B13	3.40	2.60
A14	0.54	1.50	B14	9.34	10.70

Table 4.76: Statistical analysis for sulphate in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		3.45	6.50	7.87	10.21
Std. Error of Mean		0.91	1.69	1.54	1.49
Median		2.28	5.40	8.77	10.25
Mode		0.54	8.90	0.89	0.53
Std. Deviation		3.42	6.32	5.74	5.59
Variance		11.69	39.95	32.99	31.25
Skewness		1.15	1.56	0.51	0.02
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		0.36	3.17	-0.55	-0.25
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		10.76	23.08	17.61	19.37
Minimum		0.34	0.52	0.89	0.53
Maximum		11.10	23.60	18.50	19.90
Sum		48.31	90.93	110.14	142.99
Confidence Limit	Lower Bound	1.48	2.85	4.55	6.99
	Upper Bound	5.42	10.14	11.18	13.44
Percentiles	25	0.65	1.38	2.91	6.82
	50	2.28	5.40	8.77	10.25
	75	5.62	9.23	11.37	13.26
Inter Quartile Range		4.97	7.85	8.46	6.45
WHO Rating		250 mg/l			
t		-269.81	-144.15	-157.74	-160.50
Comment		Significant	Significant	Significant	Significant

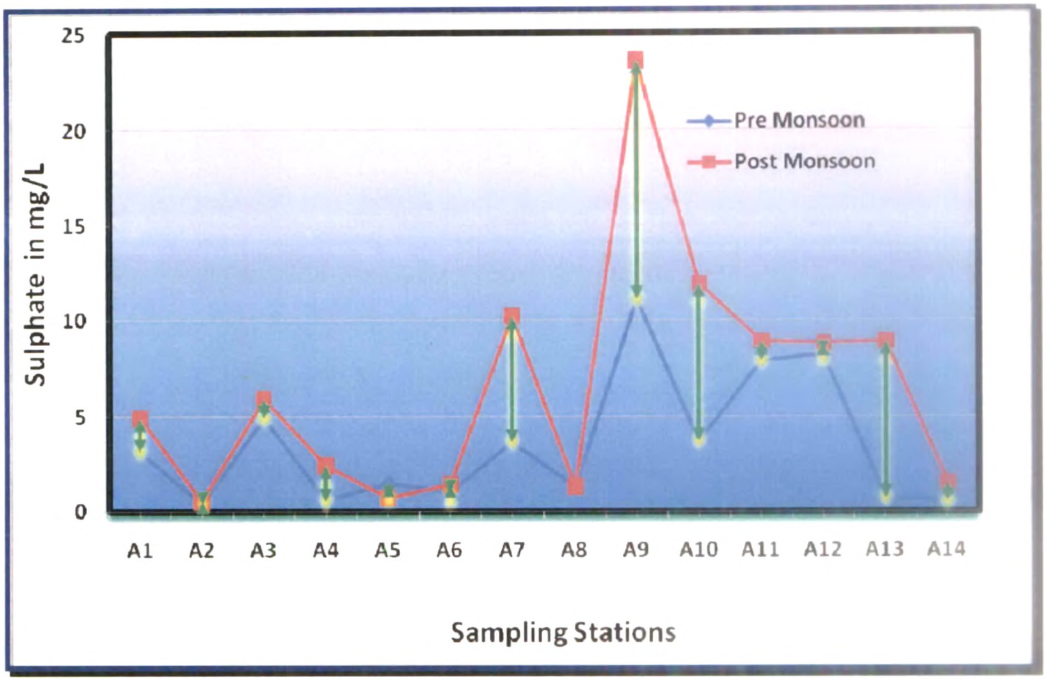

Figure 4.35: Seasonal variations of sulphate of water inside the tea gardens

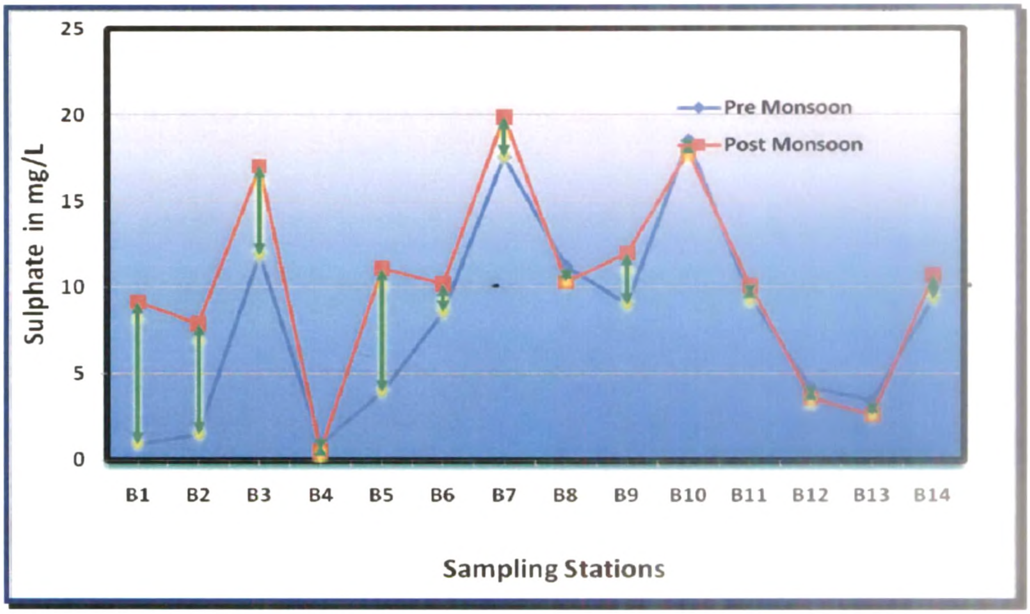

Figure 4.36: Seasonal variations of sulphate of water outside the tea gardens

ANNOVA analysis ($F = 2.51258$, $p = 0.12503$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 3.87356$, $p = 0.0598$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.15 Nitrate (NO_3^-)

The primary source of all nitrates is atmospheric nitrogen gas. This is converted into organic nitrogen by some plants by a process called nitrogen fixation. Dissolved Nitrogen in the form of Nitrate is the most common contaminant of ground water. Nitrate in ground water generally originates from non point sources such as leaching of chemical fertilizers & animal manure, ground water pollution from septic and sewage discharges etc. It is difficult to identify the natural and man made sources of nitrogen contamination of ground water. Some chemical and micro-biological processes such as nitrification and denitrification also influence the nitrate concentration in ground water (CGWB, India, 2010).Nitrate (NO_3^-) (WHO Limit: 50mg/L) is the most stable oxidized form of combined nitrogen in most environmental media. As per the BIS Standard for drinking water the maximum desirable limit of Nitrate concentration in ground water is 45 mg/l with no relaxation. Though Nitrate is considered relatively non-toxic, a high nitrate concentration in drinking water is an environmental health concern arising from increased risks of matheomoglobinemia particularly to infants (CGWB, India, 2010). In excessive amounts it poses a health risk. The toxicity of nitrate in humans is due to the body's reduction of nitrate to nitrite. This reaction takes place in saliva of humans at all ages and in the gastrointestinal tract of infants during the first three months of life. Although the nitrate contents of investigated samples is within the tolerance limit prescribed for potability, the gastric problems associated with the tea garden labourers may be due to the slow exposure of nitrate through waters over a long period of time.

The experimental results of nitrate in the study area are presented in Table 4.77. Various statistical estimates derived from NDA are summarized in Table 4.78. Figures 4.37 and 4.38 gives the variation of nitrate among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.77: Values for nitrate of the water samples in the study area

Nitrate in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.131	0.031	B1	1.214	1.054
A2	0.045	0.042	B2	0.474	0.380
A3	0.063	0.022	B3	0.949	0.893
A4	0.857	0.489	B4	0.431	0.325
A5	0.489	0.521	B5	0.097	0.133
A6	1.011	0.911	B6	0.081	0.061
A7	0.514	0.321	B7	1.062	0.715
A8	0.364	0.217	B8	0.224	0.169
A9	1.321	1.872	B9	0.163	0.112
A10	1.273	0.916	B10	0.831	0.612
A11	1.762	1.839	B11	0.089	0.134
A12	0.973	0.981	B12	0.711	0.701
A13	0.991	0.872	B13	0.342	0.456
A14	0.432	0.521	B14	0.552	0.436

Table 4.78: Statistical analysis for nitrate of water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.73	0.68	0.52	0.44
Std. Error of Mean		0.14	0.16	0.10	0.08
Median		0.69	0.52	0.45	0.41
Mode		0.05	0.52	0.08	0.06
Std. Deviation		0.52	0.60	0.38	0.31
Variance		0.27	0.36	0.15	0.10
Skewness		0.37	0.95	0.50	0.56
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-0.63	0.30	-1.02	-0.71
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		1.72	1.85	1.13	0.99
Minimum		0.05	0.02	0.08	0.06
Maximum		1.76	1.87	1.21	1.05
Sum		10.23	9.56	7.22	6.18
Confidence Limit	Lower Bound	0.43	0.34	0.29	0.26
	Upper Bound	1.03	1.03	0.74	0.62
Percentiles	25	0.31	0.17	0.15	0.13
	50	0.69	0.52	0.45	0.41
	75	1.08	0.93	0.86	0.70
Inter Quartile Range		0.77	0.76	0.71	0.57
WHO Rating		45 mg/l			
t		-318.09	-275.95	-435.08	-530.51
Comment		Significant	Significant	Significant	Significant

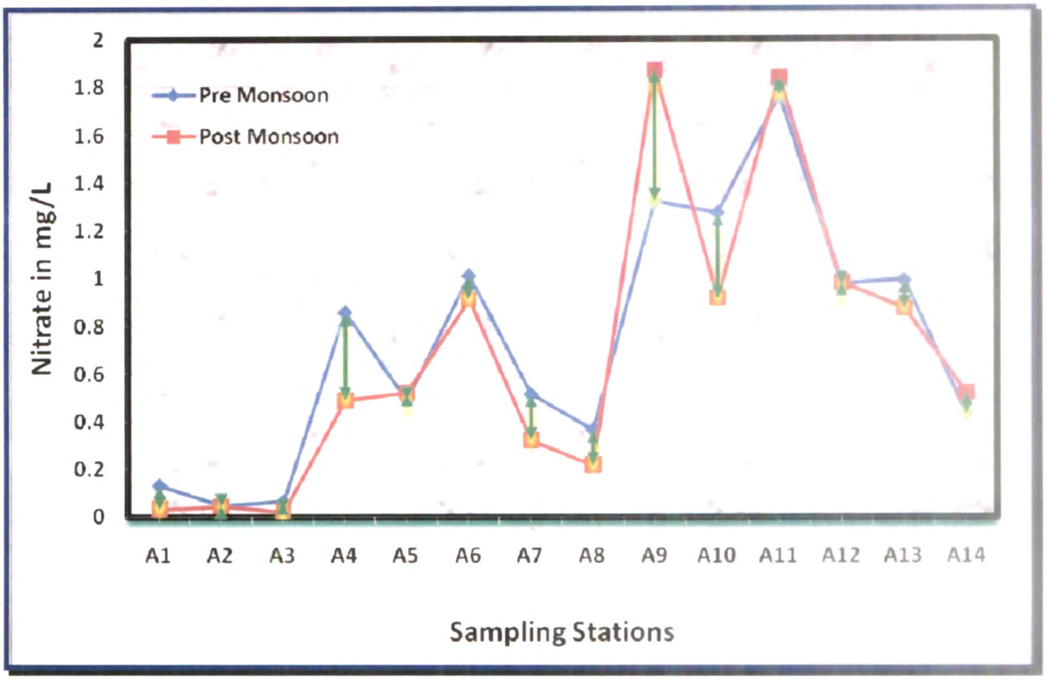

Figure 4.37: Seasonal variations of nitrate of water inside the tea gardens

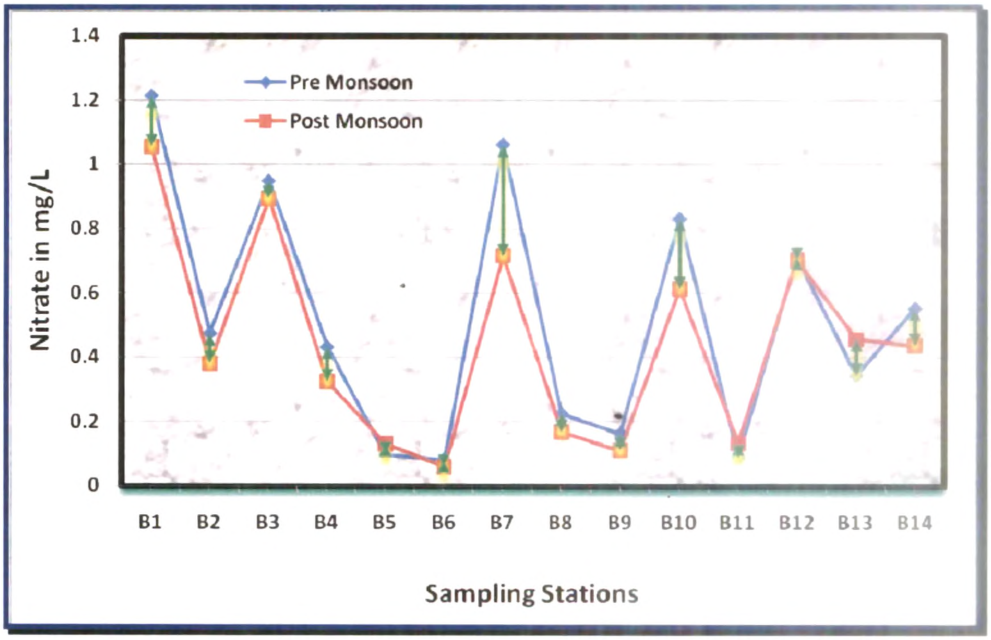

Figure 4.38: Seasonal variations of nitrate of water outside the tea gardens

Various statistical estimates and significant negative kurtosis and positive skewness indicate that the distribution of nitrate outside the tea gardens in both the seasons is flat asymmetric with long right tail. On the other hand, in the post monsoon, inside the tea gardens the distribution is sharp extending towards right of the median. ANNOVA analysis ($F = 0.04921$, $p = 0.82618$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.30316$, $p = 0.58661$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.16 Phosphate (PO_4^{-3})

Phosphorous in the natural fresh water is present in inorganic form, mainly as phosphate. The rocks in which most of the phosphorous is bound, are generally insoluble in water, and hence the P content in natural fresh water is low. The major sources of phosphorous are domestic sewage, detergents, agricultural effluents with fertilizers and industrial waste waters. The higher concentration of phosphorous is therefore, is indicative of pollution. The phosphate content of water needs serious attention as all of the samples except for few exceeded the USPH guide line value of 0.1 mg/L.

