As distance increases from the mill, the organic matter in the soil also decreases showing that the Mill has a certain area of influence beyond which the organic matter content is not dependent on the contributions from the Mill. In some cases, the soil away from the Mill even shows less organic matter than that of the 'Control'. This indicates that the 'Control' soil might be receiving some organic supplement in the form of cow dung etc., while no such thing has happened in the area surrounding the Mill except for receiving organically rich effluent.

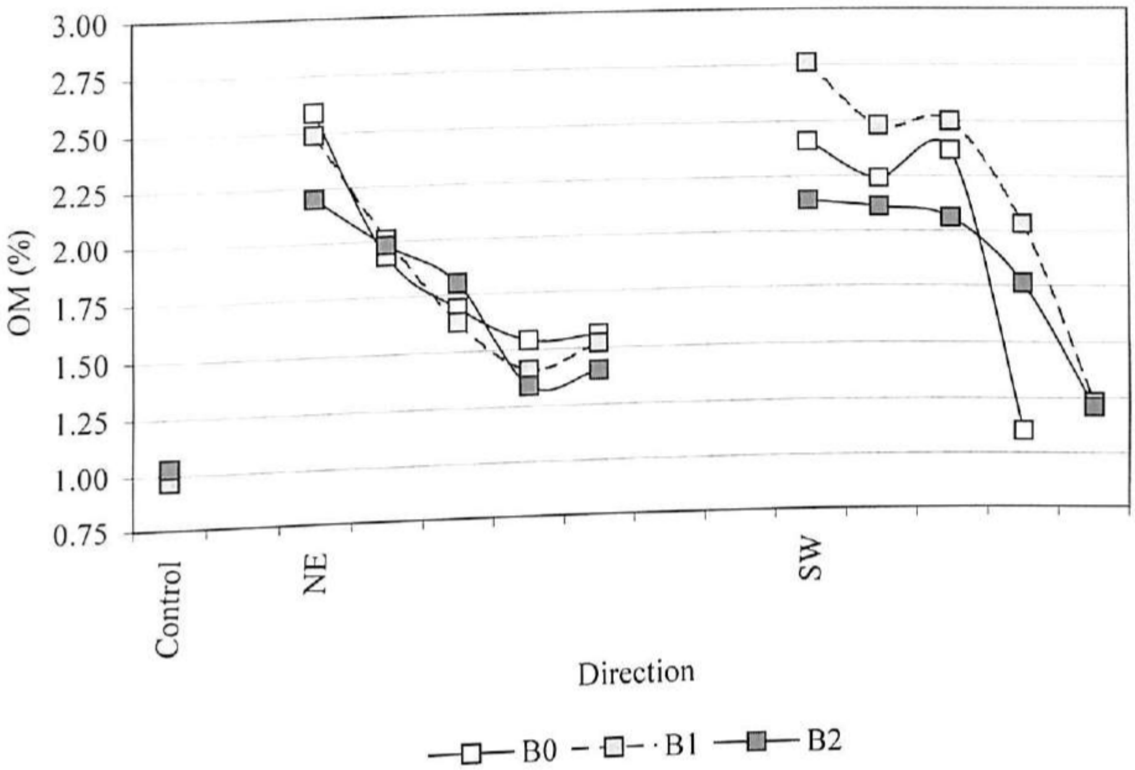
The mean values in B1 and B2 batches are found to be the same. Here also, the values are higher in the post-monsoon season compared to those in the pre-monsoon season. A similar observation was also reported by Khound (2002). The suspended and dissolved organic matter present in the effluent of the mill as well as the solid wastes deposited on the soil near the mill might have led to an enrichment of soil organic matter (Srivastava, 2001).

The general trend of the values indicates a decrease away from the Mill although the trend is not uniform in all the directions. The decreasing trend is shown for the pre-monsoon season in two directions for side A and for all the seasons in four directions for side B in Fig.3.10

3.1.8. Oil and Grease

In the present study, most of the soil samples in Side A do not have oil and grease. The soil samples of northeast side were free from oil and grease. In northern side, S6 had oil and grease in B1 and B2 batch whereas S8 in B0 batch. The sample S11 in B2, S12 in B0 and S13 in B1 batch in northwest direction had oil and grease. In western direction, S17 in B0 and B2, S18 in B1 contain oil and grease. In southwestern direction, S21 in B0, S22 in B1, S24 in B2 batches had oil and grease. In all the cases, where oil and grease was found, the value was 100 mg/kg. The control sample was free from oil and grease.

In side B, the same situation was observed like side A. In some samples (S26 in A1 & A2, S34 in B2 & A3, S38 in A1 & A2, S39 in A3, S42 in A1 and B1), 100 mg/kg of oil and grease was obtained. All these samples are nearer to the Mill. The samples in the northern direction were found free from oil and grease. No seasonal variation was observed.



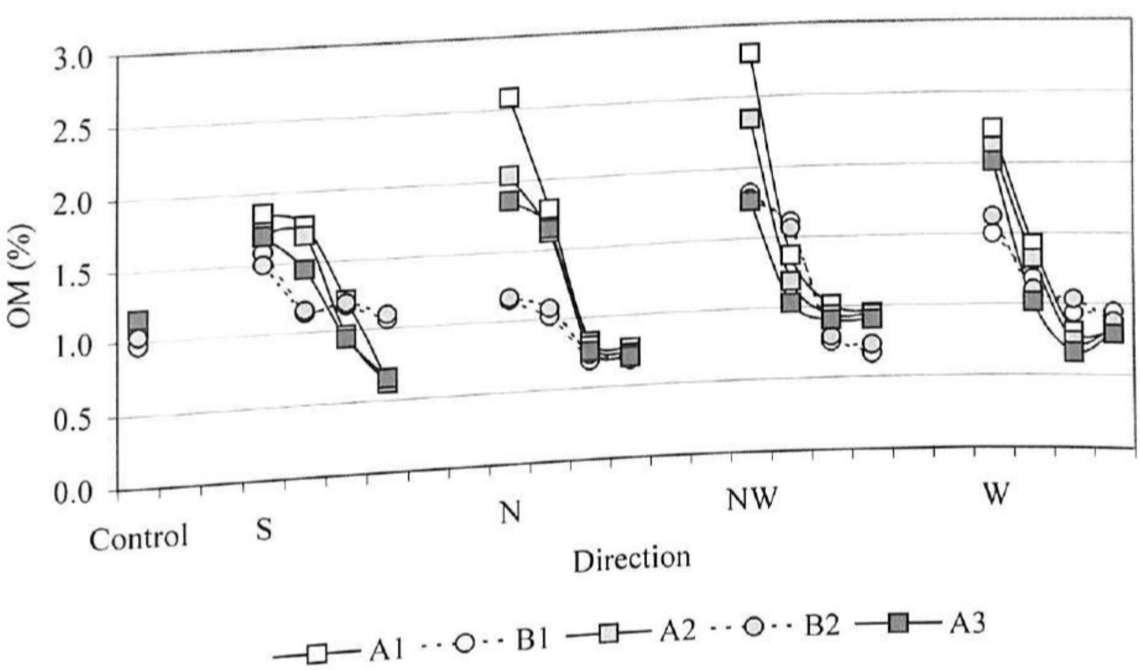


Fig. 3.10. Directional trends in organic matter content of the soil for Side A (top, only the three pre-monsoon seasons) and side B (bottom, all the seasons) in a few directions from the Mill along with the values for the 'Control' soil samples.

3.1.9 Total nitrogen

The total nitrogen present in the soil samples in the study area is given in Tables 3.8(a) and 3.8(b) for Side A and Side B respectively. Total nitrogen in the soil is contributed by inorganic and organic nitrogen compounds, which may be moderately toxic in nature. They are also the most common constituents of organic wastes (Vellidis et al., 1996).

In the study area, Side A was rich in nitrogen. For the pre-monsoon season, the values are in the ranges of 0.037 - 0.262 % (B0), 0.035 - 0.215 % (B1) and 0.034 - 0.22 % (B2). The corresponding values for the 'Control' sample are 0.035, 0.032 and 0.03 % respectively. The soil samples in north, northwest and west directions have comparatively more nitrogen than the other two directions (northeast and southwest). The sample, S11, in northwest direction, which is very near to the Mill, shows the highest amount of nitrogen (mean value 0.224 %). Almost in every direction, the values have a decreasing trend away from the Mill.

The nitrogen content was comparatively less in the Side B than the side A. Among the five seasons, the season A1 had highest range of values 0.07 - 0.18 %. The mean values for the pre-monsoon seasons of B1 (0.08 %) and B2 (0.076 %) were less than that of the post-monsoon seasons, A1 (0.11 %), A2 (0.097 %) and A3 (0.079 %).

It was found that the nitrogen content of the soil did not bear a perfect linear relationship to soil organic matter content. The plots of organic matter vs. total nitrogen for Side A had the regression coefficient (R) of 0.27 (NE direction), 0.15 (N direction), 0.50 (W direction), 0.60 (SW direction) and 0.47 (NW direction). Similarly, the regression coefficients for organic matter vs. total nitrogen content plots for Side B are 0.53 (S direction), 0.75 (N direction), 0.73 (NW direction), 0.31 (W direction), and 0.61 (SW direction). Thus, although considerable linearity was shown in W and SW directions in Side A, and S, N, NW and SW directions in Side B, the relationship between the two parameters was weak in the other directions. The results indicate that although the organic nitrogen compounds in soil are the major contributor to the soil nitrogen content, there are still other contributors of significant amounts. The results also indicate directional differential variations in the two parameters. Soil microbes make nitrogen available to plants by breaking down organic matter and steadily releasing two inorganic forms of nitrogen – ammonium and nitrate, which leads to a strong correlation between soil organic matter and the total nitrogen content.

3.1.10 Available Phosphorus

The values of available phosphorus along with the maximum, the minimum, the mean and the standard deviation for each season and each site are given in Table 3.9(a) and 3.9(b). In side A, the available phosphorus content was in the ranges of B0: 0.1 – 1.8 mg/kg, B1: 0.1 – 9.2 mg/kg and B2: 0.1 – 7.9 mg/kg. The "Control" sample had available phosphorous content of 0.09, 0.1 and 0.09 mg/kg in the three seasons, which were lower than the values from the study area. Some samples in all batches showed low values. During the first pre-monsoon season (B0), the soil samples had the lowest phosphorus content in comparison to the other two seasons. Of all the measurements, the maximum value was obtained at S17 (9.2 mg/kg) in the west direction from the Mill in the second pre monsoon season (B1) and the lowest value at S21 (0.1 mg/kg) and S25 0.1 mg/kg) in the southwest direction. It is found that the north, northwest and west directions had more phosphorus content in comparison to other two directions viz. northeast and southwest.

In side B, the available phosphorus measured in the different seasons was from 0.2– 3.35 mg/kg (A1), 0.09– 3.4 mg/kg (B1), 0.16 - 3.40 mg/kg A2), 0.09– 3.02 mg/kg (B2), 0.3– 3.00 mg/kg (A3). The highest value obtained was at S30 (the mean value 3.17 mg/kg) in the north direction and the lowest at S29 (the mean value 0.19 mg/kg) in the south direction. In all the directions, soil samples away from the Mill had lower phosphorous value with a few exceptions. Seasonal variation for all the sites was not distinct.

Variation patterns for available P with direction and distance are shown in Fig. 3.11.

3.1.11 Exchangeable Cations

(i) Calcium

The amounts of calcium in different seasons in side A and B are given in Tables 3.10(a) and 3.10(b). The values in Side A are within the ranges of 17 – 82 meq/kg (B0), 21.7 – 86.1 meq/kg (B1) and 20.1– 76.5 meq/kg (B2). In all the cases, the 'Control' values were lower than the values from the study area. This indicates that the calcium salts have influenced the study area soil composition. The mean value in B1 is more than that of the other two pre monsoon seasons. The highest value obtained was for S17 (west direction) in B1 season. This sample has also got the maximum mean value (81.5 meq/kg) among all the seasons. This site is very near to the Mill. The lowest value was measured at S2 (17 meq/kg) in the northeast

Table 3.8(a). Total Nitrogen content (%) of the soil (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.035	0.032	0.030	0.030	0.035	0.032	0.003
NE	S1	0.059	0.083	0.080	0.059	0.083	0.074	0.013
	S2	0.048	0.094	0.089	0.048	0.094	0.077	0.025
	S3	0.046	0.084	0.080	0.046	0.084	0.070	0.021
	S4	0.037	0.070	0.070	0.037	0.070	0.059	0.019
	S5	0.037	0.070	0.070	0.037	0.070	0.059	0.019
N	S6	0.110	0.215	0.220	0.110	0.220	0.182	0.062
	S7	0.134	0.208	0.210	0.134	0.210	0.184	0.043
	S8	0.116	0.083	0.080	0.080	0.116	0.093	0.020
	S9	0.148	0.067	0.070	0.067	0.148	0.095	0.046
	S10	0.094	0.035	0.034	0.034	0.094	0.054	0.034
NW	S11	0.262	0.200	0.210	0.200	0.262	0.224	0.033
	S12	0.241	0.176	0.174	0.174	0.241	0.197	0.038
	S13	0.220	0.143	0.140	0.140	0.220	0.168	0.045
	S14	0.196	0.090	0.110	0.090	0.196	0.132	0.056
	S15	0.078	0.110	0.110	0.078	0.110	0.099	0.018
W	S16	0.203	0.197	0.210	0.197	0.210	0.203	0.007
	S17	0.216	0.099	0.110	0.099	0.216	0.142	0.065
	S18	0.154	0.052	0.063	0.052	0.154	0.090	0.056
	S19	0.126	0.060	0.065	0.060	0.126	0.084	0.037
	S20	0.129	0.066	0.063	0.063	0.129	0.086	0.037
SW	S21	0.173	0.117	0.120	0.117	0.173	0.137	0.032
	S22	0.160	0.068	0.064	0.064	0.160	0.097	0.054
	S23	0.163	0.070	0.069	0.069	0.163	0.101	0.054
	S24	0.049	0.063	0.060	0.049	0.063	0.057	0.007
	S25	0.082	0.042	0.045	0.042	0.082	0.056	0.022
	Min	0.037	0.035	0.034				
	Max	0.262	0.215	0.220				
	Mean	0.131	0.102	0.105				
	SD	0.067	0.055	0.057				

Table 3.8 (b). Total Nitrogen content (%) of the soil (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.045	0.032	0.045	0.030	0.041	0.030	0.045	0.039	0.007
S	S26	0.16	0.086	0.1	0.078	0.160	0.078	0.160	0.117	0.040
	S27	0.09	0.114	0.06	0.092	0.070	0.060	0.114	0.085	0.021
	S28	0.07	0.072	0.06	0.076	0.063	0.060	0.076	0.068	0.007
	S29	0.1	0.020	0.05	0.024	0.050	0.020	0.100	0.049	0.032
N	S30	0.15	0.154	0.14	0.110	0.100	0.100	0.154	0.131	0.024
	S31	0.14	0.104	0.12	0.110	0.090	0.090	0.140	0.113	0.019
	S32	0.106	0.041	0.09	0.036	0.040	0.036	0.106	0.063	0.033
	S33	0.08	0.039	0.07	0.040	0.063	0.039	0.080	0.058	0.018
NW	S34	0.13	0.112	0.14	0.109	0.120	0.109	0.140	0.122	0.013
	S35	0.08	0.091	0.07	0.092	0.070	0.070	0.092	0.081	0.011
	S36	0.12	0.083	0.068	0.090	0.053	0.053	0.120	0.083	0.025
	S37	0.12	0.067	0.06	0.065	0.060	0.060	0.120	0.074	0.026
W	S38	0.14	0.107	0.1	0.100	0.078	0.078	0.140	0.105	0.022
	S39	0.12	0.102	0.14	0.100	0.110	0.100	0.140	0.114	0.016
	S40	0.1	0.064	0.13	0.070	0.100	0.064	0.130	0.093	0.027
	S41	0.1	0.077	0.1	0.065	0.060	0.060	0.100	0.080	0.019
SW	S42	0.18	0.120	0.13	0.120	0.176	0.120	0.180	0.145	0.030
	S43	0.13	0.072	0.17	0.080	0.078	0.072	0.170	0.106	0.043
	S44	0.1	0.076	0.11	0.070	0.050	0.050	0.110	0.081	0.024
	S45	0.07	0.039	0.09	0.040	0.030	0.030	0.090	0.054	0.025
	Min	0.070	0.020	0.050	0.024	0.030				
	Max	0.180	0.154	0.170	0.120	0.176				
	Mean	0.114	0.082	0.100	0.078	0.081				
	SD	0.030	0.033	0.034	0.027	0.038				

Table 3.9 (a). Available phosphorous content (mg/kg) of the soil of the study area (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.09	0.10	0.09	0.09	0.10	0.09	0.01
NE	S1	0.10	0.90	0.89	0.10	0.90	0.63	0.46
	S2	0.10	0.60	0.65	0.10	0.65	0.45	0.30
	S3	0.20	1.10	1.23	0.20	1.23	0.84	0.56
	S4	0.30	1.00	1.36	0.30	1.36	0.89	0.54
	S5	0.30	0.80	1.01	0.30	1.01	0.70	0.36
N	S6	0.50	3.20	2.86	0.50	3.20	2.19	1.47
	S7	0.50	2.90	3.10	0.50	3.10	2.17	1.45
	S8	1.00	3.60	3.80	1.00	3.80	2.80	1.56
	S9	0.50	1.10	1.09	0.50	1.10	0.90	0.34
	S10	0.60	1.20	1.30	0.60	1.30	1.03	0.38
NW	S11	0.90	5.30	5.43	0.90	5.43	3.88	2.58
	S12	1.00	4.10	4.68	1.00	4.68	3.26	1.98
	S13	1.80	1.30	2.01	1.30	2.01	1.70	0.36
	S14	0.60	1.60	1.80	0.60	1.80	1.33	0.64
	S15	0.40	0.90	1.10	0.40	1.10	0.80	0.36
W	S16	0.90	3.60	3.20	0.90	3.60	2.57	1.46
	S17	1.10	9.20	7.89	1.10	9.20	6.06	4.35
	S18	1.80	2.60	3.20	1.80	3.20	2.53	0.70
	S19	0.60	2.20	2.10	0.60	2.20	1.63	0.90
	S20	0.40	2.20	1.80	0.40	2.20	1.47	0.95
SW	S21	0.10	1.60	1.10	0.10	1.60	0.93	0.76
	S22	0.20	1.10	0.98	0.20	1.10	0.76	0.49
	S23	0.40	0.80	0.75	0.40	0.80	0.65	0.22
	S24	0.20	0.80	0.63	0.20	0.80	0.54	0.31
	S25	0.40	0.10	0.10	0.10	0.40	0.20	0.17
	Min	0.10	0.10	0.10				
	Max	1.80	9.20	7.89				
	Mean	0.60	2.15	2.16				
	SD	0.47	1.95	1.79				

Table 3.9 (b). Available phosphorous content (mg/kg) of the soil of the study area (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.1	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.0
S	S26	2.36	2.92	2.36	3.02	3.00	2.36	3.02	2.73	0.34
	S27	1.14	0.60	1.14	1.10	0.92	0.60	1.14	0.98	0.23
	S28	0.80	0.48	0.80	0.71	0.69	0.48	0.80	0.70	0.13
	S29	0.23	0.09	0.23	0.10	0.30	0.09	0.30	0.19	0.09
N	S30	3.35	3.40	3.40	2.83	2.90	2.83	3.40	3.17	0.28
	S31	2.28	1.44	2.28	1.69	1.70	1.44	2.28	1.88	0.38
	S32	1.20	1.22	1.20	1.35	1.30	0.56	2.80	1.47	0.94
	S33	0.56	2.80	0.56	1.65	1.76	1.20	1.35	1.25	0.07
NW	S34	0.48	0.72	0.60	0.76	2.70	0.48	2.70	1.05	0.93
	S35	0.42	0.60	0.40	0.65	1.40	0.40	1.40	0.69	0.41
	S36	0.40	0.52	0.32	0.62	1.60	0.32	1.60	0.69	0.52
	S37	0.48	0.56	0.48	0.60	1.27	0.48	1.27	0.68	0.33
W	S38	1.12	1.52	1.12	1.10	1.60	1.10	1.60	1.29	0.25
	S39	1.28	0.60	1.28	1.02	1.10	1.28	0.60	1.06	0.28
	S40	0.64	0.20	0.64	0.16	1.76	0.16	1.76	0.68	0.65
	S41	0.48	0.20	0.48	0.18	1.80	0.18	1.80	0.63	0.67
SW	S42	0.68	1.60	0.68	1.40	1.55	0.68	1.60	1.18	0.46
	S43	0.56	2.60	0.56	1.90	1.90	0.56	2.60	1.61	0.74
	S44	0.20	1.36	0.18	1.76	1.64	0.20	0.80	0.56	0.26
	S45	0.20	1.20	0.16	1.60	1.50	0.50	1.60	1.10	0.48
	Min	0.20	0.09	0.16	0.10	0.30				
	Max	3.35	3.40	3.40	3.02	3.00				
	Mean	0.94	1.23	0.94	1.21	1.62				
	SD	0.83	0.99	0.84	0.80	0.67				

direction from the Mill in the first pre-monsoon season (B0). Distance variation in this side A was not seen.

In side B, all the soil samples have much lower values of calcium in comparison to Side A. In the first post monsoon season (A1), the values were from 10.3 – 21.6 meq/kg (Control 10.9 meq/kg), second pre monsoon (B1) 7.2 - 21.3 meq/kg (Control 14.3 meq/kg), second post monsoon (A2) 10.4– 20 meq/kg (Control 10.2 meq/kg), third pre-monsoon (B2) 10.3– 16.7 meq/kg (Control 13.5 meq/kg) and third post monsoon (A3) 9.7– 21.4 meq/kg (Control 12.4 meq/kg). Since most of the samples have got calcium content less than the values of the Control sample, the soil samples in this side B have either no influence or less influence from the effluent of the Mill. In the last three seasons, (second post monsoon, A2; third pre monsoon, B2; and third post monsoon, A3), the mean values are less than the first two seasons (first post monsoon, A1 and second pre monsoon, B1). The maximum mean value was obtained at S41 (17.5 meq/kg) in the west direction.

(ii) Magnesium

Magnesium is one of the common metals present in soil. This metal is normally found along with calcium in all soils. In the present study, the values of magnesium content (Tables 3.11 (a) and 3.11 (b) for Side A and Side B respectively) were less than those of calcium. The tables also show the maximum, the minimum, the mean and the standard deviation of the magnesium content for various seasons as well as for various sites along different directions. The maximum value was measured for the first pre-monsoon season at S18 (34.4 meq/kg) in the west direction and the minimum value at S19 (1.16 meq/kg) in the same season. No distinct variation of value was seen in a particular direction with distance from the Mill. The mean values in the B1 and B2 batches are more than that of the B0 batch. This pattern bears similarity to those of calcium. Some samples have low value than the 'Control' value, which was also observed with calcium.

