

Determination of Elemental Concentration of Plant Samples of Panipat, Yamuna Nagar, Hisar Thermal Power Plants and Nearby Areas Using AAS and ICP-AES Techniques

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Abstract

This paper reports determination of concentration of zinc, iron, manganese, copper, lead, cadmium, nickel, chromium, arsenic, cobalt, sodium, potassium, calcium and magnesium in different plant samples collected from the surroundings of thermal power plants (TPP) at Panipat, Yamuna Nagar and Hisar Districts of Haryana, India. The atomic absorption spectrometry (AAS) and inductively coupled plasma atomic emission spectrometry (ICP-AES) techniques were used for determination of elemental concentration. From the results, it is found that potassium, calcium, sodium and magnesium were the major elements present in all the plant samples. Plant samples were found with high concentration of the heavy metals.

Keywords: AAS, ICP-AES, Plant, Thermal Power Plant, Heavy Metal

1. Introduction

India is the third largest producer of coal and coal based thermal power plants, which contribute about 70% of the total power generation in India. When coal is burnt in a thermal power plant under controlled conditions, the emission of sulphur oxides, fly ash and polycyclic hydrocarbons as by products takes place (Teerthe et al., 2015). Fly ash produces as by product in emission from coal based thermal power plants using coal is an amalgamated

residue of clay minerals present in it which are converted into ultra-fine particles having different minerals. The chief constituents of fly ash are SiO₂, Al₂O₃, Fe₂O₃, Fe₃O₄, TiO₂ and CaO. Along with these trace elements present in fly ash, it may contain very small quantity of unburnt carbon and few poisonous elements like Zn, Ni, Pb, Co and As which are responsible for polluting soil structure, water and hence the vegetation present in that surroundings (Ahuja et al., 2015; Wilson et al., 2005; Onder et al., 2007). One of the component of fly ash is iron oxides where Fe₃O₄ is root cause of anthropogenic substance in the affected soil, and leaves of the trees (Narayana B. et al., 2006; Boschetti W. et al., 2016; Gupta J. et al., 2014). These are considered to be stern pollutants which are responsible for putting the environment into danger and therefore the entire eco system.

In Haryana, we have chosen thermal power plants in three districts namely TPP Yamuna Nagar, TPP Panipat and TPP Hisar. TPP Yamuna Nagar has a total capacity of power generation 600 MW and total coal consumption is 6.8 MT per day. TPP Panipat has a total capacity of power generation 1360 MW and total coal consumption is 18.3 MT per day. TPP Hisar has a total capacity of power generation 1200 MW and total coal consumption is 15.9 MT per day. As far as vegetation in the vicinity of thermal power plants situated in Haryana is concerned, very few researchers are conducted to explore the effects of fly ash disposed off by thermal power plants on the plants in the

vicinity of TPP. Moreover mode of transfer of fly ash from thermal power plant to plant may be via plant leaves or through soil and hence absorption by roots of plants growing in the vicinity of TPP in question (Dafalla et al., 2014; Belay et al., 2014).

Study of plant samples near the thermal power plants is of great importance as it is related to the environment. The contaminated water and fly ash emerging out of thermal power stations affect the surroundings and hence the elemental composition of the plants. In all countries of the world, environmental pollution remains are the important issues for population, economic and political decision factors (Khan et al., 2011). In the light of all facts and figures stated above, it becomes necessary to study the biological impact of fly ash on the plants in the vicinity of thermal power plants located at Yamuna Nagar, Panipat and Hisar Districts of Haryana, India.

2. Materials and Methods

2.1 Plant Samples

The different plant samples were collected from nearby locations of thermal power plants located at Yamuna Nagar, Panipat and Hisar Districts of Haryana, India. Four samples were collected from each location. Panipat is situated in Haryana state at 29.39°N and 76.97°E. It is an industrial district having thermal power plant at its centre. Thermal power plant, Panipat and other nearby sample locations are shown in Fig. 1. Yamuna Nagar is situated in Haryana state at 30.133°N and 77.288°E. Like Panipat, Yamuna Nagar is also an industrial hub having huge scale industries along with a coal fired thermal power plant. Thermal power plant, Yamuna Nagar and other nearby sample locations are shown in Fig.2. Hisar is located at 29.09°N 75.43°E in western Haryana and having a thermal power plant. Thermal power plant, Hisar and other nearby sample locations are shown in Fig. 3.