The experimental results of phosphate in the study area are presented in Table 4.79. Various statistical estimates derived from NDA are summarized in Table 4.80. Figures 4.39 and 4.40 gives the variation of phosphate among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.79: Values for phosphate of water samples in the study area

Phosphate in mg/l					
Sample No	Inside Tea Garden		Sample No	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	2.173	2.593	B1	0.834	0.771
A2	0.151	0.034	B2	0.163	0.052
A3	0.036	0.031	B3	0.653	0.527
A4	0.157	0.142	B4	0.891	0.700
A5	0.167	0.038	B5	0.634	0.512
A6	0.745	0.512	B6	0.174	0.112
A7	0.451	0.321	B7	0.689	0.512
A8	0.041	0.012	B8	0.277	0.169
A9	0.765	0.647	B9	0.751	0.112
A10	bdl	bdl	B10	0.182	0.111
A11	1.931	1.839	B11	0.043	0.031
A12	0.117	0.012	B12	0.016	0.010
A13	0.069	bdl	B13	0.281	0.256
A14	0.047	0.011	B14	0.887	0.876

Table 4.80: *Statistical* analysis for phosphate in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.53	0.52	0.46	0.34
Std. Error of Mean		0.20	0.24	0.09	0.08
Median		0.16	0.09	0.46	0.21
Mode		0.04	0.01	0.02	0.11
Std. Deviation		0.72	0.84	0.33	0.30
Variance		0.52	0.70	0.11	0.09
Skewness		1.71	1.95	0.02	0.56
Std. Error of Skewness		0.62	0.64	0.60	0.60
Kurtosis		1.87	3.02	-1.81	-1.24
Std. Error of Kurtosis		1.19	1.23	1.15	1.15
Range		2.14	2.58	0.88	0.87
Minimum		bdl	bdl	0.02	0.01
Maximum		2.17	2.59	0.89	0.88
Sum		6.85	6.19	6.48	4.75
Confidence Limit	Lower Bound	0.09	bdl	0.29	0.16
	Upper Bound	1.04	1.05	0.72	0.57
Percentiles	25	0.06	0.02	0.17	0.10
	50	0.16	0.09	0.46	0.21
	75	0.76	0.61	0.77	0.57
Inter Quartile Range		0.70	0.60	0.65	0.59
USPH Rating		0.1 mg/l			
t		2.06	1.61	4.13	2.97
Comment		Non Significant	Non Significant	Significant	Significant

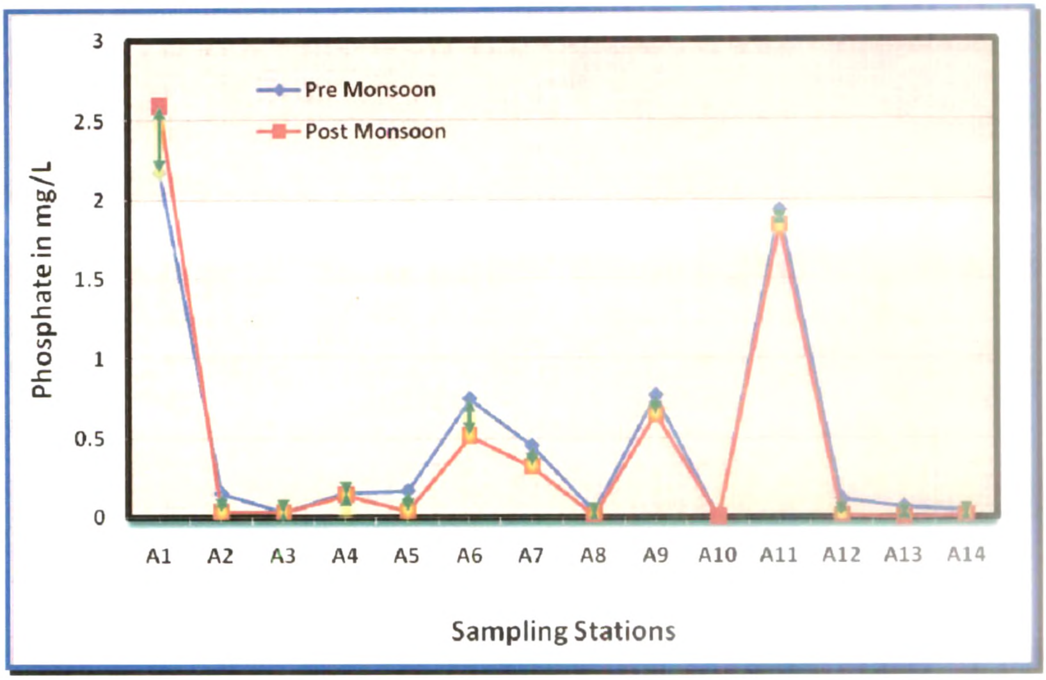

Figure 4.39: Seasonal variations of phosphate inside the tea gardens

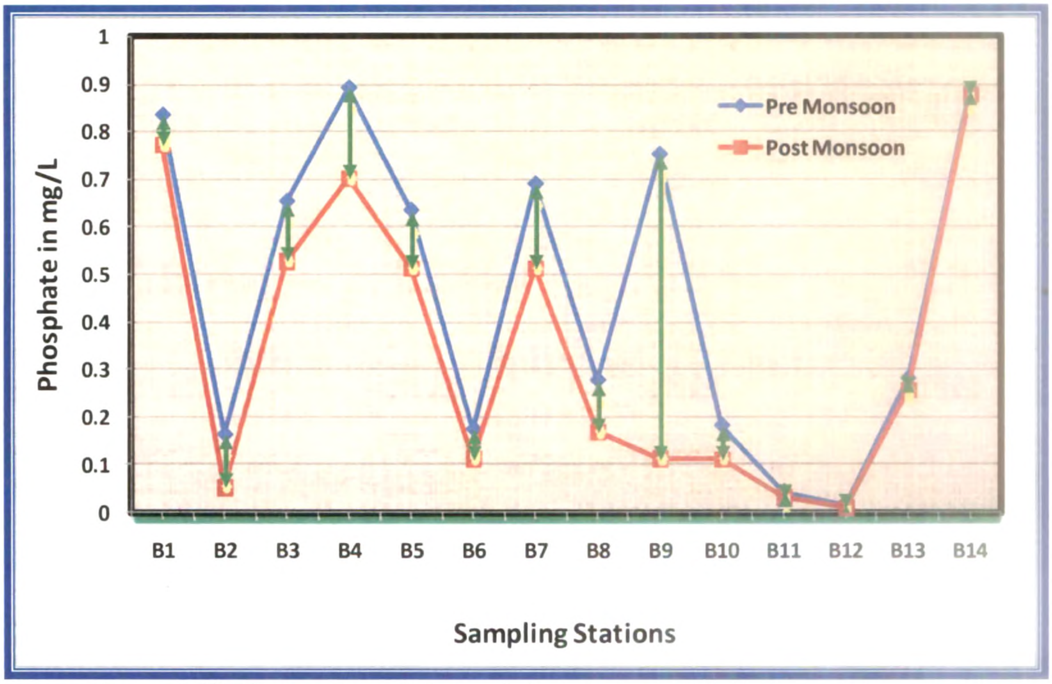

Figure 4.40: Seasonal variations of phosphate outside the tea gardens

By comparing calculated | t | value with tabulated t at 5% probability level of significance, we can reject our null hypothesis outside the tea gardens of our study area for phosphate. ANNOVA analysis ($F = 0.03008$, $p = 0.86365$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 1.0528$, $p = 0.31432$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

Large differences between mean and median, significant positive skewness and kurtosis value in pre monsoon and post monsoon indicate that the distribution of phosphate inside the tea gardens is widely off normal. Asymmetric nature of phosphate distribution is also evident from the width of the third quartile, which is much greater than the first and second quartile. A broad third quartile and positive skewness in case of phosphate represents a long asymmetric tail on the right of the median. The width of the third quartile is greater than the second quartile, which for a symmetric distribution should be equal. Flat distribution for phosphate outside the tea gardens is indicated by negative kurtosis value.

4.2.18 Fluoride (F)

Natural fluoride in drinking water was not considered a health concern until just recently. The presence of fluoride in ground water is attributed to the geological deposits, geochemistry of location and the application of fertilizers like rock phosphate or fluorapetite. Fluoride ions are likely to be leached out gradually; particularly on alkaline soil and move along the water front. The optimum level of fluorides in water for reducing dental cavities is about 1 mg/l. Health hazards like dental and skeletal flurosis may emerged out of water with high fluoride content (Susheela, A.K., 1993) The distribution of fluoride in drinking water of Darrang district was found to be within the permissible limit of W.H.O. and ISI of the value 1.5mg. Fluoride with these average values in water may cause dental carries. No fixed trend of variation of fluoride among the sampling stations could be ascertained which may be due to human activity, use of artificial fertilizers and waste disposal. The experimental results of fluoride in the study area are presented in Table 4.81. Various statistical estimates derived from NDA are summarized in Table 4.82. Figures 4.41 and 4.42 gives the variation of fluoride among different sampling stations during pre monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.81: Values for fluoride of the water samples in the study area

fluoride in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.85	0.70	B1	1.01	0.96
A2	0.51	0.62	B2	0.56	0.37
A3	bdl	bdl	B3	0.84	0.58
A4	0.71	0.34	B4	0.81	0.65
A5	0.75	0.61	B5	0.46	0.42
A6	0.72	0.58	B6	0.83	0.38
A7	0.57	0.51	B7	0.31	0.30
A8	0.54	0.46	B8	0.66	0.62
A9	0.67	0.60	B9	0.28	bdl
A10	0.91	0.63	B10	0.49	0.29
A11	0.62	0.45	B11	0.29	0.58
A12	0.64	0.55	B12	0.17	0.31
A13	0.53	0.30	B13	0.80	0.63
A14	0.89	0.62	B14	1.05	0.33

Table 4.82: Statistical analysis for fluoride in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.69	0.54	0.61	0.49
Std. Error of Mean		0.04	0.03	0.08	0.05
Median		0.67	0.58	0.61	0.42
Mode		0.51	0.62	0.17	0.58
Std. Deviation		0.14	0.12	0.29	0.20
Variance		0.02	0.01	0.08	0.04
Skewness		0.41	-0.86	-0.01	1.04
Std. Error of Skewness		0.62	0.62	0.60	0.62
Kurtosis		-1.00	-0.04	-1.31	1.04
Std. Error of Kurtosis		1.19	1.19	1.15	1.19
Range		0.40	0.40	0.88	0.67
Minimum		bdl	bdl	0.17	bdl
Maximum		0.91	0.70	1.05	0.96
Sum		8.91	6.97	8.56	6.42
Confidence Limit	Lower Bound	0.60	0.45	0.44	0.36
	Upper Bound	0.78	0.61	0.80	0.62
Percentiles	25	0.56	0.46	0.31	0.32
	50	0.67	0.58	0.61	0.42
	75	0.80	0.62	0.83	0.63
Inter Quartile Range		0.28	0.17	0.48	0.31
WHO Rating		1.5 mg/l			
t		-14.37	-20.47	-11.60	-16.90
Comment		Significant	Significant	Significant	Significant

