HEAVY METAL ACCUMULTION IN LEAF TISSUE

Heavy metals are conventionally defined as elements with metallic properties viz. conductivity, ductility, stability as cations, ligand specificity, etc. and atomic number greater than 20 (Weast, 1984).

Heavy metals are highly toxic for plants and their uptake and accumulation by plant tissues cause various morphological, physiological and biochemical responses (Sharma *et. al.,* 2009). According to Cho *et. al.,* (2003) the effect of air containing hazardous matter varies with chimney height, climatic factors, topographic layout, and wind direction and speed. Heavy metal toxicity has an inhibitory effect on plant growth, enzymatic activity, stomatal function, photosynthetic activity, and accumulation of other nutrient elements and also damages the root system (Gune, A. *et. al*., 2004).

Botanical materials such as fungi, lichens, tree bark, tree rings, grasses, leaves of higher plants and soil samples have been used to detect the deposition, accumulation and distribution of metal pollution (Celik, A. *et. al.,* 2005). Because of the different characteristics of foliar uptake, accumulation and translocation of atmospheric heavy metals by leaves, plant leaves are used as bio-indicators and/abominators of heavy metal pollution in the terrestrial environment (Celik *et. al*., 2005).

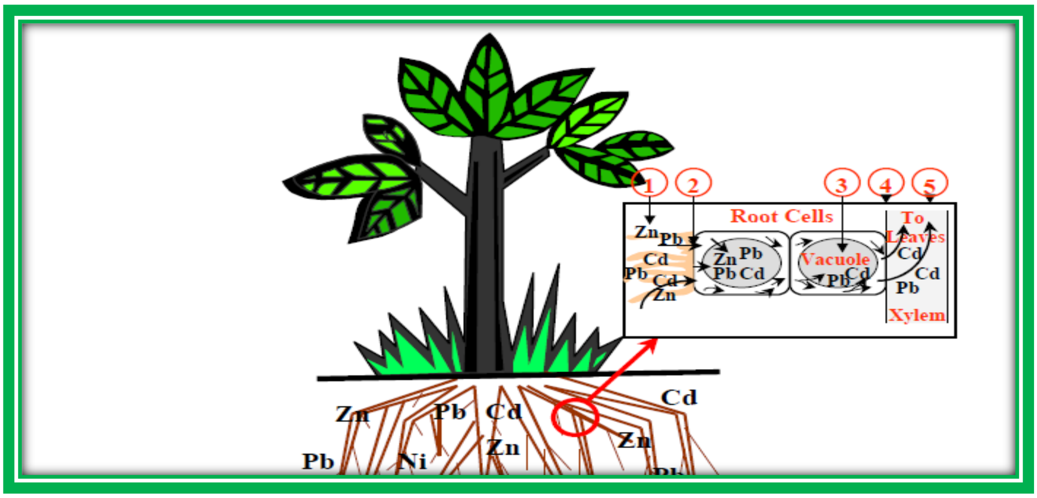

Figure. Metal uptake and accumulation in plant tissues.

Winter Sampling Season

Results:

Table 6.1: Showing lead (Pb) accumulation of leaves in studied plants growing at control vs. Pithampur Industrial area.

Lead accumulation (in µg/gm of dry weight of leaves) of studied plant spp.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.24±0.01	30.08±1.67	29.72±1.14	31.12±1.82
2	*Buteamonosperma*	1.17±0.02	22.22±1.14	21.66±1.66	28.48±0.97
3	*Calotropis gigantea*	1.03±0.01	21.30±2.26	21.24±2.26	22.37±1.40
4	*Cordia mixa*	1.16±0.02	19.93±1.76	19.91±1.76	24.78±1.01
5	*Dalbergia sissoo*	2.22±0.01	29.58±1.06	29.83±1.15	30.09±1.81
6	*Euginia Jambolana*	1.21±0.01	30.35±1.67	29.55±1.08	30.10±1.82
7	*Eucalyptus sp.*	1.15±0.02	27.75±1.52	24.93±1.46	27.77±1.52
8	*Ficus benghalensis*	1.14±0.02	24.18±2.08	23.42±0.96	26.06±1.47
9	*Ficus religiosa*	1.13±0.01	23.44±0.96	20.62±2.33	24.99±1.48
10	*Ficus glomarata*	1.12±0.01	20.66±2.34	21.29±2.26	24.57±2.02
11	*Mangifera indica*	1.20±0.01	32.52±1.06	29.62±1.70	30.11±1.80
12	*Nerium indicum*	1.18±0.02	29.52±1.06	29.49±1.06	30.08±1.83
13	*Pisidium guvajava*	1.11±0.01	21.26±2.25	21.21±2.26	24.30±1.37
14	*Pongamia pinnata*	1.10±0.01	28.13±1.48	28.11±2.89	29.60±1.07
15	*Tectona grandis*	1.09±0.02	27.75±1.52	27.07±1.47	30.37±1.67
16	*Terminalia catappa*	1.08±0.02	26.02±1.49	25.34±0.98	29.54±1.08

In the present findings lead content (Pb µg/g/ dw) accumulation of leaves of studied plants growing in control vs. Pithampur industrial areasector-1, 2 & 3 in winter sampling seasons. Lead content (Pb, µg/g/ dw) accumulation in leaves ranged between 1.03 ± 0.01 to 2.24 ± 0.01 in control samples and 31.12 ± 1.82 to 19.91± 1.76 in polluted sites respectively (Table 6.1).

In winter season higher lead (Pb, µg/g/ dw) accumulation was noted in leaves of different plant species growing at sector-1.

*M. indica (*32.52±1.06) < *E.jambolana (*30.35±1.67) < *A.indica (*30.08±1.67) < *D. sissoo (*29.58±1.06) < N. *indicum (*29.52±1.15) < *P. pinnata (*28.13±1.48) *Eucalyptus sp.* and *T. grandis* (27.75±1.52) < *T.catappa (*26.02±1.49).

Lower lead (Pb, µg/g/ dw) accumulation was occurred in leaves of plants growing in pithampur industrial area at sector-1

*F. benghalensis(*24.18±2.08) <*F.religiosa(*23.44±0.96) < *F. glomarata (*20.66±2.34), *B.monosperma (*22.22±1.14) < *C. gigantea (*21.30±2.26) < *C. mixa* (19.93±1.76).

Higher lead (Pb, µg/g/ dW) accumulation was found in leaves of plants growing at sector- 2

*D. sissoo (*29.83±1.06) < *A. indica (*29.72±1.14) < *M. indica (*29.62±1.70) < *E.jambolana (*29.55±1.08) < N. *indicum (*29.49±1.06) <*P.pinnata (*28.11±2.89) < *T.grandis (*27.07±1.47) <*T.catappa (*25.34±0.98).