In side B, the Mg values are from 0.4 – 13.2 meq/kg in A1, 0.4 – 16.8 meq/kg in B1, 0.3 – 12.7 meq/kg in A2, 0.2– 13.1 meq/kg in B2 and 0.2 – 11.0 meq/kg in A3 batch. It was observed that the 'Control' sample had more Mg than some of the values from the study area. No distinct distance variation of the values was observed. The maximum mean value observed in this side B was at S 42 (12.9 meq/kg) in the southwest direction and the minimum

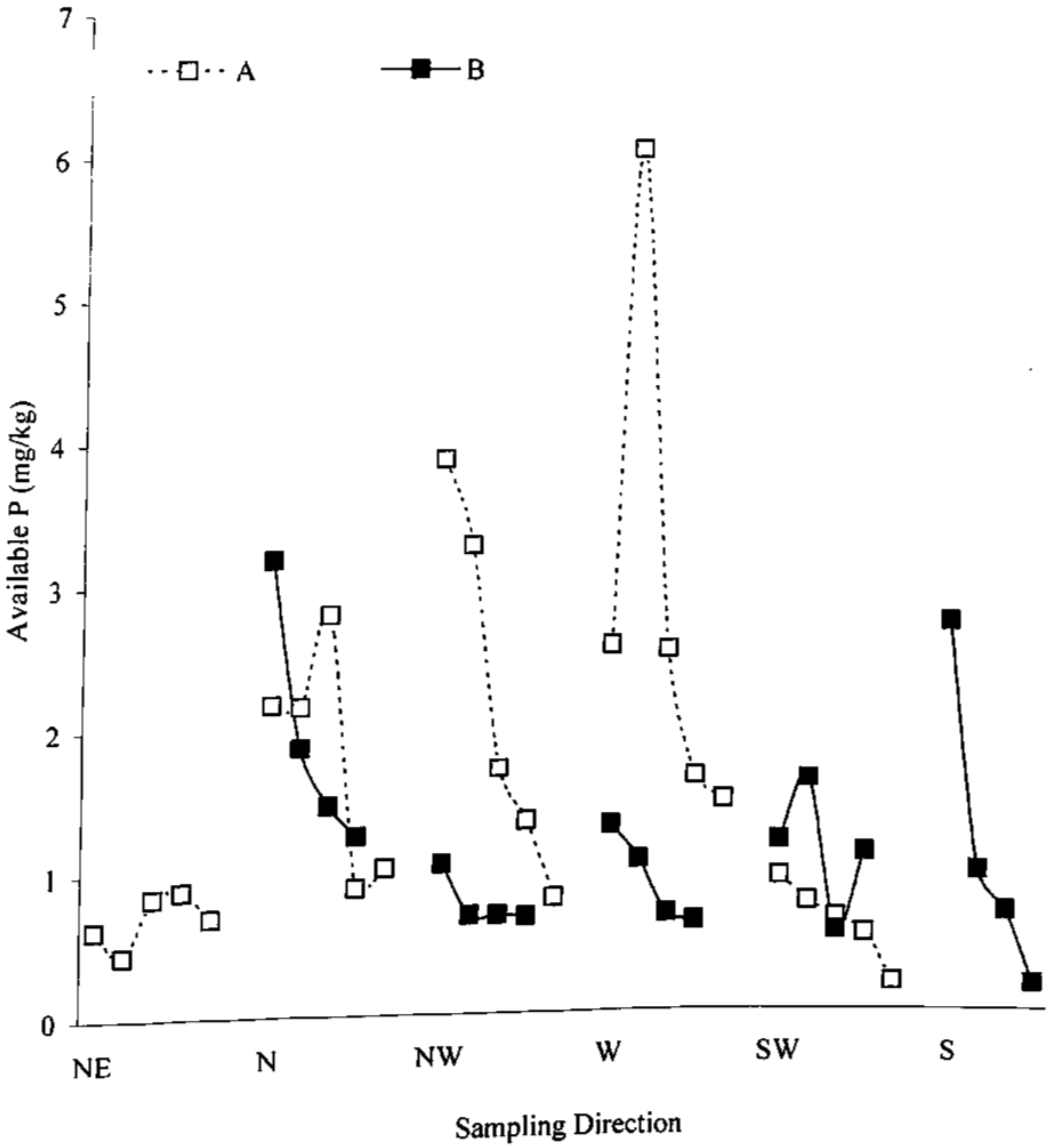


Fig. 3.11. Variation of mean values of available P with direction and distance for Side A and Side B.

Table 3.10(a). Calcium content (meq/kg) of the soil from the study area (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	16.8	14.3	13.5	13.5	16.8	14.9	1.7
NE	S1	22.8	30.6	28.6	22.8	30.6	27.3	4.1
	S2	17.0	26.3	26.2	17.0	26.3	23.2	5.3
	S3	18.4	25.4	24.3	18.4	25.4	22.7	3.8
	S4	23.0	21.7	20.1	20.1	23.0	21.6	1.5
	S5	18.0	29.5	30.1	18.0	30.1	25.9	6.8
N	S6	42.4	58.2	52.8	42.4	58.2	51.1	8.0
	S7	28.0	40.9	42.4	28.0	42.4	37.1	7.9
	S8	30.8	31.5	30.6	30.6	31.5	31.0	0.5
	S9	32.0	30.1	30.3	30.1	32.0	30.8	1.0
	S10	25.0	28.4	24.9	24.9	28.4	26.1	2.0
NW	S11	48.4	69.6	65.4	48.4	69.6	61.1	11.2
	S12	48.0	62.1	60.6	48.0	62.1	56.9	7.7
	S13	36.0	40.4	43.4	36.0	43.4	39.9	3.7
	S14	42.4	52.1	50.3	42.4	52.1	48.3	5.2
	S15	44.8	45.5	40.4	40.4	45.5	43.6	2.8
W	S16	72.4	73.9	69.2	69.2	73.9	71.8	2.4
	S17	82.0	86.1	76.5	76.5	86.1	81.5	4.8
	S18	51.0	59.3	54.5	51.0	59.3	54.9	4.2
	S19	26.8	31.8	28.9	26.8	31.8	29.2	2.5
	S20	67.5	60.4	53.2	53.2	67.5	60.4	7.2
SW	S21	26.0	25.2	22.2	22.2	26.0	24.5	2.0
	S22	22.0	24.9	19.8	19.8	24.9	22.2	2.6
	S23	24.0	32.3	30.4	24.0	32.3	28.9	4.3
	S24	22.4	30.8	23.6	22.4	30.8	25.6	4.5
	S25	39.5	31.3	28.5	28.5	39.5	33.1	5.7
	Min	17.0	21.7	19.8				
	Max	82.0	86.1	76.5				
	Mean	18.0	18.8	17.4				
	SD	17.6	18.0	16.7				

Table 3.10 (b). Calcium content (meq/kg) of the soil from the study area (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	10.9	14.3	10.2	13.5	12.4	10.2	14.3	12.6	1.7
S	S26	15.3	16.3	11.2	16.7	12.6	11.2	16.7	14.8	2.4
	S27	13.8	18.3	12.6	14.5	12.8	12.6	18.3	15.0	2.3
	S28	13.2	18.1	11.3	10.6	13.7	10.6	18.1	14.2	2.9
	S29	10.7	18.0	14.9	10.3	12.8	10.3	18.0	14.1	3.2
N	S30	21.6	14.0	11.0	10.5	9.7	9.7	21.6	14.7	4.9
	S31	13.8	12.7	11.5	12.0	21.4	11.5	21.4	15.5	4.1
	S32	12.6	17.1	12.0	12.2	10.2	10.2	17.1	13.6	2.6
	S33	10.3	10.0	20.0	14.2	10.2	10.0	20.0	14.1	4.3
NW	S34	16.5	11.6	10.4	11.4	11.6	10.4	16.5	13.0	2.4
	S35	16.6	8.8	11.8	10.5	11.2	8.8	16.6	12.6	2.9
	S36	11.8	21.3	15.4	15.2	16.3	11.8	21.3	16.9	3.4
	S37	10.8	14.5	16.4	13.8	13.6	10.8	16.4	14.2	2.0
W	S38	17.6	10.0	12.3	15.8	10.6	10.0	17.6	14.0	3.3
	S39	13.1	11.0	13.6	12.5	10.7	10.7	13.6	12.4	1.3
	S40	12.6	14.0	16.0	11.6	13.1	11.6	16.0	13.9	1.7
	S41	16.1	20.5	16.3	14.6	17.0	14.6	20.5	17.5	2.2
SW	S42	16.5	9.2	12.6	13.4	13.8	9.2	16.5	13.7	2.6
	S43	15.2	7.2	14.2	14.3	12.8	7.2	15.2	13.1	3.2
	S44	13.4	15.0	15.0	15.4	15.4	13.4	15.4	14.9	0.8
	S45	13.8	18.0	17.0	12.2	13.6	12.2	18.0	15.4	2.5
	Min	10.3	7.2	10.4	10.3	9.7				
	Max	21.6	21.3	20.0	16.7	21.4				
	Mean	14.3	14.3	13.8	13.1	13.2				
	SD	2.7	4.1	2.5	2.0	2.8				

was at S43 and S44 (0.4 meq/kg) in the same direction. The maximum mean value obtained was in the second pre-monsoon (B1) season (4.9 meq/kg) and the minimum (3.9 meq/kg) in the third post monsoon season (A3). High level of Mg usually promotes higher development of exchangeable sodium in irrigated soil (Yadav and Khera, 1993)

A comparison of the minimum, the mean and the maximum values of Ca and Mg for side B is shown in Fig. 3.12. It is clear that Ca-content in the soil always outweigh the corresponding Mg-content.

(iii) Sodium

The sodium contents of the soil in the study area are given in the Tables 3.12 (a) and 3.12 (b) for the two sides A and B respectively. The soil was also rich in sodium.

In Side A, the first pre-monsoon season (B0) had Na in the range 0.24– 2.83 meq/100g, the second pre-monsoon (B1) 0.30 – 3.64 meq /100 g and the third pre-monsoon (B2) 0.34– 2.85 meq/100 g. The control sample had 0.10, 0.11 and 0.12-meq/100 g of Na in B0, B1 and B2 batches respectively. The samples near to the Mill have more Na content in comparison to those away from it with a few exceptions. The maximum amount of Na was found at S16 (mean value 3.11 meq/100 g) in the west direction and the minimum at S5 (mean value 0.35 meq/100 g) in the northeast direction.

The soil in Side B was found to have more sodium than that of the Side B. The values are in the following ranges:

- A1 batch 1.20 – 6.36 meq/100 g
- B1 batch 2.07 – 3.16 meq/100 g
- A2 batch 1.15 – 3.18 meq/100 g
- B2 batch 2.25 – 5.84 meq/100 g
- A3 batch 1.16 – 3.44 meq/100 g.

The maximum value was obtained at S36 (mean value 4.14 meq/100 g) in the northwest direction and the minimum at S43 (mean value 1.78 meq/100 g) in the southwest direction. The seasonal variation was not distinct and the distance variation was not uniform. In all the cases, the 'Control' soil had lower values than the samples from the study area.

Table 3.11 (a). Magnesium contents (meq/kg) of the soil in the study area (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	5.02	5.37	5.18	5.02	5.37	5.19	0.18
NE	S1	21.80	26.00	26.30	21.80	26.30	24.70	2.52
	S2	13.40	16.60	15.80	13.40	16.60	15.27	1.67
	S3	4.40	5.90	6.10	4.40	6.10	5.47	0.93
	S4	6.80	7.00	6.30	6.30	7.00	6.70	0.36
	S5	4.00	6.20	6.10	4.00	6.20	5.43	1.24
N	S6	4.00	8.10	7.20	4.00	8.10	6.43	2.15
	S7	4.80	7.20	8.20	4.80	8.20	6.73	1.75
	S8	12.00	21.40	18.60	12.00	21.40	17.33	4.83
	S9	14.00	18.50	18.30	14.00	18.50	16.93	2.54
	S10	17.00	16.10	16.30	16.10	17.00	16.47	0.47
NW	S11	3.20	6.30	9.20	3.20	9.20	6.23	3.00
	S12	3.20	5.90	5.40	3.20	5.90	4.83	1.44
	S13	12.80	19.40	17.20	12.80	19.40	16.47	3.36
	S14	11.60	13.00	13.90	11.60	13.90	12.83	1.16
	S15	7.20	20.10	16.00	7.20	20.10	14.43	6.59
W	S16	4.00	11.30	10.10	4.00	11.30	8.47	3.91
	S17	4.00	10.60	10.30	4.00	10.60	8.30	3.73
	S18	34.40	30.10	28.40	28.40	34.40	30.97	3.09
	S19	1.60	9.30	10.30	1.60	10.30	7.07	4.76
	S20	9.00	16.70	15.80	9.00	16.70	13.83	4.21
SW	S21	15.20	16.30	15.40	15.20	16.30	15.63	0.59
	S22	21.60	20.80	18.70	18.70	21.60	20.37	1.50
	S23	8.40	11.50	10.50	8.40	11.50	10.13	1.58
	S24	14.80	14.20	13.70	13.70	14.80	14.23	0.55
	S25	10.80	13.20	10.80	10.80	13.20	11.60	1.39
	Min	1.60	5.90	5.40				
	Max	34.40	30.10	28.40				
	Mean	10.56	14.07	13.40				
	SD	7.61	6.60	6.00				

Table 3.11 (b). Magnesium contents (meq/kg) of the soil in the study area (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	5.5	5.4	5.3	5.2	5.0	5.0	5.5	5.3	0.2
S	S26	6.1	6.0	5.6	5.3	5.1	5.1	6.1	5.6	0.4
	S27	5.3	10.0	5.4	9.1	6.7	5.3	10.0	7.3	2.1
	S28	2.4	0.8	1.8	1.4	0.9	0.8	2.4	1.5	0.7
	S29	1.9	4.8	1.3	5.7	5.1	1.3	5.7	3.7	2.0
N	S30	5.6	4.0	5.1	6.3	5.8	4.0	6.3	5.4	0.9
	S31	4.3	0.4	4.1	1.6	0.8	0.4	4.3	2.2	1.8
	S32	4.1	12.8	3.5	8.5	7.3	3.5	12.8	7.2	3.8
	S33	0.9	1.2	0.8	2.6	1.9	0.8	2.6	1.5	0.7
NW	S34	11.2	12.9	10.3	13.1	10.2	10.2	13.1	11.5	1.4
	S35	7.2	6.8	6.6	4.3	3.5	3.5	7.2	5.7	1.7
	S36	1.5	0.9	1.0	1.1	0.9	0.9	1.5	1.1	0.3
	S37	0.8	0.4	0.8	0.8	0.8	0.4	0.8	0.7	0.2
W	S38	13.0	13.2	12.7	11.5	10.2	10.2	13.2	12.1	1.3
	S39	2.0	2.0	1.5	3.6	2.3	1.5	3.6	2.3	0.8
	S40	2.4	0.4	2.3	0.5	0.9	0.4	2.4	1.3	1.0
	S41	1.9	2.8	2.1	2.1	1.6	1.6	2.8	2.1	0.4
SW	S42	13.2	16.8	12.5	10.9	11.0	10.9	16.8	12.9	2.4
	S43	0.7	0.4	0.7	0.2	0.3	0.2	0.7	0.4	0.2
	S44	0.6	0.4	0.5	0.3	0.2	0.2	0.6	0.4	0.2
	S45	0.4	0.8	0.3	0.7	0.4	0.3	0.8	0.5	0.2
	Min	0.4	0.4	0.3	0.2	0.2				
	Max	13.2	16.8	12.7	13.1	11.0				
	Mean	4.3	4.9	3.9	4.5	3.8				
	SD	4.1	5.4	3.9	4.1	3.6				

(iv) Potassium

Potassium is one of the alkaline metals present in soil, comparatively with lesser amount than sodium. K contents of the soil samples in the present work are given in Table 3.13 (a) and 3.13 (b) respectively for the Sides, A and B.

The value were in the ranges of: first pre- monsoon (B0) 0.106 – 0.386 meq/100 g, second pre-monsoon (B1) 0.113 – 0.450 meq/100 g and third pre-monsoon (B2) 0.085 – 0.420 meq/100 g. In these three seasons, the "Control" soil sample had the values of 0.063 meq/100 g, 0.059 meq/100 g and 0.053 meq/100 g in for the seasons B0, B1 and B2 respectively. There is no distinct distance variation of the K-content. The maximum value was obtained at S14 (mean value 0.419 meq/100 g) in the northwest direction and the minimum value was at S22 (mean value 0.101 meq/100 g) in the southwest direction. The samples in the northeast direction have less K compared to the other directions.

In side B, the soil samples had more K content than those on side A. This trend is identical to that of Na. The K-values for the batch B0 were less than those of the B1 batch, but this decreasing trend was not seen in the batch, B2. The soil samples further away from the mill had less K-content. The maximum value was obtained at S36 in the northwest direction (mean value 0.21 meq/100 g) and the minimum at S31 (mean value 0.072 meq/100 g) in the North direction. It is observed that the values decreased from A1 batch to A3 batch, the exception being at B2 batch. The values show maximum variation in A1 batch (SD 0.226) and minimum at A2 batch (SD 0.102).

Since sodium and potassium occur simultaneously, a comparison of their mean values in soil from Side A and Side B is given in Fig. 3.13 and Fig. 3.14 respectively. These also show that the sodium content outweigh the potassium content in all the cases. Potassium is an essential element, but excess sodium may lead to development of toxicity in soil for plants and it is to be noted that the excess sodium in the soil near the Mill might have been contributed by the effluent release.

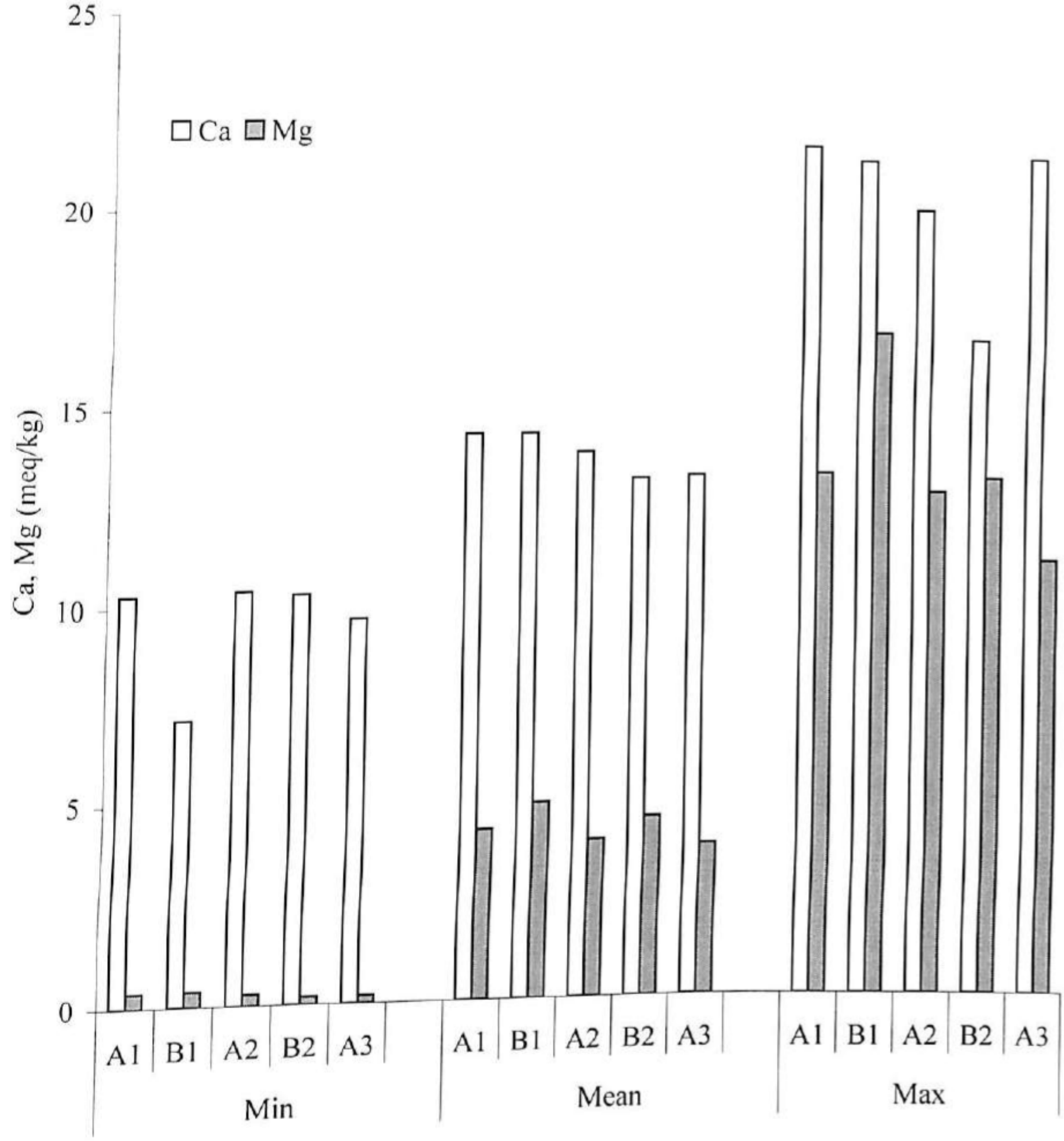


Fig. 3.12. Comparison of Ca- and Mg-contents of the Side B soil

Table 3.12 (a). Sodium content (meq/100 g) of the soil samples of the study area (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.10	0.11	0.12	0.10	0.12	0.11	0.01
NE	S1	1.06	1.13	1.06	1.06	1.13	1.08	0.04
	S2	0.74	0.85	0.53	0.53	0.85	0.71	0.16
	S3	0.58	0.71	0.62	0.58	0.71	0.64	0.07
	S4	0.71	0.60	0.49	0.49	0.71	0.60	0.11
	S5	0.24	0.30	0.52	0.24	0.52	0.35	0.15
N	S6	2.76	2.76	1.98	1.98	2.76	2.50	0.45
	S7	1.66	2.42	1.86	1.66	2.42	1.98	0.39
	S8	1.84	1.67	1.12	1.12	1.84	1.54	0.38
	S9	1.36	1.88	1.27	1.27	1.88	1.50	0.33
	S10	1.56	2.58	1.93	1.56	2.58	2.02	0.52
NW	S11	1.51	1.71	1.11	1.11	1.71	1.44	0.31
	S12	1.28	1.65	1.03	1.03	1.65	1.32	0.31
	S13	2.11	2.40	1.84	1.84	2.40	2.12	0.28
	S14	1.69	1.62	1.04	1.04	1.69	1.45	0.36
	S15	1.68	0.78	1.02	0.78	1.68	1.16	0.47
W	S16	2.83	3.64	2.85	2.83	3.64	3.11	0.46
	S17	1.43	1.03	0.86	0.86	1.43	1.11	0.29
	S18	1.14	1.11	0.73	0.73	1.14	0.99	0.23
	S19	1.26	1.09	0.62	0.62	1.26	0.99	0.33
	S20	1.46	0.96	1.01	0.96	1.46	1.14	0.28
SW	S21	1.27	1.19	0.84	0.84	1.27	1.10	0.23
	S22	1.42	1.22	1.08	1.08	1.42	1.24	0.17
	S23	1.65	0.80	0.34	0.34	1.65	0.93	0.66
	S24	1.33	0.83	0.65	0.65	1.33	0.94	0.35
	S25	1.39	0.84	0.74	0.74	1.39	0.99	0.35
	Min	0.24	0.30	0.34				
	Max	2.83	3.64	2.85				
	Mean	1.44	1.43	1.09				
	SD	0.58	0.80	0.59				

Table 3.12 (b). Sodium content (meq/100 g) of the soil samples of the study area (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.13	0.11	0.13	0.12	0.12	0.11	0.13	0.12	0.01
S	S26	3.65	2.16	2.51	3.64	1.16	1.16	3.65	2.62	1.06
	S27	2.50	2.20	2.80	2.85	1.44	1.44	2.85	2.36	0.58
	S28	2.50	2.20	2.62	2.70	2.93	2.20	2.93	2.59	0.27
	S29	2.76	2.80	2.72	2.83	2.52	2.52	2.83	2.73	0.12
N	S30	4.21	2.32	2.13	2.26	2.59	2.13	4.21	2.70	0.86
	S31	4.20	2.07	2.41	2.48	2.11	2.07	4.20	2.65	0.88
	S32	2.65	2.22	2.26	2.86	2.67	2.22	2.86	2.53	0.28
	S33	2.40	3.16	3.18	3.06	2.83	2.40	3.18	2.93	0.33
NW	S34	5.02	2.88	2.11	2.53	2.24	2.11	5.02	2.96	1.19
	S35	3.90	2.76	2.65	2.25	2.10	2.10	3.90	2.73	0.71
	S36	6.36	3.10	3.17	4.63	3.44	3.10	6.36	4.14	1.39
	S37	3.02	3.10	3.16	5.84	2.37	2.37	5.84	3.50	1.35
W	S38	3.20	2.13	2.16	3.26	2.55	2.13	3.26	2.66	0.55
	S39	3.40	2.14	2.18	3.18	2.45	2.14	3.40	2.67	0.58
	S40	2.40	2.50	2.60	3.03	2.37	2.37	3.03	2.58	0.27
	S41	2.20	2.18	2.30	3.06	2.62	2.18	3.06	2.47	0.37
SW	S42	3.10	2.20	1.15	2.80	2.45	1.15	3.10	2.34	0.75
	S43	1.60	2.18	1.30	2.42	1.39	1.30	2.42	1.78	0.50
	S44	1.20	2.35	1.54	3.17	2.61	1.20	3.17	2.17	0.80
	S45	1.46	2.80	2.00	2.83	2.70	1.46	2.83	2.36	0.61
	Max	1.20	2.07	1.15	2.25	1.16				
	Min	6.36	3.16	3.18	5.84	3.44				
	Mean	3.09	2.47	2.35	3.08	2.38				
	SD	1.24	0.38	0.57	0.84	0.54				