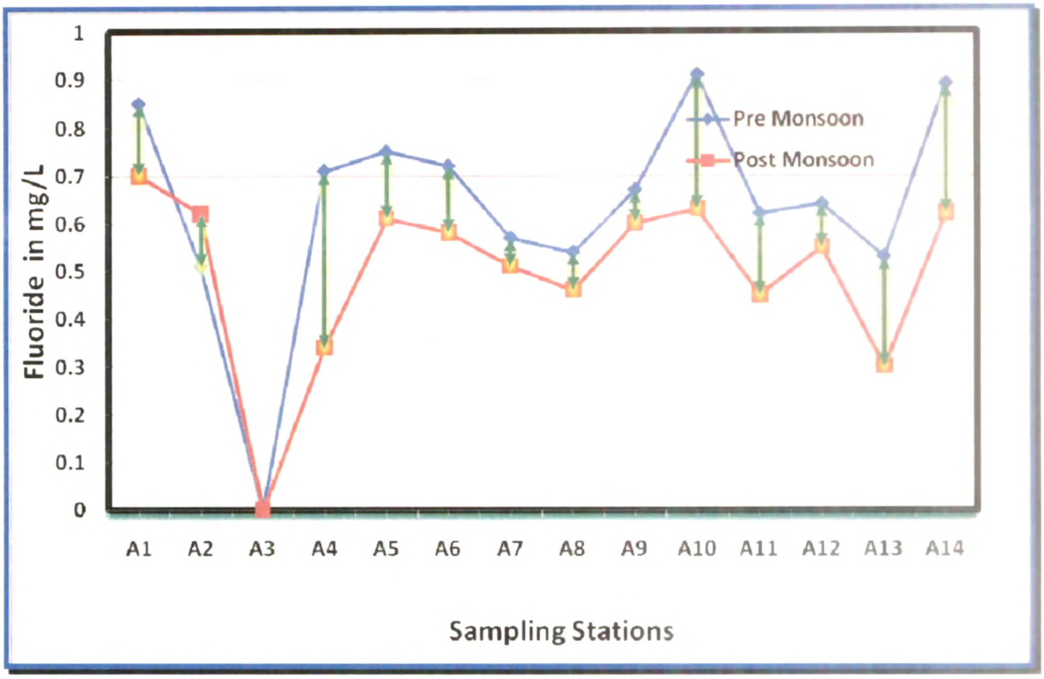

Figure 4.41: Seasonal variations of fluoride of water inside the tea gardens

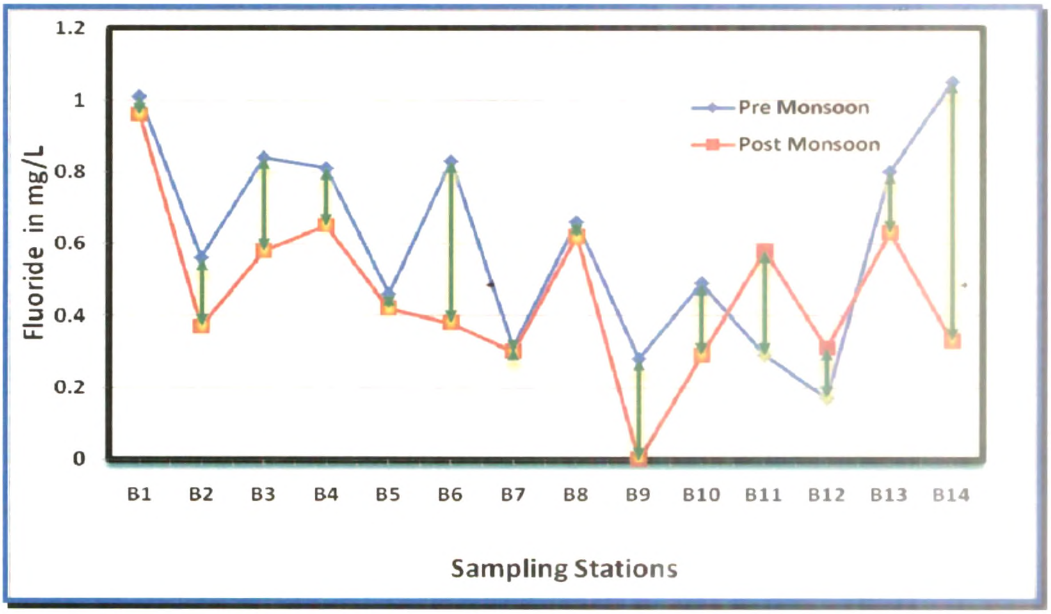

Figure 4.42: Seasonal variations of fluoride of water outside the tea gardens

ANNOVA analysis (F = 3.1946, p = 0.08555) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 2.41791, p = 0.13204) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.19 Iron (Fe)

Iron is a non-hazardous element that can be a nuisance in a water supply. Iron is the more frequent contaminants in water supplies; Water percolating through soil and rock can dissolve minerals containing iron and hold it in solution. Occasionally, iron pipes also may be a source of iron in water. In deep wells, where oxygen content is low, the iron bearing water is clear and colourless (iron is dissolved). Water from the tap may be clear, but when exposed to air, iron is oxidized and changes from colourless, dissolved forms to coloured, solid forms. These solid sediments are responsible for the staining properties of water containing high concentrations of iron. Iron can affect the flavor and colour of food and water. They may react with tannins in coffee, tea and some alcoholic beverages to produce a black sludge, which affects both taste and appearance. The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. It is contributed to ground water mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks. The permissible Iron concentration in ground water is less than 1.0 mg/litre as per the BIS Standard for drinking water. Iron (W.H.O limit: 0.3 mg/L) at 1.0 mg/L can cause the bitter astringent taste of water. Iron is one of the most disturbing constituents in water supplies throughout India. Water with high iron concentration causes most of the staining problems which appear around toilet bowls or on fixtures where water stands or drips. Although iron occurs naturally in groundwater, the higher concentration of iron in tubewell waters with respect to other water sources in the area may be due to soil origin and age-old corroded iron pipes used.

Table 4.83: Values for Fe of the water samples in the study area

Fe in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.75	0.40	B1	0.42	0.27
A2	0.93	0.43	B2	0.32	0.29
A3	2.98	3.65	B3	2.92	2.87
A4	0.76	0.46	B4	1.46	2.88
A5	0.34	0.28	B5	0.76	3.00
A6	0.51	0.32	B6	0.32	1.14
A7	0.45	0.43	B7	3.29	3.65
A8	0.30	0.36	B8	0.36	0.03
A9	3.21	2.37	B9	2.37	1.18
A10	0.12	0.21	B10	1.21	2.10
A11	0.31	0.25	B11	0.25	0.56
A12	0.55	0.65	B12	1.65	1.45
A13	2.12	0.43	B13	0.89	0.99
A14	2.76	1.13	B14	1.75	1.89

Table 4.84: Statistical analysis for iron in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		1.15	0.81	1.28	1.59
Std. Error of Mean		0.30	0.26	0.27	0.31
Median		0.65	0.43	1.05	1.32
Mode		0.12	0.43	0.32	0.03
Std. Deviation		1.11	0.99	1.01	1.16
Variance		1.22	0.98	1.02	1.35
Skewness		1.08	2.37	0.82	0.34
Std. Error of Skewness		0.60	0.60	0.60	0.60
Kurtosis		-0.56	5.23	-0.40	-1.12
Std. Error of Kurtosis		1.15	1.15	1.15	1.15
Range		3.09	3.44	3.04	3.62
Minimum		0.12	0.21	0.25	0.03
Maximum		3.21	3.65	3.29	3.65
Sum		16.09	11.37	17.97	22.30
Confidence Limit	Lower Bound	0.51	0.24	0.70	0.92
	Upper Bound	1.79	1.38	1.87	2.26
Percentiles	25	0.33	0.31	0.35	0.49
	50	0.65	0.43	1.05	1.32
	75	2.28	0.77	1.91	2.87
Inter Quartile Range		1.95	0.46	1.56	2.38
WHO Rating		0.3 mg/l			
t		2.87	1.94	3.65	4.16206
Comment		Significant	Non Significant	Significant	Significant

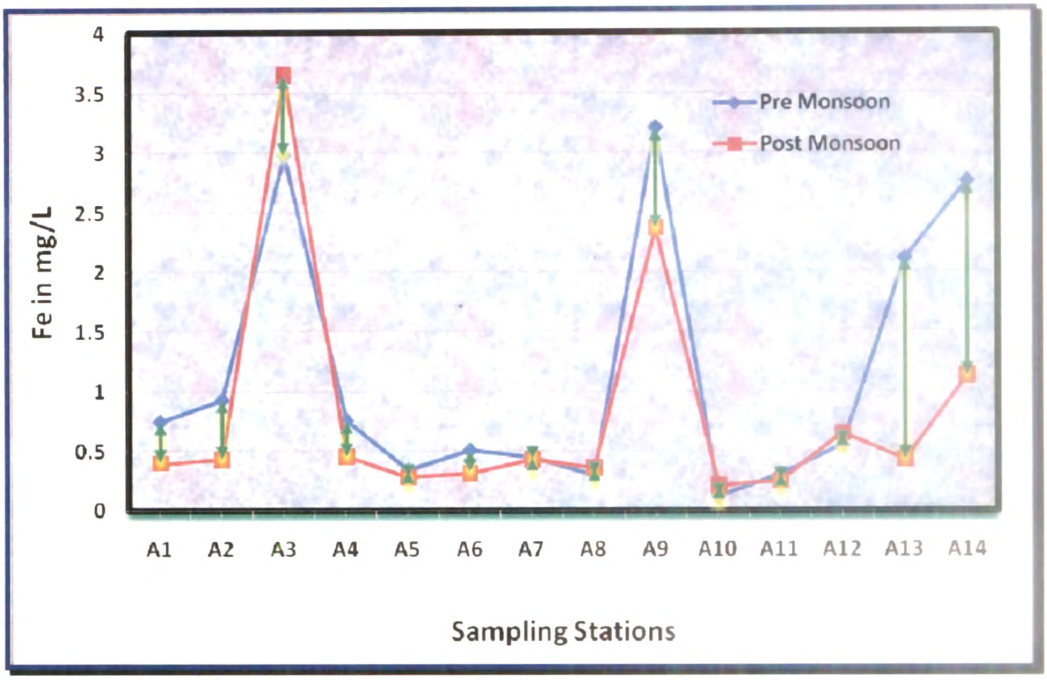

Figure 4.43: Seasonal variations of iron of water inside the tea gardens

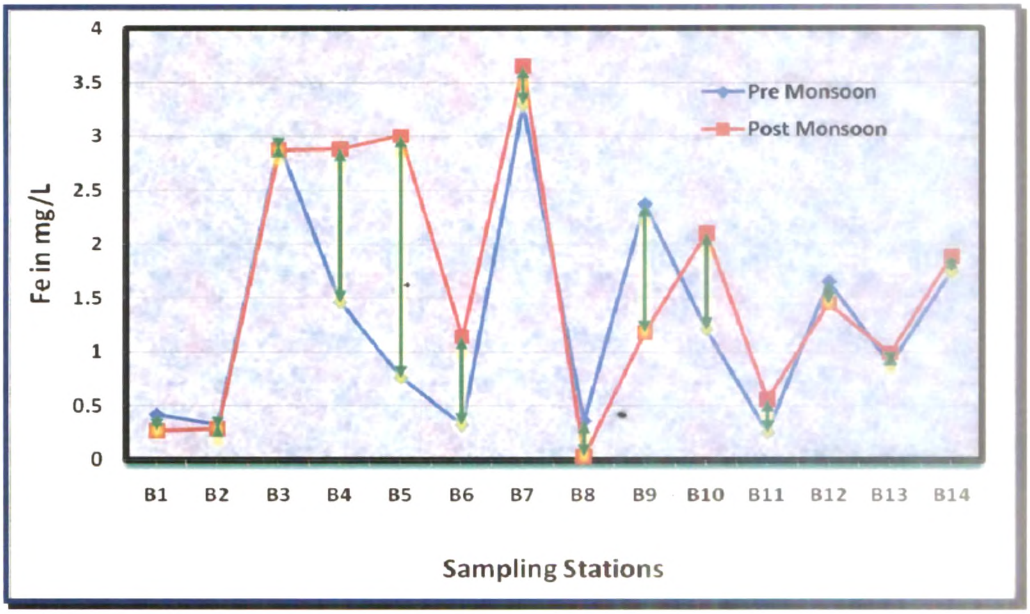

Figure 4.44: Seasonal variations of iron of water outside the tea gardens

The experimental results of iron in the study area are presented in Table 4.83. Various statistical estimates derived from NDA are summarized in Table 4.84. Figure 4.43 and 4.44gives the variation of iron among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. Iron content of some of the drinking water sources in the area exceeds the W.H.O guideline value of 0.3 mg/l. The iron content of the area may also promote the growth of iron bacteria, leaving a slimy coating in piping. A broad third quartile and positive skewness in case of iron represents a long asymmetric tail on the right of the median. The width of the third quartile is 1.8 times greater than the second quartile, which for a symmetric distribution should be equal. Flat distribution for iron in the area is indicated by negative kurtosis value.