Fig. 1: Thermal power plant, Panipat and other nearby sample locations.



Fig. 2: Thermal power plant, Panipat and other nearby sample locations.



Fig. 3: Thermal power plant, Hisar and other nearby sample locations.

The sample analysis was done in the months of December 2017 and June 2018 for all the locations. For the successful and better analysis, sample preparation is the most important work. The plant root sample was first immersed in detergent solution to wash the soil attached for 30 seconds, rinsed with tap water and then with distilled water (Kierdorf et al., 2014; Liu et al., 2014; Wang et al., 2010; Zhang et al., 2015). The sample was allowed to get dry in an oven at 110°C at one hour interval for 7 hours to get constant weight. Now one gm. of the sample was grinded in mortar and pestle. It was sieved using a 0.5mm diameter sieve. For wet ashing, i.e., wet digestion, the grinded and weighted sample was taken in a beaker and 20ml concentrated HNO₃ was added in it. It was kept as such for two hours with covered beaker. Now the sample was heated on hot plate for ten minutes and then was allowed to cool. 10ml of 70% HClO₄ was added in it and again the beaker was placed on the hot plate until the solution was reduced to 2-3ml and allowed to cool. After cooling, it was transferred to 100ml volumetric flask and distilled water was added in it to make 100ml solution. It was stirred and after stirring, it was filtered using Whatman filter paper no. 42 and the sample was

ready for the atomic absorption spectrometry (AAS) and inductively coupled plasma atomic emission spectrometry (ICP-AES) studies. For the first group elements Na and K, the AAS study was done using Zeenit 700 P Analytic Zena spectrometer and for all other elements, ICPE 9000 Shimadzu spectrometer were used. The detail of the various sample locations is given in table 1.

Table 1: Sample Locations

Sample Location	Thermal Power Plant Name
Sutana	Panipat
Asan Kla	Panipat
Asan Khurd	Panipat
Khukhrana	Panipat
Power Plant Colony Panipat	Panipat
Rattan Pura	Yamuna Nagar
Ram Pur	Yamuna Nagar
IshharPur	Yamuna Nagar
Bhadimajra	Yamuna Nagar
Power Plant Colony Yamuna Nagar	Yamuna Nagar
Devi GarhPunia	Hisar
DhaniGaran	Hisar
Sarsod	Hisar
Khedar	Hisar
Power Plant Colony Hisar	Hisar

3. Results and Discussion

The results of the elemental determination obtained using AAS and ICPE techniques for the analysis of plant roots are shown in Table 2 to 7. The concentration of the trace elements was found in ppm range. The samples were analyzed for the elements Na, K, Mg, Mn, Ca, Fe, Cu, Zn, K, Ni, As, Cr, Cd and Pb. One sample location each in the Tables 2 to 7 is shown in bold letter, which is the most distant from thermal power plant and is used as a reference and is assumed to be free from the additional elemental concentrations. Elemental concentrations of other sample locations are found to be larger than the elemental concentration of this location

From Tables 2 to 7, it is observed that the concentration of K is highest in all the plant samples. The concentrations of the elements Ca, Mg and Na are also found to be higher. Fe and Zn shows more or less same concentrations in all the plant samples. It found that the calcium concentration increased so also Magnesium as well as Potassium increases proportionately. The concentrations of the elements Cd, Ni, Cr, and As were found in the range less than 1ppm (Rodushkin et al., 1999; Niamat et al., 2012; Bailey et al., 1950; Michael et al., 1999; Tatro, 2000; Boumans, 1987). Ni, Cd and Pb are the toxic elements, which occur naturally in plants as a result of uptake near the thermal power plants.

Table 2: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in December from the surroundings of Thermal Power Plant, Panipat.