Lower lead (Pb, µg/g/dw) accumulation was occurred in leaves of plants growing in at sector-2

*Eucalyptus sp. (*24.93±1.46) < *F. benghalensis (*23.42±0.96) < *B. monosperma (*21.66±1.66) < *F. glomarata (*21.29±2.26) < *C.gigantea (*21.24±2.26) <*P.guvajava (*21.21±2.26)<*F. religiosa(*20.62±2.33) < *C. mixa (*19.91±1.76)

Higher lead (Pb, µg/g/ dw) accumulation was noted in leaves of plants growing at sector-3

*A. indica (*31.12±1.82) <*T. grandis (*30.37±1.67) < *M. indica (*30.11±1.80) < *D. sissoo (*30.09±1.81) < N. *indicum (*30.08±1.83) < *P. pinnata (*29.60±1.07) < *T.catappa (*29.54±1.08) < *B.monosperma (*28.48±0.97) < *Eucalyptus sp. (*27.77±1.52) < *F. benghalensis (*26.06±1.47).

Lower lead (Pb, µg/g/ dw) accumulation was occurred in leaves of growing at sector-3

*F. religiosa (*24.99±1.48) < *C. mixa (*24.78±1.01) < *F. glomarata (*24.57±2.02) < *P.guvajava (*24.30±1.37) < *C. gigantea (* 22.37±1.40)

Table 6. 2 : Showing cadmium accumulation of leaves in studied plants growing at control vs. Pithampur Industrial area-1, 2 & 3.

Cadmium accumulation (in µg/gm of dry weight of leaves) of studied plant spp.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	0.56±0.01	1.38±0.02	1.39±0.01	1.41±1.35
2.	*Buteamonosperma*	0.32±0.02	0.92±0.06	0.87±0.06	1.28±0.04
3	*Calotropis gigantea*	0.27±0.02	0.86±0.06	0.83±0.06	0.91±0.06
4	*Cordia mixa*	0.31±0.02	0.75±0.08	0.74±0.08	1.09±0.05
5	*Dalbergia sissoo*	0.37±0.02	1.33±0.04	1.38±0.01	1.40±0.145
6	*Euginia Jambolana*	0.39±0.01	1.36±0.04	1.32±0.04	1.42±1.40
7	*Eucalyptus sp.*	0.30±0.02	1.24±0.04	1.17±0.05	1.25±0.04
8	*Ficus benghalensis*	0.29±0.02	0.99±0.05	0.94±0.07	1.22±0.05
9	*Ficus religiosa*	0.28±0.02	0.95 ±0.05	0.78±0.07	1.19±0.05
10	*Ficus glomarata*	0.27±0.03	0.79±0.07	0.85±0.06	1.16±0.05
11	*Mangifera indica*	0.36±0.01	1.30±0.04	1.35±0.03	1.42±1.40
12	*Nerium indicum*	0.33±0.01	1.30±0.04	1.29±0.04	1.39±0.23
13	*Pisidium guvajava*	0.26±0.03	0.84±0.06	0.81±0.06	1.04±0.04
14	*Pongamia pinnata*	0.25±0.02	1.27±0.04	1.26±0.04	1.34±0.03
15	*Tectona grandis*	0.24±0.03	1.24±0.04	1.23±0.0.04	1.37±0.02
16	*Terminalia catappa*	0.23±0.03	1.21±0.05	1.20±0.05	1.31±0.04

In winter sampling season higher cadmium (Cd, µg/g/ dw) accumulation was found in leaves of different plants species growing at sector-1.

*A. indica (*1.38±0.02) < *E.jambolana (*1.36±0.04)< *D. sissoo (*1.33±0.04)< *M. indica and* N. *indicum (*1.30±0.04) < *T.catappa (*1.21±0.05)< *P. pinnata (*1.27±0.04)< *Eucalyptus sp.* and *T. grandis (*1.24±0.04).

Lower cadmium (Cd, µg/g/ dw) accumulation was occurred in leaves of different plants growing at sector-1.

*F. benghalensis (*0.99±0.05) < *F.religiosa (*0.95±0.05) < *B.monosperma (*0.92±0.06) < *C. gigantea (*0.86±0.06) < *P.guvajava (*0.84±0.06) < *F. glomarata (*0.79±0.07) < *C. mixa (*0.75±0.08).

Higher cadmium (Cd, µg/g/dw) accumulation was noted in leaves of different plants at growing at sector-2.

*A. indica (*1.39±0.01) < *D. sissoo (*1.38±0.01) < *M. indica (*1.35±0.04) < N. *indicum (*1.29±0.04) < *P. pinnata (*1.26±0.04) < *T.grandis (*1.23±0.04) < *T.catappa (*1.20±0.05), *Eucalyptus sp. (*1.17±0.05)

Lower cadmium (Cd, µg/g/ Dw) accumulation was found in leaves of different plants at sector-2.

*F. benghalensis (*0.94± 0.07) < *F. glomarata (*0.85±0.06) < *B.monosperma (*0.87±0.06) < *C. gigantea (*0.83±0.06) < *P.guvajava (*0.81±0.06) < *F.religiosa (*0.78±0.07) < *C. mixa (*0.74± 0.08)

Higher cadmium (Cd, µg/g/ dW) accumulation was observed in leaves of different plants at sector-3.

*M. indica and E.jambolana (*1.42±1.40) < *A. indica (*1.41±1.35) < *D. sissoo (*1.40±0.145) < N. *indicum (*1.39±0.23) < *T. grandis (*1.37±0.02) < *P. pinnata (*1.34±0.03) < *T.catappa (*1.31±0.04).

Lower cadmium (Cd, µg/g/ dw) accumulation was found in leaves of different plants at sector-3.

*B.monosperma (*1.28±0.04) < *Eucalyptus sp. (*1.25±0.04) < *F. benghalensis (*1.22±0.05) < *F.religiosa (*1.19±0.05) < *F. glomarata (*1.16±0.05) < *C. mixa (*1.09±0.05) < *P.guvajava (*1.04±0.04) < *C. gigantea (*0.91±0.06).

Table 6. 3: Showing copper accumulation of leaves of studied plants growing in control vs. Pithampur Industrial area-1, 2 & 3.

Copper accumulation (in µg/gm of dry weight of leaves) of studied plant spp.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.68±0.00	26.11±1.07	26.07±1.06	30.22±1.20
2	*Buteamonosperma*	2.29±0.29	20.57±1.98	20.15±1.52	24.71±2.53
3	*Calotropis gigantea*	1.31±0.01	20.13±1.52	20.70±1.52	20.55±1.98
4	*Cordia mixa*	2.28±0.30	19.29±1.70	19.27±1.70	20.96±1.94
5	*Dalbergia sissoo*	2.34±0.01	25.41±1.57	26.12±1.07	30.24±1.22
6	*Euginia Jambolana*	2.32±0.01	26.14±1.01	25.11±2.01	29.24±1.19
7	*Eucalyptus sp.*	2.27±0.30	23.67±4.15	22.02±2.63	23.68±4.16
8	*Ficus benghalensis*	2.26±0.30	20.71±1.99	20.60±1.99	23.03±3.59
9	*Ficus religiosa*	2.25±0.31	20.61±1.98	19.32±1.70	22.36±3.04
10	*Ficus glomarata*	2.22±0.31	19.67±2.05	20.01±1.51	21.35±2.07
11	*Mangifera indica*	2.16±0.01	25.19±2.02	25.79±2.28	31.25±1.25
12	*Nerium indicum*	2.32±0.30	25.07±1.02	25.05±2.02	29.23±1.23
13	*Pisidium guvajava*	2.20±0.31	20.09±1.52	20.03±1.52	20.81±1.99
14	*Pongamia pinnata*	2.19±0.30	24.36±3.07	24.02±3.62	25.44±1.55
15	*Tectona grandis*	2.17±0.29	23.67±4.15	23.34±4.02	26.16±1.00
16	*Terminalia catappa*	2.16±0.29	23.02±3.59	22.68±3.50	25.09±2.01

In winter sampling season higher copper (Cu, µg/g/ dw) accumulation was occurred in leaves of different plants at sector-1.