ANNOVA analysis ($F = 0.72235$, $p = 0.40313$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.5655$, $p = 0.45881$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.20 Lead (Pb)

Lead has no beneficial effect on humans or animals. Chronic exposure occurring over an extended period of time to even low levels of lead can have severe effects since lead is accumulated and stored in the bone. Lead is a general toxicant that accumulates in the skeleton. Infants, children up to six years of age and pregnant women are very susceptible to its adverse health effects (Park, K., 2005). When the concentration is so high that storage in the bone is saturated, blood lead levels begin to affect nerve tissue. If drinking water is found to contain lead level exceeding I.S.I guideline value of 0.01 ppm, it needs attention for lead contamination. **In the present study, the entire drinking water samples contain lead above the permissible limit. Lead above the permissible level in water can cause severe health problems among the people in the area.**

Lead is one of the hazardous and potentially harmful polluting agents. It inhibits the formation of haemoglobin by reacting with –SH group and interfering with many enzyme functions (Sarma H.P., 1997) Lead is exceptional in that most lead in drinking water arises from in buildings and the remedy consists principally of removing plumbing and fittings containing lead. In the present study, the entire drinking water samples contain lead above the permissible limit. The presence of lead at higher concentration in almost all the sources may be attributed to the domestic and waste discharge along with pesticides (including mainly batteries, chemicals used to control pest and other lead based paint) at the open dumping site and surface runoff. Lead above the permissible level in water can cause severe health threat among the people in our study area. Considering the various toxic effects of lead the appreciable concentrations of this metallic constituent in many of the sources should be of concern. Since water in the region is soft and towards acidic side, the lead dissolution from the plumbing system is therefore more prone (Park, K., 2005). Large differences between mean and median, significant positive skewness and kurtosis value indicate that the distribution of lead in the study area is widely off normal. Asymmetric nature of lead distribution is also evident from the width of the third quartile, which is much greater than the first and second quartile in the all seasons for both inside and outside of the tea gardens. The experimental results of lead in the study area are presented in Table 4.85. Various statistical estimates derived from NDA are summarized in Table 4.86. Figures 4.45 and 4.46 gives the variation of lead among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.85: Values for lead of the water samples in the study area

Lead in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.081	0.073	B1	0.186	0.101
A2	0.035	0.081	B2	0.070	0.093
A3	0.013	0.087	B3	0.359	0.351
A4	bdl	0.041	B4	0.108	0.095
A5	0.445	0.250	B5	bdl	0.096
A6	0.102	0.076	B6	0.015	0.081
A7	0.164	0.110	B7	0.073	0.045
A8	0.073	0.052	B8	0.191	0.133
A9	0.058	0.042	B9	0.194	0.174
A10	0.081	0.080	B10	0.043	0.041
A11	0.199	0.183	B11	bdl	0.001
A12	0.163	0.140	B12	0.395	0.353
A13	0.152	0.133	B13	bdl	0.011
A14	0.051	0.012	B14	0.221	0.115

Table 4.86: Statistical analysis for lead in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.124	0.097	0.169	0.121
Std. Error of Mean		0.031	0.017	0.037	0.029
Median		0.081	0.081	0.186	0.096
Mode		0.081	0.012	0.015	0.001
Std. Deviation		0.112	0.063	0.124	0.108
Variance		0.012	0.004	0.015	0.012
Skewness		2.159	1.178	0.707	1.469
Std. Error of Skewness		0.616	0.597	0.661	0.597
Kurtosis		5.769	1.541	-0.324	1.639
Std. Error of Kurtosis		1.191	1.154	1.279	1.154
Range		0.432	0.238	0.380	0.352
Minimum		bdl	0.012	bdl	0.001
Maximum		0.445	0.250	0.395	0.353
Sum		1.617	1.360	1.855	1.690
Confidence Limit	Lower Bound	0.047	0.050	0.082	0.067
	Upper Bound	0.118	0.101	0.267	0.230
Percentiles	25	0.055	0.050	0.070	0.044
	50	0.081	0.081	0.186	0.096
	75	0.164	0.135	0.221	0.143
Inter Quartile Range		0.070	0.043	0.192	0.146
EPA Rating		0.015 mg/l			
t		3.35	4.90	3.37	3.65
Comment		Significant	Significant	Significant	Significant

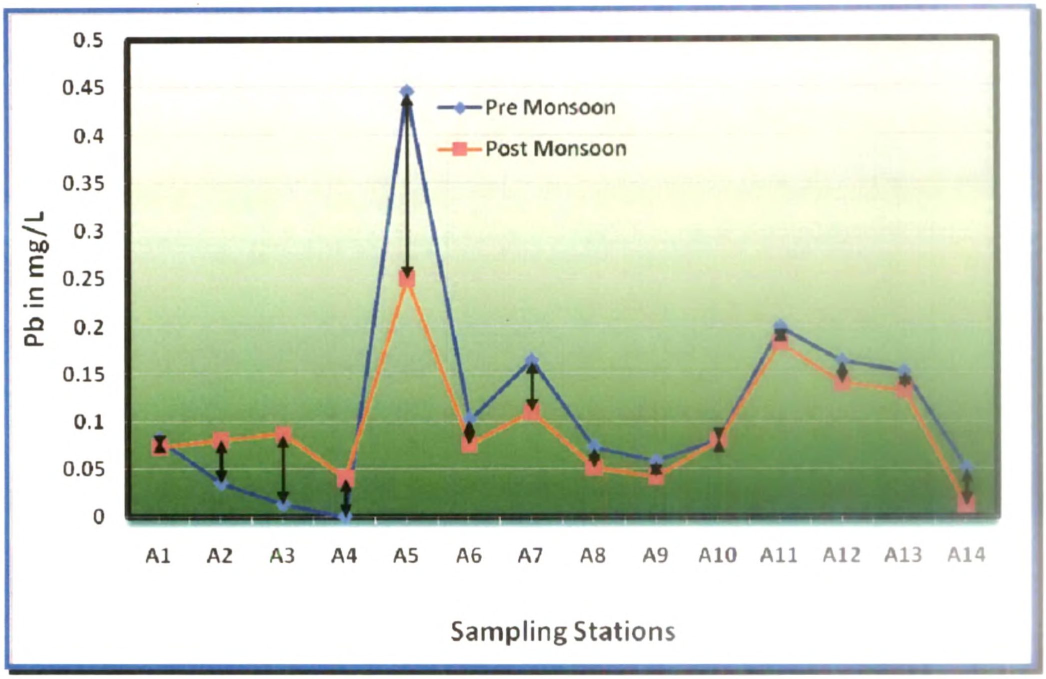

Figure 4.45: Seasonal variations of lead of water inside the tea gardens

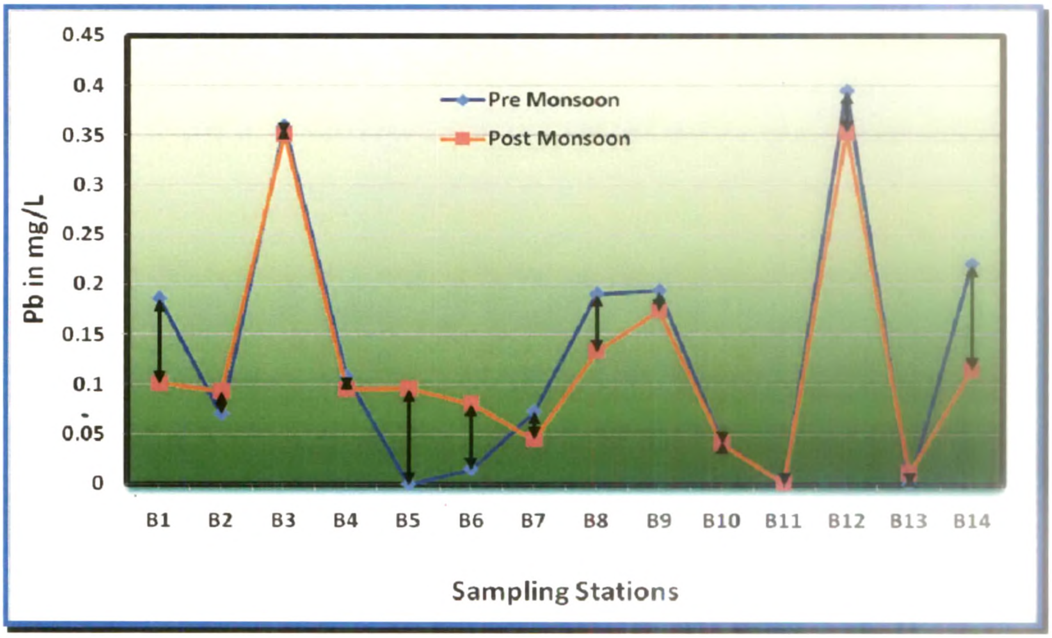

Figure 4.46: Seasonal variations of lead of water outside the tea gardens

ANNOVA analysis ($F = 0.28548$, $p = 0.59767$) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis ($F = 0.06776$, $p = 0.79668$) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.21 Arsenic (As)

Arsenic in the study area can enter the water supply from natural deposits in the earth or from industrial and agricultural pollution. It is widely believed that naturally occurring arsenic dissolves out of certain rock formations when ground water levels drop significantly. High arsenic levels are often used to indicate improper well construction, or the location or overuse of chemical fertilizers or herbicides. None of the water samples in the present study meets or falls below the current standard for arsenic, which is 50 ppb (W.H.O, 2004). So, no threat of arsenosis from these water sources of this area is ascertained.

The experimental results of arsenic in the study area are presented in Table 4.87. Various statistical estimates derived from NDA are summarized in Table 4.88. Figures 4.47 and 4.48 gives the variation of arsenic among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.87: Values for arsenic in water samples in the study area

Arsenic in ppb					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon(ppb)	Post Monsoon(ppb)		Pre Monsoon(ppb)	Post Monsoon(ppb)
A1	2.51	1.70	B1	0.12	bdl
A2	bdl	bdl	B2	0.59	0.32
A3	3.80	1.08	B3	1.60	0.41
A4	1.60	1.33	B4	0.94	1.33
A5	0.45	0.41	B5	bdl	0.00
A6	0.19	bdl	B6	0.62	0.21
A7	2.01	1.08	B7	9.91	10.15
A8	0.39	0.00	B8	0.95	1.22
A9	10.5	9.76	B9	2.82	1.38
A10	0.43	bdl	B10	10.74	6.21
A11	bdl	bdl	B11	4.79	1.98
A12	4.81	3.11	B12	0.98	1.23
A13	5.72	2.89	B13	3.82	1.61
A14	0.34	bdl	B14	1.85	0.26

Table 4.88: Statistical analysis for arsenic in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		2.729	1.526	3.056	1.879
Std. Error of Mean		0.891	0.695	0.971	0.762
Median		1.805	0.745	1.600	1.225
Mode		0.190	0.000	0.120	0.000
Std. Deviation		3.086	2.600	3.501	2.852
Variance		9.523	6.758	12.258	8.132
Skewness		1.624	2.769	1.592	2.388
Std. Error of Skewness		0.637	0.597	0.616	0.597
Kurtosis		2.756	8.596	1.499	5.564
Std. Error of Kurtosis		1.232	1.154	1.191	1.154
Range		10.310	9.760	10.620	10.150
Minimum		bdl	bdl	bdl	bdl
Maximum		10.500	9.760	10.740	10.150
Sum		32.750	21.360	39.730	26.310
Confidence Limit	Lower Bound	0.822	0.000	0.627	0.072
	Upper Bound	5.051	3.809	5.618	4.294
Percentiles	25	0.400	0.000	0.780	0.248
	50	1.805	0.745	1.600	1.225
	75	4.558	1.998	4.305	1.703
Inter Quartile Range		4.420	2.890	2.880	1.350
WHO Rating		50 ppb			
t		-59.310	-69.770	-50.978	-63.140
Comment		Significant	Significant	Significant	Significant