Sample location	Sample Code	Elemental concentration (ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Sutana	A	31.24	32.48	19.75	6.12	1.12	0.114	0.89	0.17	0.56	1.23	1271	43218	3418	1623
	B	32.08	34.28	21.01	6.23	1.05	0.109	0.86	0.18	0.55	1.21	1245	42378	3523	1598
	C	31.00	33.19	21.25	6.87	1.08	0.113	0.79	0.19	0.54	1.20	1301	41980	3612	1609
	D	35.42	36.52	20.08	6.40	1.10	0.107	0.80	0.23	0.57	1.22	1296	42091	3409	1567
Asan Kla	A	35.78	33.28	22.31	7.12	1.02	0.111	0.78	0.29	0.54	1.30	2346	44271	3326	1543
	B	31.56	35.48	21.32	7.25	1.05	0.108	0.76	0.25	0.55	1.28	2351	43076	3219	1529
	C	33.21	36.41	24.31	7.38	1.03	0.110	0.77	0.27	0.52	1.30	2149	44009	3128	1552
	D	34.18	33.15	23.12	7.33	1.08	0.109	0.79	0.26	0.53	1.31	2230	43567	3329	1530
Asan Khurd	A	35.14	39.48	25.22	7.89	1.11	0.112	0.80	0.30	0.64	1.37	2139	43096	4013	1523
	B	32.19	35.44	24.39	7.96	1.01	0.112	0.81	0.31	0.68	1.35	2098	44109	4009	1549
	C	31.10	37.15	21.01	7.90	1.00	0.111	0.82	0.33	0.66	1.33	2087	44210	4012	1555
	D	31.08	36.66	22.45	8.01	1.08	0.108	0.78	0.31	0.61	1.25	2100	44390	4010	1601
Khukhrana	A	51.04	48.99	33.48	13.65	1.02	0.109	1.01	0.40	0.71	1.33	3209	43599	4326	2319
	B	52.36	49.13	34.25	12.58	1.07	0.113	1.10	0.42	0.73	1.38	3315	44009	4318	2210
	C	52.87	53.17	33.07	14.90	1.04	0.108	1.09	0.43	0.74	1.39	3320	44987	4438	2209
	D	53.49	54.01	34.26	15.02	1.06	0.109	1.08	0.44	0.77	1.41	3409	44506	4429	2307
Power Plant Colony Panipat	A	56.44	55.07	38.21	16.25	1.09	0.107	1.41	0.50	0.78	1.40	3508	48093	4457	2806
	B	54.52	59.25	35.23	14.23	1.05	0.113	1.42	0.54	0.79	1.38	3517	48912	4507	2304
	C	57.22	60.11	36.24	15.20	1.09	0.110	1.32	0.55	0.76	1.40	3526	49023	4512	2298
	D	54.31	60.32	33.30	14.35	1.11	0.112	1.35	0.53	0.81	1.39	3529	48034	4523	2287

Table 3: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in June from the surroundings of Thermal Power Plant, Panipat