*A. indica(*26.11±1.07) < *E. Jambolana(*26.14±1.01) < *D. sissoo(*25.41±1.57) < *M. indica(*25.19±2.02) < *N.indicum(*25.07±1.02) < *P. pinnata(*24.36±3.07) < *T. grandis(*23.67±4.15) < *T. catappa(*23.02±3.59).

Lower copper (Cu, µg/g/ dw) accumulation was observed in leaves of different plants at sector-1.

Eucalyptus sp. (23.67±4.15) < *F. benghalensis(*20.71±1.99)< *F. religiosa(*20.61±1.98) *B.monosperma(*20.57±1.98)< *C. gigantea(*20.13±1.52) < *P.guvajava(*20.09±1.52)< *F. glomarata(*19.67±2.05) < *C. mixa(*19.29±1.70).

In winter sampling season higher copper (Cu, µg/g/ dw) accumulation was occurred in leaves of different plants at sector-2.

*A. indica(*26.07±1.06)< *D. sissoo(*26.12±1.07)< *M. indica(*25.79±2.28)< *E.jambolana(*25.11±2.01)< N. *indicum(*25.05±2.02)< *P. pinnata(*24.02±3.62)< *T.grandis(*23.34±4.02)< *T.catappa (*22.68±3.50)< *F. benghalensis (*20.60±1.99).

Lower copper (Cu, µg/g/ Dw) accumulation was observed in leaves of different plants at sector-2.

*B.monosperma (*20.15±1.52) < *P.guvajava (*20.03±1.52) < *F. glomarata (*20.01±1.51) < *Eucalyptus sp. (*22.02±2.63) < *F. religiosa (*19.32±1.70) < *C. mixa (*19.27±1.70).

In winter sampling season higher copper (Cu, µg/g/ dw) accumulation was found in leaves of different plants growing at sector-3.

*M. indica(*31.25±1.25) < *D. sissoo (*30.24±1.22) < *A. indica(*30.22±1.20) < *E.jambolana (*29.24±1.19) < N. *indicum(*29.23±1.23) < *T.grandis(*26.16±1.00) < *P.pinnata(*25.44±1.55) < *T.catappa (*25.09±2.01) < *B.monosperma(*24.71±2.53).

Lower copper (Cu, µg/g/ dw) accumulation occurred in leaves of different plants growing at sector-3.

*Eucalyptus sp. (*23.68±4.16) < *F. benghalensis(*23.03±3.59) < *F. religiosa(*22.36±3.04) < *F.glomarata(*21.35±2.07) < *C. mixa (*20.96±1.94) < *P.guvajava(*20.81±1.99) < *C. gigantea (*20.55±1.98).

Table 6.4 : Showing nickel accumulation of leaves in studied plants growing at control vs. Pithampur Industrial area-1, 2 & 3.

Nickel accumulation (in µg/gm of dry weight of leaves) of studied plant spp.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.71±0.01	29.37±0.93	29.36±0.92	30.41±1.15
2.	*Buteamonosperma*	2.31±0.01	21.34±1.43	20.62±1.91	27.88±2.51
3	*Calotropis gigantean*	1.25±0.02	20.56±1.96	20.19±0.91	21.32±1.45
4	*Cordia mixa*	2.30±0.01	20.05±2.47	20.04±2.47	22.29±2.04
5	*Dalbergia sissoo*	2.41±0.01	29.32±0.99	29.39±0.92	30.31±1.19
6	*Euginia Jambolana*	2.38±0.00	29.36±0.95	29.30±0.99	28.40±1.18
7	*Eucalyptus sp.*	2.29±0.01	25.83±3.05	23.05±2.98	25.84±3.05
8	*Ficus benghalensis*	2.28±0.02	22.71±1.65	21.72±1.65	24.79±3.05
9	*Ficus religiosa*	2.27±0.02	21.71±1.65	20.07±2.48	23.72±2.04
10	*Ficus glomarata*	2.26±0.02	20.10±2.48	20.22±2.49	22.70±2.49
11	*Mangifera indica*	2.21±0.01	28.59±2.09	29.34±0.95	30.32±1.20
12	*Nerium indicum*	2.36±0.01	28.57±2.09	28.56±2.09	28.32±1.21
13	*Pisidium guvajava*	2.25±0.02	20.21±2.49	20.14±2.46	22.22±2.04
14	*Pongamia pinnata*	2.23±0.02	27.20±2.99	26.52±3.51	29.33±0.99
15	*Tectona grandis*	2.22±0.01	25.83±3.05	25.47±3.21	29.38±0.93
16	*Terminalia catappa*	2.21±0.02	24.42±2.47	24.05±2.61	29.27±1.00

In winter sampling season Nickel (Ni , µg/g/ dw) accumulation of leaves of studied plants growing in control vs. Pithampur Industrial areasector-1, 2 & 3. Nickel (Ni, µg/gm Dw) accumulation of leaves ranged between 2.71±0.01 to 1.25±0.02 in control and 30.41±1.15 to 20.04 ±2.47 in polluted site repectively

(**Table –6.4)**.

In winter sampling season higher nickel (Ni, µg/g/ dw) accumulation was noted in leaves of different plants growing at sector-1.

*A. indica (*29.37±0.93) < *D. sissoo (*29.32±0.92) < *E.jambolana (*29.36±0.95) < *M. indica (*28.59±2.09) < N. *indicum (*28.57±2.09) < *P. pinnata (*27.20±2.99) < *T. grandis (*25.83±3.05) < *Eucalyptus sp. (*25.83±3.05) < *T.catappa (*24.42±2.47).

Lower nickel (Ni, µg/g/ dw) accumulation was occurred in leaves of different plants at sector-1.

*F.benghalensis (*22.71±1.65) < *F. religiosa (*21.71±1.65) < *C. gigantea (*20.56±2.47) < *B.monosperma* (21.34±1.43) < *P.guvajava (*20.21±2.49) < *F. glomarata (*20.10±2.48) < *C. mixa (*20.05±2.47).

In winter sampling season higher nickel (Ni, µg/g/ dW) accumulation in leaves of different plants at sector-2.

*D. sissoo (*29.39±0.92) < *A. indica (*29.36±0.92) < *M. indica (*29.34±0.95) < *E.jambolana (*29.30±0.99) < *N.indicum (*28.56±2.09) < *P. pinnata (*26.52±3.51) < *T. grandis (*25.47±3.21) < *T.catappa (*24.05±2.61) < *Eucalyptus sp. (*23.05±2.98).