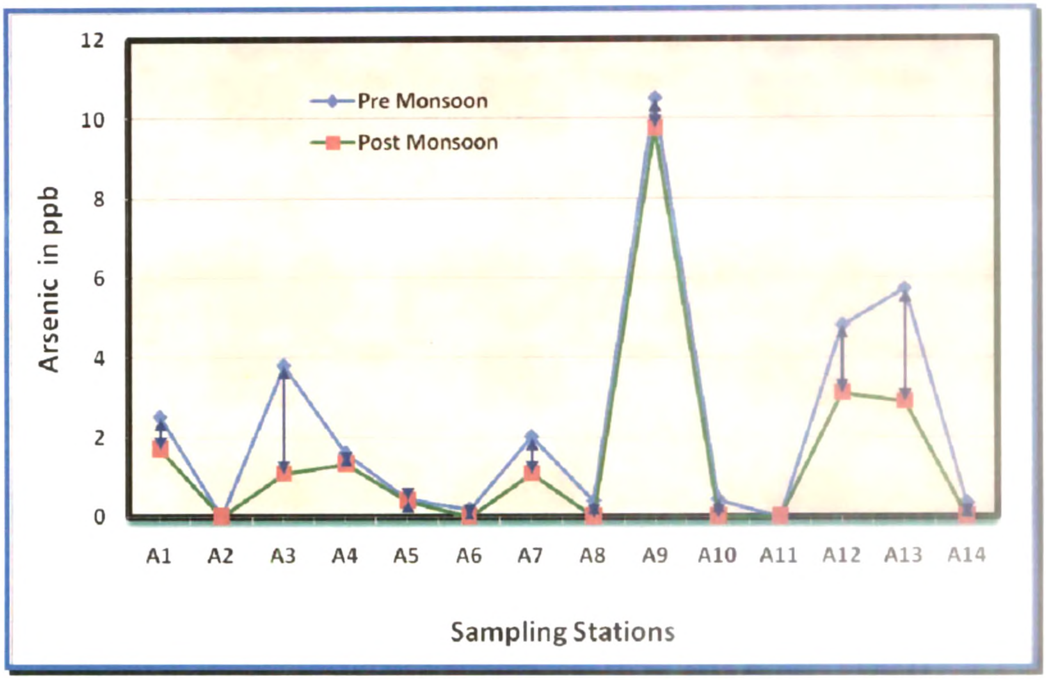

Figure 4.47: Seasonal variations of arsenic in water inside the tea gardens

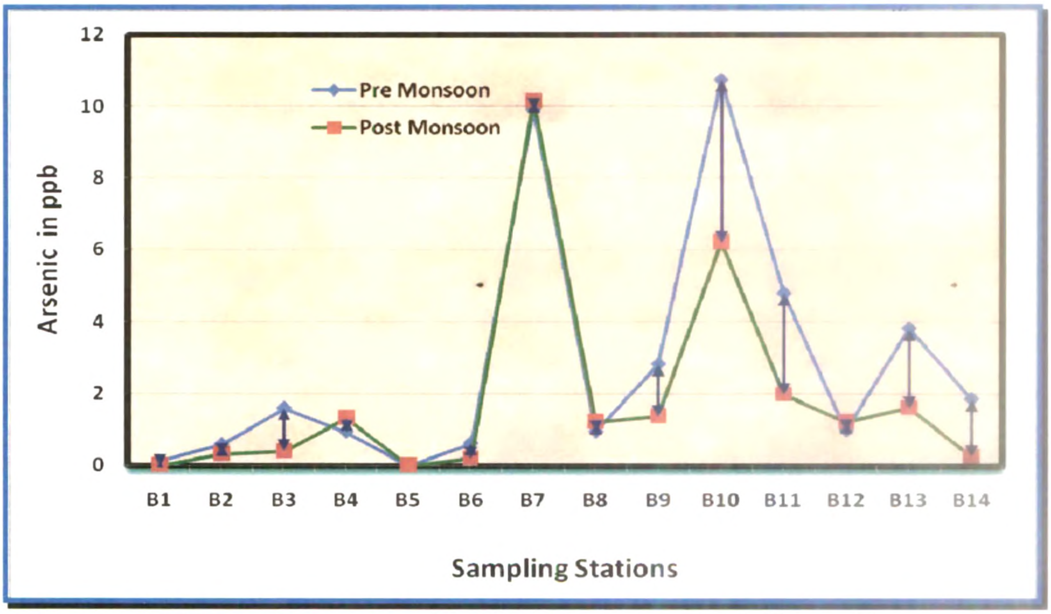

Figure 4.48 Seasonal variations of arsenic in water outside the tea gardens

ANNOVA analysis (F = 0.58656, p = 0.45065) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.63955, p = 0.43112) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

Wide data range and high standard deviation in case of arsenic is likely to bias the normal distribution statistic. This observation is supported by large differences between mean and median. Positive kurtosis and skewness value point towards sharp arsenic distribution with a long right tail in the study area.

4.2.22 Cadmium (Cd)

Cadmium is a metal with an oxidation state of +2. It is chemically similar to zinc and occurs naturally with zinc and lead in sulphide ores. Fertilizers produced from phosphate ores constitute a major source of diffuse cadmium pollution. Cadmium is considered potentially hazardous to human health and detected relatively frequently in drinking water. In most of the samples under investigation, the cadmium contents were much above the guideline value of 0.003 ppm (WHO, 1993). Cadmium above the permissible limit can potentially cause nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure along with kidney, liver, bone and blood damage from a lifetime exposure. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10-35 years (Park K., 2005)

The experimental results of cadmium in the study area are presented in Table 4.89. Various statistical estimates derived from NDA are summarized in Table 4.90. Figures 4.49 and 4.50 gives the variation of cadmium among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.89: Values for cadmium of the water samples in the study area

Cadmium in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.214	0.248	B1	bdl	bdl
A2	0.189	0.112	B2	bdl	bdl
A3	0.106	0.098	B3	bdl	bdl
A4	bdl	0.016	B4	bdl	0.015
A5	0.092	0.086	B5	0.207	0.198
A6	bdl	0.023	B6	0.251	0.169
A7	0.159	0.154	B7	0.098	0.081
A8	0.005	bdl	B8	0.115	0.111
A9	0.094	0.272	B9	0.162	0.146
A10	0.181	0.154	B10	0.096	0.102
A11	bdl	0.015	B11	0.025	0.001
A12	bdl	bdl	B12	bdl	bdl
A13	0.063	0.051	B13	bdl	bdl
A14	0.099	0.079	B14	0.099	0.093

Table 4.90: Statistical analysis for cadmium in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.120	0.109	0.132	0.102
Std. Error of Mean		0.020	0.025	0.025	0.022
Median		0.103	0.092	0.107	0.102
Mode		0.005	0.154	0.025	0.001
Std. Deviation		0.064	0.085	0.072	0.065
Variance		0.004	0.007	0.005	0.004
Skewness		-0.173	0.829	0.425	-0.235
Std. Error of Skewness		0.687	0.637	0.752	0.717
Kurtosis		-0.500	-0.113	-0.100	-0.570
Std. Error of Kurtosis		1.334	1.232	1.481	1.400
Range		0.209	0.257	0.226	0.197
Minimum		bdl	bdl	bdl	bdl
Maximum		0.214	0.272	0.251	0.198
Sum		1.202	1.308	1.053	0.916
Confidence Limit	Lower Bound	0.073	0.053	0.070	0.064
	Upper Bound	0.177	0.245	0.195	0.184
Percentiles	25	0.085	0.030	0.097	0.048
	50	0.103	0.092	0.107	0.102
	75	0.183	0.154	0.196	0.158
Inter Quartile Range		.077	0.130	0.087	0.085
WHO Rating		0.003 mg/l			
t		4.012	3.901	3.202	3.245
Comment		Significant	Significant	Significant	Significant

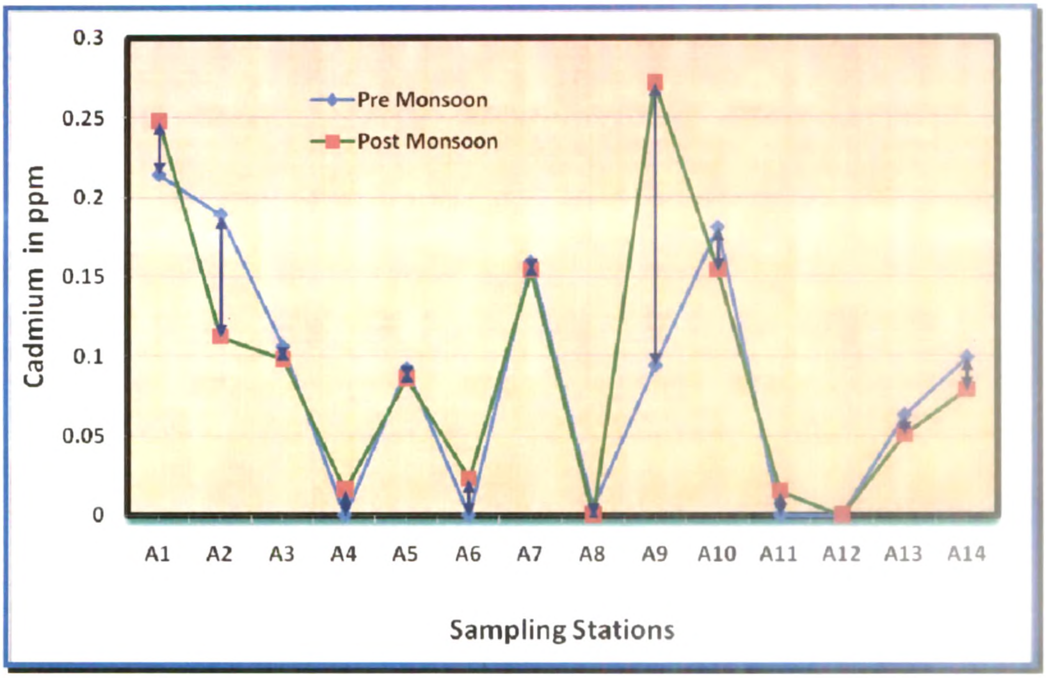

Figure 4.49: Seasonal variations of cadmium in water inside the tea gardens

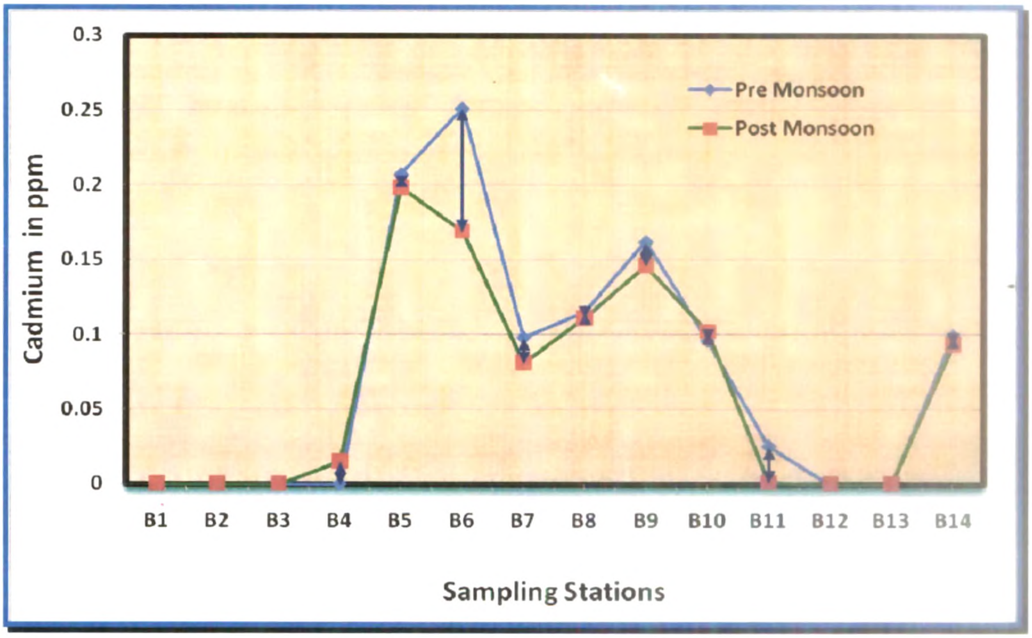

Figure4.50: Seasonal variations of cadmium in water outside the tea gardens

ANNOVA analysis (F = 0.06403, p = 0.80222) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.12766, p = 0.72376) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

Differences between mean and median, significant positive skewness and negative kurtosis value in pre monsoon and post monsoon inside and outside of the tea gardens respectively indicate that the distribution of cadmium in the study area is highly flat asymmetric distribution with a long left tail in the study area. On the other hand, positive sckewness and negative Kurtosis in case of cadmium in the post monsoon and premonsoon inside and outside the tea gardens respectively, indicative of flat asymmetric distribution of cadmium with a long right tail in the study area. This is also evident from the width of the third quartile, which is much greater than the first and second quartile. The cadmium contamination of groundwater in the area should be accorded maximum attention.

4.2.23 Copper (Cu)

Copper occurs in the earth in free native state and the form of its ores depending upon the geographical locations and proximity of industry. The municipal waste and sewage, corrosion of Cu containing pipelines or fittings are the principal anthropogenic source of cupper in the surface water. Copper in water is exceedingly toxic to aquatic biota and toxicity varies with the species of plants and animals. The toxicity also depends on factors such as pH, hardness, presence of other toxicants and the species of the copper present. Copper in excess of 1.0mg/L may impart some taste of water (Train, 1979). The permissible limit for copper in drinking water is 2.0 mg/L. This was set to ensure the water tastes good and to minimize staining of laundry and plumbing fixtures. The distribution of copper in groundwater of the study area is found to be within the permissible limit of W.H.O.(2004) with an average of 0.038 ppm. Asymmetric nature of copper distribution is also apparent from the normal distribution statistics with positive skewness and kurtosis values.