Table 3.13 (a). Potassium contents (meq/100 g) of the soil of the study area (side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.063	0.059	0.053	0.053	0.063	0.058	0.005
NE	S1	0.185	0.206	0.186	0.185	0.206	0.192	0.012
	S2	0.251	0.298	0.290	0.251	0.298	0.280	0.025
	S3	0.126	0.263	0.243	0.126	0.263	0.211	0.074
	S4	0.216	0.311	0.341	0.216	0.341	0.289	0.065
	S5	0.160	0.213	0.231	0.160	0.231	0.201	0.037
N	S6	0.320	0.301	0.362	0.301	0.362	0.328	0.031
	S7	0.348	0.390	0.285	0.285	0.390	0.341	0.053
	S8	0.285	0.317	0.304	0.285	0.317	0.302	0.016
	S9	0.272	0.267	0.263	0.263	0.272	0.267	0.005
	S10	0.126	0.298	0.150	0.126	0.298	0.191	0.093
NW	S11	0.110	0.312	0.174	0.110	0.312	0.199	0.103
	S12	0.124	0.373	0.200	0.124	0.373	0.232	0.128
	S13	0.349	0.328	0.130	0.130	0.349	0.269	0.121
	S14	0.386	0.450	0.420	0.386	0.450	0.419	0.032
	S15	0.361	0.301	0.263	0.263	0.361	0.308	0.049
W	S16	0.163	0.142	0.080	0.080	0.163	0.128	0.043
	S17	0.348	0.319	0.310	0.310	0.348	0.326	0.020
	S18	0.283	0.315	0.139	0.139	0.315	0.246	0.094
	S19	0.136	0.152	0.160	0.136	0.160	0.149	0.012
	S20	0.238	0.298	0.143	0.143	0.298	0.226	0.078
SW	S21	0.294	0.300	0.241	0.241	0.300	0.278	0.032
	S22	0.106	0.113	0.085	0.085	0.113	0.101	0.015
	S23	0.214	0.298	0.164	0.164	0.298	0.225	0.068
	S24	0.168	0.263	0.115	0.115	0.263	0.182	0.075
	S25	0.284	0.319	0.120	0.120	0.319	0.241	0.106
	Min	0.106	0.113	0.080				
	Max	0.386	0.450	0.420				
	Mean	0.234	0.286	0.216				
	SD	0.090	0.075	0.091				

Table 3.13 (b). Potassium contents (meq/100 g) of the soil of the study area (side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.071	0.059	0.061	0.053	0.058	0.053	0.071	0.060	0.007
S	S26	0.690	0.130	0.158	0.614	0.140	0.130	0.690	0.346	0.280
	S27	0.560	0.250	0.146	0.073	0.100	0.073	0.560	0.226	0.199
	S28	0.360	0.260	0.391	0.290	0.160	0.160	0.391	0.292	0.091
	S29	0.100	0.520	0.437	0.470	0.202	0.100	0.520	0.346	0.184
N	S30	0.350	0.050	0.080	0.084	0.150	0.050	0.350	0.143	0.121
	S31	0.320	0.078	0.072	0.110	0.120	0.072	0.320	0.140	0.103
	S32	0.140	0.285	0.196	0.243	0.150	0.140	0.285	0.203	0.062
	S33	0.100	0.354	0.238	0.365	0.260	0.100	0.365	0.263	0.107
NW	S34	0.820	0.105	0.140	0.116	0.170	0.105	0.820	0.270	0.308
	S35	0.570	0.152	0.100	0.216	0.120	0.100	0.570	0.232	0.194
	S36	0.240	0.560	0.241	0.543	0.210	0.210	0.560	0.359	0.176
	S37	0.140	0.680	0.306	0.714	0.280	0.140	0.714	0.424	0.257
W	S38	0.380	0.106	0.116	0.102	0.140	0.102	0.380	0.169	0.119
	S39	0.530	0.143	0.105	0.181	0.110	0.105	0.530	0.214	0.179
	S40	0.220	0.690	0.164	0.300	0.120	0.120	0.690	0.299	0.229
	S41	0.100	0.700	0.221	0.429	0.110	0.100	0.700	0.312	0.254
SW	S42	0.620	0.104	0.086	0.120	0.120	0.086	0.620	0.210	0.230
	S43	0.300	0.110	0.130	0.126	0.100	0.100	0.300	0.153	0.083
	S44	0.100	0.200	0.116	0.230	0.130	0.100	0.230	0.155	0.057
	S45	0.130	0.220	0.135	0.510	0.170	0.130	0.510	0.233	0.159
	Min	0.100	0.050	0.072	0.073	0.100				
	Max	0.820	0.700	0.437	0.714	0.280				
	Mean	0.339	0.285	0.179	0.292	0.153				
	SD	0.224	0.221	0.101	0.195	0.050				

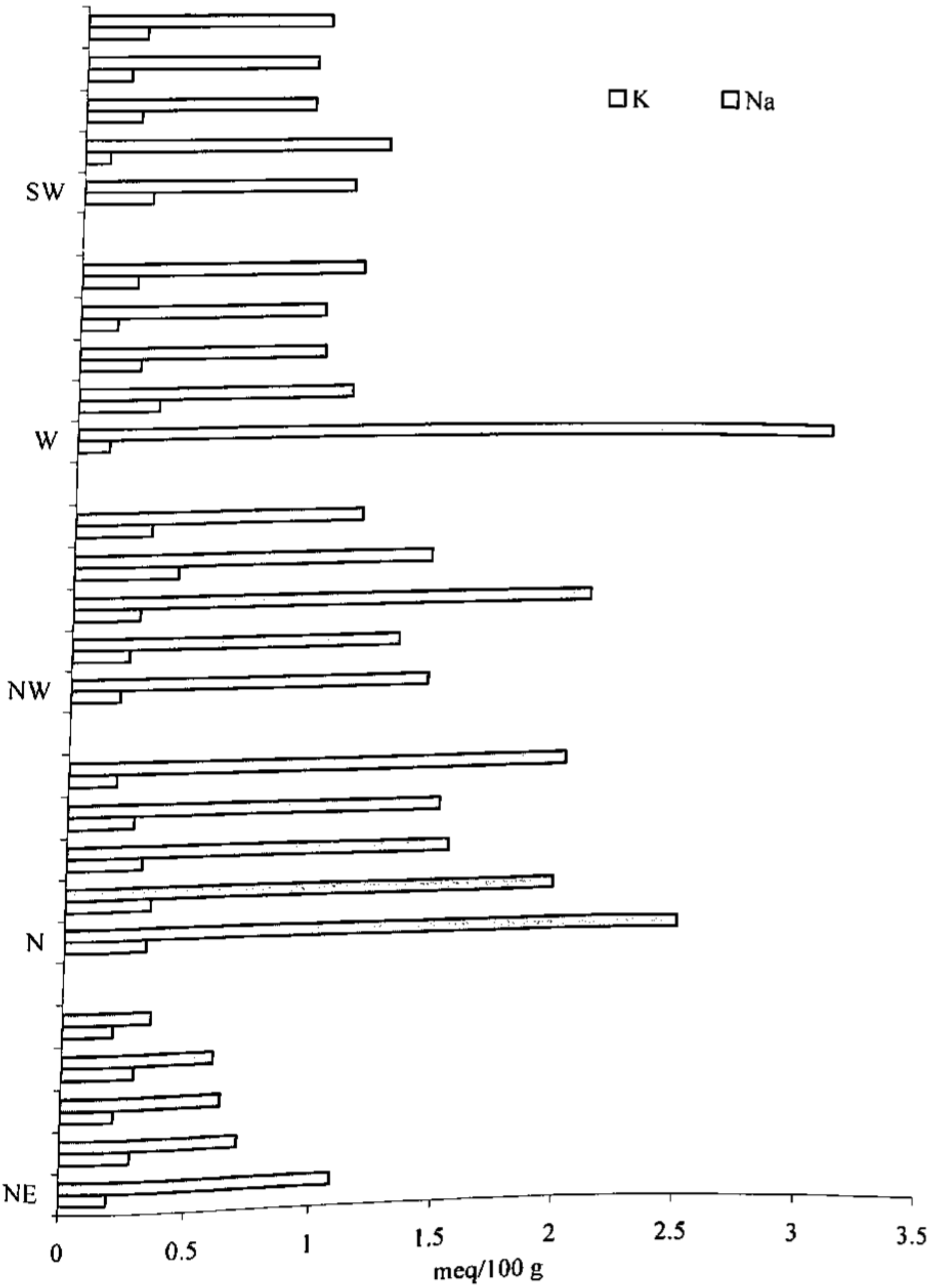


Fig. 3.13. Variation of mean contents of sodium and potassium with distance from the Mill along the different directions for Side A

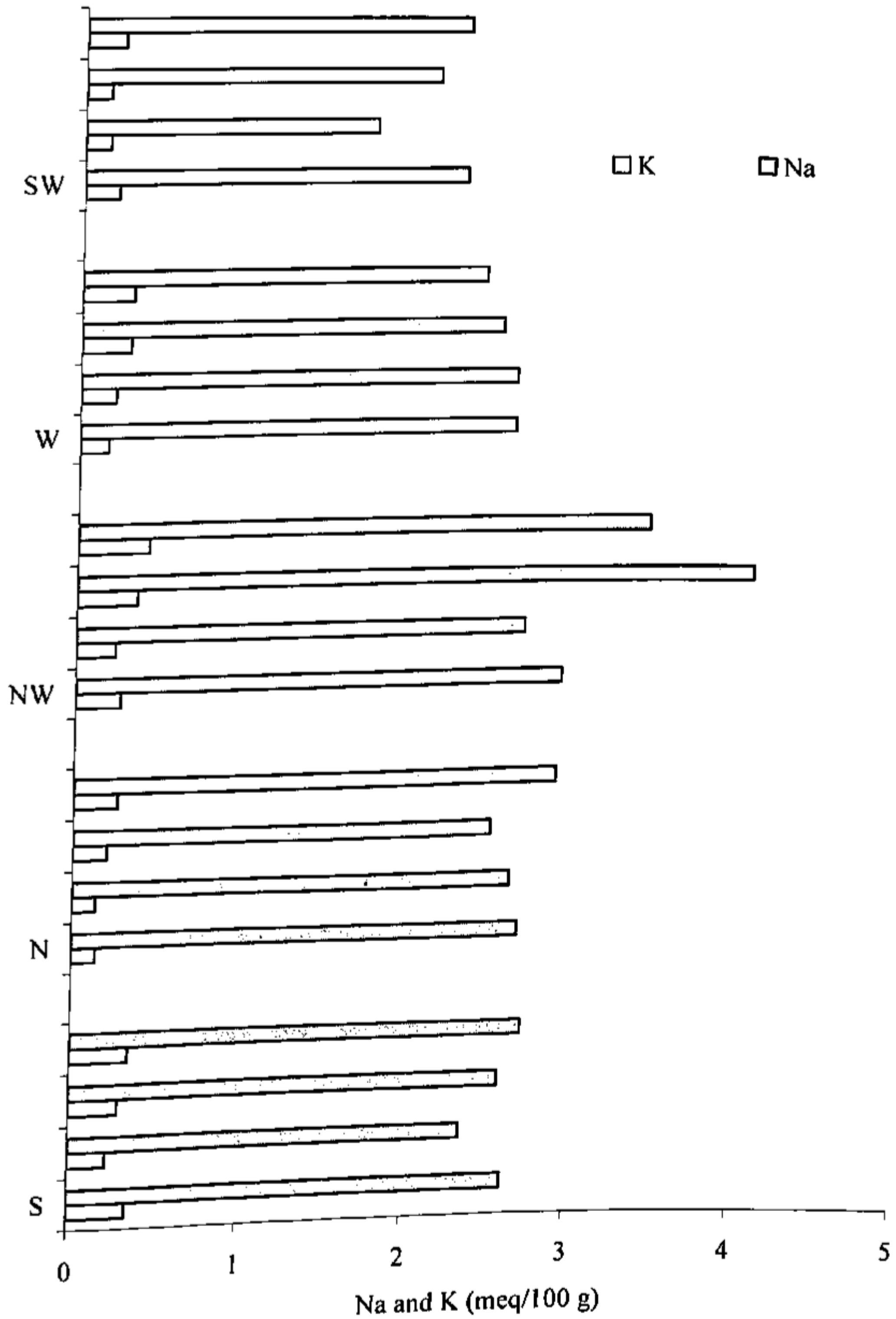


Fig. 3.14. Variation of mean contents of sodium and potassium with distance from the Mill along the different directions for Side B

3.1.12. Trace Metals

Inorganic pollutants like toxic heavy metals, namely Al, As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn are ubiquitous and play an extremely important role in the environment A wide range of contaminants from industrial activities, sewage sludge disposal, metal processing and energy production may pollute soils. Prasanthi et al. (2001) observed high content of trace metals near an industry.

Industrial effluents and municipal wastewaters usually contain high amount of heavy metals such as As, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn (Larsen et al., 1975; Arora et al., 1985; Irshad et al., 1997.). Their continuous use on agricultural land may result in metal accumulation in surface soil (Gupta et al., 1986). Some heavy metals are essential trace amounts, namely Zn, Cu, Fe, Mn, Mo and Co for plants and in addition Cr, Ni, Sn for animals; whereas As, Cd, Hg and Pb have not been known to have any function for either plants or animals (Greenland and Hayes, 1981). Higher concentration of these metals in the ecosystem may lead to an excessive accumulation of metals, becoming toxic to plants and possible danger to human health problem. A number of cases of health problems related to environment Cd and Hg poisoning and elevated levels of Pb in the blood of infants have been reported (Singh and Steinnes, 1994).

Some of the metals are phytotoxic and some are toxic to both plants and animals through their entry into food chain (Khalid and Tinsly, 1980; Sameni *et al.*, 1987; Roads and Manning 1989). Anthropogenic pollution by heavy metals and their phytotoxicities has been reported by many other investigators (Chen, 1991, Sheppard, 1992)

For a few elements, determined in this study, a comparison of the contents for "Control" sample with average for world soils (Bowen, 1966; Angelone and Bini, 1992) is given below:

Metals	Average content World soil (mg/kg)
Cu	20
Mn	850
Ni	40
Pb	10
Zn	50

No such average ranges have been reported for soils of India in the available literature.

The results obtained in the present work are discussed below:

(a) Aluminium (Al)

The Al contents of the soil are given in Table 3.14(a) and (b). The study reveals that the soil in the study area is very rich in Al. There is distinct variation of the values for all the samples from B0 to B2 batch in side A. The values are in the following ranges:

- 10.0 – 89.0 g/kg in B0 batch
- 10.0 – 77.0 g/kg in B1 batch
- 10.0 – 68.0 g/kg in B2 batch.

A decreasing trend away from the Mill indicates that the effluent discharges from the Mill have a direct impact on Al-content of the surrounding soil. The variation along the distance from the Mill is not uniform at any direction. In side B, the amount of Al present in soil samples has comparatively low value than side A which is not surprising since the Side A is closest to the Mill receiving the discharges.

In side B, the values are from 9.0 – 41.0 g/kg in A1 batch, 8.0 – 56.0 g/kg in B1 batch, 7.0 – 29.0 g/kg in A2 batch, 7.0 – 45.0 g/kg in B2 batch and 6.0 – 33.0 g/kg in A3 batch. The entire site has very high content of Al. The values of Al in most of the soil samples in this side decreased from B1 to B2, similarly as in side A. The distance variation from the Mill was not uniform. The variations of the values from season to season of all the samples are also not uniform. Excess Al^{3+} concentration in soil is caused by low soil pH (<5). The concentration of Al in soil thus depends on soil pH as well as the concentration of organic and inorganic compounds that can form complexes with Al (Dobermann and Fairhurst, 2000). The concentration of soluble Al in soil water is very small (Manahan, 1975) but that fraction is easily mobile and exchangeable and plays an important role in soil fertility.

Table 3.14 (a) Al-contents of the soil in Side A (g/kg)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.58	0.55	0.53	0.53	0.58	0.55	0.026
NE	S1	13	10	10	10	13	11	2
	S2	12	10	9	9	12	10	2
	S3	13	13	10	10	13	12	2
	S4	14	10	9	9	14	11	3
	S5	10	10	11	10	11	10	1
N	S6	79	70	56	56	79	68	12
	S7	72	71	53	53	72	65	11
	S8	57	55	42	42	57	51	8
	S9	54	51	23	23	54	43	17
	S10	26	21	19	19	26	22	4
NW	S11	63	61	56	56	63	60	4
	S12	61	60	48	48	61	56	7
	S13	53	49	34	34	53	45	10
	S14	48	45	35	35	48	43	7
	S15	38	37	30	30	38	35	4
W	S16	89	77	68	68	89	78	11
	S17	46	43	41	41	46	43	3
	S18	52	50	40	40	52	47	6
	S19	43	37	30	30	43	37	7
	S20	43	36	29	29	43	36	7
SW	S21	46	40	34	34	46	40	6
	S22	15	15	10	10	15	13	3
	S23	16	13	10	10	16	13	3
	S24	16	15	10	10	16	14	3
	S25	16	13	10	10	16	13	3
	Min	10	10	9				
	Max	89	77	68				
	Mean	40	36	29				
	SD	23	22	18				

Table 3.14 (b). Al-content of the soil in Side B (g/kg)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.58	0.55	0.54	0.55	0.53	0.53	0.58	0.55	0.019
S	S26	28	30	27	23	7	7	30	23	9
	S27	26	35	29	25	22	22	35	27	5
	S28	19	21	22	17	10	10	22	18	5
	S29	13	15	12	10	7	7	15	11	3
N	S30	30	30	24	20	10	10	30	23	8
	S31	21	18	14	13	10	10	21	15	4
	S32	10	8	8	7	6	6	10	8	1
	S33	9	8	7	8	8	7	9	8	1
NW	S34	24	8	12	13	8	8	24	13	7
	S35	16	20	15	13	8	8	20	14	4
	S36	15	18	15	10	7	7	18	13	4
	S37	10	12	10	10	10	10	12	10	1
W	S38	16	17	18	16	13	13	18	16	2
	S39	22	20	15	12	12	12	22	16	5
	S40	15	20	14	12	19	12	20	16	3
	S41	41	56	21	45	33	21	56	39	13
SW	S42	35	30	28	18	17	17	35	26	8
	S43	12	12	12	11	8	8	12	11	2
	S44	12	10	10	10	9	9	12	10	1
	S45	12	10	8	8	6	6	12	9	2
	Min	9	8	7	7	6				
	Max	41	56	29	45	33				
	Mean	19	20	16	15	11				
	SD	9	12	7	9	7				

(b) Arsenic (As)

Table 3.15 (a) and Table 3.15 (b) are representing the values of arsenic in soil in Side A and Side B respectively. The values decreased from season B0 to B2. In most of the cases, as the distance increased from the Mill, the values showed a decrease. The "Control" sample was free from As. The maximum value was obtained at S11 (mean value 16.44 μg/kg) in NW direction. In side B, the distant samples in N and S direction were free from As in all the seasons. In the first two seasons (A1 and B1), the values were found more in comparison to other seasons. Most of the samples in NW, SW and W directions had considerable values. The distance variation was very much distinct. The maximum mean value (4.99(μg/kg) was obtained at B1 season

(c) Cadmium (Cd)

It has been estimated that anthropogenic emissions of Cd are in the range of 30,000 t per year (Sanita di Toppi and Gabberielli, 1999). In Table 3.16 (a) and 3.16 (b), the Cd contents for all the samples for each of the batches are given for side A and side B respectively. The permissible limit of Cd in the surface soil is 3 mg/kg (Bansal, 1998). However, Cd is a very mobile element in the environment (Cieæko et al., 2004).

The soil samples in the directions, N (range 1-3 mg/kg), NW (range 1.3 – 3.6 mg/kg) and W (range 1.6 – 3.2 mg/kg) have more Cd content in comparison to NE (range 0.9 – 3.2 mg/kg) and SW (range 1.4 – 2.7 mg/kg) directions. The maximum value obtained was at S11 (3.6 mg/kg), which was very near to the effluent discharge point from the Mill, in B1 batch. The values in B1 batch were more in comparison to other two seasons (B0 and B2). The standard deviation values show that there is large consistency of values (0.7) among the site for all the batches.

The dyes used in printing and dyeing of textile materials contain Cd. Again fly ash dumping may also contribute to the increased value of Cd around the Mill, since fly ash contains 5 – 10 mg/kg of Cd (Gillham and Simpson, 1973). Interestingly, the soil samples have more Cd in

Side B in comparison to those of Side A. The reason is not clear, however, it is likely that due to natural or other reasons, the Cd-wastes are accumulating in the Side B.

The sample S38 in the west direction had the maximum mean value (18.5 mg/kg) and S45 in SW had the least mean value (3.3 mg/kg). In most of the cases, the values away from the Mill exhibited a decreasing trend. Another observation was that the Cd-content decreased from A1 season to A3 season. In all the cases the "Control" has low Cd content.

(d) Chromium (Cr)

The values of Cr in side A and B are given in Table 3.17 (a) and 3.17 (b). The Cr present in the soil samples indicates contribution of the effluent of the Mill release to the surrounding area. In this study, Cr does not show any directional trend. The ranges of Cr in the present study in side A are as follows:

- 24.7 - 298.8 mg/kg in B0 batch
- 48 – 288 mg/kg in B1 batch
- 41.5 – 257 mg/kg in B2 batch

The maximum value was obtained at S15 (298.8 mg/kg) in NW direction and the minimum at S5 (24.7 mg/kg) in NE direction. The maximum permissible limit of Cr in soil is 100 mg/kg (Sastry et al., 2001). Except S1 (NE direction), S22 and S24 (SW direction), almost all the samples in side A have more Cr than the maximum permissible limit. No distinct seasonal variation or distance variation was observed in this side. Chromium can strongly attach to soil and only a small amount can dissolve in water and move deeper in the soil to underground water.