Sample location	Sample Code	Elemental concentration(ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Sutana	A	30.79	31.95	18.79	6.20	1.11	0.119	0.87	0.15	0.58	1.24	1269	43210	3421	1628
	B	30.91	32.39	20.06	6.15	1.07	0.110	0.84	0.17	0.54	1.22	1252	42289	3515	1586
	C	31.04	32.97	21.22	6.86	1.09	0.112	0.80	0.16	0.56	1.21	1312	41998	3620	1614
	D	33.76	33.01	20.11	6.56	1.11	0.109	0.80	0.22	0.52	1.23	1301	42097	3412	1568
Asan Kla	A	36.20	32.99	22.40	7.18	1.05	0.112	0.79	0.27	0.53	1.35	2344	44280	3329	1550
	B	30.98	34.68	20.96	7.20	1.06	0.109	0.77	0.26	0.57	1.26	2348	43088	3224	1532
	C	32.87	35.64	24.22	7.34	1.07	0.115	0.74	0.24	0.55	1.36	2138	44001	3119	1553
	D	33.95	32.18	22.94	7.25	1.09	0.110	0.75	0.22	0.54	1.34	2235	43410	3325	1541
Asan Khurd	A	34.96	37.26	25.11	7.81	1.10	0.111	0.86	0.33	0.68	1.35	2140	43089	4014	1528
	B	32.24	34.48	23.99	7.78	1.07	0.115	0.83	0.30	0.64	1.33	2102	44101	4008	1558
	C	31.38	36.23	21.14	7.82	1.05	0.114	0.80	0.34	0.61	1.31	2104	44175	4015	1568
	D	31.21	35.21	22.78	8.12	1.06	0.109	0.82	0.35	0.63	1.29	2105	44356	4017	1627
Khukhrana	A	50.27	49.25	33.44	13.15	1.08	0.107	1.04	0.43	0.77	1.30	3215	43448	4331	2322
	B	51.28	48.17	34.20	12.48	1.03	0.111	1.16	0.41	0.75	1.32	3289	44001	4322	2218
	C	52.49	52.96	32.95	14.70	1.09	0.109	1.09	0.40	0.71	1.37	3317	44875	4440	2217
	D	53.02	53.99	34.11	15.42	1.04	0.111	1.04	0.42	0.70	1.40	3415	44445	4435	2323
Power Plant Colony PNP	A	55.78	54.82	38.30	16.76	1.06	0.109	1.39	0.56	0.79	1.44	3512	48086	4468	2809
	B	53.98	58.23	37.25	14.48	1.07	0.110	1.40	0.51	0.75	1.36	3510	48852	4514	2307
	C	55.22	60.02	36.78	15.43	1.10	0.113	1.38	0.52	0.74	1.42	3523	49021	4519	2276
	D	54.54	59.79	35.75	14.29	1.12	0.111	1.37	0.53	0.82	1.35	3530	48079	4530	2255

Table 4: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in December from the surroundings of Thermal Power Plant, Yamuna Nagar.

Sample location	Sample Code	Elemental concentration(ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Bhadimajra	A	52.23	54.36	32.89	12.36	1.11	0.107	1.12	0.48	0.76	1.79	3245	43518	4452	2356
	B	53.40	65.28	33.28	11.98	1.09	0.113	1.09	0.49	0.74	1.80	3328	44018	4568	2347
	C	51.99	64.36	32.08	13.52	1.06	0.112	1.07	0.47	0.72	1.82	3378	44875	4456	2312
	D	50.58	66.12	33.01	14.09	1.02	0.108	1.06	0.49	0.75	1.69	3446	44604	4503	2425
Ram Pur	A	42.85	52.20	23.12	7.08	1.14	0.106	0.89	0.28	0.53	1.64	2430	44542	3456	1642
	B	43.69	53.35	22.89	7.13	1.16	0.104	0.84	0.21	0.54	1.87	2412	43287	3315	1603
	C	45.36	54.32	23.88	7.20	1.11	0.113	0.80	0.25	0.58	1.80	2289	43489	3254	1599
	D	41.28	52.21	22.01	7.11	1.10	0.112	0.78	0.23	0.52	1.79	2285	43501	3406	1586
IshharPur	A	43.46	57.37	23.99	7.36	1.17	0.110	0.81	0.39	0.69	1.76	2287	43148	4125	1607
	B	41.27	54.33	22.87	7.54	1.16	0.111	0.81	0.34	0.63	1.61	2112	44112	4114	1624
	C	44.22	56.29	22.14	7.83	1.12	0.109	0.80	0.36	0.64	1.63	2102	44378	4110	1638
	D	42.12	55.75	21.68	8.25	1.11	0.107	0.79	0.35	0.67	1.64	2185	44345	4187	1704
Rattan Pura	A	41.45	53.36	22.34	7.87	1.19	0.112	0.93	0.21	0.59	1.83	1652	43897	3872	1898
	B	40.14	52.31	22.01	7.09	1.13	0.107	0.94	0.23	0.56	1.72	1585	43564	3713	1765
	C	43.23	51.21	20.89	7.16	1.11	0.110	0.92	0.20	0.55	1.64	1587	42996	3709	1699
	D	42.21	54.37	21.78	7.11	1.09	0.109	0.92	0.21	0.51	1.86	1498	42876	3689	1601
Power Plant Colony YNR	A	60.01	64.09	36.52	15.23	1.10	0.109	1.50	0.53	0.73	1.77	3512	47369	4547	2905
	B	60.22	65.34	34.22	13.88	1.12	0.111	1.53	0.58	0.74	1.76	3517	48409	4648	2401
	C	61.20	64.84	34.44	14.27	1.10	0.112	1.49	0.59	0.71	1.73	3598	49156	4663	2356
	D	62.08	63.37	31.09	14.09	1.15	0.110	1.46	0.59	0.87	1.79	3566	48287	4591	2399