Lower nickel (Ni, µg/g/ dw) accumulation was observed in leaves of different plants at sector-2.

*F.benghalensis (*21.72±1.65) < *B.monosperma (*20.62±1.91) < *F.glomarata (*20.22±2.49) < *C.gigantea (*20.19±0.91) < *P.guvajava (*20.14±2.46) < *F.religiosa (*20.07±2.48) < *C. mixa (*20.04±2.47).

In winter sampling season higher nickel (Ni, µg/g/ dW) accumulation was found in leaves of different plants growing at sector-3.

*A.indica (*30.41±1.15) < *M.indica (*30.32±1.20) < *D.sissoo (*30.31±1.19) < *P.pinnata (*29.33±0.99) < *T.grandis (*29.38±0.93) < *T.catappa (*29.27±1.00) < *E.jambolana (*28.40±1.18) < N. *indicum (*28.32±1.21) < *B.monosperma (*27.88±2.51) < *Eucalyptus sp.(*25.84±3.05).

Lower nickel (Ni, µg/g/ dw) accumulation was observed in leaves of different plants at sector-3.

*F. benghalensis (*24.79±3.05) < *F. religiosa (*23.72±2.04) < *F.glomarata (*22.70±2.49) < *C. mixa (*22.29±2.04) < *P.guvajava (*22.22±2.04) < *C. gigantean (*21.32±1.45).

Summer Sampling Season

Table 6.5: Showing lead accumulation of leaves in studied plants growing at control vs. Pithampur Industrial area 1, 2 &3.

Lead accumulation (in µg/gm of dry weight of leaves) of studied plant sps.					
S.No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.23±0.01	14.26±0.01	14.77±0.01	14.78± 0.01
2	*Buteamonosperma*	0.21±0.04	10.68±0.29	10.77±0.50	12.49±0.96
3	*Calotropis gigantea*	1.03±0.01	4.62±0.13	4.87± 0.15	5.22± 0.54
4	*Cordia mixa*	0.17±0.04	11.39±1.10	10.63±0.50	12.44±0.96
5	*Dalbergia sissoo*	2.24±0.01	14.30±0.48	14.78±0.01	14.79± 0.63
6	*Euginia Jambolana*	2.22±0.02	14.13±0.65	14.14±0.65	14.15±0.63
7	*Eucalyptus sp.*	0.22±0.05	14.79±0.63	12.28±1.00	14.78±0.01
8	*Ficus benghalensis*	0.16±0.04	10.85±0.30	10.51±0.43	11.11±0.89
9	*Ficus religiosa*	0.17±0.04	10.82±0.30	14.30±0.48	10.75±0.50
10	*Ficus glomarata*	0.15±0.04	10.79±0.31	10.69±0.29	10.80±0.30
11	*Mangifera indica*	2.22±0.01	14.12±0.62	14.14±0.62	14.15± 0.62
12	*Nerium indicum*	1.21±0.01	14.12±0.65	14.13±0.63	14.74± 0.04
13	*Pisidium guvajava*	0.18±0.05	10.64±0.30	10.62±0.30	10.64±0.30
14	*Pongamia pinnata*	0.10±0.01	19.42±0.94	14.12±0.62	19.43±0.45
15	*Tectona grandis*	0.09±0.02	19.29±0.94	12.47±0.96	19.40±0.94
16	*Terminalia catappa*	0.07±0.03	19.31±0.94	12.41±0.97	19.39±0.94

In the present investigstions lead (Pb µg/g/ dw) accumulation of leaves of studied plant species growing in control vs. Pithampur industrial areasector-1, 2 & 3 in Summer sampling seasons (**Table –6.5.)**.

Lead content (Pb, µg/g/ dw) accumulation of leaves ranged between 0.07± 0.03 to 2.23 ± 0.01 in control samples and 4.62± 0.13 to 14.79± 0.63 in polluted site in summer respectively (**Table –6.5.)**.

In summer sampling season higher lead (Pb µg/g/ dw) accumulation was found in leaves of different plants species growing at sector-1.

P.pinnata (19.42±0.94) < *T.catappa* (19.31±0.94) < *T. grandis* (19.29±0.94) < *Eucalyptus sp.* (14.79±0.63) < *D.sissoo* (14.30±0.48) < *A. indica* (14.26±0.01) < *E. jambolana* (14.13±0.65) < *M. indica* and *N. indicum* (14.12±0.65).

Lower lead (Pb, µg/g/ dw) accumulation was noted in leaves of plants growing at sector-1.

C. mixa (11.39±1.10) < *F. benghalensis* (10.85±0.30) < *F. religiosa* (10.82±0.31) < *F.glomarata* (10.79±0.31) < *B.monosperma* (10.68±0.29) < *P. guvajava* (10.64±0.30) < *C. gigantea* (4.62±0.13).

In summer sampling season higher lead (Pb, µg/g/ dw) accumulation was occurred in leaves of different plants at sector-2.

D.sissoo (14.78±0.01) < *A.indica* (14.77±0.01) < *F.religiosa* (14.30±0.48) < *E.jambolana* and *M.indica* (14.14±0.62) < *P.pinnata* (14.12±0.62).

Lower lead (Pb µg/g/ Dw) accumulation was found in leaves of plants growing at sector-2

T.grandis (12.47±0.96) < *T.catappa* (12.41±0.97) < B. *monosperma* (10.77±0.50) < *F.glomarata* (10.69±0.29) < *C. mixa* (10.63±0.50) < *P.guvajava* (10.62±0.30) < *F.benghalensis* (10.51±0.43) and *C. gigantea* (4.87± 0.15).

In summer sampling season higher lead (Pb µg/g/ dw) accumulation was found in leaves of different plants at sector-3.

P. pinnata (19.43±0.45) < *T. grandis* (19.40±0.94) < *T. catappa* (19.39±0.94) < *D. sissoo* (14.79±0.63) < *Eucalyptus sp.* (14.78±0.01) < *A.indica* (14.78±0.01) < *N. indicum*(14.74±0.04) < *M. indica* (14.15± 0.62).

Lower lead (Pb µg/g/ dw) accumulation was found in leaves of plants growing at sector-3.

E.jambolana(14.15±0.63) < B. *monosperma* (12.49±0.96) < *C. mixa* (12.44±0.96) < *F.benghalensis*(11.11±0.89) < *F.religiosa* (10.75±0.50)< *P.guvajava* (10.64±0.30) < *C. gigantea* (5.22± 0.54)

Table 6.6: Showing cadmium accumulation of leaves in studied plant leaves (Control vs. Pithampur Industrial area. 1, 2 & 3).