Table 3.15 (a). As content of the soil in Side A (μg/kg)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	BDL	BDL	BDL	BDL	BDL	BDL	BDL
NE	S1	10.05	6.34	2.38	2.38	10.05	6.26	3.84
	S2	9.01	4.30	1.20	1.20	9.01	4.84	3.93
	S3	2.44	0.64	0.03	0.03	2.44	1.04	1.26
	S4	1.65	0.74	BDL	0.74	1.65	1.20	0.64
	S5	0.95	0.35	0.30	0.30	0.95	0.53	0.36
N	S6	19.27	14.85	5.07	5.07	19.27	13.06	7.27
	S7	13.70	3.26	5.81	3.26	13.70	7.59	5.44
	S8	6.52	6.04	2.78	2.78	6.52	5.11	2.03
	S9	1.28	2.11	1.50	1.28	2.11	1.63	0.43
	S10	1.95	1.05	0.46	0.46	1.95	1.15	0.75
NW	S11	27.01	13.36	8.95	8.95	27.01	16.44	9.42
	S12	23.80	20.50	4.70	4.70	23.80	16.33	10.21
	S13	14.84	9.11	4.62	4.62	14.84	9.52	5.12
	S14	6.05	2.74	BDL	2.74	6.05	4.40	2.34
	S15	0.86	0.22	0.13	0.13	0.86	0.40	0.40
W	S16	10.03	9.46	9.50	9.46	10.03	9.66	0.32
	S17	3.30	2.74	1.55	1.55	3.30	2.53	0.89
	S18	5.17	6.31	5.50	5.17	6.31	5.66	0.59
	S19	1.62	2.14	1.96	1.62	2.14	1.91	0.26
	S20	0.56	0.92	0.85	0.56	0.92	0.78	0.19
SW	S21	9.16	10.20	8.54	8.54	10.20	9.30	0.84
	S22	8.87	6.72	4.28	4.28	8.87	6.62	2.30
	S23	2.03	1.11	1.07	1.07	2.03	1.40	0.54
	S24	4.23	1.06	1.10	1.06	4.23	2.13	1.82
	S25	1.14	0.95	0.66	0.66	1.14	0.92	0.24
	Min	0.56	0.22	BDL				
	Max	27.01	20.50	9.50				
	Mean	7.42	5.09	3.17				
	SD	7.37	5.28	2.94				

Table 3.15 (b). As-content of the soil in Side B (μg/mg)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
S	S26	0.004	0.002	0.002	0.001	0.001	0.001	0.004	0.002	0.001
	S27	0.010	0.001	0.001	BDL	BDL	0.001	0.010	0.004	0.005
	S28	0.000	BDL	0.000	BDL	BDL	0.000	0.000	BDL	BDL
	S29	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
N	S30	14.521	11.080	8.306	1.375	BDL	1.375	14.521	8.821	5.577
	S31	4.360	2.015	1.168	0.640	0.002	0.002	4.360	1.637	1.692
	S32	1.073	0.980	0.630	BDL	BDL	0.630	1.073	0.894	0.234
	S33	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
NW	S34	15.040	21.780	9.640	0.008	0.010	0.008	21.780	9.296	9.506
	S35	7.035	19.760	3.260	BDL	0.008	0.008	19.760	7.516	8.653
	S36	3.214	0.453	0.005	0.001	BDL	0.001	3.214	0.918	1.545
	S37	1.250	0.950	1.070	0.850	0.023	0.023	1.250	0.829	0.474
W	S38	6.042	2.850	1.530	0.615	0.008	0.008	6.042	2.209	2.395
	S39	4.260	1.580	0.973	0.540	0.084	0.084	4.260	1.487	1.645
	S40	0.130	0.078	0.005	0.004	BDL	0.004	0.130	0.054	0.061
	S41	0.080	0.006	0.006	0.005	0.003	0.003	0.080	0.020	0.034
SW	S42	10.530	11.280	11.320	9.750	0.041	0.041	11.320	8.584	4.819
	S43	9.420	7.920	3.629	1.852	0.970	0.970	9.420	4.758	3.735
	S44	3.550	2.060	0.663	0.037	0.019	0.019	3.550	1.266	1.523
	S45	4.020	2.054	1.680	0.805	0.056	0.056	4.020	1.723	1.501
	Min	BDL	BDL	BDL	BDL	BDL				
	Max	15.040	21.780	11.320	9.750	0.970				
	Mean	4.697	4.991	2.438	1.177	0.102				
	SD	4.879	6.979	3.567	2.533	0.274				

Table 3.16 (a). Cadmium (Cd) contents of the soil in Side A (mg/kg)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.6	0.6	0.6	0.6	0.6	0.6	0.0
NE	S1	1.2	1.6	1.9	1.2	1.9	1.6	0.4
	S2	2.7	2.8	3.2	2.7	3.2	2.9	0.2
	S3	1.6	1.1	1.2	1.1	1.6	1.3	0.3
	S4	0.9	1.5	1.2	0.9	1.5	1.2	0.3
	S5	1.0	1.2	2.8	1.0	2.8	1.7	1.0
N	S6	2.6	3.0	2.8	2.6	3.0	2.8	0.2
	S7	1.3	1.1	1.0	1.0	1.3	1.1	0.2
	S8	1.0	1.1	1.6	1.0	1.6	1.2	0.3
	S9	1.5	2.0	1.8	1.5	2.0	1.8	0.3
	S10	1.8	2.0	1.9	1.8	2.0	1.9	0.1
NW	S11	3.4	3.6	3.5	3.4	3.6	3.5	0.1
	S12	1.5	2.0	3.3	1.5	3.3	2.3	0.9
	S13	1.7	2.0	1.7	1.7	2.0	1.8	0.2
	S14	1.7	1.8	1.7	1.7	1.8	1.7	0.1
	S15	1.9	1.8	1.3	1.3	1.9	1.7	0.3
W	S16	3.1	3.2	2.9	2.9	3.2	3.1	0.1
	S17	1.6	2.6	2.2	1.6	2.6	2.1	0.5
	S18	2.3	3.0	2.5	2.3	3.0	2.6	0.4
	S19	2.9	2.5	2.6	2.5	2.9	2.7	0.2
	S20	2.1	2.8	2.7	2.1	2.8	2.5	0.4
SW	S21	2.7	2.5	2.0	2.0	2.7	2.4	0.4
	S22	1.6	2.3	2.2	1.6	2.3	2.0	0.4
	S23	1.7	2.5	2.3	1.7	2.5	2.2	0.4
	S24	1.8	2.0	1.5	1.5	2.0	1.8	0.3
	S25	1.4	2.0	1.8	1.4	2.0	1.7	0.3
	Min	0.9	1.1	1.0				
	Max	3.4	3.6	3.5				
	Mean	1.9	2.2	2.1				
	SD	0.7	0.7	0.7				

Table 3.16 (b). Cadmium (Cd) content of the soil in Side B (mg/kg)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0
S	S26	12.4	11.3	6.6	6.2	9.8	6.2	12.4	9.3	2.8
	S27	11.4	9.6	8.2	8.0	5.1	5.1	11.4	8.5	2.3
	S28	4.6	2.1	4.1	4.0	4.2	2.1	4.6	3.8	1.0
	S29	5.2	6.8	5.2	4.7	3.2	3.2	6.8	5.0	1.3
N	S30	20.5	10.1	11.4	8.1	7.1	7.1	20.5	11.4	5.3
	S31	10.4	11.0	10.0	6.9	5.1	5.1	11.0	8.7	2.6
	S32	9.3	9.0	11.0	7.5	5.6	5.6	11.0	8.5	2.1
	S33	7.0	7.2	9.2	6.2	4.7	4.7	9.2	6.9	1.6
NW	S34	21.7	18.0	13.6	11.8	6.8	6.8	21.7	14.4	5.7
	S35	20.7	18.0	19.0	13.2	12.5	12.5	20.7	16.7	3.6
	S36	19.7	16.3	16.8	7.2	6.0	6.0	19.7	13.2	6.2
	S37	10.0	8.7	5.5	3.7	4.2	3.7	10.0	6.4	2.8
W	S38	26.3	19.9	18.4	16.7	11.2	11.2	26.3	18.5	5.5
	S39	18.1	18.3	14.1	12.0	11.7	11.7	18.3	14.8	3.2
	S40	8.3	5.7	15.0	3.1	4.3	3.1	15.0	7.3	4.7
	S41	5.9	8.4	9.2	8.5	5.0	5.0	9.2	7.4	1.8
SW	S42	13.5	10.9	10.4	12.0	11.2	10.4	13.5	11.6	1.2
	S43	16.6	15.7	13.8	13.0	13.1	13.0	16.6	14.4	1.6
	S44	14.7	11.0	7.1	3.6	4.8	3.6	14.7	8.2	4.6
	S45	3.9	2.8	2.6	3.5	3.8	2.6	3.9	3.3	0.6
	Min	3.9	2.1	2.6	3.1	3.2				
	Max	26.3	19.9	19.0	16.7	13.1				
	Mean	13.0	11.0	10.6	8.0	7.0				
	SD	6.5	5.2	4.7	3.9	3.3				

In side B, the Cr values were low in comparison to the other side A. The samples in the directions NW (range 68 – 142.5 mg/kg), W (range 86.8 – 142.6 mg/kg) and SW (range 86 – 116.7 mg/kg) have more Cr in comparison to N (range 30 – 102.5 mg/kg) and S (range 56.3 – 116.2 mg/kg) directions. The maximum mean value was obtained at S34 (125.5 mg/kg) in the NW direction. A decreasing trend was observed as distance increased from the Mill.

(e) Copper (Cu)

The copper present in soils of the study area are presented in Table 3.18 (a) and Table 3.18 (b) for Sides A and B respectively. The minimum, the maximum, the mean and the standard deviation of the values are also given. It is observed that the values increase from first pre - monsoon season, B0 to the second pre – monsoon, B1 and then decrease. The soil appears to be rich in Cu. The sample S2 had the maximum mean value (389.5 mg/kg) and S25 had the minimum (77.5 mg/kg). In all the seasons the "Control" sample had very low Cu-content (11.7 mg/kg).

In Side B, huge amount of copper was measured in most of the samples in all the directions. The maximum value was obtained at S26 (1203 mg/kg) in the south direction. Most of the samples in A1 season had very high values but in the other four seasons, the values decreased. As the distance increased from the Mill, the values had a decreasing trend. Almost all the samples in both the sides have more than the average for world soils 20mg/kg .
Copper forms complexes with organic matter present in soil (Miller and Donahue, 1992). Copper toxicity was mainly influenced by pH and, to a lesser extent, by organic matter and clay content (Daoust et.al 2006). Cu toxicity increases in the presence of Ca and Mn (Mathias and Cummings, 1973).

(f) Iron (Fe)
The iron contents of the soil in the study area are given in the Tables 3.19 (a) and 3.19 (b) for the two sides A and B respectively. It is observed that huge amounts of iron are present in the soils of the study area. The samples in every direction had sufficient amount of iron. The amount of iron had a decreasing trend from B0 to B2 season. The distance variation was not uniform. The maximum value was obtained at S6 (mean value 20.30 g/kg) and the minimum

Table 3.17 (a). Chromium (Cr) content of the soil in Side A (mg/kg)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	15.4	15.2	16.0	15.2	16.0	15.5	0.4
NE	S1	102.6	118.0	105.0	102.6	118.0	108.5	8.3
	S2	67.2	84.0	89.0	67.2	89.0	80.1	11.4
	S3	70.5	76.0	70.0	70.0	76.0	72.2	3.3
	S4	25.8	48.0	68.0	25.8	68.0	47.3	21.1
	S5	24.7	52.0	41.5	24.7	52.0	39.4	13.8
N	S6	143.8	136.0	132.0	132.0	143.8	137.3	6.0
	S7	128.5	142.0	128.0	128.0	142.0	132.8	7.9
	S8	252.0	174.0	127.0	127.0	252.0	184.3	63.1
	S9	119.5	139.0	122.0	119.5	139.0	126.8	10.6
	S10	100.5	127.0	116.0	100.5	127.0	114.5	13.3
NW	S11	231.0	258.0	231.0	231.0	258.0	240.0	15.6
	S12	248.3	253.0	246.0	246.0	253.0	249.1	3.6
	S13	285.9	261.0	257.0	257.0	285.9	268.0	15.7
	S14	276.1	280.0	224.0	224.0	280.0	260.0	31.3
	S15	298.8	288.0	230.0	230.0	298.8	272.3	37.0
W	S16	252.5	263.0	215.0	215.0	263.0	243.5	25.2
	S17	257.0	239.0	186.0	186.0	257.0	227.3	36.9
	S18	266.2	254.0	78.8	78.8	266.2	199.7	104.9
	S19	251.6	272.0	152.0	152.0	272.0	225.2	64.2
	S20	263.8	285.0	200.0	200.0	285.0	249.6	44.2
SW	S21	201.4	216.0	169.0	169.0	216.0	195.5	24.1
	S22	35.3	95.0	74.0	35.3	95.0	68.1	30.3
	S23	154.3	143.0	96.0	96.0	154.3	131.1	30.9
	S24	44.7	79.0	70.0	44.7	79.0	64.6	17.8
	S25	114.5	152.0	102.0	102.0	152.0	122.8	26.0
	Min	24.7	48.0	41.5				
	Max	298.8	288.0	257.0				
	Mean	168.7	177.4	141.2				
	SD	93.9	82.0	65.2				

Table 3.17. (b). Chromium (Cr) content of the soil in Side B (mg/kg).

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	15.4	15.2	14.8	14.6	15.0	14.6	15.4	15.0	0.3
S	S26	113.0	101.3	74.0	86.3	74.2	74.0	113.0	89.8	17.1
	S27	105.6	116.2	66.8	57.2	62.1	57.2	116.2	81.6	27.2
	S28	87.6	92.3	88.7	80.1	69.0	69.0	92.3	83.5	9.3
	S29	56.3	62.3	59.0	60.0	64.0	56.3	64.0	60.3	3.0
N	S30	98.5	102.5	93.5	71.0	50.9	50.9	102.5	83.3	21.8
	S31	76.3	78.0	62.8	66.4	43.3	43.3	78.0	65.4	13.9
	S32	81.4	74.6	43.8	55.2	30.0	30.0	81.4	57.0	21.3
	S33	62.8	71.2	51.6	59.4	54.0	51.6	71.2	59.8	7.7
NW	S34	130.0	142.5	126.4	120.8	107.8	107.8	142.5	125.5	12.7
	S35	123.0	106.7	118.3	98.3	99.2	98.3	123.0	109.1	11.2
	S36	117.0	112.0	114.6	122.4	104.0	104.0	122.4	114.0	6.8
	S37	76.0	68.0	75.7	78.2	78.6	68.0	78.6	75.3	4.3
W	S38	142.6	133.7	97.4	107.3	88.6	88.6	142.6	113.9	23.3
	S39	121.5	103.8	98.5	102.0	97.0	97.0	121.5	104.6	9.8
	S40	143.0	129.1	106.2	96.4	86.8	86.8	143.0	112.3	23.3
	S41	114.6	115.6	112.0	93.7	98.6	93.7	115.6	106.9	10.1
SW	S42	116.5	110.4	115.5	102.0	96.5	96.5	116.5	108.2	8.7
	S43	114.0	110.0	114.3	93.7	95.2	93.7	114.3	105.4	10.2
	S44	113.8	116.7	96.5	98.5	94.0	94.0	116.7	103.9	10.5
	S45	102.4	109.0	105.6	101.1	86.0	86.0	109.0	100.8	8.8
	Min	56.3	62.3	43.8	55.2	30.0				
	Max	143.0	142.6	126.4	122.4	107.8				
	Mean	104.8	102.8	91.1	87.5	79.0				
	SD	24.5	22.2	24.5	20.6	22.1				

at S14 (mean value 2.64 g/kg). Almost all the soil samples in this area could be seen with a reddish brown colour when dry.

In side B, the same situation was observed like in side A. As a whole, the Fe-content of the soil samples had a decreasing trend from batch A1 to A3 with some exception. In some cases, the distance variation could be observed but it is to be noted that even the samples at locations away from the Mill have got sufficient amount of iron. The "Control" sample had also large iron content (mean value 0.71 g/kg) indicating that the soil was naturally rich in Fe-content.

Injury due to high soil iron concentration is not common under neutral or high pH soil conditions. Toxic situations occur primarily on acid soils (< pH 5.0) and where excess soluble iron salts have been applied as foliar sprays or soil amendments. The first symptoms of iron toxicity are necrotic spots on the leaves (Vitosh et al., 1994) of the plants grown in soil. Iron is an essential nutrient for all organisms, used in a variety of enzyme systems, including those for photosynthesis, respiration, and nitrogen fixation (Falkowski et. al. 1998; Morel and Prince, 2003). Iron is very insoluble under oxidizing conditions above pH 4 (Kraemer, 2004). Under poor drainage the iron becomes reduced and in the presence of organic matter is frequently mobilized

(g) Mercury (Hg)

Mercury is one of the heavy metals present in the soil of industrial area. The amounts of mercury present in the study area are depicted in Tables 3.20 (a) and 3.20 (b) for Side A and Side B respectively. The values show high content of Hg in almost all the directions from the Mill. Some samples in the third pre-monsoon batch, B2, possess Hg below detection level. From the first pre–monsoon (B0) season to the third pre–monsoon (B2) season, the values had a tendency to decrease with a few exceptions. The sample S25 did not show detectable amount of Hg at any season. The maximum value obtained was at S20 (mean value 10.020 mg/kg) and the minimum at S24 (mean value 0.007 mg/kg).

As the side B is at a larger distance from the Mill, it is likely that the soil in side B has less mercury content than the side A. The samples at maximum distance from the Mill in the south and north directions had Hg at below detection level in some of the seasons in this side. The distance variation can be seen in this side. From A1 to A3 batch, the values decreased. The

Table 3.18 (a). Cu-contents of the soil in Side A (mg/kg)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	12.5	11.5	11.0	11.0	12.5	11.7	0.8
NE	S1	325.9	352.0	380.0	325.9	380.0	352.6	27.1
	S2	389.5	401.0	378.0	378.0	401.0	389.5	11.5
	S3	302.8	365.0	308.0	302.8	365.0	325.3	34.5
	S4	115.9	183.0	210.0	115.9	210.0	169.6	48.5
	S5	142.5	200.0	185.0	142.5	200.0	175.8	29.8
N	S6	243.1	267.0	285.0	243.1	285.0	265.0	21.0
	S7	240.8	283.0	264.0	240.8	283.0	262.6	21.1
	S8	221.4	272.0	236.0	221.4	272.0	243.1	26.1
	S9	210.6	270.0	262.0	210.6	270.0	247.5	32.2
	S10	227.7	285.0	210.0	210.0	285.0	240.9	39.2
NW	S11	328.7	380.0	345.0	328.7	380.0	351.2	26.2
	S12	320.5	317.0	275.0	275.0	320.5	304.2	25.3
	S13	328.0	386.0	326.0	326.0	386.0	346.7	34.1
	S14	315.7	370.0	318.0	315.7	370.0	334.6	30.7
	S15	336.5	328.0	268.0	268.0	336.5	310.8	37.3
W	S16	131.4	152.0	85.0	85.0	152.0	122.8	34.3
	S17	80.8	110.0	76.0	76.0	110.0	88.9	18.4
	S18	96.3	92.0	46.0	46.0	96.3	78.1	27.9
	S19	75.0	101.0	68.0	68.0	101.0	81.3	17.4
	S20	98.6	104.0	72.0	72.0	104.0	91.5	17.1
SW	S21	100.3	100.0	85.0	85.0	100.3	95.1	8.8
	S22	103.5	109.0	96.0	96.0	109.0	102.8	6.5
	S23	104.0	93.0	64.0	64.0	104.0	87.0	20.7
	S24	62.6	95.0	81.0	62.6	95.0	79.5	16.2
	S25	85.4	90.0	57.0	57.0	90.0	77.5	17.9
	Min	62.6	90.0	46.0				
	Max	389.5	401.0	380.0				
	Mean	199.5	228.2	199.2				
	SD	106.7	115.4	114.9				

Table 3.18 (b). Cu-contents of the soil in Side B (mg/kg).

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	12.5	11.5	13.9	14.5	14.0	11.5	14.5	13.3	1.3
S	S26	1203.0	638.0	624.0	645.0	610.0	610.0	1203.0	744.0	256.9
	S27	715.0	500.0	328.0	380.0	317.0	317.0	715.0	448.0	166.0
	S28	523.0	132.0	118.0	128.0	123.0	118.0	523.0	204.8	178.0
	S29	216.0	116.0	125.0	116.0	102.0	102.0	216.0	135.0	46.0
N	S30	1004.0	538.0	440.0	452.0	418.0	418.0	1004.0	570.4	246.6
	S31	725.0	201.0	135.0	154.0	164.0	135.0	725.0	275.8	252.3
	S32	246.0	165.0	116.0	129.0	125.0	116.0	246.0	156.2	53.6
	S33	133.0	98.0	90.0	96.0	100.0	90.0	133.0	103.4	17.0
NW	S34	278.0	218.5	368.0	327.0	307.0	218.5	368.0	299.7	56.0
	S35	368.0	345.5	315.0	286.0	257.0	257.0	368.0	314.3	44.6
	S36	316.0	326.0	302.0	255.0	213.0	213.0	326.0	282.4	47.4
	S37	346.0	330.5	315.0	289.0	186.0	186.0	346.0	293.3	63.6
W	S38	462.0	171.5	205.0	200.0	185.0	171.5	462.0	244.7	122.2
	S39	189.0	135.0	164.0	166.0	160.0	135.0	189.0	162.8	19.2
	S40	151.0	160.0	135.0	141.0	127.0	127.0	160.0	142.8	13.0
	S41	184.0	160.0	135.0	122.0	120.0	120.0	184.0	144.2	27.4
SW	S42	454.0	436.0	482.0	438.0	375.0	375.0	482.0	437.0	39.2
	S43	372.0	368.0	360.0	374.0	385.0	360.0	385.0	371.8	9.1
	S44	280.0	254.0	252.0	260.0	210.0	210.0	280.0	251.2	25.6
	S45	105.0	110.0	125.0	86.0	80.0	80.0	125.0	101.2	18.3
	Min	105.0	98.0	90.0	86.0	80.0				
	Max	1203.0	638.0	624.0	645.0	610.0				
	Mean	413.5	270.2	256.7	252.2	228.2				
	SD	294.1	158.7	147.5	148.4	136.5				

Table 3.19 (a). Iron (Fe) content (g/kg) of the soil in Side A of the study area

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	0.71	0.72	0.7	0.7	0.72	0.71	0.01
NE	S1	20	18	13	13	20	17.0	3.6
	S2	19	20	12	12	20	17.0	4.4
	S3	11	15	10	10	15	12.0	2.6
	S4	12	10	9	9	12	10.3	1.5
	S5	10	10	6	6	10	8.7	2.3
N	S6	26	22	12	12	26	20.0	7.2
	S7	23	23	10	10	23	18.7	7.5
	S8	10	11	7	7	11	9.3	2.1
	S9	11	13	7	7	13	10.3	3.1
	S10	16	16	10	10	16	14.0	3.5
NW	S11	15	12	12	12	15	13.0	1.7
	S12	10	10	6	6	10	8.7	2.3
	S13	11	10	6	6	11	9.0	2.6
	S14	4	2	15	2	15	7.0	7.0
	S15	5	3	2	2	5	3.3	1.5
W	S16	11	7	3	3	11	7.0	4.0
	S17	5	8	4	4	8	5.7	2.1
	S18	10	10	7	7	10	9.0	1.7
	S19	8	10	7	7	10	8.3	1.5
	S20	9	10	5	5	10	8.0	2.6
SW	S21	10	10	4	4	10	8.0	3.5
	S22	8	9	5	5	9	7.3	2.1
	S23	8	9	6	6	9	7.7	1.5
	S24	8	9	5	5	9	7.3	2.1
	S25	8	9	6	6	9	7.7	1.5
	Min	4	2	2				
	Max	26	23	15				
	Mean	11.5	11.4	7.6				
	SD	10.9	10.8	7.1				

Table 3.19 (b). Iron (Fe) content (g/kg) of the soil in Side B of the study area

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	0.7	0.72	0.7	0.7	0.73	0.7	0.73	0.712	0.015
S	S26	30	15	13	15	12	12	30	17	7
	S27	20	4	5	6	9	4	20	9	7
	S28	6	4	3	3	3	3	6	4	1
	S29	4	4	3	3	2	2	4	3	1
N	S30	12	4	4	3	3	3	12	5	4
	S31	7	2	2	2	2	2	7	3	2
	S32	4	1	1	1	1	1	4	2	1
	S33	2	2	1	1	1	1	2	1	1
NW	S34	11	11	10	9	10	9	11	10	1
	S35	11	9	10	9	9	9	11	10	1
	S36	9	8	8	7	2	2	9	7	3
	S37	10	10	9	8	8	8	10	9	1
W	S38	22	15	15	11	9	9	22	14	5
	S39	13	13	10	10	10	10	13	11	2
	S40	15	9	12	9	9	9	15	11	3
	S41	17	11	10	8	8	8	17	11	4
SW	S42	18	16	16	13	11	11	18	15	3
	S43	11	10	9	9	9	9	11	10	1
	S44	10	9	9	8	8	8	10	9	1
	S45	10	10	9	9	9	9	10	9	1
	Min	1	1	1	1	1				
	Max	30	16	16	15	12				
	Mean	12	8	8	7	7				
	SD	7	5	4	4	4				

maximum value was obtained at S42 (mean value 1.087 mg/kg) in the southwest direction near the Mill and the minimum at S29 (south) and S33 (north).

(h) Manganese (Mn)

The amount of manganese present in the soil samples in different directions from the sides A and B are given in Tables 3.21 (a) and Table 3.21 (b).
In Side A, the first pre-monsoon season (B0) had Mn in the range 13.2 – 146.9 mg/kg, the second pre-monsoon (B1) 42.0 – 135.0 mg/kg and the third pre-monsoon (B2) 32.0 – 128.0 mg/kg. The control sample had 19.3, 12.6 and 12.1 mg/kg of Mn in B0, B1 and B2 batches respectively. The samples near to the Mill had more Mn content in comparison to those away from it with a few exceptions. The maximum amount of Mn was found at S16 (mean value 136.6 mg/kg) in the west direction and the minimum at S5 (mean value 29.1 mg/kg) in the northeast direction.

In Side B, the amounts of Mn are present in the following ranges:

- A1 batch 16.5- 162.7 mg/kg
- B1 batch 17.2 – 128.0 mg/kg
- A2 batch 20.0 – 135.0 mg/kg
- B2 batch 15.4 – 120.4 mg/kg
- A3 batch 16.7 – 111.5 mg/kg

The values have a decreasing trend from A1 batch to A3 batch. The distance variation was almost distinct. The maximum amount of Mn was obtained at S42 (mean value 123.5 mg/kg) in the southwest direction and the minimum at S29 (mean value 18.2 mg/kg) in the south direction. The soil samples in the south direction had less amount of Mn in comparison to north, west, northwest and southwest directions. As a whole, the soil samples had less content of Mn than the World average of 850 mg/kg.

Levels of Mn in the soil are controlled mainly by the soil's Mn reserve, pH, and the availability of electrons (e^-) (Adams, 1981; Sparrow and Uren, 1987).