Table 5: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in June from the surroundings of Thermal Power Plant, Yamuna Nagar.

Sample location	Sample Code	Elemental concentration (ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Bhadimajra	A	51.20	52.49	33.48	13.01	1.13	0.103	1.06	0.43	0.78	1.73	3198	43602	4554	2398
	B	52.54	62.39	34.01	12.21	1.09	0.111	1.05	0.41	0.79	1.70	3264	44123	4657	2399
	C	53.08	61.57	33.09	12.97	1.08	0.109	1.04	0.40	0.75	1.66	3289	44989	4523	2358
	D	52.67	62.38	34.18	13.58	1.04	0.107	1.04	0.42	0.73	1.61	3367	44612	4608	2475
Ram Pur	A	41.64	53.36	22.02	7.24	1.09	0.110	0.88	0.27	0.55	1.56	2412	44547	3478	1623
	B	42.38	51.21	21.94	7.36	1.14	0.104	0.85	0.24	0.53	1.74	2407	43312	3386	1599
	C	43.62	52.30	23.56	7.78	1.12	0.112	0.83	0.26	0.50	1.69	2385	43548	3304	1618
	D	41.29	51.29	22.97	7.54	1.10	0.105	0.79	0.24	0.53	1.66	2346	43612	3457	1685
IshharPur	A	42.54	55.42	22.85	7.62	1.10	0.113	0.83	0.32	0.68	1.82	2310	43325	4228	1701
	B	42.32	55.46	21.28	7.89	1.13	0.111	0.82	0.32	0.66	1.70	2107	44289	4198	1712
	C	43.29	53.48	22.10	7.52	1.08	0.114	0.81	0.31	0.64	1.69	2109	44456	4168	1689
	D	40.23	51.86	22.03	8.31	1.11	0.109	0.77	0.30	0.60	1.65	2200	44419	4235	1701
Rattan Pura	A	42.29	54.20	23.19	7.20	1.18	0.110	0.95	0.18	0.54	1.87	1668	43884	3901	1873
	B	41.32	53.28	22.89	7.18	1.13	0.107	0.92	0.19	0.55	1.69	1613	43579	3874	1754
	C	42.64	52.17	21.07	7.23	1.12	0.111	0.91	0.17	0.53	1.58	1599	42967	3745	1684
	D	40.20	51.32	22.00	7.58	1.11	0.103	0.90	0.20	0.56	1.79	1502	42901	3695	1616
Power Plant Colony YNR	A	61.29	60.25	37.22	14.55	1.11	0.105	1.57	0.54	0.72	1.62	3614	47384	4587	2915
	B	61.35	62.21	35.96	14.22	1.13	0.110	1.48	0.52	0.74	1.77	3588	48427	4756	2446
	C	62.48	61.08	35.24	13.94	1.12	0.112	1.41	0.51	0.76	1.79	3604	49228	4632	2344
	D	61.59	60.33	34.04	13.86	1.11	0.114	1.32	0.50	0.89	1.82	3589	48419	4608	2380

Table 6: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in December from the surroundings of Thermal Power Plant, Hisar.