Table 4.91: Values for copper of the water samples in the study area

copper in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.193	0.147	B1	0.089	0.081
A2	0.131	0.089	B2	0.165	0.098
A3	0.089	0.067	B3	bdl	0.005
A4	0.081	0.032	B4	0.029	0.009
A5	0.033	0.021	B5	bdl	0.004
A6	0.055	0.043	B6	0.031	0.001
A7	bdl	0.001	B7	0.063	0.047
A8	bdl	0.011	B8	0.068	0.055
A9	0.034	0.012	B9	0.044	0.027
A10	0.089	0.083	B10	0.009	0.021
A11	0.021	0.017	B11	0.059	0.033
A12	0.019	0.018	B12	bdl	0.005
A13	0.021	0.039	B13	bdl	0.007
A14	0.055	0.037	B14	0.081	0.062

Table 4.92: Statistical analysis for copper in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.068	0.068	0.064	0.033
Std. Error of Mean		0.015	0.011	0.014	0.008
Median		0.055	0.035	0.061	0.024
Mode		0.021	0.001	0.009	0.005
Std. Deviation		0.052	0.040	0.043	0.032
Variance		0.003	0.002	0.002	0.001
Skewness		1.347	1.474	1.379	0.883
Std. Error of Skewness		0.637	0.597	0.687	0.597
Kurtosis		1.738	2.178	2.917	-0.301
Std. Error of Kurtosis		1.232	1.154	1.334	1.154
Range		0.174	0.146	0.156	0.097
Minimum		bdl	0.001	bdl	0.001
Maximum		0.193	0.147	0.165	0.098
Sum		0.821	0.617	0.638	0.455
Confidence Limit	Lower Bound	0.035	0.019	0.022	0.012
	Upper Bound	0.130	0.096	0.104	0.071
Percentiles	25	0.024	0.016	0.031	0.005
	50	0.055	0.035	0.061	0.024
	75	0.089	0.071	0.083	0.057
Inter Quartile Range		0.081	0.066	0.057	0.064
WHO Rating		2 mg/l			
t		-134.764	-179.758	-152.873	-233.377
Comment		Significant	Significant	Significant	Significant

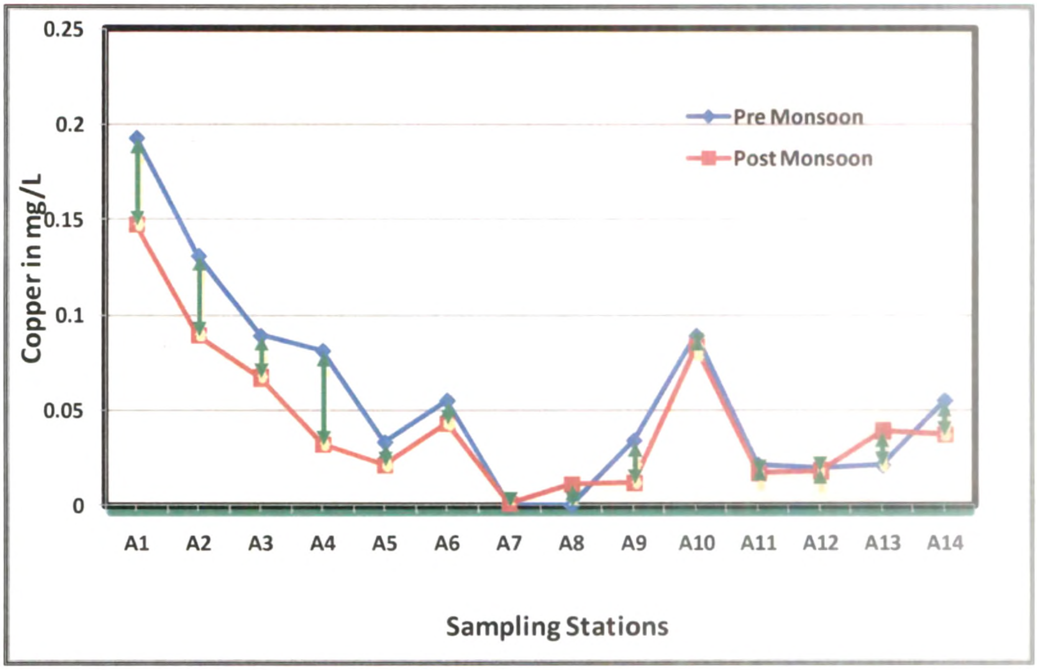

Figure 4.51: Seasonal variations of copper of water inside the tea gardens

Copper is regarded as harmless and essential metals for humans, the adults daily requirement is about 2.0mg (De A.K., 2000). But exposure to excessive amount of Cu for a long time may lead to liver damage. Excessive dose of Cu may also lead to mucosal irritation, widespread capillary damage, renal damage and depression. The experimental results of copper in the study area are presented in Table 4.91. Various statistical estimates derived from NDA are summarized in Table 4.92. Figures 4.51 and 4.52 gives the variation of copper among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. Significant differences between mean, median and mode indicate that the distribution of Cu in the study area is widely off normal.

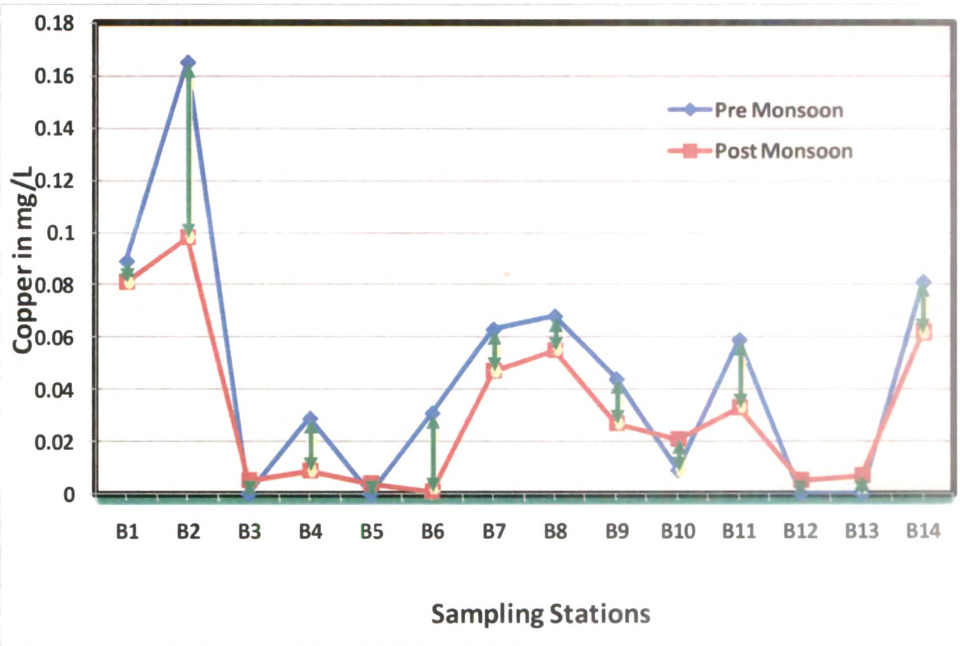

Table 4.52: Seasonal variations of copper in water outside the tea gardens

Significant t- Test for copper in this area also rejects the null hypothesis. ANNOVA analysis (F = 0.6262, p = 0.43591) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.629, p = 0.4349) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.24 Manganese (Mn)

Manganese is one of the most abundant metals in the Earth's crust, usually occurring with iron. It is a component of over 100 minerals but is not found naturally in its pure (elemental) form (ATSDR, 2000). Manganese is an element essential for the functioning of many cellular enzymes (e.g., manganese superoxide dismutase, pyruvate carboxylase) and can serve to activate many others (e.g., kinases, decarboxylases, transferases, hydrolases) (IPCS, 2002). The most environmentally and biologically important manganese compounds are those that contain Mn2+, Mn4+ or Mn7+ (US EPA', 1994). Manganese occurs naturally in many surface water and groundwater sources and in soils that may erode into these waters. However, human activities are also responsible for much of the manganese contamination in water in some areas.

The experimental results of manganese in the study area are presented in Table 4.93 Various statistical estimates derived from NDA are summarized in Table 4.94. Figures 4.53 and 4.54 gives the variation of manganese among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area.

Table 4.93: Values for manganese of the water samples in the study area

Manganese in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	bdl	bdl	B1	3.561	3.440
A2	bdl	bdl	B2	0.791	0.601
A3	0.004	bdl	B3	bdl	bdl
A4	0.032	0.026	B4	0.084	bdl
A5	0.082	0.065	B5	0.007	bdl
A6	0.002	bdl	B6	bdl	0.003
A7	bdl	bdl	B7	bdl	bdl
A8	bdl	0.002	B8	bdl	bdl
A9	bdl	bdl	B9	bdl	bdl
A10	0.006	0.001	B10	bdl	bdl
A11	bdl	bdl	B11	bdl	0.004
A12	0.008	bdl	B12	0.389	0.107
A13	0.086	0.028	B13	0.097	0.085
A14	bdl	bdl	B14	3.561	3.440

Table 4.94: Statistical analysis for manganese in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.031	0.024	1.213	1.097
Std. Error of Mean		0.014	0.012	0.614	0.610
Median		0.008	0.026	0.389	0.107
Mode		0.002	0.001	3.561	3.440
Std. Deviation		0.037	0.026	1.626	1.614
Variance		0.001	0.001	2.643	2.604
Skewness		0.973	1.012	1.123	1.165
Std. Error of Skewness		0.794	0.913	0.794	0.794
Kurtosis		-1.196	0.881	-0.952	-0.912
Std. Error of Kurtosis		1.587	2.000	1.587	1.587
Range		0.084	0.064	3.554	3.437
Minimum		bdl	bdl	bdl	bdl
Maximum		0.086	0.065	3.561	3.440
Sum		0.220	0.122	8.490	7.680
Confidence Limit	Lower Bound	bdl	bdl	bdl	bdl
	Upper Bound	0.033	0.020	1.340	1.262
Percentiles	25	0.004	0.002	0.084	0.004
	50	0.008	0.026	0.389	0.107
	75	0.082	0.047	3.561	3.440
Inter Quartile Range		0.014	0.008	0.490	0.231
WHO Rating		0.05 mg/l			
t		-4.257	-8.188	1.638	1.510
Comment		Significant	Significant	Non Significant	Non Significant

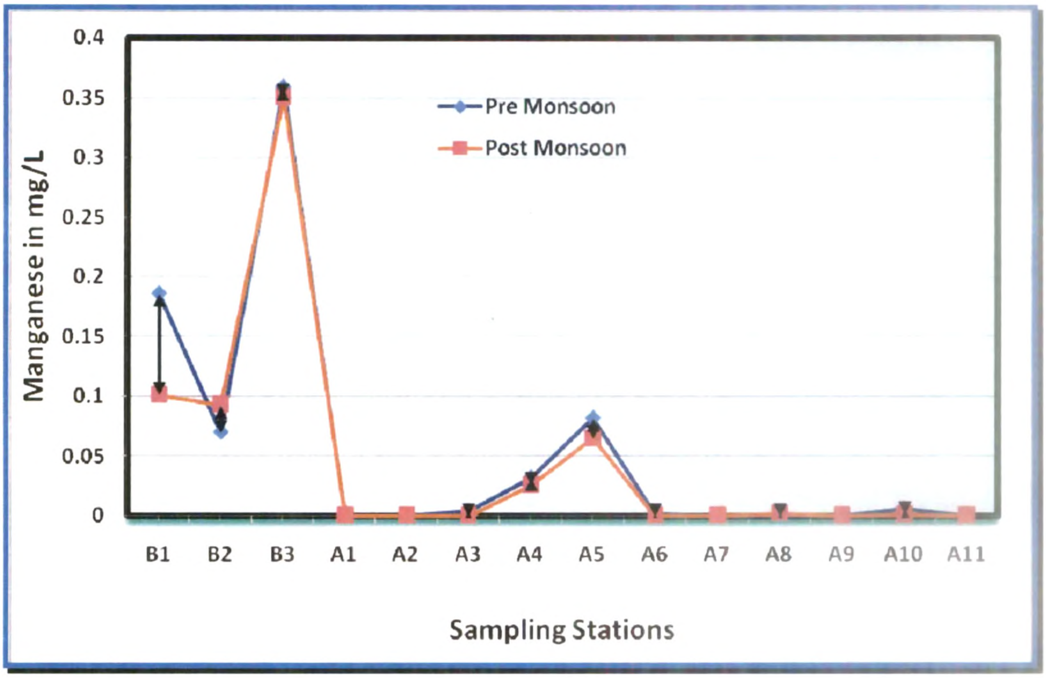

Figure 4.53: Seasonal variations of manganese in water inside the tea gardens

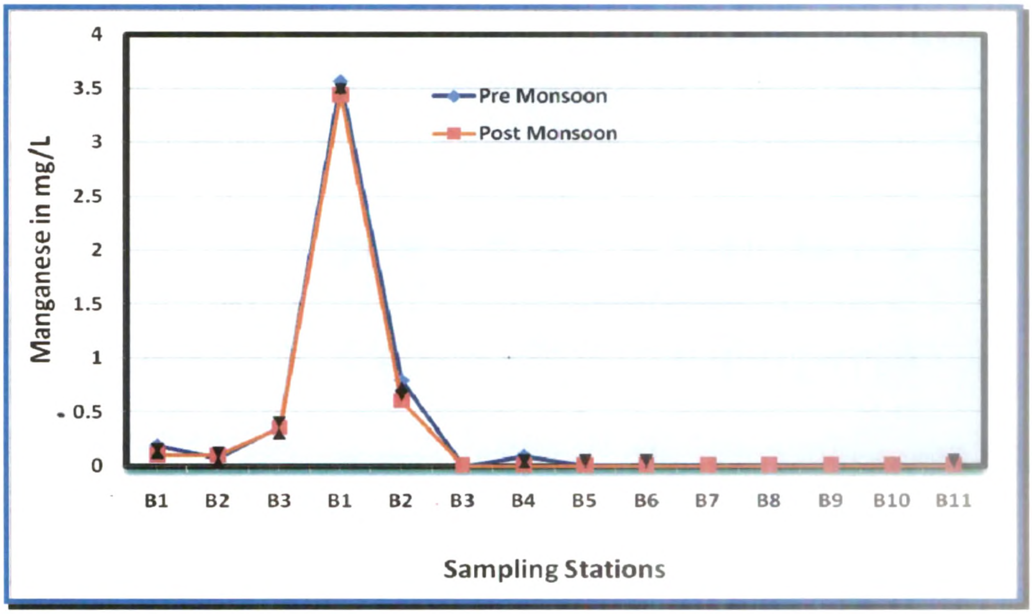

Figure 4.54: Seasonal variations of manganese in water outside the tea gardens

ANNOVA analysis (F = 0.54266, p = 0.46793) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.01492, p = 0.90373) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

Manganese at concentrations above 0.15 ppm stains plumbing fixtures and laundry and produces undesirable taste in drinks. The W.H.O limit for manganese in drinking water is 0.05 ppm. It is observed that as many as seven samples under observation contain manganese either at toxic or alert level. Thus, manganese contamination of groundwater in the area needs proper attention. A broad third quartile and positive skewness in case of manganese represents a long asymmetric tail on the right of the median. Heaviness of the tail for manganese distribution in the area is evident from very high positive kurtosis value.