Cadmium accumulation (in µg/gm dry weight of leaves) of studied plant sps.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	0.45 ±0.02	1.16 ±0.05	1.19 ±0.00	1.28 ± 0.01
2	*Buteamonosperma*	0.13±0.02	0.66±0.21	0.90±0.01	1.13±0.01
3	*Calotropis gigantea*	0.27 ±0.02	0.51 ±0.01	0.53 ± 0.03	0.57 ± 0.01
4	*Cordia mixa*	0.08±0.02	1.05±0.02	0.86±0.01	1.11±0.01
5	*Dalbergia sissoo*	0.56 ±0.01	1.08 ±0.02	0.12 ± 0.02	1.29 ± 0.01
6	*Euginia Jambolana*	0.37 ±0.02	1.15 ±0.01	1.14 ± 0.00	1.15 ± 0.01
7	*Eucalyptus sp.*	0.14±0.02	1.29±0.01	1.12±0.01	1.28 ±0.01
8	*Ficus benghalensis*	0.09±0.01	0.68±0.02	0.70±0.01	0.92±0.01
9	*Ficus religiosa*	0.09±0.03	0.62±0.02	1.01±0.02	0.87±0.01
10	*Ficus glomarata*	0.06±0.02	0.76±0.21	0.67±0.21	0.63±0.02
11	*Mangifera indica*	0.39 ±0.01	1.12 ± 0.00	1.14 ± 0.01	1.15 ± 0.01
12	*Nerium indicum*	0.36±0.01	1.15 ± 0.04	1.18 ±0.01	1.26 ± 0.01
13	*Pisidium guvajava*	0.11±0.03	0.63±0.21	0.62±0.21	0.75±5.52
14	*Pongamia pinnata*	0.05±0.02	1.20±0.01	1.12 ±0.00	1.22±0.01
15	*Tectona grandis*	0.03±0.01	1.10±0.01	1.11±0.01	1.18±0.01
16	*Terminalia catappa*	0.01±0.00	1.12±0.01	1.10±0.01	1.17±0.01

In summer season higher values of cadmium (Cd, µg/g/ dw) accumulation in leaves of studied plants growing in control vs. Pithampur Industrial areasector-1, 2 & 3 (**Table –6.6).**

Cadmium (Cd µg/g/ dw) accumulation of leaves ranged between 0.01± 0.00 to 0.45 ± 0.02 in control samples and 0.51 ± 0.01 to 1.29 ± 0.01 in polluted site in summer season respectively **(Table –6.6).**

In summer samping season higher cadmium (Cd, µg/g/ dw) accumulation was observed in leaves of different plants at sector-1.

*Eucalyptus sp. (*1.29±0.01), *P. pinnata (*1.20±0.01) *A. indica* (1.16±0.05), *E.jambolana* (1.15 ±0.01) *N.indicum* (1.15 ±0.04) < *M. indica* (1.12 ± 0.00) and *T. catappa (*1.12±0.01) *T. grandis (*1.10±0.01)

Lower cadmium (Cd, µg/g/ dw) accumulation was noted in leaves of different plants growing at sector-1.

F.glomarata (0.76±0.21) < *F.benghalensis* (0.68±0.02) < *B. monosperma* (0.66±0.21) < *P.guvajava* (0.63±0.21) < *F. religiosa* (0.62±0.02) < *C. gigantea* (0.51 ±0.01).

Higher cadmium (Cd, µg/g/ dw) accumulation was occurred in leaves of different plants growing at sector-2.

A. indica (1.19 ±0.00) < *N.indicum* (1.18 ±0.01) < *E.jambolana* (1.14 ± 0.00) < *M. indica* (1.14 ± 0.01) < *Eucalyptus sp.* (1.12±0.01) < *P. pinnata* (1.12 ±0.00) < *T. grandis* (1.11±0.01) < *T. catappa* (1.10±0.01) < *F. religiosa* (1.01±0.02)

Lower cadmium (Cd, µg/g/ dw) accumulation was found in leaves of plants growing at sector-2.

B.monosperma (0.90±0.01) < *C. mixa* (0.86±0.01) < *F. benghalensis* (0.70±0.01) < *F. glomarata* (0.67±0.21) < *P.guvajava* (0.62±0.21) < *C. gigantea* (0.53 ± 0.03 < *D. sissoo* (0.12±0.02).

In summer samping season higher cadmium (Cd, µg/g/ dw) accumulation was noted in leaves of different plants at sector-3.

D. sissoo (1.29 ± 0.01) < *A. indica* (1.28 ± 0.01) < *Eucalyptus sp.* (1.28 ±0.01) < *N.indicum* (1.26±0.01) < *P.pinnata* (1.22±0.01) < *T. catapp* (1.17±0.01) < *T.grandis* (1.18±0.01) < *E.jambolana* (1.15±0.01) < *M.indica* (1.15±0.01) <*B.monosperma* (1.13±0.01) < *C.mixa* (1.11±0.01).

Lower cadmium (Cd, µg/g/ dw) accumulation was found in leaves of plants at sector-3.

F.benghalensis (0.92±0.01) <*F.religiosa* (0.87±0.01) < *F.glomarata* (0.63±0.02) < *P.guvajava* (0.75±5.52) < *C. gigantea* (0.57 ± 0.01).

Table 6.7: Showing **c**opper accumulation of leaves in studied plants growing in control vs. Pithampur Industrial area.

Copper accumulation of (in µg/gm of dry weight of leaves) of stuied plant spp.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.42 ±0.02	13.88 ±0.62	13.99 ±0.58	14.45 ±0.05
2	*Buteamonosperma*	0.91±0.04	18.11±1.17	19.09±1.00	12.69±0.91
3	*Calotropis gigantea*	1.31 ±0.01	4.50 ±0.03	4.46 ±0.05	4.47 ±0.01
4	*Cordia mixa*	0.91±0.03	19.50±1.09	19.06±1.01	12.64±0.91
5	*Dalbergia sissoo*	2.68±0.00	13.51 ±0.59	13.16±0.98	14.54±0.01
6	*Euginia Jambolana*	2.34 ±0.01	13.85 ±0.61	13.97±0.41	14.00 ±0.39
7	*Eucalyptus sp.*	0.90±0.06	14.54±0.01	12.53±0.95	14.44 ± 0.05
8	*Ficus benghalensis*	0.93±0.03	18.27±1.16	18.30±1.16	19.10±1.00
9	*Ficus religiosa*	0.88±0.03	18.24±1.16	13.50±0.59	19.07±1.01
10	*Ficus glomarata*	0.94±0.03	18.22±1.16	18.13±1.16	18.22±1.16.
11	*Mangifera indica*	2.32±0.01	13.18 ±0.57	13.18 ±0.07	13.20 ±0.05
12	*Nerium indicum*	2.16±0.01	13.86 ±0.60	14.03±0.40	14.38 ±0.01
13	*Pisidium guvajava*	0.90±0.03	18.07±1.17	18.06±1.17	18.21 ±1.16
14	*Pongamia pinnata*	2.18±0.02	17.19±0.99	13.18±0.07	17.80±0.99
15	*Tectona grandis*	2.15±0.01	17.76±1.00	12.67±0.91	17.77±0.99
16	*Terminalia catappa*	2.05±0.03	17.69±0.99	12.63±0.92	17.76±0.99

In summer sampling season copper (Cu, µg/g/ dw) accumulation in leaves of studied plants growing in control vs. Pithampur Industrial areasector-1, 2 & 3. copper (Cu, µg/g/ dw) accumulation of leaves ranged between 2.68±0.00 to 0.88±0.03 in control and 19.10±1.00 to 4.46 ±0.05 in polluted site repectively (**Table –6.7.)**.