Sample location	Sample Code	Elemental concentration(ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Sarsod	A	44.06	58.78	24.38	7.64	1.24	0.124	0.84	0.33	0.61	1.36	2220	43258	4141	1587
	B	44.89	59.13	24.11	7.73	1.18	0.119	0.82	0.34	0.65	1.34	2129	44264	4110	1589
	C	45.13	59.33	25.02	7.99	1.16	0.120	0.80	0.35	0.63	1.31	2110	44312	4135	1601
	D	45.01	60.24	24.78	8.14	1.13	0.118	0.79	0.37	0.66	1.29	2122	44354	4126	1599
DhaniGaran	A	43.87	60.12	22.99	7.26	1.20	0.124	0.82	0.28	0.59	1.31	2352	45315	3420	1572
	B	43.25	59.88	21.88	7.78	1.23	0.117	0.81	0.24	0.62	1.26	2412	44018	3328	1516
	C	44.20	59.99	23.12	7.95	1.19	0.119	0.80	0.23	0.60	1.35	2285	44088	3279	1603
	D	44.09	61.02	22.96	7.76	1.17	0.116	0.83	0.24	0.59	1.34	2316	43645	3346	1614
Devi Garh Punia	A	44.43	59.54	22.35	7.83	1.38	0.121	0.90	0.26	0.59	1.34	2089	45578	3675	1659
	B	43.89	58.25	21.89	7.61	1.21	0.118	0.91	0.24	0.56	1.32	2043	45612	3643	1642
	C	43.12	57.99	22.08	7.12	1.29	0.119	0.93	0.25	0.61	1.29	2108	44968	3618	1610
	D	42.01	58.01	21.87	7.99	1.31	0.116	0.89	0.23	0.60	1.28	2073	45012	3528	1598
Khedar	A	56.19	61.03	33.16	12.06	1.15	0.117	1.21	0.43	0.78	1.30	3231	43667	4482	2318
	B	54.11	61.14	34.98	12.34	1.13	0.118	1.19	0.44	0.79	1.31	3325	44121	4440	2324
	C	57.06	61.25	34.21	13.92	1.14	0.120	1.18	0.41	0.78	1.34	3331	45017	4425	2229
	D	58.13	60.97	33.88	14.01	1.12	0.119	1.17	0.40	0.77	1.40	3419	44985	4512	2343
Power Plant Colony Hisar	A	58.11	61.22	37.89	14.23	1.11	0.119	1.39	0.56	0.81	1.46	3517	48102	4396	2818
	B	58.76	61.35	36.18	13.98	1.10	0.118	1.40	0.55	0.80	1.42	3535	48328	4448	2315
	C	59.05	60.88	34.99	14.12	1.14	0.117	1.37	0.51	0.79	1.45	3652	49123	4602	2287
	D	57.98	61.54	35.18	13.99	1.13	0.121	1.33	0.50	0.84	1.44	3608	49005	4619	2235

Table 7: Concentration of Elements of significance observed in AAS and ICPE analysis of Plant samples collected in June from the surroundings of Thermal Power Plant, Hisar.

Sample location	Sample Code	Elemental concentration(ppm)													
		Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Sarsod	A	44.08	59.26	24.48	7.53	1.22	0.137	0.85	0.33	0.66	1.34	2318	43269	4235	1601
	B	45.14	58.75	24.36	7.79	1.19	0.129	0.86	0.31	0.62	1.30	2210	44287	4220	1603
	C	45.17	60.02	25.47	7.80	1.18	0.131	0.87	0.39	0.60	1.28	2201	44356	4354	1609
	D	45.32	61.04	24.89	8.25	1.15	0.124	0.83	0.38	0.64	1.30	2168	44410	4200	1568
DhaniGaran	A	43.15	61.07	22.10	7.32	1.29	0.132	0.89	0.25	0.60	1.37	2361	45325	3558	1588
	B	43.02	60.28	21.62	7.56	1.24	0.125	0.82	0.21	0.61	1.32	2456	44121	3489	1524
	C	44.11	60.22	23.45	7.88	1.17	0.126	0.81	0.26	0.58	1.30	2287	44109	3385	1618
	D	43.96	61.45	22.99	7.72	1.18	0.142	0.80	0.27	0.57	1.36	2323	43658	3358	1628
Devi Garh Punia	A	43.87	58.76	22.85	7.96	1.32	0.125	0.96	0.29	0.58	1.30	2086	45611	3698	1732
	B	42.94	58.09	21.32	7.87	1.25	0.123	0.94	0.20	0.53	1.36	2121	45599	3657	1658
	C	42.99	57.23	22.44	7.45	1.24	0.124	0.91	0.23	0.67	1.35	2112	44987	3712	1701
	D	43.08	58.32	21.32	7.86	1.30	0.120	0.87	0.21	0.62	1.34	2098	45123	3609	1658
Khedar	A	55.76	61.45	33.65	12.14	1.17	0.120	1.23	0.46	0.79	1.31	3330	43712	4531	2341
	B	54.58	61.76	34.99	12.25	1.17	0.128	1.25	0.45	0.70	1.30	3329	44252	4458	2350
	C	56.88	60.94	34.88	13.98	1.16	0.134	1.29	0.48	0.73	1.36	3354	45128	4438	2289
	D	57.82	61.08	33.75	14.14	1.13	0.126	1.27	0.42	0.75	1.47	3468	44990	4589	2359
Power Plant Colony Hisar	A	57.99	61.64	37.73	14.36	1.14	0.139	1.42	0.59	0.84	1.49	3526	48203	4447	2972
	B	59.05	61.28	36.25	13.99	1.15	0.130	1.49	0.57	0.88	1.46	3540	48412	4496	2453
	C	57.23	60.45	34.86	14.28	1.18	0.127	1.44	0.58	0.83	1.41	3672	49159	4726	2294
	D	58.36	61.76	35.47	13.70	1.17	0.135	1.42	0.54	0.87	1.40	3618	49147	4771	2262