4.2.25 Zinc (Zn)

Zinc is present in high concentrations in the wastes from pharmaceutical, galvanizing paint, pigments, several insecticides, cosmetics etc. and their discharge increases its concentration in appreciable amount in waters. Zinc imparts undesirable, bitter astringent taste to water at levels above 5.0mg/L may appear opalescent and develops a greasy film on boiling. In natural surface waters, the concentration of zinc is usually below 10 μg/litre, and in groundwaters, 10– 40 μg/litre (Elinder *et al.*, 1986). At very high concentrations zinc may cause some toxic effects. Symptoms of Zn toxicity in humans include vomiting, dehydration, electrolyte imbalance, abdominal pain, nausea, lethargies, dizziness and lack of muscular co-ordination. The experimental results of zinc in the study area are presented in Table 4.95. The distribution of copper in groundwater of the study area is found to be within the permissible limit of 5.0mg/L (W.H.O., 1984). Various statistical estimates derived from NDA are summarized in Table 4.96. Figures 4.55 and 4.56 gives the variation of zinc among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area

Table 4.95: Values for zinc of the water samples in the study area

Zinc in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	0.021	0.011	B1	0.447	0.418
A2	0.028	0.027	B2	0.619	0.541
A3	0.640	0.553	B3	0.027	0.022
A4	0.177	0.172	B4	0.595	0.321
A5	0.114	0.066	B5	0.197	0.195
A6	0.021	0.012	B6	0.389	0.231
A7	0.389	0.236	B7	0.417	0.355
A8	0.389	0.346	B8	1.956	1.493
A9	0.227	0.308	B9	0.501	0.541
A10	0.096	0.177	B10	0.515	0.413
A11	0.647	0.402	B11	0.283	0.211
A12	0.088	0.064	B12	0.642	0.511
A13	0.086	0.067	B13	0.578	0.481
A14	0.483	0.321	B14	0.591	0.472

Table 4.96: Statistical analysis for Zinc in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		0.243	0.197	0.554	0.443
Std. Error of Mean		0.060	0.045	0.118	0.090
Median		0.146	0.175	0.508	0.416
Mode		0.021	0.011	0.027	0.541
Std. Deviation		0.225	0.169	0.440	0.339
Variance		0.051	0.029	0.194	0.115
Skewness		0.813	0.663	2.664	2.415
Std. Error of Skewness		0.597	0.597	0.597	0.597
Kurtosis		-0.753	-0.414	9.049	7.848
Std. Error of Kurtosis		1.154	1.154	1.154	1.154
Range		0.626	0.542	1.929	1.471
Minimum		0.021	0.011	0.027	0.022
Maximum		0.647	0.553	1.956	1.493
Sum		3.406	2.762	7.757	6.205
Confidence Limit	Lower Bound	0.113	0.100	0.300	0.248
	Upper Bound	0.373	0.295	0.808	0.639
Percentiles	25	0.072	0.055	0.363	0.226
	50	0.146	0.175	0.508	0.416
	75	0.413	0.327	0.601	0.519
Inter Quartile Range		0.341	0.272	0.238	0.292
WHO Rating		5 mg/l			
t		-79.180	-106.673	-37.714	-50.486
Comment		Significant	Significant	Significant	Significant

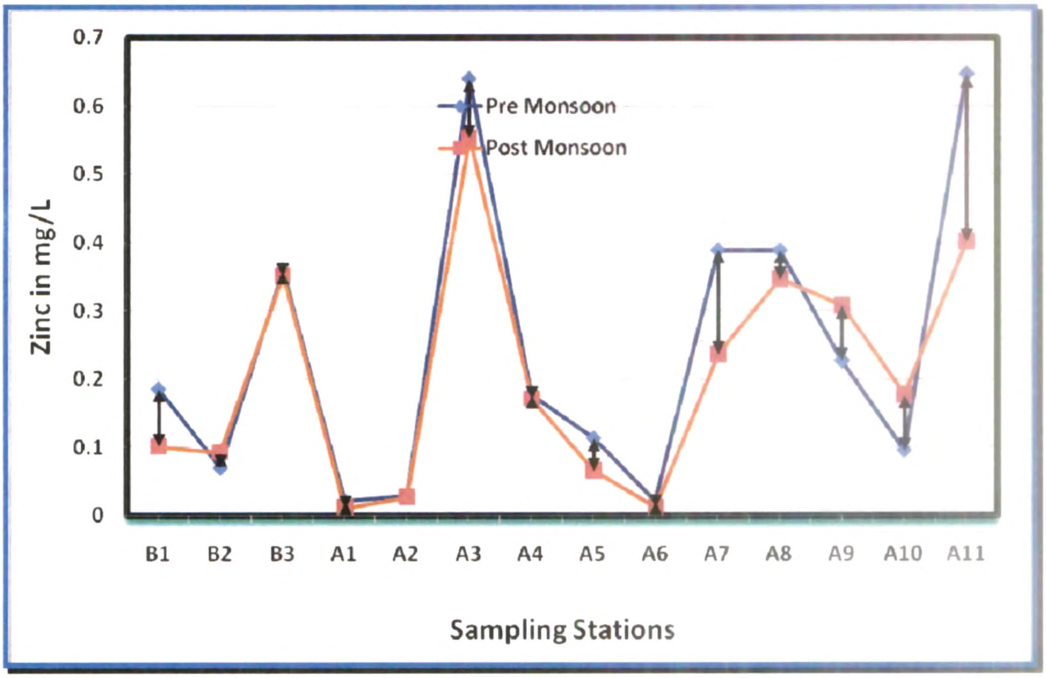

Figure4.55: Seasonal variations of zinc in water inside the tea gardens

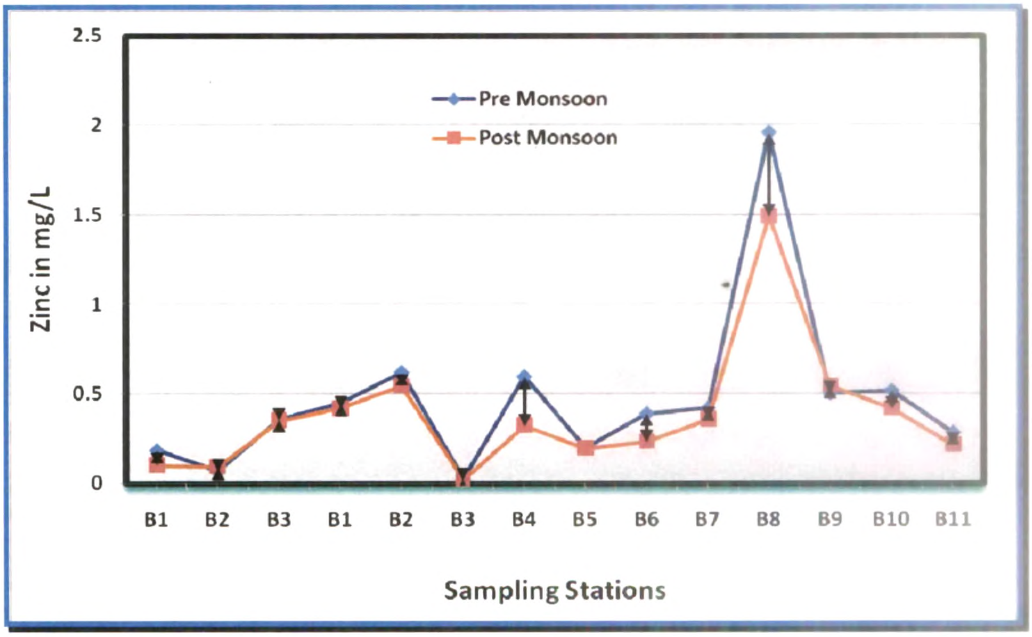

Figure 4.56: Seasonal variations of zinc in water outside the tea gardens

ANNOVA analysis (F = 0.38261, p = 0.54159) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.57804, p = 0.45392) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

Although the groundwaters of the study area are by and large safe with regard to zinc as may be seen from Table 4.95, its distribution is still not uniform in the area. Wide data range and high standard deviation in case of zinc is likely to bias the normal distribution statistic. This observation is supported by positive kurtosis and skewness value, which point towards sharp zinc distribution with a long right tail in the study area.

4.2.26 Sodium (Na)

Sodium and potassium are naturally occurring elements and they remains mostly in solutions without undergoing any precipitation. According to National Academy of Sciences (1977), high concentration of sodium can cause cardiovascular diseases and woman may suffer toxemia during pregnancy. Na is linked with high blood pressure. Moreover, at very high concentration sodium causes corrosion to metal surface and become toxic to plants. In the present study the sodium content of all the water samples were found to lie within the WHO permissible limit 200mg/L (WHO, 1984)

The experimental results of sodium in the study area are presented in Table 4.97. Various statistical estimates derived from NDA are summarized in Table 4.98. Figures 4.57 and 4.58 gives the variation of sodium among different sampling stations during pre-monsoon and post monsoon respectively inside and outside the tea gardens of the study area. Differences between mean and median, significant positive skewness and kurtosis value indicate that the distribution of sodium in the study area is highly asymmetric. This is also evident from the width of the third quartile, which is much greater than the first and second quartile.

Table 4.97: Values for sodium of the water samples in the study area

Sodium in mg/l					
Sample No	Inside Tea Garden		Sample No	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	43	55	B1	21	27
A2	21	27	B2	36	40
A3	14	16	B3	18	20
A4	18	20	B4	16	bdl
A5	19	17	B5	12	29
A6	21	27	B6	27	31
A7	34	40	B7	41	39
A8	13	bdl	B8	25	27
A9	bdl	bdl	B9	50	45
A10	27	29	B10	13	32
A11	14	25	B11	20	27
A12	25	30	B12	19	26
A13	10	bdl	B13	bdl	bdl
A14	34	31	B14	21	28

Table 4.98: Statistical analysis for sodium in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		22.5	28.8	24.5	30.9
Std. Error of Mean		2.7	3.3	3.1	2.0
Median		21.0	27.0	21.0	28.5
Mode		14.0	27.0	21.0	27.0
Std. Deviation		9.7	11.0	11.3	7.1
Variance		94.9	122.0	128.3	49.9
Skewness		0.8	1.3	1.2	0.8
Std. Error of Skewness		0.6	0.7	0.6	0.6
Kurtosis		0.0	2.5	0.8	0.1
Std. Error of Kurtosis		1.2	1.3	1.2	1.2
Range		33.0	39.0	38.0	25.0
Minimum		bdl	bdl	bdl	bdl
Maximum		43.0	55.0	50.0	45.0
Sum		293.0	317.0	319.0	371.0
Confidence Limit	Lower Bound	18.46	21.67	16.11	25.60
	Upper Bound	31.94	37.73	29.49	34.20
Percentiles	25	14.00	20.00	17.00	27.00
	50	21.00	27.00	21.00	28.50
	75	30.50	31.00	31.50	37.25
Inter Quartile Range		16.25	10.25	12.50	7.00