In summer sampling season higher copper (Cu, µg/g/dw) accumulation was noted in leaves of different plants at sector-1.

*C. mixa (*19.50±1.09) < *F. benghalensis (*18.27±1.16) < *F. religiosa (*18.24±1.16) < *F. glomarata (*18.22±1.16) < *B.monosperma (*18.11±1.17) < *P.guvajava (*18.07±1.17) < *T.grandis(*17.76±1.00) < *T. catappa (*17.69±0.99) < *P. pinnata (*17.19±0.99).

Lower copper (Cu, µg/g/dw) accumulation was found in leaves of different plants growing at sector-1.

*A. indica (*13.88 ±0.62) < *E. jambolana (*13.85 ±0.61)< *N. indicum* (13.86 ±0.60) < *D. sissoo (*13.51 ±0.59) < *M. indica* (13.18 ±0.57) < *C. gigantea (*4.50 ±0.03).

In summer sampling season higher copper (Cu, µg/g/ dw) accumulation was ocuurd in leaves of different plants growing at sector-2.

*B.monosperma (*19.09±1.00) < *C.mixa (*19.06±1.01) < *F.benghalensis (*18.30±1.16) < *F. glomarata (*18.13±1.16) < *P.guvajava (*18.06±1.17).

Lower copper (Cu, µg/g/ dw) accumulation was observed in leaves of different plants growing at sector-2.

A.indica (13.99±0.58) < *E. jambolana (*13.97±0.41) < *F. religiosa (*13.50±0.59) < *P. pinnata (*13.18±0.91) < *T. grandis (*12.67±0.91) < *T.catappa (*12.63±0.92) < *Eucalyptus sp. (* 12.53±0.95) < *C. gigantea* (4.46 ±0.05).

In summer sampling season higher copper (Cu, µg/g/ dw) accumulation was found in leaves of different plants at sector-3.

*F. benghalensis (*19.10±1.00) < *F.religiosa (*19.07±1.01) < *F.glomarata* (18.22±1.16)) < *P.guvajava (*18.21±1.16) < *P.pinnata* (17.80±0.99) < *T. grandis (*17.77±0.99) < *T. catappa (*17.76±0.99).

Lower copper (Cu, µg/g/ dw) accumulation was ocurred in leaves of different plants growing at sector-3.

*D. sissoo (*14.54±0.01) < *A. indica (*14.45 ±0.05) < *Eucalyptus sp. (*14.44 ± 0.05) < *N. indicum (*14.38 ±0.01) < *E. jambolana (*14.00 ±0.39) < *C. gigantea (*4.47±0.01).

Table 6.8 : Showing nickel accumulation of leaves of studied plants growing in control vs. Pithampur Industrial area. 1, 2 & 3.

Nickel accumulation (in µg/gm dry weight of leaves) of studied plant sps.					
S. No.	**Name of Plants**	**Control**	**Sector-1**	**Sector-2**	**Sector-3**
1	*Azadirechata indica*	2.51 ±0.01	23.93±1.54	28.26±0.99	28.60 ±1.14
2.	*Buteamonosperma*	1.94±0.01	10.94±1.05	11.30±1.08	21.68±1.13
3.	*Calotropis gigantea*	1.25±0.02	5.05±0.03	6.74 ±1.51	8.41±0.57
4.	*Cordia mixa*	2.01±0.01	11.59±1.06	11.26±1.09	21.61±1.02
5	*Dalbergia sissoo*	2.71±0.01	11.45±0.545	6.40 ±1.51	27.29±1.73
6	*Euginia Jambolana*	2.41±0.01	26.57 ±0.58	26.57±0.58	26.61±0.01
7	*Eucalyptus sp.*	1.92±0.02	27.29±1.73	21.56±1.03	28.62 ±1.14
8	*Ficus benghalensis*	2.02±0.01	11.13±1.06	11.12±1.07	11.32±1.08
9	*Ficus religiosa*	1.96±0.02	11.07±1.06	11.40±0.54	11.27±1.09
10	*Ficus glomarata*	2.03±0.01	11.04±1.06	10.96±1.05	11.05±1.06
11	*Mangifera indica*	2.38 ±0.00	23.25±1.75	23.93±2.32	27.25 ±1.27
12	*Nerium indicum*	2.21 ±0.01	19.30+0.05	24.60±2.04	25.29±1.53
13	*Pisidium guvajava*	1.97±0.02	10.90±1.05	10.89±1.05	11.03±1.05
14	*Pongamia pinnata*	2.22±0.03	28.86±1.00	23.25 ± 1.75	28.87±1.07
15	*Tectona grandis*	2.20±0.02	28.76±0.97	21.67±0.99	28.83±1.00
16	*Terminalia catappa*	2.16±0.02	28.77±0.97	21.55±1.04	28.85±0.96

In summer season nickel content (Ni, µg/g/ dw) accumulation of leaves of studied plants growing in control vs. Pithampur Industrial areasector-1, 2 & 3. Lead content (Pb µg/g/dw) accumulation of leaves ranged between2.51±0.01 to 1.25±0.02 in control and 28.85±0.96 to 6.74 ±1.51 in polluted site(**Table –6.8)**.

In summers sampling season higher nickel (Ni, µg/g/ dw) accumulation was noted in leaves of different plants at sector-1.

*P. pinnata (*28.86±1.00) < *T.grandis (*28.76±0.97) < *T.catappa (*28.77±0.97) < *Eucalyptus sp. (*27.29±1.73) < *E. jambolana (*26.57 ±0.58) < *A. indica (*23.93±1.54) < *M. indica (*23.25±1.75).

Lower nickel (Ni, µg/g/ dw) accumulation was found in leaves of different plants growing at sector-1.

N. indicum (19.30±0.05) < *C. mixa* (11.59±1.06) < *D. sissoo* (11.45±0.545) < *F. benghalensis* (11.13±1.06) < *F.religiosa* (11.07±1.06) < *F. glomarata* (11.04±1.06) < *B.monosperma* (10.94±1.05) < *P.guvajava* (10.90±1.05) < *C. gigantea* (5.05±0.03).

In summer sampling season higher nickel (Ni, µg/g/ dw) accumulation was occure in leaves of different plants growing at sector-2.

A. indica(28.26±0.99) < *E. jambolana*(26.57±0.58) < *N. indicum* (24.60±2.04)< *M. indica* (23.93±2.32) < *P. pinnata* (23.25±1.75) < *T. grandis* (21.67±0.99) < *Eucalyptus sp.* (21.56±1.03) < *T. catappa* (21.55±1.04).

Lower nickel (Ni, µg/g/ dw) accumulation was observed in leaves of different plants growing at sector-2.

F.religiosa (11.40±0.54) < *B.monosperma* (11.30±1.08) < *C.mixa* (11.26±1.09) < *F.benghalensis* (11.12±1.07) < *F. glomarata* (10.96±1.05) < *P. guvajava* (10.89±1.05) < *C. gigantea* (6.74 ±1.51) < *D. sissoo* (6.40 ±1.51).