$$r = \frac{\sum xy}{\sqrt{\sum x^2 \times \sum y^2}}$$

3.1 Correlation Studies

Study of correlation reduces the range of uncertainty associated with decision making. The correlation coefficient 'r' was calculated using the equation

The correlation matrix for the concentration of the elements present in the plant samples are given in the tables below.

Table 8: Correlation matrix for the elemental concentration of different plant samples collected in December 2017 from the surroundings of Thermal Power Plant, Panipat.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.9781	0.9972	0.9937	0.6518	0.0173	0.9343	0.9413	0.8861	-0.2643	0.9987	0.7229	0.8090	0.9975
Fe		1	0.9873	0.9858	0.7737	0.2138	0.9796	0.9906	0.9412	-0.0987	0.9721	0.8251	0.8708	0.9896
Mn			1	0.9990	0.6690	0.0866	0.9418	0.9565	0.9182	-0.2477	0.9924	0.7343	0.8500	0.9995
Cu				1	0.6571	0.1089	0.9347	0.9552	0.9308	-0.2636	0.9868	0.7209	0.8694	0.9976
Pb					1	0.5104	0.8789	0.8447	0.6998	0.5538	0.6529	0.9935	0.6075	0.6858
Cd						1	0.2632	0.3259	0.4483	0.5385	-0.0190	0.4252	0.5187	0.0875
Ni							1	0.9904	0.8927	0.0918	0.9332	0.9197	0.8034	0.9496
Cr								1	0.9462	0.0263	0.9335	0.8826	0.8775	0.9609
As									1	-0.1301	0.8635	0.7282	0.9851	0.9142
Co										1	-0.2557	0.4746	-0.1794	-0.2246
Na											1	0.7264	0.7791	0.9937
K												1	0.6264	0.7507
Ca													1	0.8422
Mg														1

Table 9: Correlation matrix for the elemental concentration of different plant samples collected in June 2018 from the surroundings of Thermal Power Plant, Panipat.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.9877	0.9900	0.9940	-0.1127	-0.8580	0.9335	0.9034	0.9280	-0.2306	0.9331	0.7796	0.8511	0.9943
Fe		1	0.9947	0.9938	-0.0466	-0.7809	0.9696	0.9485	0.9589	-0.1069	0.9296	0.8543	0.8898	0.9870
Mn			1	0.9975	-0.1456	-0.8282	0.9414	0.9539	0.9575	-0.1407	0.9610	0.8357	0.8815	0.9795
Cu				1	-0.1420	-0.8395	0.9376	0.9407	0.9616	-0.1983	0.9476	0.8035	0.8955	0.9879
Pb					1	0.5313	0.1901	-0.1598	-0.1401	0.4514	-0.3722	0.1571	-0.1129	-0.0301
Cd						1	-0.6175	-0.6864	-0.7273	0.5622	-0.8698	-0.4314	-0.6426	-0.8182
Ni							1	0.9108	0.9132	0.0569	0.8309	0.9047	0.8500	0.9503
Cr								1	0.9693	0.0588	0.9385	0.9014	0.9110	0.8902
As									1	-0.1356	0.9012	0.8041	0.9778	0.9315
Co										1	-0.1217	0.4238	-0.1938	-0.2347
Na											1	0.7973	0.8016	0.8946
K												1	0.7075	0.7728
Ca													1	0.8690
Mg														1