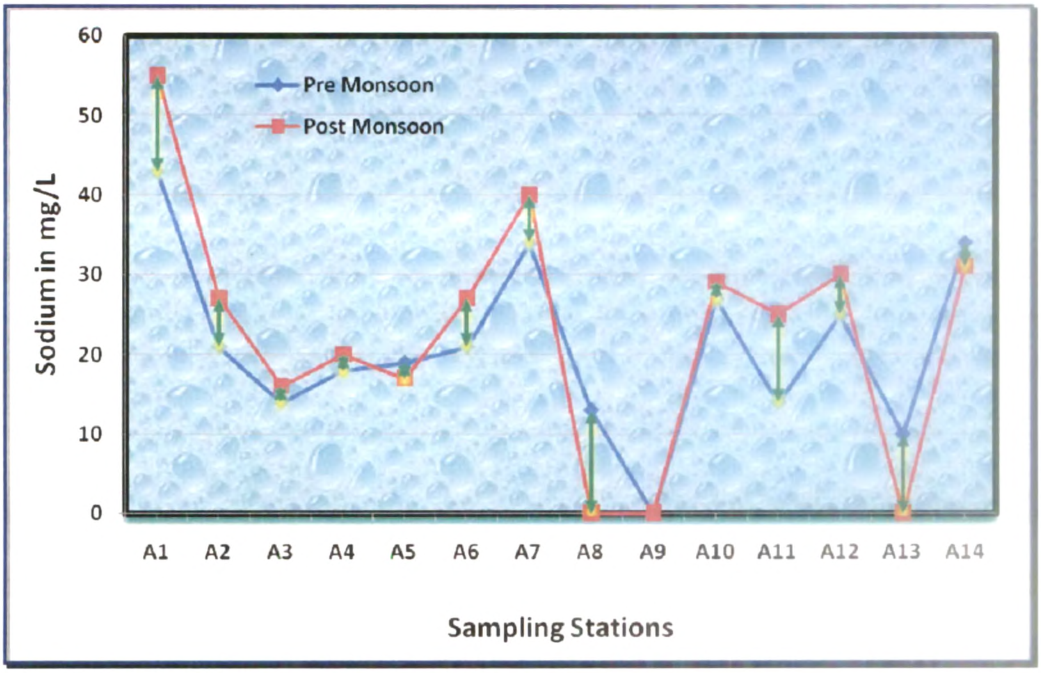

Figure 4.57: Seasonal variations of sodium in water inside the tea gardens

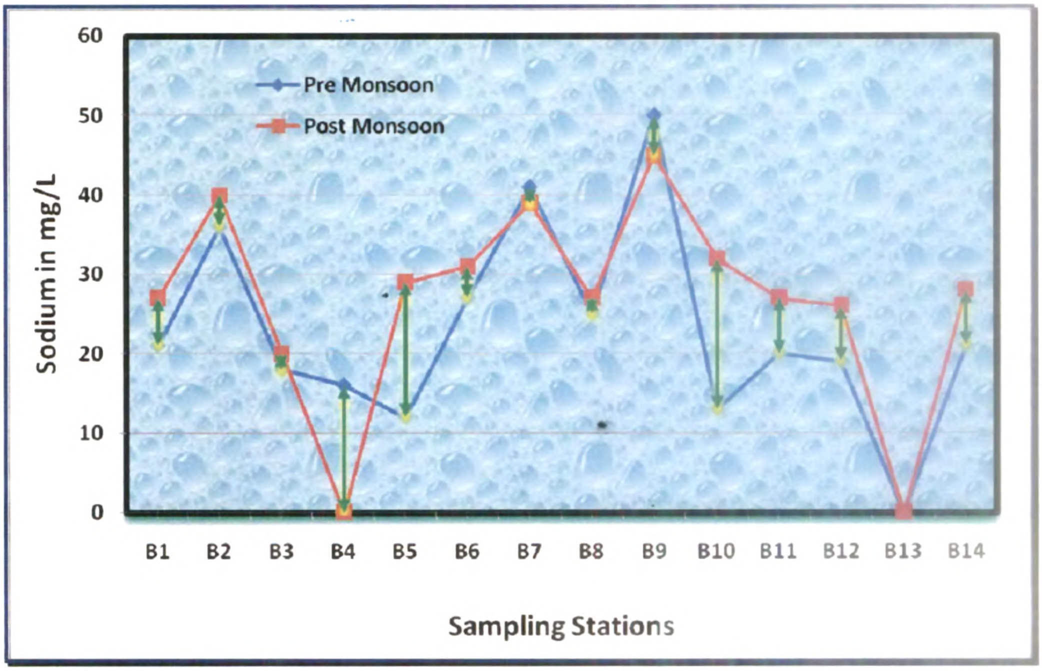

Figure 4.58: Seasonal variations of sodium in water outside the tea gardens

ANNOVA analysis (F = 0.1117, p = 0.74089) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 0.58585, p = 0.45092) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.

4.2.27 Potassium (K)

Potassium is an essential element in humans and is seldom, if ever, found in drinking water at levels that could be a concern for healthy humans (WHO, 2009). Potassium has similar chemistry like sodium and it remains in solution without undergoing any precipitation. Potassium is naturally occurring element; however its concentration is lower than calcium, sodium and even magnesium. In some water samples from rural areas of Jind district the potassium concentration levels were found to be lower in comparison to the sodium concentration (Garg *et al.*, 1998) Major source is weathering of rocks but the quantities increase due to disposal of waste waters. As such, potassium is not very much significant from the health point of view, but quantities may be laxative. Ingestion of excessive amounts (>200mg/L) may be detrimental to the human nervous and digestive system.

The ranges of potassium concentration in the study area is as follows

BDL to 9 mg/L (Pre monsoon, inside tea garden)

BDL to 11mg/L (Post monsoon, inside tea garden)

BDL to 11mg/L (Pre monsoon, outside tea garden)

BDL to 15mg/L (Post monsoon, outside tea garden)

The experimental results of potassium in the study area are presented in Table 4.99. Various statistical estimates derived from NDA are summarized in Table 4.100.

Table 4.99: Values for potassium of the water samples in the study area

Potassium in mg/l					
Sample No.	Inside Tea Garden		Sample No.	Outside Tea Garden	
	Pre Monsoon	Post Monsoon		Pre Monsoon	Post Monsoon
A1	bdl	1	B1	3	9
A2	9	11	B2	8	6
A3	2	7	B3	4	7
A4	bdl	bdl	B4	3	8
A5	4	5	B5	6	5
A6	5	7	B6	3	bdl
A7	7	10	B7	2	4
A8	2	3	B8	1	8
A9	1	bdl	B9	2	4
A10	2	1	B10	1	7
A11	5	4	B11	bdl	bdl
A12	3	2	B12	11	2
A13	6	bdl	B13	2	7
A14	3	5	B14	5	15

Table 4.100: Statistical analysis for potassium in water

Descriptive Statistics		Inside Tea Garden		Outside Tea Garden	
		Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
Mean		4.1	5.1	3.9	6.8
Std. Error of Mean		0.7	1.0	0.8	0.9
Median		3.5	5.0	3.0	7.0
Mode		2.0	1.0	2.0	7.0
Std. Deviation		2.4	3.4	2.9	3.3
Variance		5.7	11.5	8.6	10.7
Skewness		0.7	0.5	1.4	1.2
Std. Error of Skewness		0.6	0.7	0.6	0.6
Kurtosis		-0.1	-0.7	1.7	3.1
Std. Error of Kurtosis		1.2	1.3	1.2	1.2
Range		8.0	10.0	10.0	13.0
Minimum		bdl	bdl	bdl	bdl
Maximum		9.0	11.0	11.0	15.0
Sum		49.0	56.0	51.0	82.0
Confidence Limit	Lower Bound	1.81	2.47	1.79	3.54
	Upper Bound	6.19	8.53	7.71	9.96
Percentiles	25	2.00	2.00	2.00	4.25
	50	3.50	5.00	3.00	7.00
	75	5.75	7.00	5.50	8.00
Inter Quartile Range		4.25	7.00	6.25	3.50

Figure 4.59 and 4.60 given below gives the seasonal variation of potassium among different sampling stations during pre-monsoon and post monsoon inside and outside the tea gardens of the study area respectively. Significant positive skewness and kurtosis value point towards sharp potassium distribution with a long right tail outside the tea gardens in both seasons. Large differences between mean, mode and median also imply that distribution of K inside and outside the tea gardens of the study area is widely off normal.

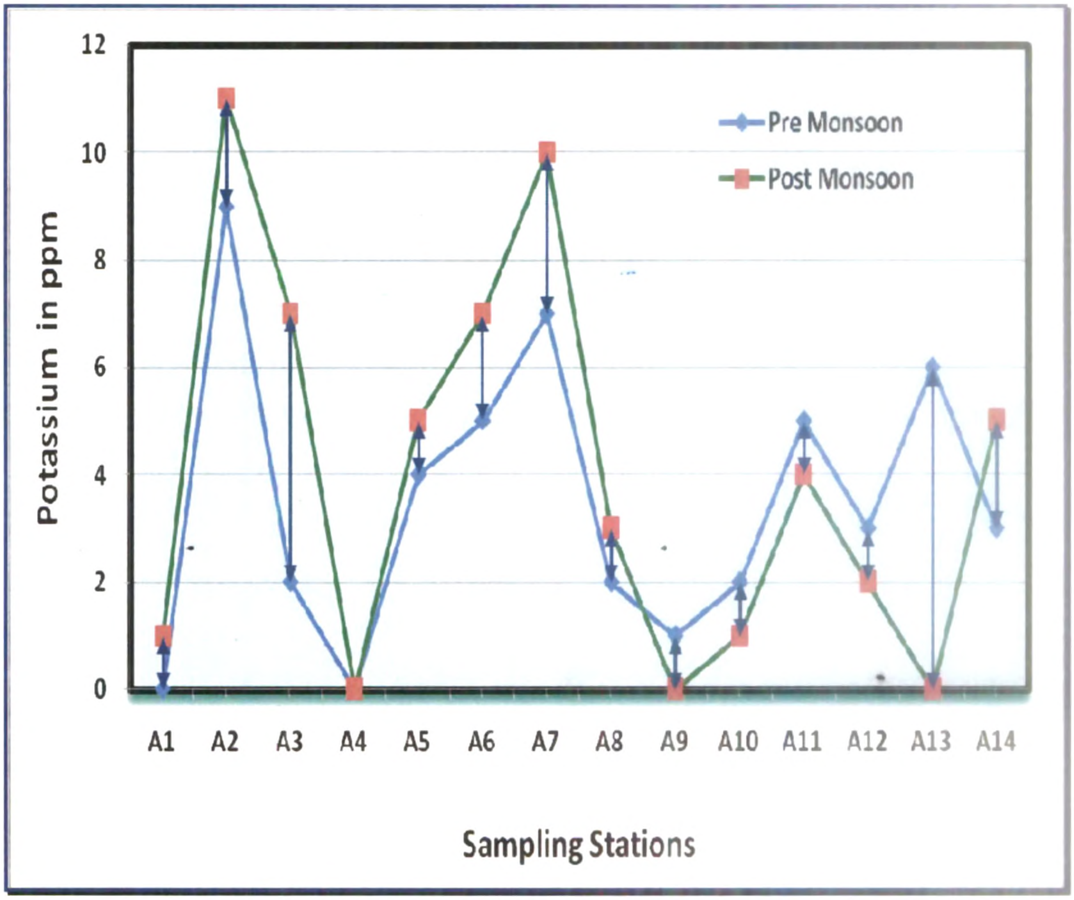

Figure 4.59: Seasonal variations of potassium in water inside the tea gardens

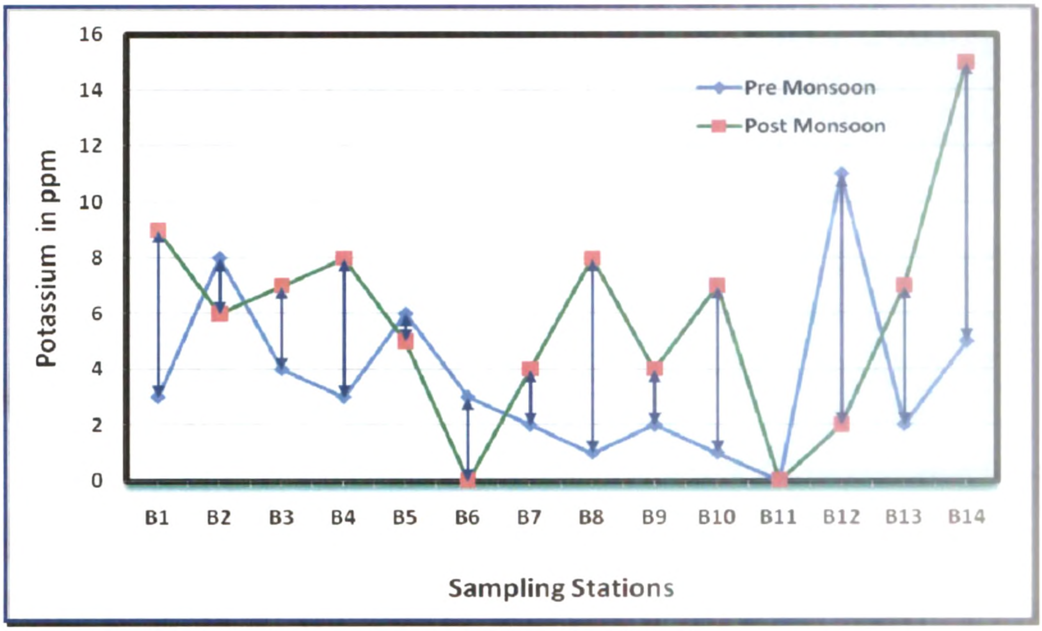

Figure 4.60: Seasonal variations of potassium in water outside the tea gardens

ANNOVA analysis (F = 0.17009, p = 0.68341) at the 0.05 level, suggests that the means are not significantly different during the pre and post monsoon season inside the tea gardens. ANNOVA analysis (F = 2.83352, p = 0.10429) at the 0.05 level, also suggests that the means are not significantly different during the pre and post monsoon season outside the tea gardens.