(i) Nickel(Ni)

The nickel present in the soil samples in the study area is given in Tables 3.22(a) and 3.22(b). The amount of Ni present in Side A was within the range 21.5 – 101.0 mg/kg. The soil samples in this side is rich with nickel. The maximum mean value for different samples in different directions are as follows:

- 34.2 – 66.6 mg/kg in NE direction
- 55.2 – 91.6 mg/kg in N direction
- 48.5 – 65.6 mg/kg in NW direction
- 57.4 – 83.9 mg/kg in W direction
- 34.0 – 53.4 mg/kg in SW direction

From the results it can be concluded that almost all the samples are rich with high content of Ni (World average, 40 mg/kg).
In Side B, almost all the samples in all the seasons have high content of Ni like Side A. With distance away from the Mill, the amount of Ni present in soil decreased. The "Control" has a very low range of values (2.1 – 2.7 mg/kg). The maximum mean value obtained was at S34 (68.4 mg/kg), which was very near to the earthen dam in the NW direction from the Mill and the minimum at S33 (41.1 mg/kg) at the distant sample in N direction from the Mill.
Ni concentration in anthropogenically-polluted soils can reach 200 – 2600 mg/kg. The primary sources of nickel pollution are the burning of coal and oil, emission of smelters and metal works, municipal wastes, sewage, phosphate fertilizers and pesticides (Izosimova et al., 2005). In the present work, the Mill has a direct influence on soil quality with respect to Ni content

Table 3.20 (a) Mercury (Hg) content (mg/kg) of soil samples in the study area (Side A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	BDL	BDL	BDL	BDL	BDL	BDL	BDL
NE	S1	3.6	2.7	0.6	0.6	3.6	2.30	1.54
	S2	2.1	1.05	1.024	1.024	2.1	1.39	0.61
	S3	2.8	1.3	BDL	BDL	2.8	2.05	1.06
	S4	4.6	0.36	0.028	0.028	4.6	1.66	2.55
	S5	1.8	0.08	BDL	BDL	1.8	0.94	1.22
N	S6	0.2	1.34	0.4	0.2	1.34	0.65	0.61
	S7	1.5	0.56	0.03	0.03	1.5	0.70	0.74
	S8	7.6	3.71	BDL	BDL	7.6	5.66	2.75
	S9	5.8	2.8	1.05	1.05	5.8	3.22	2.40
	S10	1.5	0.63	0.04	0.04	1.5	0.72	0.73
NW	S11	10.4	5.8	1.46	1.46	10.4	5.89	4.47
	S12	7.6	3.2	2.73	2.73	7.6	4.51	2.69
	S13	2.2	0.9	0.1	0.1	2.2	1.07	1.06
	S14	3.6	1.05	BDL	BDL	3.6	2.33	1.80
	S15	8.6	9.14	3.3	3.3	9.14	7.01	3.23
W	S16	6.6	2.1	0.8	0.8	6.6	3.17	3.04
	S17	20.6	9.5	2.4	2.4	20.6	10.83	9.17
	S18	13.7	5.34	6.04	5.34	13.7	8.36	4.64
	S19	10.2	9.7	4.5	4.5	10.2	8.13	3.16
	S20	14	9.85	6.2	6.2	14	10.02	3.90
SW	S21	2.7	2.04	1.5	1.5	2.7	2.08	0.60
	S22	0.9	0.54	0.02	0.02	0.9	0.49	0.44
	S23	1.2	2.3	BDL	1.2	2.3	1.75	0.78
	S24	BDL	0.02	BDL	BDL	0.02	0.007	BDL
	S25	BDL	BDL	BDL	BDL	BDL	BDL	BDL
	Min	BDL	BDL	BDL				
	Max	20.60	9.85	6.20				
	Mean	5.82	3.17	1.79				
	SD	5.18	3.28	2.02				

Table 3.20 (b) Mercury (Hg) content (mg/kg) of soil samples in the study area (Side B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
S	S26	0.008	0.006	0.008	0.005	0.002	0.002	0.008	0.006	0.002
	S27	0.005	0.014	0.007	0.005	0.001	0.001	0.014	0.006	0.005
	S28	0.002	0.006	0.005	0.006	0.003	0.002	0.006	0.004	0.002
	S29	BDL	0.001	BDL	BDL	BDL	0.001	0.001	0.001	0.000
N	S30	0.018	0.02	0.016	0.025	0.022	0.016	0.025	0.020	0.003
	S31	0.082	0.051	0.05	0.008	0.0012	0.001	0.082	0.038	0.034
	S32	0.006	0.005	0.002	0.001	0.001	0.001	0.006	0.003	0.002
	S33	BDL 1	0.002	BDL	0.001	BDL	0.001	0.002	0.002	0.001
NW	S34	2.73	0.065	0.055	0.05	0.004	0.004	2.730	0.581	1.202
	S35	0.012	0.008	0.001	0.001	BDL	0.001	0.012	0.006	0.005
	S36	0.01	0.009	0.006	BDL 1	0.001	0.001	0.010	0.007	0.004
	S37	0.008	0.008	0.005	0.005	0.001	0.001	0.008	0.005	0.003
W	S38	1.15	0.56	0.52	0.091	0.002	0.002	1.150	0.465	0.457
	S39	0.952	1.04	0.83	0.5	0.075	0.075	1.040	0.679	0.395
	S40	0.93	0.858	0.526	0.15	0.1	0.100	0.930	0.513	0.386
	S41	0.73	0.7	0.42	0.07	0.025	0.025	0.730	0.389	0.335
SW	S42	2.02	1.35	1.11	0.95	0.003	0.003	2.020	1.087	0.730
	S43	1.25	0.975	0.554	0.076	0.002	0.002	1.250	0.571	0.546
	S44	0.008	0.005	0.005	BDL	BDL	0.005	0.008	0.006	0.002
	S45	0.0073	0.001	0.001	BDL	BDL	0.001	0.007	0.003	0.004
	Min	BDL	0.001	BDL	BDL	BDL				
	Max	2.73	1.35	1.11	0.95	0.1				
	Mean	0.552	0.284	0.229	0.122	0.016				
	SD	0.814	0.446	0.344	0.253	0.030				

Table 3.21 (a) Manganese content (mg/kg) of the soil in Side A of the study area

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	19.3	12.6	12.1	12.1	19.3	14.7	4.0
NE	S1	132.7	102.0	110.0	102.0	132.7	114.9	15.9
	S2	58.3	69.0	61.0	58.3	69.0	62.8	5.6
	S3	26.9	54.0	55.0	26.9	55.0	45.3	15.9
	S4	25.4	50.0	53.0	25.4	53.0	42.8	15.1
	S5	13.2	42.0	32.0	13.2	42.0	29.1	14.6
N	S6	101.5	117.0	98.0	98.0	117.0	105.5	10.1
	S7	72.8	89.0	75.0	72.8	89.0	78.9	8.8
	S8	71.6	80.0	62.0	62.0	80.0	71.2	9.0
	S9	62.2	72.0	68.0	62.2	72.0	67.4	4.9
	S10	64.7	75.0	60.0	60.0	75.0	66.6	7.7
NW	S11	76.1	68.0	62.0	62.0	76.1	68.7	7.1
	S12	70.2	74.0	70.0	70.0	74.0	71.4	2.3
	S13	74.3	55.0	52.0	52.0	74.3	60.4	12.1
	S14	50.3	68.0	66.0	50.3	68.0	61.4	9.7
	S15	52.5	60.0	62.0	52.5	62.0	58.2	5.0
W	S16	146.9	135.0	128.0	128.0	146.9	136.6	9.6
	S17	116.0	130.0	126.0	116.0	130.0	124.0	7.2
	S18	108.1	116.0	98.0	98.0	116.0	107.4	9.0
	S19	63.3	75.0	70.0	63.3	75.0	69.4	5.9
	S20	44.7	59.0	43.0	43.0	59.0	48.9	8.8
SW	S21	98.4	103.0	97.0	97.0	103.0	99.5	3.1
	S22	86.5	92.0	68.0	68.0	92.0	82.2	12.6
	S23	87.4	90.0	73.0	73.0	90.0	83.5	9.2
	S24	64.3	73.0	70.0	64.3	73.0	69.1	4.4
	S25	62.8	60.0	63.0	60.0	63.0	61.9	1.7
	Min	13.2	42.0	32.0				
	Max	146.9	135.0	128.0				
	Mean	73.2	80.3	72.9				
	SD	31.9	25.0	23.9				

Table 3.21 (b) Manganese content (mg/kg) of the soil in Side B of the study area

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	19.3	12.6	13.5	12.9	12.6	12.6	19.3	14.2	2.9
S	S26	162.7	111.0	132.2	86.0	75.0	75.0	162.7	113.4	35.4
	S27	129.6	50.6	62.6	78.0	56.3	50.6	129.6	75.4	32.0
	S28	56.3	77.0	76.0	64.0	70.0	56.3	77.0	68.7	8.7
	S29	16.5	17.2	20.0	19.4	18.0	16.5	20.0	18.2	1.5
N	S30	128.6	128.0	135.0	66.0	59.7	59.7	135.0	103.5	37.2
	S31	142.0	67.5	74.4	68.0	50.0	50.0	142.0	80.4	35.6
	S32	76.5	63.0	70.0	66.0	62.0	62.0	76.5	67.5	5.9
	S33	37.8	23.2	32.2	27.6	30.2	23.2	37.8	30.2	5.4
NW	S34	60.8	52.7	54.7	41.5	28.5	28.5	60.8	47.6	12.8
	S35	48.1	40.1	50.5	52.0	48.8	40.1	52.0	47.9	4.6
	S36	40.0	34.6	32.2	36.7	47.8	32.2	47.8	38.3	6.1
	S37	21.2	23.9	24.8	22.0	24.3	21.2	24.8	23.2	1.6
W	S38	135.6	120.0	117.0	97.0	83.5	83.5	135.6	110.6	20.5
	S39	129.0	76.5	86.0	89.0	63.0	63.0	129.0	88.7	24.7
	S40	86.7	67.0	58.0	62.0	60.0	58.0	86.7	66.7	11.6
	S41	21.8	20.3	24.4	15.4	16.7	15.4	24.4	19.7	3.7
SW	S42	136.9	122.9	125.6	120.4	111.5	111.5	136.9	123.5	9.2
	S43	72.6	60.7	54.3	53.8	40.2	40.2	72.6	56.3	11.8
	S44	55.0	45.8	48.5	44.3	45.0	44.3	55.0	47.7	4.4
	S45	24.0	22.9	26.0	25.0	31.0	22.9	31.0	25.8	3.1
	Min	16.5	17.2	20.0	15.4	16.7				
	Max	162.7	128.0	135.0	120.4	111.5				
	Mean	79.1	61.2	65.2	56.7	51.1				
	SD	48.3	35.7	37.1	28.5	23.6				

Table 3.22 (a) Nickel content (mg/kg) of the soil in Side A of the study area

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	2.7	2.5	2.6	2.5	2.7	2.6	0.1
NE	S1	64.8	73.0	62.0	62.0	73.0	66.6	5.7
	S2	45.5	66.0	58.0	45.5	66.0	56.5	10.4
	S3	34.7	54.0	50.0	34.7	54.0	46.2	10.2
	S4	35.3	47.0	40.0	35.3	47.0	40.8	5.9
	S5	32.6	40.0	30.1	30.1	40.0	34.2	5.2
N	S6	80.8	93.0	101.0	80.8	101.0	91.6	10.2
	S7	66.0	71.0	65.0	65.0	71.0	67.3	3.2
	S8	69.5	70.0	63.0	63.0	70.0	67.5	3.9
	S9	61.6	58.0	46.0	46.0	61.6	55.2	8.2
	S10	60.0	61.0	53.0	53.0	61.0	58.0	4.4
NW	S11	58.7	70.0	68.0	58.7	70.0	65.6	6.0
	S12	62.8	67.0	60.0	60.0	67.0	63.3	3.5
	S13	44.6	58.0	43.0	43.0	58.0	48.5	8.2
	S14	56.4	50.0	40.0	40.0	56.4	48.8	8.2
	S15	62.4	55.0	39.0	39.0	62.4	52.1	12.0
W	S16	90.6	84.0	77.0	77.0	90.6	83.9	6.8
	S17	83.7	86.0	75.0	75.0	86.0	81.6	5.8
	S18	59.3	65.0	63.0	59.3	65.0	62.4	2.9
	S19	75.1	70.0	57.0	57.0	75.1	67.4	9.3
	S20	61.3	63.0	48.0	48.0	63.0	57.4	8.2
SW	S21	58.3	60.0	42.0	42.0	60.0	53.4	9.9
	S22	21.5	49.0	36.0	21.5	49.0	35.5	13.8
	S23	33.0	41.0	28.0	28.0	41.0	34.0	6.6
	S24	47.5	46.0	41.0	41.0	47.5	44.8	3.4
	S25	51.4	49.0	27.0	27.0	51.4	42.5	13.4
	Min	21.5	40.0	27.0				
	Max	90.6	93.0	101.0				
	Mean	56.7	61.8	52.5				
	SD	17.0	13.7	17.3				

Table 3.22 (b) Nickel content (mg/kg) of the soil in Side B of the study area

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	2.7	2.5	2.1	2.6	2.5	2.1	2.7	2.5	0.2
S	S26	55.0	56.0	51.0	47.6	46.0	46.0	56.0	51.1	4.4
	S27	53.8	50.0	52.0	50.0	46.0	46.0	53.8	50.4	2.9
	S28	48.0	52.0	51.5	48.0	49.0	48.0	52.0	49.7	1.9
	S29	50.0	51.6	50.2	46.8	47.0	46.8	51.6	49.1	2.1
N	S30	55.6	53.0	54.3	50.0	41.0	41.0	55.6	50.8	5.8
	S31	53.0	48.0	45.0	45.1	46.0	45.0	53.0	47.4	3.3
	S32	58.2	54.0	48.0	42.0	38.0	38.0	58.2	48.0	8.3
	S33	37.9	44.6	44.0	39.0	40.0	37.9	44.6	41.1	3.0
NW	S34	78.4	74.4	68.5	61.5	59.3	59.3	78.4	68.4	8.2
	S35	60.8	57.0	58.0	52.0	47.0	47.0	60.8	55.0	5.5
	S36	53.0	50.2	50.5	48.0	41.8	41.8	53.0	48.7	4.2
	S37	58.0	53.0	51.0	52.8	48.0	48.0	58.0	52.6	3.6
W	S38	62.7	66.8	58.1	60.0	57.9	57.9	66.8	61.1	3.7
	S39	60.1	56.7	46.8	46.0	37.9	37.9	60.1	49.5	8.9
	S40	54.0	49.2	42.8	44.0	37.6	37.6	54.0	45.5	6.3
	S41	58.0	60.0	52.5	48.0	42.0	42.0	60.0	52.1	7.4
SW	S42	68.2	68.0	58.0	48.7	50.2	48.7	68.2	58.6	9.3
	S43	57.0	53.0	54.0	50.0	49.7	49.7	57.0	52.7	3.0
	S44	56.6	55.0	54.0	47.0	46.0	46.0	56.6	51.7	4.9
	S45	64.5	57.0	56.0	53.0	43.8	43.8	64.5	54.9	7.5
	Min	37.9	44.6	42.8	39.0	37.6				
	Max	78.4	74.4	68.5	61.5	59.3				
	Mean	57.1	55.5	52.3	49.0	45.7				
	SD	8.1	7.2	5.9	5.3	5.9				

(j) Lead (Pb)

In the present study, the amounts of lead measured in the soil are presented in Table 3.23 (a) and Table 3.23 (b). It is found that substantial amounts of lead are available in all the soil (World average, 10 mg/kg) samples in all the directions.

In side A, the lead content was in the ranges of B0: 27.0 – 53.0 mg/kg, B1: 37.0 – 71.0 mg/kg and B2: 12.0 – 67.0 mg/kg, whereas the " Control" had 4.0, 5.0, and 4.0 mg/kg in B0, B1 and B2 batches respectively. The variations of the values for the sites in different distances are not uniform. The values were higher in the second pre-monsoon season (B1).

In Side B also, the soil had large amounts of lead indicating that the effluent of the Mill had carried sufficient amount of lead salts with it and spread the same over large distances. The distant samples in every direction had got less value than the near ones of the Mill. The Pb-content of the soil in the study area is more than the World average content of 10.0 mg/kg. The maximum mean value was measured at S42 (61.6 mg/kg) in the SW direction and the minimum at S29 (26.3 mg/kg) in the S direction. The values had a decreasing trend from A1 batch to A3 batch.

Presence of toxic heavy metals like Pb and Hg reduces soil fertility and agricultural output (Lokhande, and Kelkar, 1999). Pb has not been known to have any beneficial function for plants or animals (Greenland and Hayes, 1981), but the health problems created by high levels of Pb are well documented (Singh and Steinnes, 1994).

(k) Zinc (Zn)

The amounts of Zn present in the study area soil are presented in Table 3.24 (a) and Table 3.24 (b) with the minimum, the maximum, the mean and the standard deviations of the values.

The values are very high in every direction and for all the samples. The variation of values along each direction does not show any uniform trend. The maximum mean value was obtained at S16 (675.1 mg/kg) in the west direction and the minimum at S25 (201.9 mg/kg) in the southwest direction. The maximum mean value was obtained for B1 batch and similar observations have been recorded also in case of Pb, Ni and Mn in Side A.

Table 3.23 (a). Lead content (mg/kg) of the soil samples in study area of Side (A).

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	4	5	4	4	5	4	0
NE	S1	53	62	67	53	67	61	7
	S2	51	71	41	41	71	54	15
	S3	48	60	61	48	61	56	7
	S4	33	45	42	33	45	40	6
	S5	40	48	40	40	48	43	5
N	S6	50	39	34	34	50	41	8
	S7	48	47	41	41	48	45	4
	S8	27	42	43	27	43	37	9
	S9	39	40	35	35	40	38	3
	S10	49	55	49	49	55	51	3
NW	S11	52	50	39	39	52	47	7
	S12	49	57	56	49	57	54	4
	S13	40	53	47	40	53	47	7
	S14	41	50	40	40	50	44	6
	S15	33	47	40	33	47	40	7
W	S16	39	43	44	39	44	42	3
	S17	50	56	49	49	56	52	4
	S18	43	60	55	43	60	53	9
	S19	45	62	60	45	62	56	9
	S20	48	60	56	48	60	55	6
SW	S21	42	60	43	42	60	48	10
	S22	36	47	45	36	47	43	6
	S23	31	49	42	31	49	41	9
	S24	34	40	26	26	40	33	7
	S25	30	37	12	12	37	26	13
	Min	27	37	12				
	Max	53	71	67				
	Mean	42	51	44				
	SD	8	9	12				

Table 3.23 (b). Lead content (mg/kg) of the soil in Side B of the study area

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	4.0	4.5	4.4	4.4	4.3	4.0	4.5	4.3	0.2
S	S26	53.0	40.0	37.0	31.0	28.0	28.0	53.0	37.8	9.7
	S27	52.0	57.0	28.0	30.0	35.0	28.0	57.0	40.4	13.2
	S28	34.0	23.0	22.0	26.0	33.0	22.0	34.0	27.6	5.6
	S29	28.7	23.4	20.0	27.0	32.5	20.0	32.5	26.3	4.8
N	S30	49.0	26.0	24.0	26.0	31.0	24.0	49.0	31.2	10.3
	S31	43.0	26.0	27.0	23.0	21.0	21.0	43.0	28.0	8.7
	S32	43.5	33.0	30.0	32.0	36.0	30.0	43.5	34.9	5.3
	S33	32.6	32.9	25.0	29.0	32.0	25.0	32.9	30.3	3.3
NW	S34	60.0	63.0	56.7	58.0	56.0	56.0	63.0	58.7	2.8
	S35	62.0	59.0	62.0	58.0	60.0	58.0	62.0	60.2	1.8
	S36	61.0	64.0	59.0	60.0	62.0	59.0	64.0	61.2	1.9
	S37	58.0	56.0	43.0	58.0	55.5	43.0	58.0	54.1	6.3
W	S38	62.0	47.0	51.0	56.0	41.0	41.0	62.0	51.4	8.1
	S39	57.8	42.0	48.0	52.0	59.0	42.0	59.0	51.8	7.0
	S40	40.5	29.0	32.0	20.0	36.0	20.0	40.5	31.5	7.7
	S41	38.6	29.2	27.0	21.0	30.0	21.0	38.6	29.2	6.3
SW	S42	70.6	68.5	71.4	65.3	32.0	32.0	71.4	61.6	16.7
	S43	52.6	48.7	26.5	25.0	25.0	25.0	52.6	35.6	13.9
	S44	30.5	26.4	27.5	26.0	27.5	26.0	30.5	27.6	1.8
	S45	28.0	27.8	29.2	30.0	25.5	25.5	30.0	28.1	1.7
	Min	28.0	23.0	20.0	20.0	21.0				
	Max	70.6	68.5	71.4	65.3	62.0				
	Mean	47.9	41.1	37.3	37.7	37.9				
	SD	12.9	15.5	15.3	15.9	13.0				

In Side B, the soil samples in the western direction had sufficient amounts of Zn (range 0.92 – 1.87 g/kg) in comparison to other directions. The study reveals that there is a decreasing trend of values from A1 batch to A3 batch. Again, as the distance increased from the Mill, the values had a decreasing trend.

Excessive Zn in soil may cause damage to plants and at lower pH the yield is reduced (Leeper, 1978).

General discussion of the trace metal concentrations

The high concentration of metal ions in the effluent amended soils is due to the stagnation of precipitated insoluble metal salts, which deposit on the surface of the soil particles. The soluble metallic species percolate through soil bed and move towards the water table of the area (Nemade and Shrivastava, 1996, 1998; Shrivastava et al. 1989; Shrivastava and Chaudhury, 2000). These facts are clearly evident from the concentration of metals in soil and ground water samples.

The present study should be regarded as an indication of detail investigation on heavy metals (such as solid phase speciation, mobility, adsorption and desorption studies) of terrestrial ecosystems in the vicinity of an industry.

The soil is as a whole very rich in Al which is a natural constituent of the soil, but a large amount is also contributed by the Textile Mill wastes. In any particular direction from the Mill, the general pattern of variation is a decrease away from the Mill. This is illustrated in Figs. 3.15 for the Side A and the Side B with respect to the minimum, the maximum and the mean values at each site.

Table 3.24 (a) Zinc (Zn) content of soil samples (mg/kg) in the study area of Side (A)

Direction	Season	B0	B1	B2	Min	Max	Mean	SD
	Control	12.36	12.40	12.50	12.36	12.50	12.42	0.07
NE	S1	448.20	408.00	410.00	408.00	448.20	422.07	22.65
	S2	436.10	447.00	407.00	407.00	447.00	430.03	20.68
	S3	452.70	483.00	478.00	452.70	483.00	471.23	16.24
	S4	460.70	482.00	476.00	460.70	482.00	472.90	10.98
	S5	402.00	436.00	411.00	402.00	436.00	416.33	17.62
N	S6	441.80	409.00	387.00	387.00	441.80	412.60	27.58
	S7	468.50	473.00	436.00	436.00	473.00	459.17	20.19
	S8	414.50	438.00	440.00	414.50	440.00	430.83	14.18
	S9	530.10	602.00	460.00	460.00	602.00	530.70	71.00
	S10	725.50	660.00	582.00	582.00	725.50	655.83	71.84
NW	S11	509.36	551.00	528.00	509.36	551.00	529.45	20.86
	S12	511.42	505.00	511.00	505.00	511.42	509.14	3.59
	S13	501.70	526.00	483.00	483.00	526.00	503.57	21.56
	S14	480.40	525.00	475.00	475.00	525.00	493.47	27.44
	S15	455.90	480.00	368.00	368.00	480.00	434.63	58.95
W	S16	730.20	695.00	600.00	600.00	730.20	675.07	67.35
	S17	663.50	682.00	614.00	614.00	682.00	653.17	35.16
	S18	695.20	735.00	682.00	682.00	735.00	704.07	27.59
	S19	667.50	710.00	645.00	645.00	710.00	674.17	33.01
	S20	612.70	647.00	615.00	612.70	647.00	624.90	19.17
SW	S21	434.80	495.00	426.00	426.00	495.00	451.93	37.56
	S22	430.10	466.00	414.00	414.00	466.00	436.70	26.62
	S23	335.62	400.00	328.00	328.00	400.00	354.54	39.55
	S24	271.30	302.00	317.00	271.30	317.00	296.77	23.30
	S25	156.80	248.00	201.00	156.80	248.00	201.93	45.61
	Min	156.80	248.00	201.00				
	Max	730.20	735.00	682.00				
	Mean	489.46	512.20	467.76				
	SD	136.66	124.40	112.45				

Table 3.24 (b) Zinc (Zn) content of soil samples (mg/kg) in the study area of Side (B)

Direction	Season	A1	B1	A2	B2	A3	Min	Max	Mean	SD
	Control	12.4	12.4	12.1	12.5	12.0	12.0	12.9	12.4	0.4
S	S26	447.0	423.0	436.0	440.0	372.0	372.0	447.0	423.6	30.1
	S27	431.0	418.0	470.0	426.0	380.0	380.0	470.0	425.0	32.2
	S28	452.0	417.0	423.0	408.0	376.0	376.0	452.0	415.2	27.4
	S29	337.2	305.0	328.0	316.0	295.0	295.0	337.2	316.2	17.0
N	S30	503.0	518.0	528.0	382.0	326.0	326.0	528.0	451.4	91.5
	S31	328.8	360.0	372.0	316.0	304.0	304.0	372.0	336.2	28.9
	S32	238.2	265.0	248.0	228.0	218.0	218.0	265.0	239.4	18.2
	S33	210.0	198.0	206.0	187.0	160.0	160.0	210.0	192.2	20.0
NW	S34	640.0	541.0	506.0	427.0	316.0	316.0	640.0	486.0	122.0
	S35	263.7	287.0	236.0	240.0	204.0	204.0	287.0	246.1	31.2
	S36	383.5	314.0	306.0	297.0	263.0	263.0	383.5	312.7	44.1
	S37	349.0	368.0	351.0	330.0	342.0	330.0	368.0	348.0	13.9
W	S38	1573.0	1564.0	1872.0	1052.0	985.0	985.0	1872.0	1409.2	378.3
	S39	1583.0	1119.0	1043.0	1148.0	1073.0	1043.0	1583.0	1193.2	221.6
	S40	1445.0	1012.0	1192.0	1052.0	995.0	995.0	1445.0	1139.2	187.7
	S41	1474.0	1053.0	1204.0	1009.0	915.0	915.0	1474.0	1131.0	218.3
SW	S42	346.4	318.0	328.0	326.5	315.0	315.0	346.4	326.8	12.3
	S43	511.0	527.0	506.0	478.0	440.0	440.0	527.0	492.4	34.2
	S44	346.0	402.0	378.0	365.0	348.0	346.0	402.0	367.8	23.2
	S45	294.0	314.0	307.0	476.0	440.0	294.0	476.0	366.2	85.1
	Min	210.0	198.0	206.0	187.0	160.0				
	Max	1583.0	1564.0	1872.0	1148.0	1073.0				
	Mean	607.8	536.2	562.0	495.2	453.4				
	SD	478.7	359.7	428.8	303.6	286.2				

Although not much, the soil is also contaminated with the toxic As. No distinction was made between As(III) and As(V) in the measurements, and the values presented are total As-content of the soil. Despite being present in very small amounts, the values still exhibit some amount of enrichment near the Mill. Similar conclusion may be made with respect to Cd – the only difference being its increased enrichment in Side B compared to Side A. A plot of the mean values of Cd at each sampling site for both the sides (Fig 3.16) shows the trends in Cd-contents of the soil.