In summer season higher value of nickel (Ni, µg/g/ dw) accumulation of leaves in different plants growing at sector-3.

P. pinnata (28.87±1.07) < *T. catappa* (28.85±0.96) < *T. grandis* (28.83±1.00)< *Eucalyptus sp.* (28.62 ±1.14) < *A. indica* (28.60 ±1.14) < *D. sissoo* (27.29±1.73) < *M. indica* (27.25 ±1.27) < *E. jambolana*(26.61±0.01).

Lower nickel (Ni, µg/g/ dw) accumulation was observed in leaves of different plants growing at sector-3.

B.monosperma (21.68±1.13) < *C.mixa* (21.61±1.02) < *F.benghalensis* (11.32±1.08) < *F.religiosa* (11.27±1.09), *F.glomarata* (11.05±1.06) < *P.guvajava* (11.03±1.05) < *C. gigantea* (8.41±0.57).

Discussion:

Four heavy metal i.e. Pb,Cd, Cu,Ni, studied in different plant species growing naturally in and around the sectors of Pithampur industrial area. Status of heavy metal accumulation analysed in 13 tall trees, one small tree & 2 shrub spp. As relvealed by studies that the greater amount of heavy metals with other gaseous pollutants emmitted by sector-3 as compared to rest of two sectors, therefore more the deposition of them on leaves of plants through the leaf tissue, stomata and soil. After accumulation in cells of leaves they interfere the biological activities of plants suffer by heavy metal toxicity of Pb,Cd,Cu and Ni etc. by their effects on decreasing level of protein contents.

Present study indicated that the increased amount of heavy metals was seen in plants occur at sector-3 and then in sector 1 and 2 according to pollution load present there.

In present investigations, studies of total heavy metals revealed that the plant species like *Azadirechta indica* of sector - 3 accumulated maximum and C*ordia mixa* of sector - 2 analysed with minimum presence of total heavy metals in winter seasons. On the other hand in summer season *pongamia pinnata* of sector - 3 showed highest and C*alotropis gigantea* of sector - 1 shown lowest amount of heavy metals. There may be a correlation between adsorption of external materials and texture of leaf of a plant species. The leaves with thick, leathery and waxy coating with smooth surface i.e. C*ordia mixa* & C*alotropis gigantea* adsorbed low quantity of external materials present in air in comparion to thin texture leaves of *Azadirechta indica* and *Pongamia pinnata.* One more aspect was emerged during studies that all tree spp. affected more by air pollution then short heighted tree *Terminalia catappa* and shrubs i.e. C*alotropis gigantea* & *Nerium indicum.*

As far as correlation of protein content and heavy metal is concerned all the studied plant species shown negative correlation except *Ficus benghalensis* and *Pisidium guvajava* during summer that indicates the effect of heavy metals low or high on plant species with not much reduction in protein contents.

During winter season (+) ve correlation shown by *Ficus glomarata* for Cd, Cu, & Ni while (-) ve correlation with Pb only. Same results were shown by *M.indica.* All other species given (-) ve correlation for all heavy metals except *Terminalia catappa* which shown (+) ve correlation at the same time. They found less affected by heavy metals present in air means low accumulation capacity with lower reduction in protein contents too. Although, analysis of accumulation of individual & total heavy metals studied in plant species on the basis of control vs. polluted sampling sites, which highlighted the low or high absorption capacity of different plant species dependent on different leaf architecture.

But a plant species if showing a positive correlation between heavy metal accumulation and % decrease in protein content also recognized as a tolerant sp. which is in stress of air pollution without affected much and these can be represented as resistant one at metabolic level.

Whilst, effect of heavy metals always be an adverse because Pb, Cd and Ni not necessary for plant metabolism in trace amount present in air or soil, except Cu.

Heavy metal like lead decreases carbohydrate and protein content in wheat (Tiwari *et. al.,* 2013). These heavy metals can also destroy the photosynthetic electron chain which lead to O_2 production (Sandalio *et. al.,* 2001).

Accumulation of lead found highest in *Mangifera indica, Tectona grandis, Azadirechata indica,* during winter and *Pongamia pinnata, Dalbergia sissoo* during summers. The lowest amount of lead absorption measured in *Buteamonosperma, Cordia mixa and Calotropis gigantea* during winter and summer respectively.

In previous studies, normal (0.2-0.8 μg/g dry weight; D.W.) and toxic (5-30 μg/g D.W.) limits of Cd for plants were detected (Bowen 1979; Kabata-Pendias and Pendias 1986).

Cadmium was reported to affect chlorophyll biosynthesis and inhibit protochlorophyll reductase and aminolevulinic acid (ALA) synthesis (Stobart *et al*., 1985). Excessive amount of Cd may cause decreased uptake of nutrient elements, inhibition of various enzyme activities, induction of oxidative stress including alterations in enzymes of the antioxidant defence system (Sandalio *et. a*l., 2001).

Highest amount of absorbed Cd reported in *Azadirechata indica*, *Euginia jambolana*, *Mangifera indica* and *Eucalyputs sp*., *Dalbergia sissoo*, during winter and summer resapectively. Lowest range of Cd observed in *Cordia mixa*, *Calotropis gigantea* during winter and summer seasons.

The primary targets of Cd toxicity are also PS II and an enzymatic phase of photosynthesis, particularly ribulose-1, 5-bisphosphate carboxylase/oxygenase (Krantev *et. al.,* 2008). It may cause decrease in various enzymatic activities disturbances in chloroplast metabolism by inhibiting chlorophyll biosynthesis and reducing the activity of enzyme involved in CO_2 fixation (Stobart *et. al.* 1985) including alterations in enzymes of the antioxidant defense systems.

The acceptable concentrations of copper for plants range from 2 to 20 ppm and the phytotoxic level is 30 ppm depending on plant species (Kabata-Pendias and Piotrowska 1984).

The highest accumulation of Cu analysed in *Euginia jambolana*, *Dalbergia sissoo*, *Mangifera indica* and *Cordia mixa*, *Ficus benghalesis*, *Calotropis gigantea* during winters and summers.

Copper is a trace element in some important pigments of plants (Wilkonson 1994; Govindjee 1995). Since Cu is one of the principle components of many enzymes involved in oxidation and reduction, the protochlorophyllide system is highly sensitive to copper deficiency and toxicity (Raven and Johnson 1986; Ouzounidou 1994; Celik *et. al.*, 2005).

Leaf chlorosis, disturbed water balance and reduced stomatal opening are characteristic effects of toxic Ni concentrations (Clemens 2006), but they are also caused by many heavy metals (as part of heavy metal toxicity syndrome) and even occur more generally as a stress response. This may be due to the retention of Ni in the plant system. Enzyme activity which is directly responsible for plant growth may be directly inhibited due to Ni accumulation. Severe cases of acute Ni toxicity have been found to divert the metabolic pathway and may even cause death of the plant (Kisku G C. *et. al.,* 2000).

Reduction in chlorophyll content under Ni stress was evident. Ni as an inhibitor of photosynthesis has also been reported by Fernandez and Henriques 1991; Pandey and Singh 2001. Due to reduction in the rate of photosynthesis, the production of chlorophyll content was hampered. Chlorophyll content was also reduced by Ni subjected to decrease in stomatal conduction (Pandey and Singh 2001).