In estimating Cr, again only the total Cr was determined without distinguishing between Cr(III) and Cr(VI). The soil is considerably rich in this toxic metal. The Side A is conspicuous by the presence of high Cr-content compared to the Side B. The seasonal trends for each site are shown separately for the Sides, A and B, in Fig. 3.17(a) and Fig. 3.16(b) respectively.

Cu-enrichment of the soil is again more in Side B than in Side A and the reason for the same may be similar to that of Cd. The variation trends with distance and direction from the Mill are shown in Fig 3.18 with respect to the minimum, the maximum and the mean values at each site for the two sides respectively.

Considering the amounts present, Fe cannot be regarded as trace metal. It is present in large quantities in the soil and the results are in conformity with the generally iron-rich quality of Assam soil. Because of very large amounts of Fe being present in the distant soil samples, no definite conclusion can be made about any contribution from the activities from the Textile Mill. This can also be seen from Fig. 3.19 for variation of the minimum, the maximum and the mean contents of iron in the soil for Side A and Side B respectively with distance.

The trace metal, Hg, is present in many sites in the study area with appreciable concentration. It is to be noted that the soil close to the Mill showed presence of more Hg than the soil away from it, and therefore, whatever Hg was found in the soil, was likely to have its origin in the activities of the Mill.

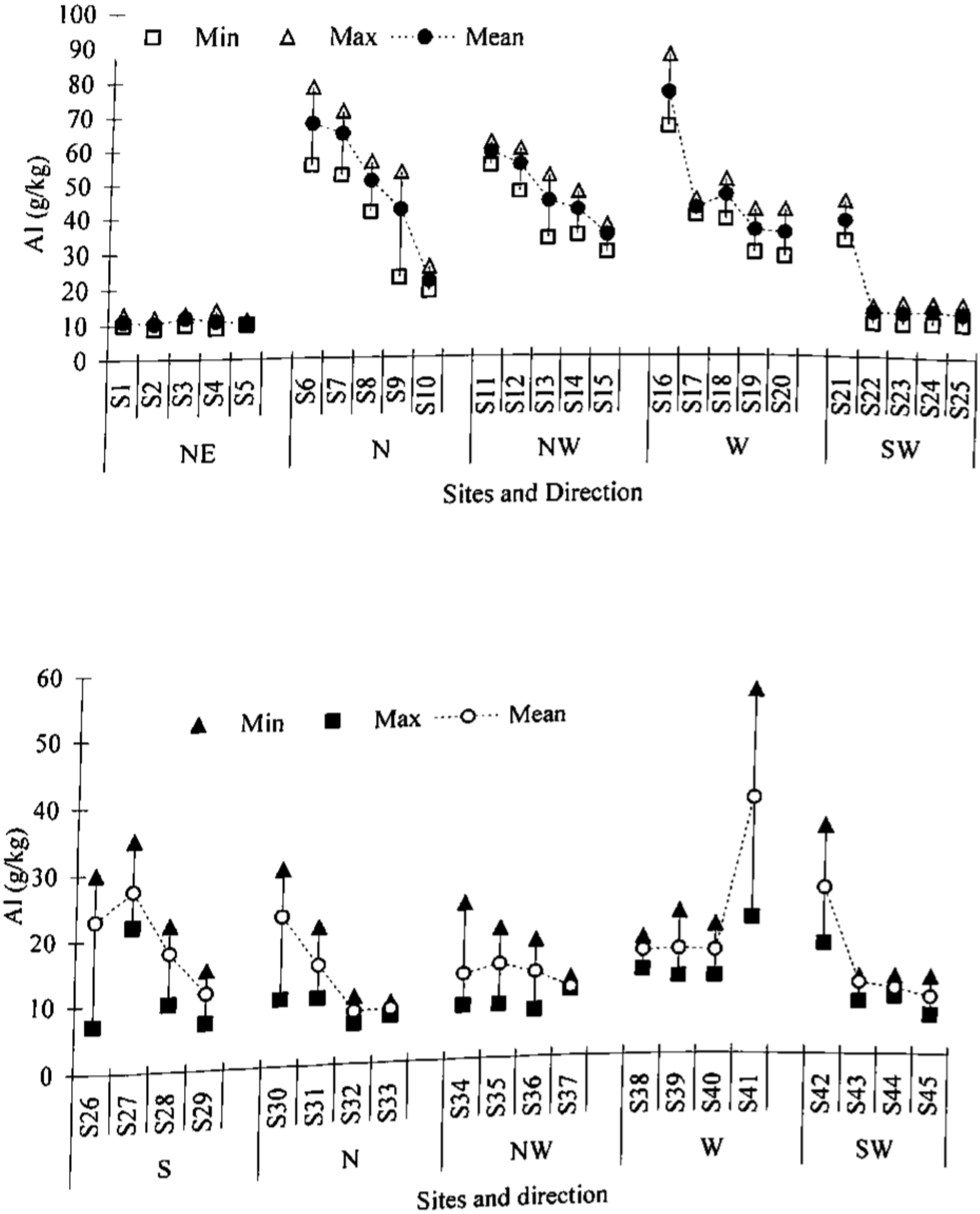


Fig. 3.15. Variation pattern of minimum, maximum and mean Al-content in the soil of the study area for Side A (top) and Side B (bottom) with respect to the sampling sites and sampling direction.

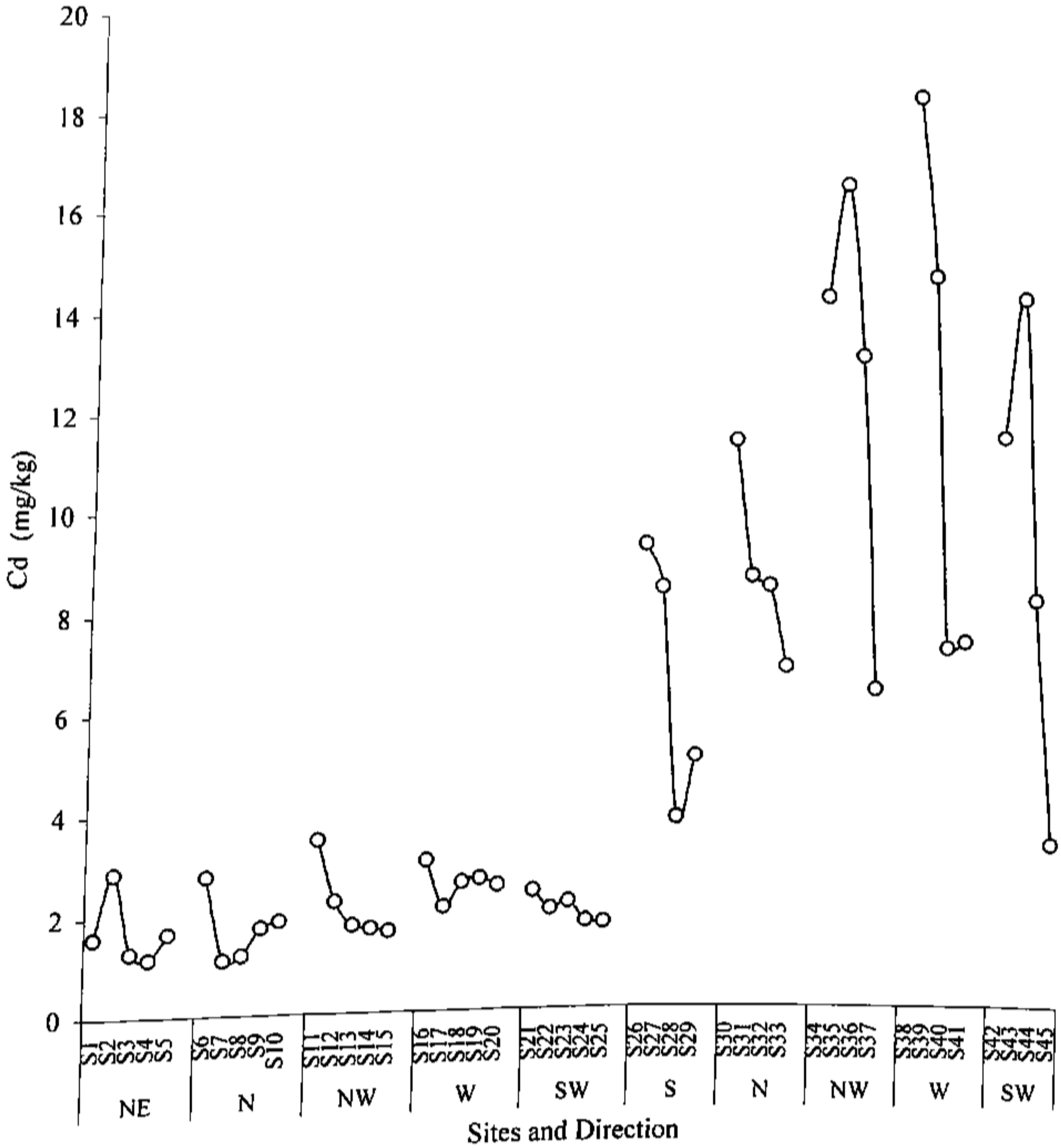


Fig. 3.16. Variation pattern of mean Cd-content in the soil of the study area for Side A (S1 to S25) and Side B (S26 to S45) with respect to the sampling sites and directions.

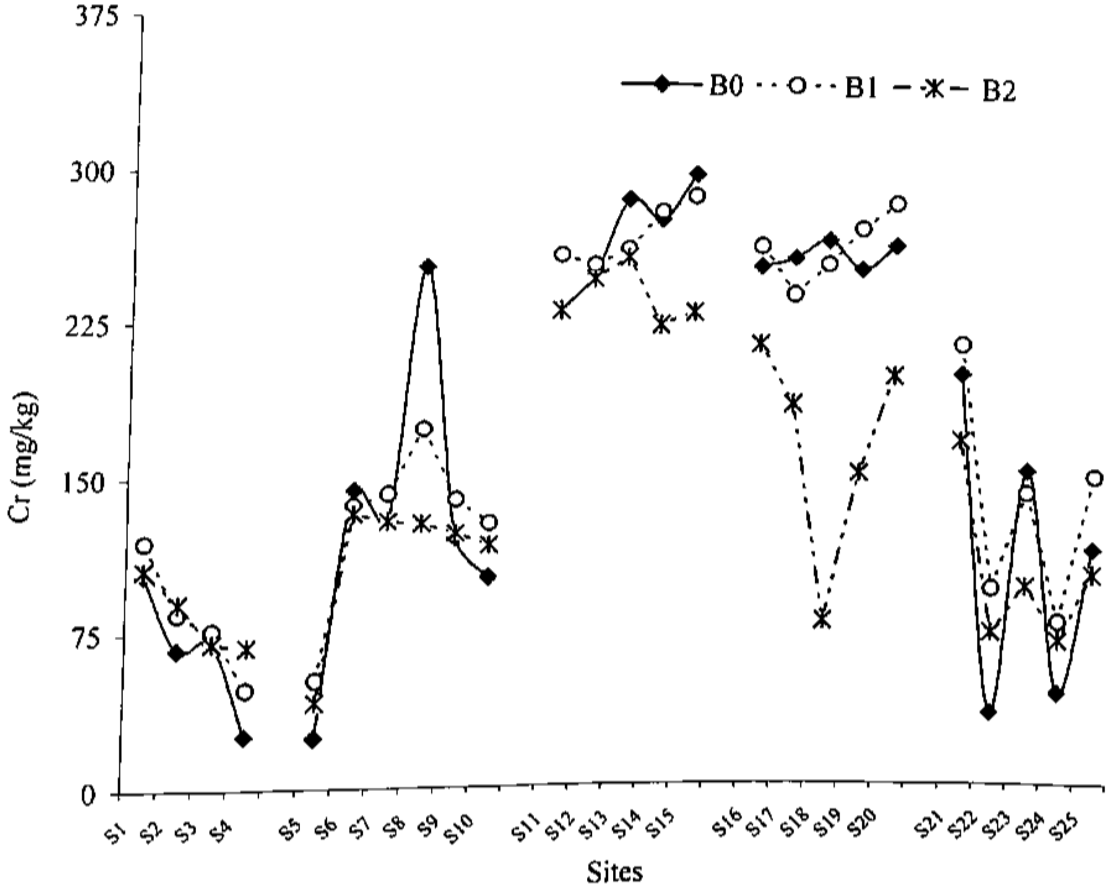
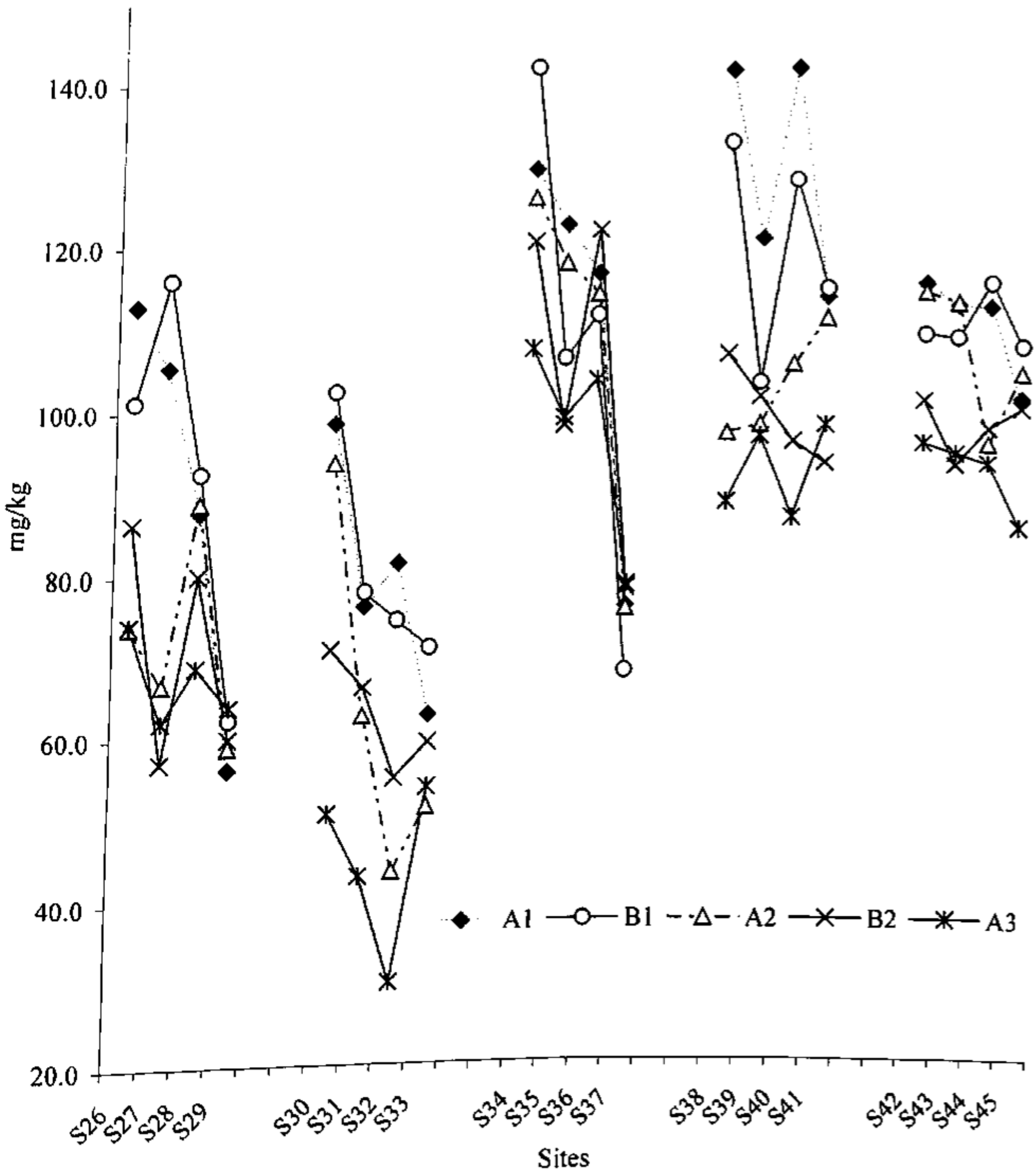
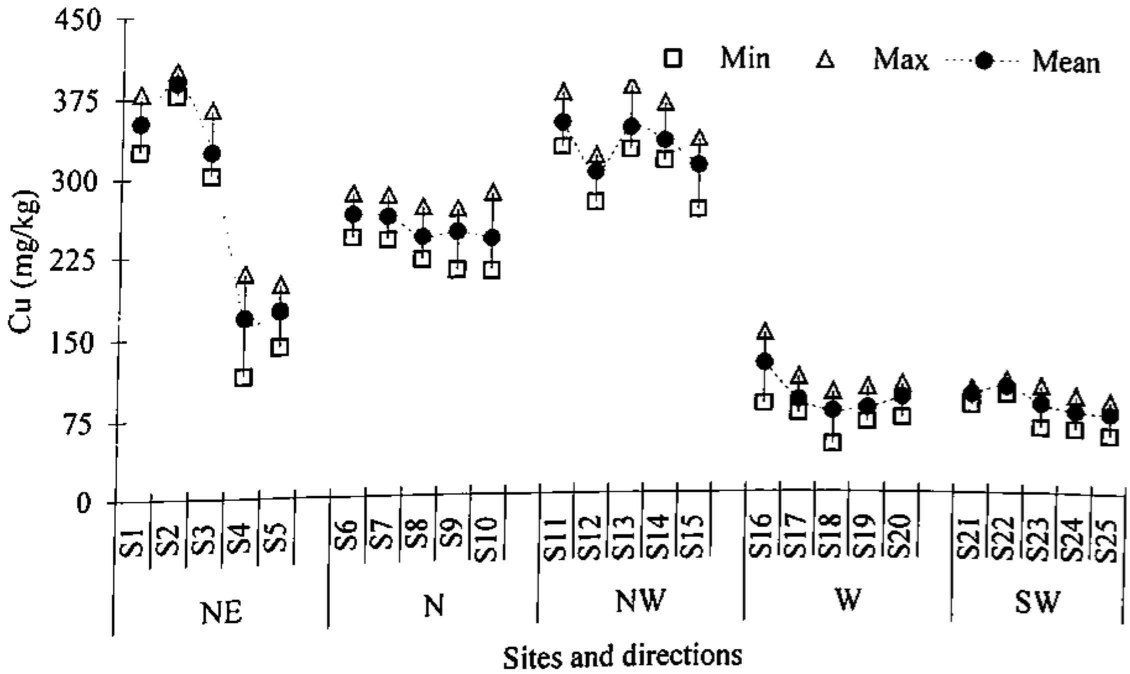
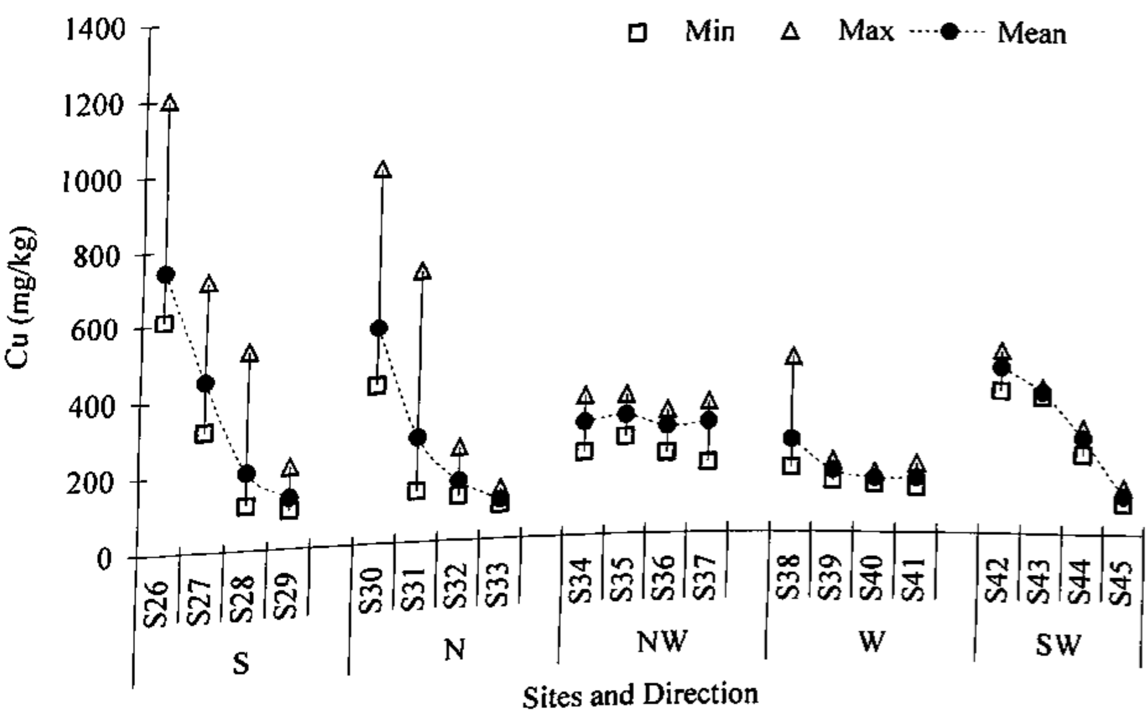


Fig. 3.17 (a). Variation pattern of total Cr-content in Side A with respect to the sampling seasons and sampling sites.

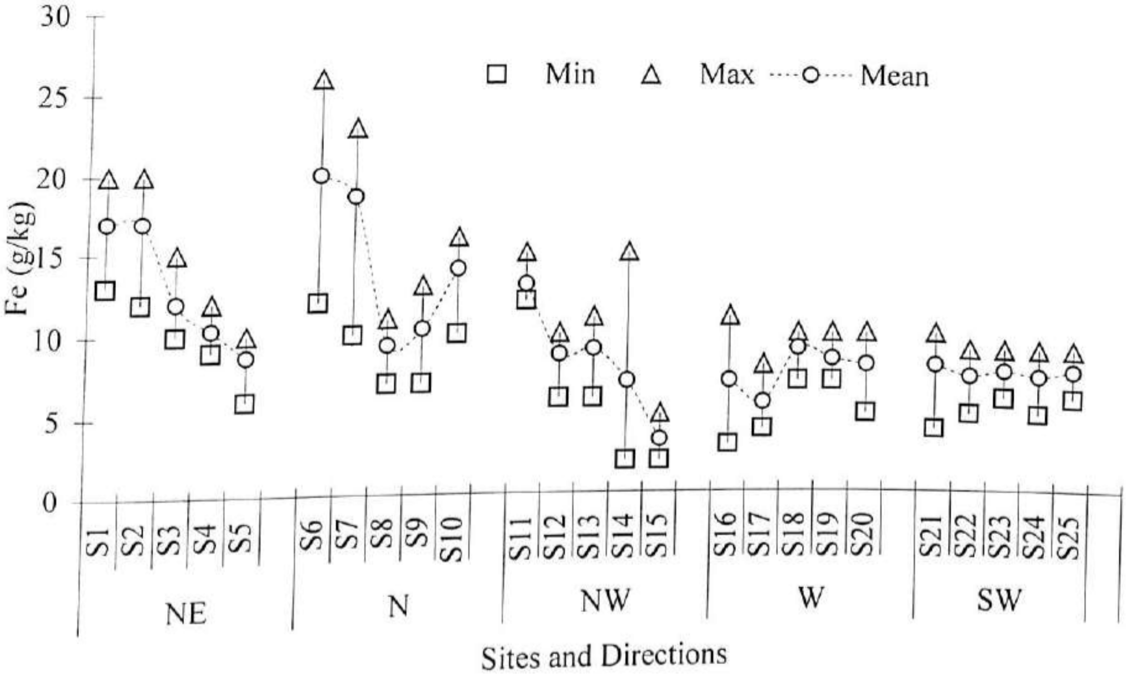


ig. 3.17 (b). Variation pattern of total Cr-content in Side B with respect to the sampling
easons and sampling sites.





'ig. 3.18. Variation pattern of minimum, maximum and mean Cu-content in the soil for Side \ (top) and Side B (bottom) with respect to the sampling sites and sampling direction.



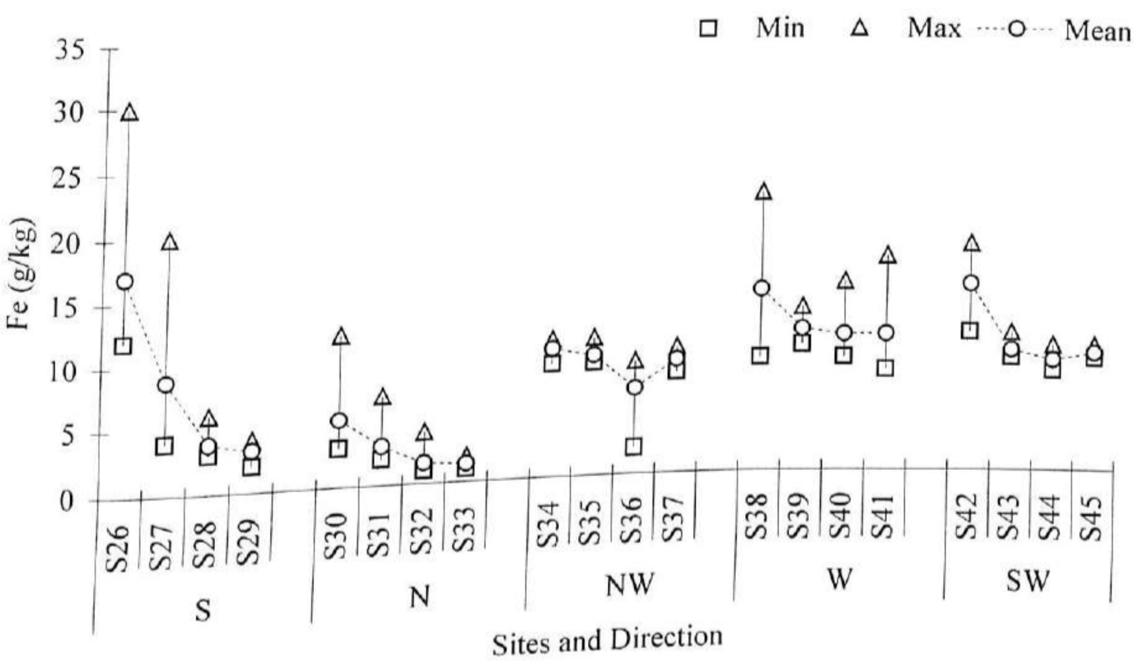


Fig. 3.19. Variation pattern of minimum, maximum and mean Fe-content in the soil for Side A (top) and Side B (bottom) with respect to the sampling sites and sampling direction.

Although the soil was found to have considerable amount of Mn in all the sites in all directions from the Mill, yet the values are less than the world average for Mn-content of soil. The average contents of Mn in the soil are shown in a bar graph (Fig. 3.20) for both the sides. The soil is also appreciably rich in Ni-content and the variation of the average values with distance is presented in Fig. 3.21.

The soil near the Textile Mill has been receiving a significant contribution of Pb from the Mill wastes and this can be seen from the considerable Pb-content of the soil – which are more than the world average. The variation of the Pb-content with distance from the Mill in different directions and in different seasons is shown in Fig. 3.22. The largest values are generally observed close to the Mill indicating definite input from the Mill activities. It is also to be noted that Pb-content had very similar but large values at the first few sites on both Side A and Side B – a clear indication that Pb accumulates close to the Mill as well as close to the earthen bandh away from the Mill. Topography of the area might have led to such preferential accumulation as was also observed in case of Cd and Cu.

The trends in variation of the Zn content of the soil in Side A and Side B are shown in Fig. 3.23. It is seen that with one or two exceptions, the Zn-content decreased away from the Mill. As is found in case of a few other trace metals, Zn also shows much more enrichment in Side B than in Side A.

All the results of trace metal estimation can be summarized by the general trend of enrichment of the soil either in Side A or in Side B, indicating a substantial input from the Mill effluent and other wastes being dumped into the area. Several metals can be found in much more amount in Side B than in Side A which may be attributed to soil conditions, topography, flow of the effluent, etc.

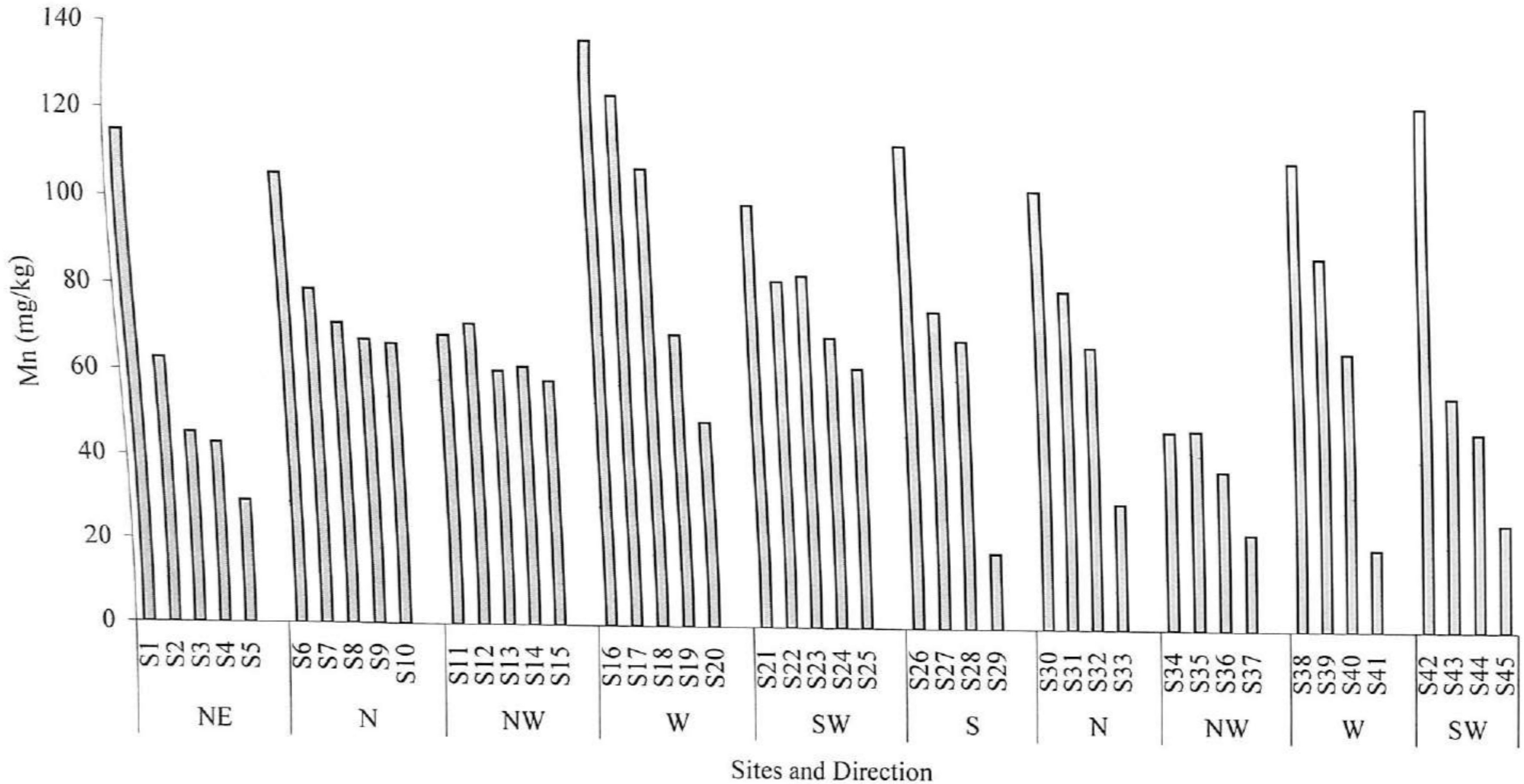


Fig. 3.20 Variation pattern of mean Mn-content in the soil of the study area for Side A (S1 to S25) and Side B (S26 to S45) with respect to the sampling sites and directions.

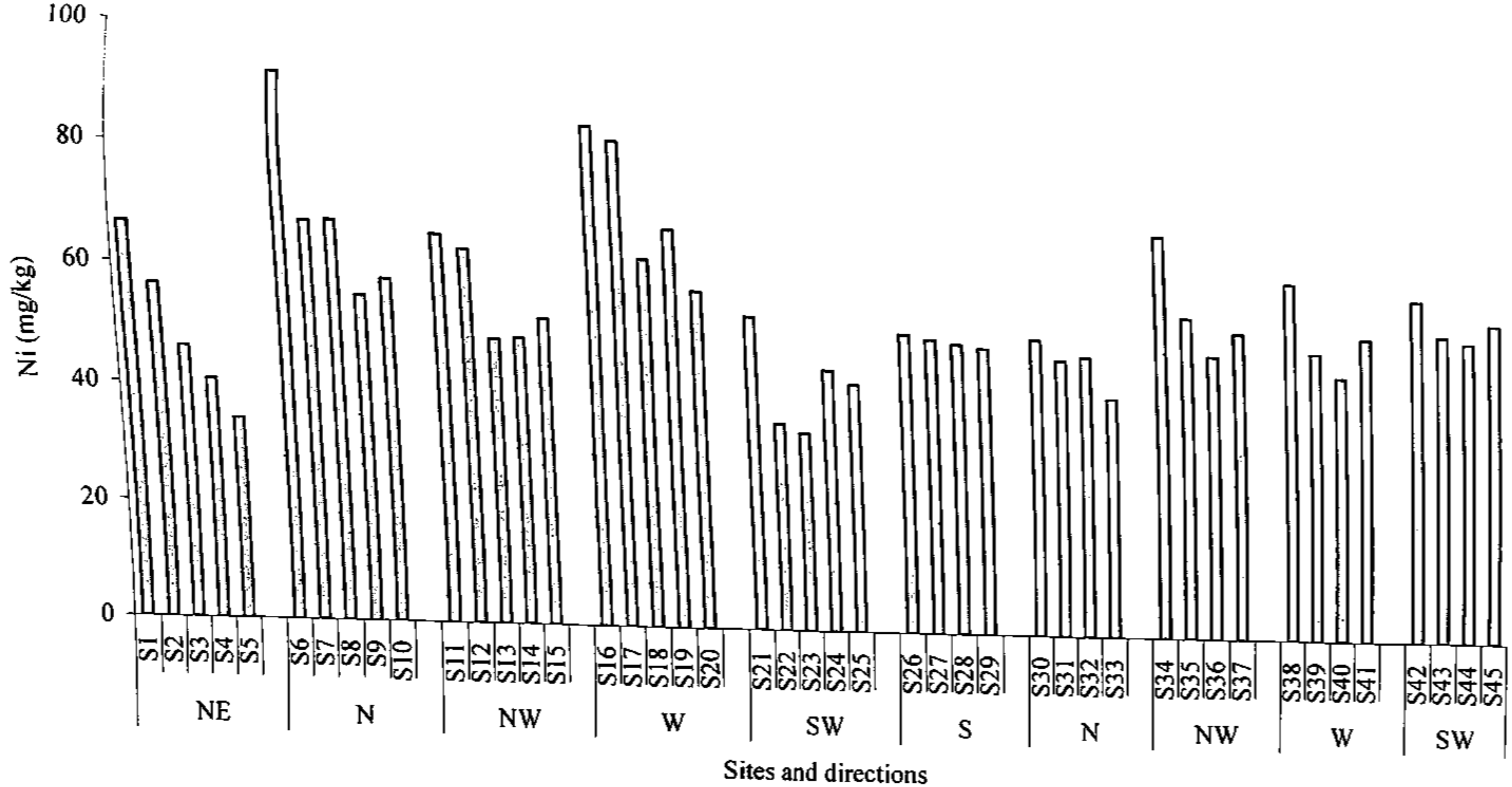
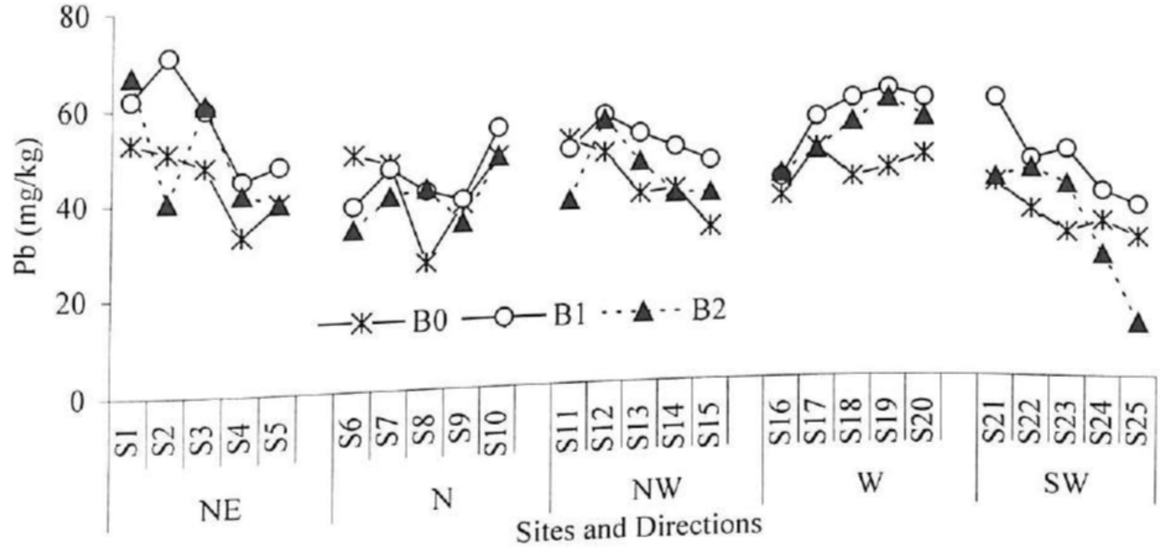


Fig. 3.21. Variation pattern of mean Ni-content in the soil of the study area for Side A (S1 to S25) and Side B (S26 to S45) with respect to the sampling sites and directions.



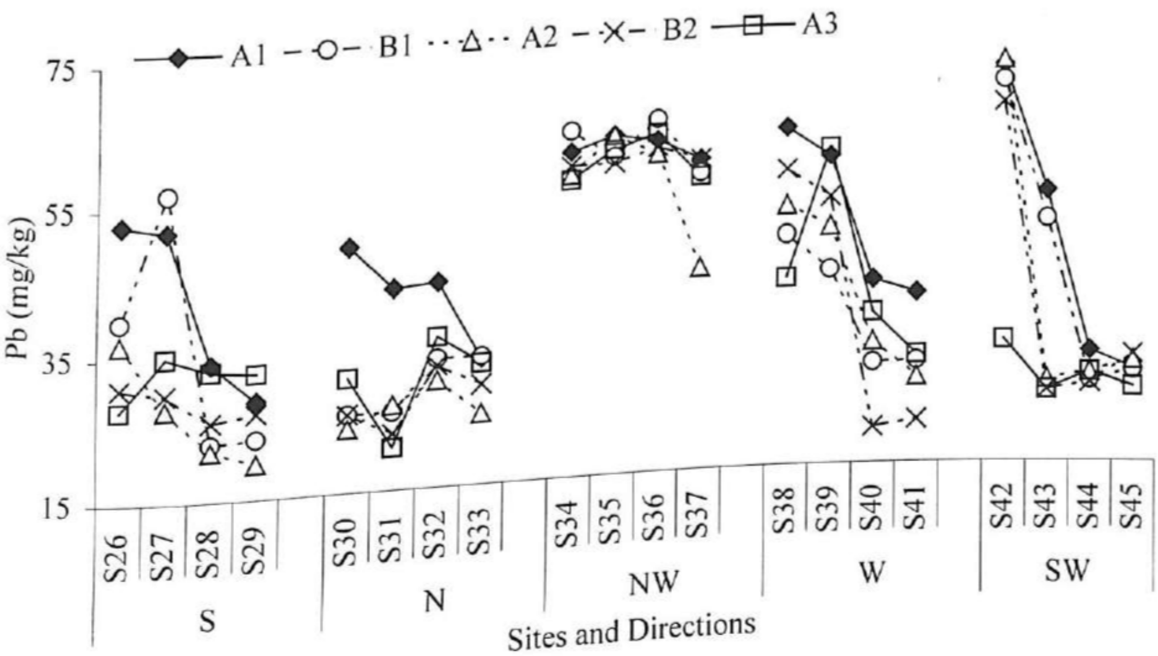


Fig. 3.22. Pb-content of the soil in Side A (top) and Side B (bottom) with respect to sampling sites and sampling seasons.

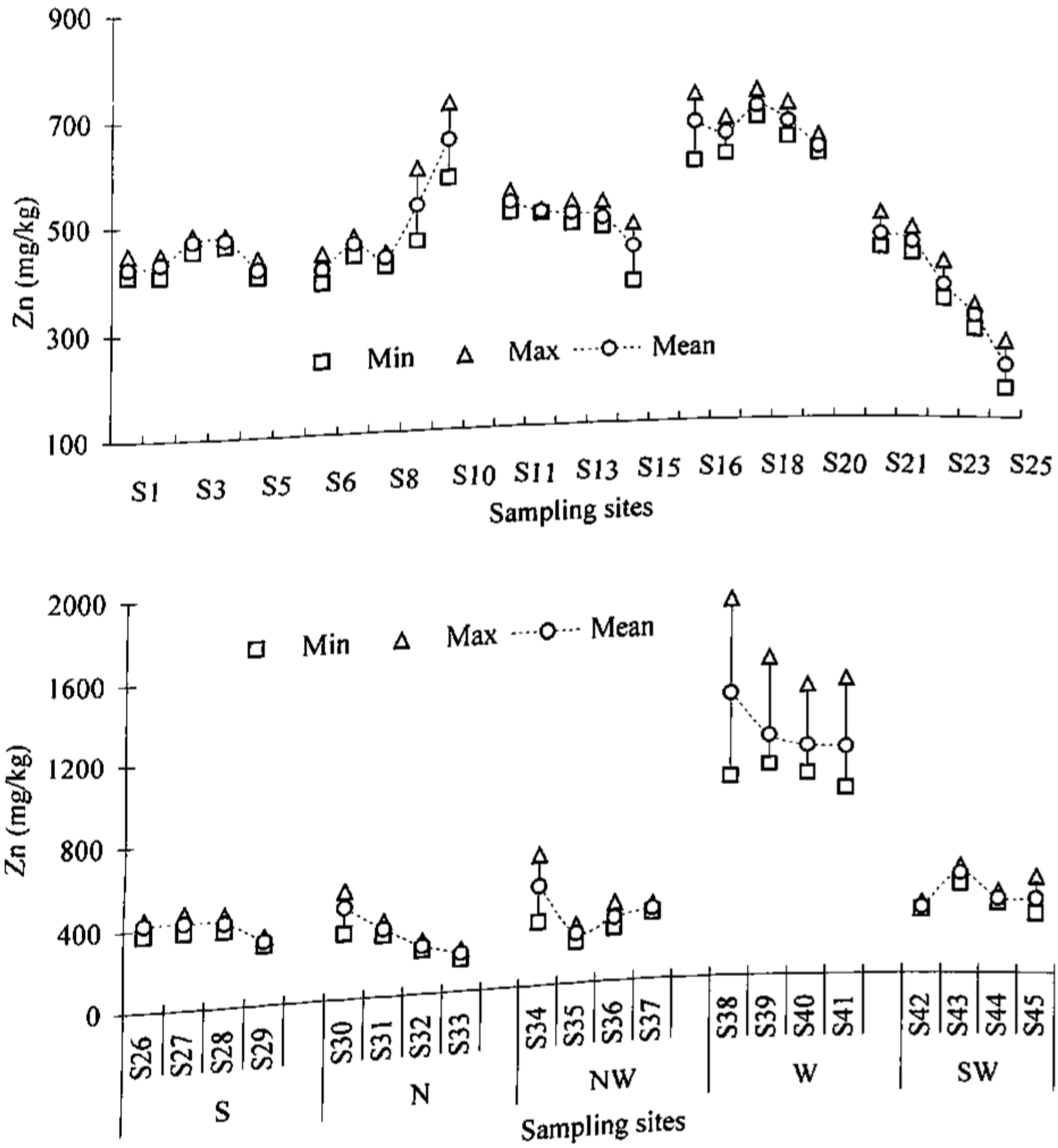


Fig. 3.23. Zn-content of the soil in Side A (top) and Side B (bottom) with respect to sampling sites and sampling seasons.

3.2 Drinking water quality

Altogether 7 drinking water samples from various sources around the textile mill were analyzed in this work for various water quality parameters. For comparison, the same parameters were determined with respect to a Control water sample collected from an unimpacted zone. Water samples were collected in five seasons over three years as shown below:

S/N	Name	Season
1	A1	2002 Post- monsoon
2	B1	2003 Pre-monsoon
3	A2	2003 Post- monsoon
4	B2	2004 Pre-monsoon
5	A3	2004 Post- monsoon

A parameter-wise discussion of the results is given below:

3.2.1 pH

The pH values of the drinking water samples are shown in Table 3.25. The values are in the following ranges:

- 6.1 to 7.9 for A1,
- 6.4 to 8.2 for B1,
- 6.6 to 8.2 for A2,
- 8.1 to 8.4 for B2, and
- 6.8 to 7.9 for A3.

It is seen that all the values are within the WHO permissible limits for drinking water. The pH had a tendency to increase during the summer, which is likely to be due to entry of runoff from the surrounding areas. In general, the water is neutral to slightly alkaline which is suitable for drinking purposes (Sikdar et.al. 1994). It is evident from the present study that pH values have not exceeded permissible limit according to (WHO) standards but depending only upon the pH value the quality of water cannot be judged (Garg, et al., 1990).

Table 3.25 also shows the minimum, the maximum and the mean values of pH for each of the sampling seasons and each of the water sources including a 'Control' sample collected from a no-impact zone. The corresponding standard deviations were also calculated and shown in the table with respect to both. How the minimum, the maximum and the mean values of pH change from one source to another is shown in Fig. 3.24. It is clear that the 'Control' sample had the lowest spread of pH (6.7 – 7.6) while the sample DW3 had the largest spread (6.1 – 8.4). It can be inferred that all the sources of drinking water had some influence from the Mill operations as far as pH was concerned. Excepting DW1 and DW6, all the other samples had mean pH more than that of the 'Control' sample. It further means that the effluents of the mill and other activities in the surroundings had a tendency to raise the pH of the drinking water samples.

3.2.2 Electrical Conductivity (EC)

The electrical conductivity values (Table 3.26) for all the samples were in the range of 0.13 – 0.64 mS/cm. When these values are compared to those of the 'Control' sample, it is seen that the conductivity of the water in the impact zone of the Mill was much more with one or two exceptions (Fig. 3.25). The results indicate entry of considerable load of dissolved salts into water. The values varied from season to season, and it was observed that the values were generally high during the season A2 and low during the season, B1. In general, most of the samples were found to have more electrical conductivity during the post-monsoon than in the pre-monsoon. The samples collected from the location, DW3, were found to be very rich in dissolved ionic matter.