Ni like heavy metal accumulation revealed highest in leaves of plant species such as *Azadirechata indica*, *Dalbergia sissoo*, *Mangifera indica* and *Pongamia pinnata* during winter and summer respectively. Low level of Ni absorption found in plant leaves of *Cordia mixa*, *Calotropis gigantea* and *Dalbergia sissoo* species recorded in winter and summer seasons respectively.

Apart from heavy metal accumulation results of winter and summer seasons the absorption capacity of plant species depends more on their leaf architecture. As sensitive species like *Tectona grandis and Pongamia pinnata* has been reported with long petiole, shiny surface, broad leaf lamina and thick, glossy leaf respectively.

Many plant species of Pithampur industrial area have been noted as intermediately tolerant ones (*Azadirechata indica, Buteamonosperma, Dalbergia sissoo, Euginia Jambolana, Pisidium guvajava)* with higher accumulation of heavy metals and APTI indices might be due to their petiole, leathery, glossy surface with thick leaf lamina affected less by air pollutants.

A good number of resistant plant species were also reported from polluted areas during investigations such as *Calotropis gigantea, Cordia mixa*, *Ficus religiosa and Ficus glomarata.* Their resistants quality and air pollution tolerant capacity might be due to special leaf characheristics like sessile or short petole,shiny surface covered with wax etc.

REFERENCES

Azevedo H., Pinto C.G., Fernandes J., Loureiro S., Santos C. (2005). Cadmium effects on sunflower growth andphotosynthesis. *Journal of Plant Nutrition*. 28: 2211-2220.

Bowen. H. J. M. (1979). Environmental chemistry of the elements. London: Academic.

Barceló J., Cabot C., and Poschenrieder C. (1986). Cadmium induced decrease of water stress resistance in bush bean plants (*Phaseolus vulgaris* L. cv Contender), II effects of Cd on endogenous abscisic acid levels. *Journal of Plant Physiology* 125: 27–34.

Celik A., Kartal. A. A., Akdogan A., & Kaska Y. (2005). Determining the heavy metal pollution in Denizli (Turkey) by using Robinia pseudo-acacia. Environment International, 31, 105–112.

Clemens S. (2006). Toxic metal accumulation, responses to exposure and mechanisms of tolerance in plants. Biochimie 88:1707–1719

Çelik A., Kartal A.A., Akdogan A. Y. (2005). Determining the heavy metal pollution in Denizli (Turkey) by using *Robinio pseudo-acacia* L. *Environ. International.* 31:105-112.

Cho M., Chardonnens A.N., Dietz K.J. (2003). Differential heavy metal tolerance of *Arabidopsis halleri* and *Arabidopsis thaliana*: a leaf slice test. *New Phytol.* 158: 287-293.

Fernandes J. C., and Henriques F. S. (1991). Biochemical, Physiological and structural effects of excess copper in plants. *The Botanical Review.* **57**: 246-273

Govindjee R. (1995). Sixty-tree years since Kautsky: chlorophyll a fluorescence. *Australian Journal of Plant Physiology*. 22, 131–1

Gune A., Alpaslan M., Inan L A. (2004). Plant growth and fertilizer. Ankara Univ. Agriculture Pub. No: 1539, Ankara, Turkey (in Turkish).

Jarup L. (2003). Hazard of heavy metal contamination. *Br. Med. Bull.* 68: 167-182.

Kebata-Pendias A., and Pendias H. (1984). Trace elements in soil and plants. Boca Raton F.L. CRC Press.

Kabata-Pendias A., & Pendias H. (1986). Trace elements in soils and plants. Boca Raton: CRC Press INC.

Krantev A., Yordanova R., Janda T., Szalai G., Popova L. (2008). Treatment with salicilyc acid decreases the effect of cadmium on photosynthesis in maize plants. *Journal Plant Physiology.* (165): 920–93.

Kisku. G.C., Barman S.C., and Bhargava S.K. (2000). Contamination of soil and plants with potentially toxic elements and its impact on the environment. *Water, Air, Soil Pollut.* 120,121-137.

Ouzounidou G. (1994). Copper-induced changes on growth, metal content and photosynthetic function of Alyssum montanum L. plants. Environmental and Experimental Botany, 34, 165–172.

Poschenrieder C.H., B. Gunse and J. Barcelo (1989). Influence of cadmium on water relations, stomatal resistance and abscisic acid content in expanding bean leaves. Plant Physiol., 90, 1365-1371

Stobart A.K., Griffits W., Bukhari I.A., Sherwood R.P. (1985). The effect of Cd^{2+} on the biosynthesis of chlorophyll in leaves of barley. *Physiol. Plant*. 63: 293–298.

Raven P. H., & Johnson G. B. (1986). Biology. St.Louis: Times Mirror/Mosby College Publishing.

Reimann C., Koller F., Kashulina G., Niskavaara H., & Englmaier E. (2001). Influence of extreme pollution on the inorganic chemical composition of some plants. *Environmental Pollution* 115, 239–252.

Sandalio L.M., Dalurzo H.C., Gomez M., Romero-Puertas M.C., del Río L.A. (2001). Cadmium-induced changes in the growth and oxidative metabolism of pea plants. *J. Exp. Bot.* 522: 115-126.

Pandey., R. S. Singh., P. (2001). *J Eco Occu Hlth*. 1, 87.

Shafiq M., Iqbal M.Z. (2005). The toxicity effects of heavy metals on germination and seedlings growth of *Cassia Siamea Lamk. J. New Seeds.*7: 95-105.

Singh D., Nath K., Sharma Y.K. (2007). Response of wheat seed germination and seedling growth under copper stress. *J.Environ.Biol*. 28(2):409-414.

Smiri M., Chaoui A. El., Ferjani E. (2009). Respiratory metabolism in the embryonic axis of germinating pea seed exposed to cadmium. *J. Plant Physiol*. 166(3): 259-269.

Sharma R. K., Agrawal M., Marshall F. (2009). Heavy metals in vegetables collected from production and market sites of a tropical urban area of India. *Food and Chemical Toxicology.* 47: 583–591.

Tiwari Udita., Agnihotri R.K., Shrotriya Swati., Sharma Rajendra. (2013). Effect of Lead Nitrate Induced Heavy Metal Toxicity on some Biochemical Constituents of Wheat (*Triticum aestivum* L).*Research journal of agriculture sciences*. 4(2): 283-285.

Weast R.C. (1984). Hand book of Chemistry and Physics 64th Edn.Boca Raton, CRC Press.

Wisłocka M., Krawczyk J., Klink A., & Morrison L.(2006). Bioaccumulation of heavy metals by selected plant species from uranium mining dumps in the Sudety Mts., Poland. Polish Journal of Environmental Studies, 15(5), 811–818.

Wang H., Zhao S.C., Liu R.L., Zhou W., Jin J.Y. (2009). Changes of photosynthetic activities of maize (Zea mays L.) seedlings in response to cadmium stress. *Photosynthetica.* 47(2): 277-283.