3.2.3 Total Alkalinity

The total alkalinity values for all the seasons and for all the water samples are given in Table 3.27 along with those of the 'Control' one. The maximum alkalinity was recorded

Table 3.25. pH of the drinking water samples of the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	6.7	7.6	6.7	7.4	6.9	6.7	7.6	7.0	0.4
DW1	6.3	6.4	6.6	8.2	7.0	6.3	8.2	6.9	0.8
DW2	7.1	7.1	7.1	8.1	6.8	6.8	8.1	7.2	0.5
DW3	6.1	8.0	7.2	8.4	7.9	6.1	8.4	7.5	0.9
DW4	6.5	8.2	6.6	8.3	7.9	6.5	8.3	7.5	0.9
DW5	6.7	8.1	6.8	8.4	7.6	6.7	8.4	7.5	0.7
DW6	6.4	7.1	6.6	8.1	6.9	6.4	8.1	7.0	0.6
DW7	7.9	8.2	8.2	8.3	6.8	6.8	8.3	7.9	0.6
Min	6.1	6.4	6.6	8.1	6.8				
Max	7.9	8.2	8.2	8.4	7.9				
Mean	6.7	7.6	6.9	8.2	7.3				
SD	0.6	0.7	0.5	0.3	0.5				

Table 3.26. Electrical conductivities (mS/cm) of the water from the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	0.21	0.21	0.19	0.16	0.20	0.16	0.21	0.19	0.02
DW1	0.38	0.29	0.33	0.32	0.33	0.29	0.38	0.33	0.03
DW2	0.38	0.24	0.16	0.17	0.24	0.16	0.38	0.24	0.09
DW3	0.64	0.34	0.42	0.37	0.24	0.24	0.64	0.40	0.15
DW4	0.51	0.49	0.40	0.22	0.19	0.19	0.51	0.36	0.15
DW5	0.50	0.49	0.33	0.29	0.19	0.19	0.50	0.36	0.13
DW6	0.25	0.26	0.21	0.27	0.27	0.21	0.27	0.25	0.02
DW7	0.27	0.13	0.26	0.19	0.21	0.13	0.27	0.21	0.06
Min	0.25	0.13	0.16	0.17	0.19				
Max	0.64	0.49	0.42	0.37	0.33				
Mean	0.42	0.32	0.30	0.26	0. 24				
SD	0.15	0.13	0.10	0.08	0.05				

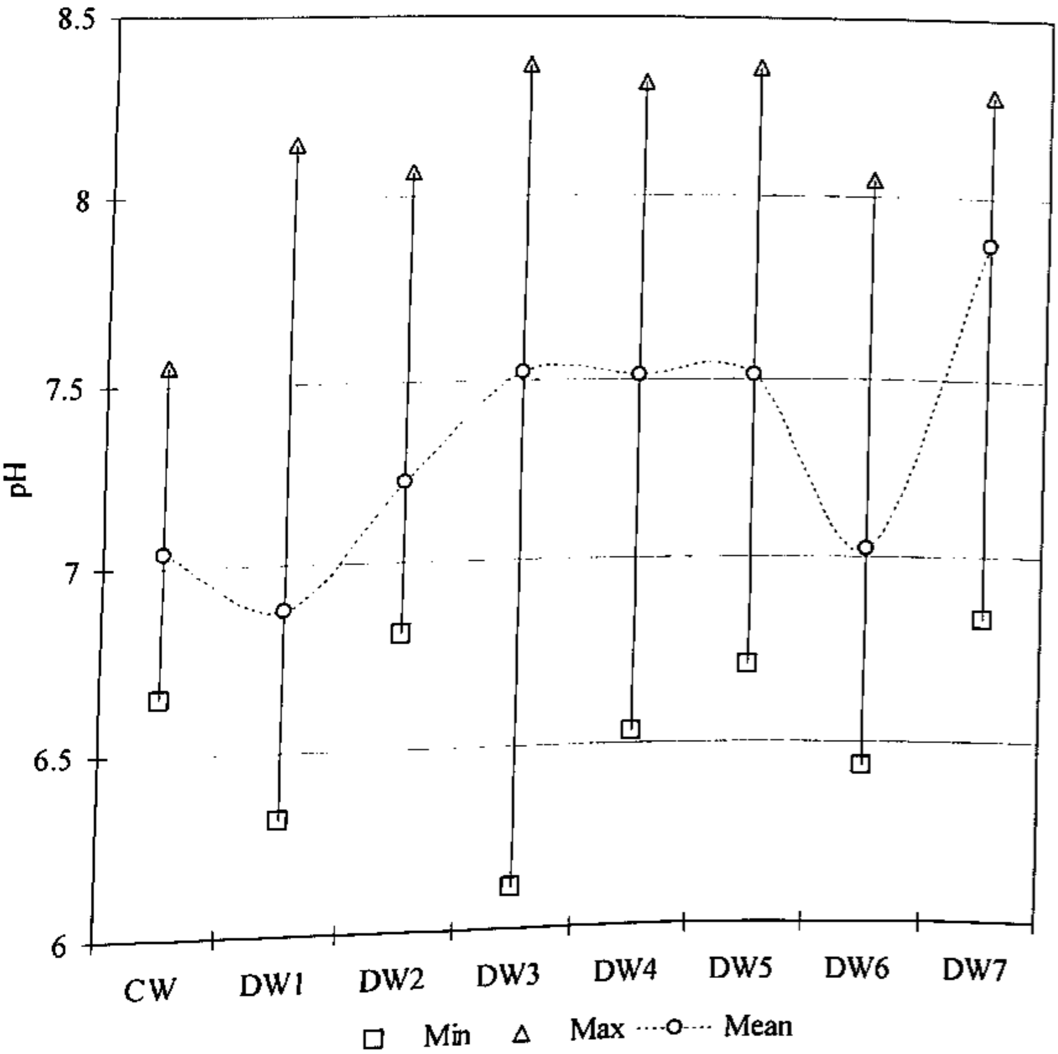


Fig. 3.24. Nature of variation of pH with respect to the minimum, maximum and mean values of the seven drinking water samples from the study area as compared to that of the 'Control' sample (CW)

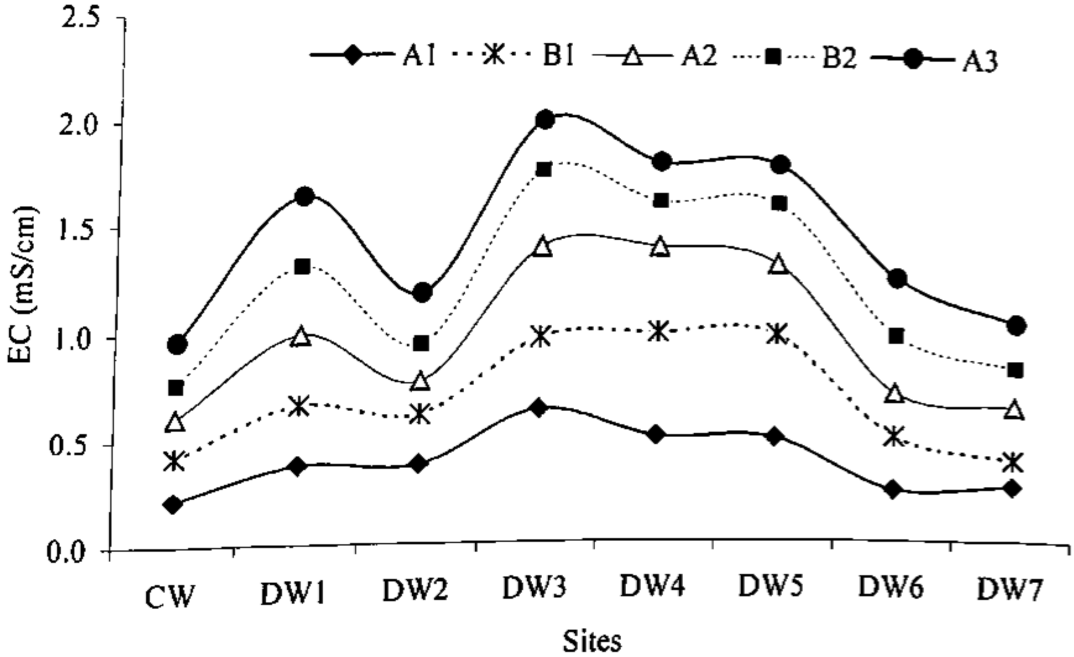


Fig. 3.25. Seasonal variation of mean Electrical conductivity for the seven drinking water samples from the study area as compared to that of the 'Control' sample (CW)

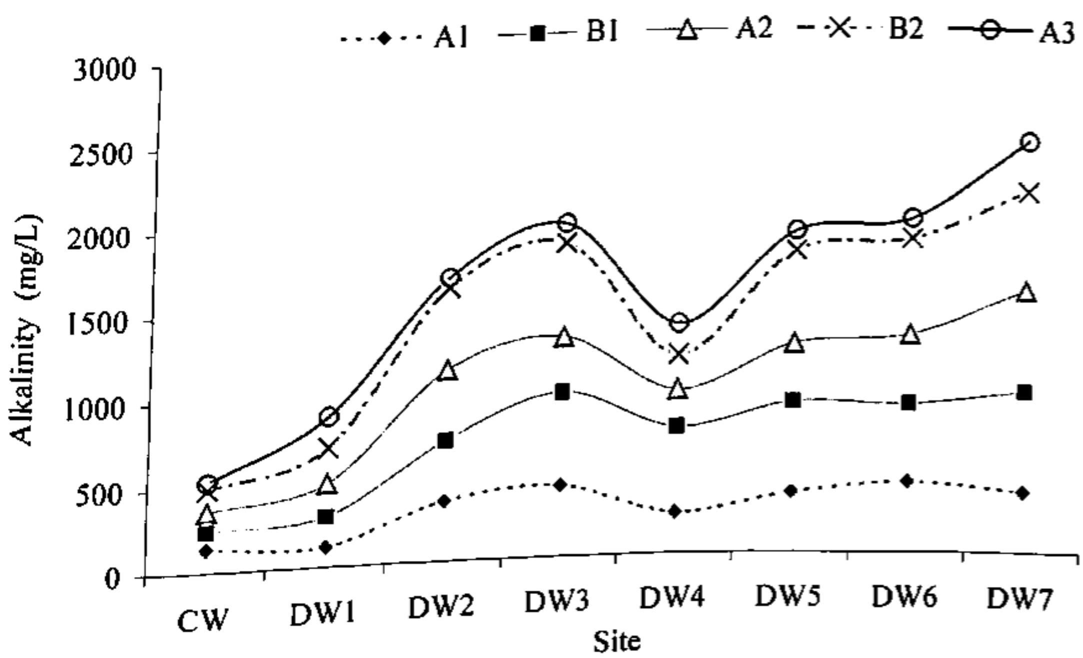


Fig. 3.26. Seasonal variation of mean Total Alkalinity for the seven drinking water samples from the study area as compared to that of the 'Control' sample (CW)

Table 3.27. Total Alkalinity (mg $CaCO_3$/L) of the drinking water samples

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	140	105	115	130	43	43	140	107	38
DW1	120	183	197	209	183	120	209	178	34
DW2	362	358	412	482	61	61	482	335	161
DW3	427	549	326	563	122	122	563	397	182
DW4	246	509	222	203	183	183	509	273	134
DW5	362	538	342	560	122	122	560	385	177
DW6	427	465	405	580	122	122	580	400	169
DW7	370	594	593	603	305	305	603	493	144
Min	120	183	197	203	61				
Max	427	594	593	603	305				
Mean	300	408	340	414	151				
SD	123	181	150	199	82				

Table 3.28. Total Dissolved Solids (mg/L) of the drinking water from the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	154	178	142	150	163	142	178	157	14
DW1	168	179	176	289	376	168	376	238	92
DW2	365	416	386	641	495	365	641	461	112
DW3	789	848	402	542	438	402	848	604	204
DW4	845	920	236	465	258	236	920	545	322
DW5	368	432	189	378	408	189	432	355	96
DW6	196	984	150	468	370	150	984	434	334
DW7	452	902	638	714	525	452	902	646	175
Min	168	179	638	714	495				
Max	845	984	150	289	258				
Mean	455	669	311	500	410				
SD	269	342	173	184	120				

at DW7 (603 mg/L) in the season, B2 and minimum at DW2 (61 mg/L) in the season, A3 (Fig. 3.26). In most of the cases, the values increase from the first post-monsoon to the pre-monsoon season and then decreases. For all the sites, the minimum values are recorded in the season, A3, which indicates that the ground water samples are affected by surface water, which percolates into it. For each season, the "Control" value is less than the values observed for the study area. Some samples have recorded alkalinity values almost in the higher range of permissible limit. This shows that continuous discharge of effluents by the mill may raise the total alkalinity of the water in the area above the permissible limit. Higher amount of alkalinity imparts bitter taste to drinking water although the same may not be harmful to human beings (Trivedy and Goel, 1986; Singh et.al., 1999).

3.2.4 Total Dissolved Solids (TDS)

The TDS of water is probably the most used criterion of its quality (Rani et al. 2006). In the study area, almost all the samples have TDS content (Range 150– 984 mg/L) within permissible limit (WHO 1000 mg/L). In terms of dissolved solids, DW1 had the least content for all the seasons (Table 3.28). The TDS content was more in the first pre-monsoon (B1) season than the previous post-monsoon season (Fig. 3.27). The mean value was also found to be the maximum in the first pre-monsoon season (B1) and minimum in the next season. The sample DW2 (tube well) showed lower variations compared to other sources.

The TDS contributes to the content of the ionic matter present in water and its impact on human health depends on its exact chemical composition. Several of the constituents of the dissolved solids may have properties requiring special attention. A few of the important constituents of TDS, which need special attention, include alkalinity, hardness, fluoride, metals, organics and nutrients (Peavy et. al., 1987).

3.2.5 Total Solids (TS)

The values of total solids for all the samples with maximum, minimum, mean and standard deviation with respect to all the seasons are given in Table 3.29. In the present study, substantial amounts of solids were found for DW3 (Range 584 – 1218 mg/L) and

DW4 (Range 339 – 1388 mg/L), but the highest value was obtained at DW6 (1464 mg/L) in the season, B1 amongst all the samples. In case of TS, distinct seasonal variation was observed. The pre-monsoon values are more than those of the previous post-monsoon season. Subsequently in the next post-monsoon season, the TS is less than those for the pre-monsoon season. This is because of the pre-monsoon shower bringing in more solids of different forms enhancing the total solid content of water. The Control samples have less total solids than the water samples of the study area for all the seasons.

Water with high solids (TS, TDS and TSS) contents were of inferior palatability and may induce an unfavourable physiological reaction in the transient consumer (Sahu and Behra, 1995)

The total suspended solids (TSS) can be obtained by simply subtracting the TDS values from the corresponding TS values. The relationship between TDS, TSS and TS with respect to their mean values is shown in Fig. 3.28. This shows that the drinking water samples from the study area have different solid loads.

3.2.6. Total Hardness

The results of total hardness for all the seasons and for all the samples are given in Table 3.30. The results indicate that all the drinking water samples could not be considered as 'hard'. The range of values is 30 – 190 mg/L that is above the standard limit of 100 mg/L(WHO,1984). The values were comparatively higher in the water samples collected during the post-monsoon season. Because there is no rainfall at this time, and the water volume decreases, the conditions lead to accumulation of the contaminants. The hardness has no known adverse effects on human health but Keller (1979) observed a correlation between hardness of water and its role in heart and kidney problem. Similar observations have also been made by Park and Park (1986).

3.2.7. Phenol

Phenol is used as a slimicide (a chemical that kills bacteria and fungi found in watery slimes), as a disinfectant, and in medical products. The presence of phenol in water can cause serious problems because mutagens may be formed during disinfection by chlorination (Onodera et. al. 1998). The US Environmental Protection Agency (US EPA) has decided that water (lakes, streams) should not contain more than 0.3 mg

Table 3.29. Total Solids (mg/L) of the drinking water from the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	176	214	162	170	195	162	214	183	21
DW1	202	219	214	374	512	202	512	304	136
DW2	533	689	558	951	749	533	951	696	168
DW3	1150	1218	584	758	618	584	1218	866	299
DW4	1263	1388	339	640	355	339	1388	797	499
DW5	522	662	273	490	624	273	662	514	152
DW6	258	1464	199	632	522	199	1464	615	508
DW7	737	1320	963	1094	817	737	1320	986	231
Min	202	219	214	374	817	202	817	365	262
Max	1263	1464	963	1094	355				
Mean	666	994	447	706	600				
SD	419	517	274	300	203				

Table 3.30. Total Hardness (mg/L) of the drinking water from the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	20	20	30	30	60	20	60	32	16
DW1	50	30	50	30	104	30	104	53	30
DW2	90	70	80	50	100	50	100	78	19
DW3	190	100	172	60	60	60	190	116	62
DW4	50	40	36	30	128	30	128	57	40
DW5	100	70	80	40	64	40	100	71	22
DW6	40	30	32	20	52	20	52	35	12
DW7	90	80	84	30	80	30	90	73	24
Min	40	30	32	30	52				
Max	190	100	172	60	128				
Mean	87	60	76	37	84				
SD	53	29	47	13	27				

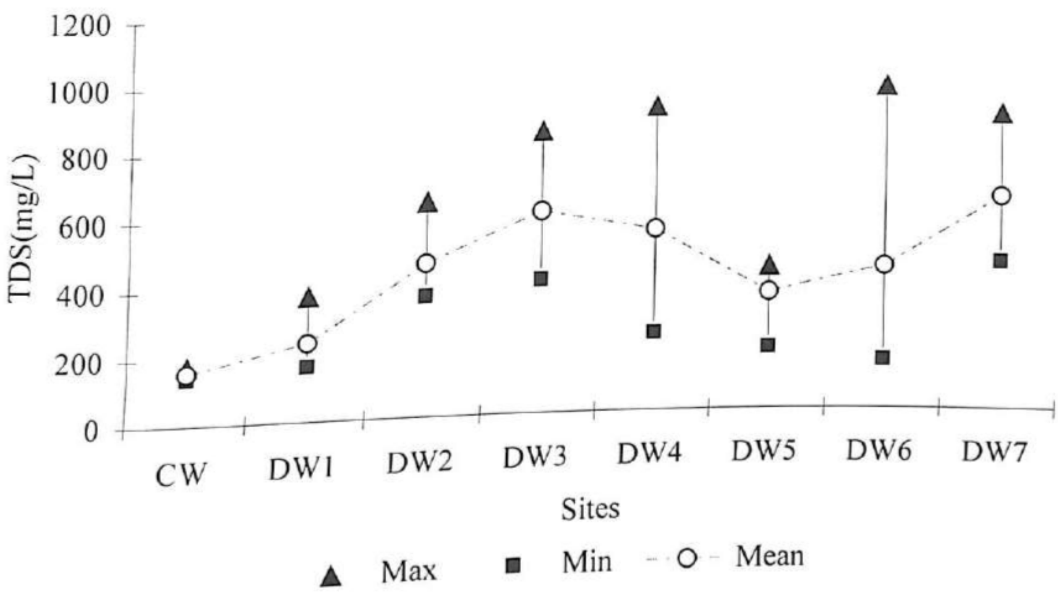


Fig. 3.27. Variation of the minimum, the maximum and the mean values of TDS in the drinking water samples of the study area.

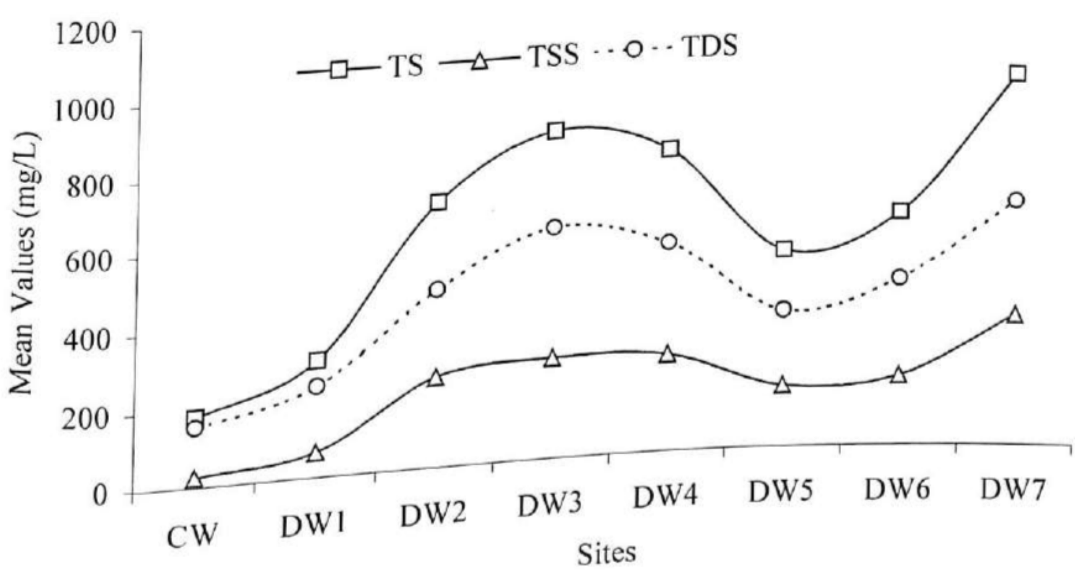


Fig. 3.28. Variation of the mean values of TDS, TSS and TS in the drinking water samples of the study area.

phenol per liter to protect human health from the possible harmful effects of exposure to phenol (Source: Toxicological Profile, 1989). In the present study, some of the drinking water samples did contain phenol as shown in Table 3.31. Among the seven drinking water samples, three samples (DW5, DW6 and DW7) did not have detectable amount of phenol in all the seasons. The "Control" sample was also free from phenol. The other four samples had phenol in the range of 0.08 – 0.61 mg/L, which are much above the EPA permissible limit. The people have used these water sources for a long time. It is likely that the use of various disinfectants by the local people and also the use of aromatic phenolic compounds in the Mill might be responsible for enhancing the presence of phenol in the four drinking water sources.

The variation of the phenol content with season for the four water samples, whose water was contaminated with phenol, is shown in Fig. 3.29. The sample, DW1, had high phenol in all the seasons, but the other samples showed some variations.

3.2.8 Chloride (Cl^-)

The chloride content of the drinking water samples is given in Table 3.32. The values range from 14.2 to 85.2 mg/L. In the present investigation, the chloride content of water samples was within the ISI standard value of 250 mg/L (Rani et al., 2006). The minimum value was obtained at DW3 in first post-monsoon (A1) season and the maximum for DW4 in second pre-monsoon season (B2). Seasonal variation was not observed. Low Cl^- content indicates that the drinking water sources are not contaminated by domestic sewage and human and animal excreta. When Cl^- is present at concentration above 250 mg/L, it imparts an unpalatable taste to waters although no adverse effects have been observed on human beings regularly consuming water with much higher concentration of chloride (Vermani and Narula, 1995).

The seasonal variation of the chloride content of the drinking water sources is shown in Fig. 3.30.

Table 3.31 Phenol (mg/L) in the drinking water samples of the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
DW1	0.61	0.60	0.57	0.60	0.53	0.53	0.61	0.58	0.03
DW2	0.37	0.30	0.24	0.15	0.08	0.08	0.37	0.23	0.12
DW3	0.38	0.32	0.26	0.30	0.30	0.26	0.38	0.31	0.04
DW4	0.38	0.31	0.26	0.20	0.17	0.17	0.38	0.26	0.08
DW5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
DW6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
DW7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Min	0.37	0.30	0.24	0.20	0.08				
Max	0.61	0.60	0.57	0.60	0.53				
Mean	0.44	0.38	0.33	0.30	0.27				
SD	0.12	0.15	0.16	0.20	0.20				

Table 3.32 Cl (mg/L) of the drinking water from the study area

Site	Sampling season					Min	Max	Mean	SD
	A1	B1	A2	B2	A3				
CW	13.9	5.2	14.2	3.5	14.2	3.5	14.2	10.2	5.4
DW1	30.2	26.5	28.4	17.8	24.6	17.8	30.2	25.5	4.8
DW2	42.9	42.6	24.9	21.5	21.5	21.5	42.9	30.7	11.1
DW3	86.4	85.2	40.5	21.3	35.5	21.3	86.4	53.8	30.1
DW4	56.2	56.8	36.6	14.2	20.7	14.2	56.8	36.9	19.7
DW5	43.4	42.6	37.2	24.9	29.7	24.9	43.4	35.6	8.1
DW6	69.1	63.9	42.6	35.8	35.8	35.8	69.1	49.4	15.9
DW7	80.2	78.1	41.2	21.3	23.9	21.3	80.2	48.9	28.6
Min	30.2	26.5	24.8	14.2	20.7				
Max	80.2	85.2	42.6	35.8	35.8				
Mean	58.3	56.5	36.0	22.4	27.4				
SD	25.0	26.6	9.9	9.2	7.5				