Table 10: Correlation matrix for the elemental concentration of different plant samples collected in December 2017 from the surroundings of Thermal Power Plant, Yamuna Nagar.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.9414	0.9505	0.9644	-0.4811	0.8848	0.9629	0.9273	0.8561	-0.1940	0.9177	0.9190	0.7999	0.9500
Fe		1	0.9752	0.9853	-0.6336	0.8925	0.8515	0.9857	0.9731	-0.4755	0.9406	0.7857	0.9279	0.9592
Mn			1	0.9929	-0.7225	0.8663	0.8656	0.9328	0.9030	-0.4822	0.9614	0.7548	0.8389	0.9808
Cu				1	-0.6669	0.9163	0.9009	0.9490	0.9228	-0.4362	0.9356	0.7955	0.8808	0.9915
Pb					1	-0.4935	-0.3540	-0.5206	-0.5765	0.8736	-0.6641	-0.0968	-0.5213	-0.6847
Cd						1	0.9157	0.8534	0.8518	-0.2902	0.7213	0.7815	0.9024	0.9397
Ni							1	0.8274	0.7487	-0.0222	0.7802	0.9323	0.7391	0.9135
Cr								1	0.9814	-0.4048	0.9267	0.8215	0.9295	0.9056
As									1	-0.5306	0.8762	0.71591	0.9724	0.8829
Co										1	-0.4528	0.1696	-0.5047	-0.4260
Na											1	0.7455	0.7575	0.8926
K												1	0.6760	0.7702
Ca													1	0.8602
Mg														1

Table 11: Correlation matrix for the elemental concentration of different plant samples collected in June 2018 from the surroundings of Thermal Power Plant, Yamuna Nagar.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.9483	0.9607	0.9674	-0.2334	0.1404	0.9635	0.9428	0.8752	-0.1804	0.9189	0.9132	0.7940	0.9538
Fe		1	0.9792	0.9906	-0.4521	0.1371	0.8546	0.9457	0.9734	-0.4124	0.9150	0.7765	0.9212	0.9889
Mn			1	0.9965	-0.4196	-0.0285	0.8760	0.9175	0.9125	-0.4428	0.9373	0.7663	0.8260	0.9940
Cu				1	-0.4338	0.0529	0.8782	0.9441	0.9392	-0.4149	0.9451	0.7916	0.8594	0.9935
Pb					1	-0.0089	0.0342	-0.4657	-0.5574	0.8240	-0.5529	0.0177	-0.4647	-0.3962
Cd						1	0.1309	0.3355	0.2926	0.4905	0.0960	0.4144	0.3705	0.0041
Ni							1	0.8378	0.7499	0.0295	0.7891	0.9366	0.6948	0.8770
Cr								1	0.9420	-0.2541	0.9582	0.8694	0.8550	0.9074
As									1	-0.4289	0.877	0.7190	0.9699	0.9310
Co										1	-0.4095	0.2133	-0.3616	-0.4334
Na											1	0.7810	0.7375	0.9038
K												1	0.6536	0.7575
Ca													1	0.8698
Mg														1

Table 12: Correlation matrix for the elemental concentration of different plant samples collected in December 2017 from the surroundings of Thermal Power Plant, Hisar.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.8521	0.9974	0.9991	-0.7965	-0.3944	0.9639	0.9308	0.9945	0.8029	0.9885	0.6367	0.8647	0.9951
Fe		1	0.8533	0.8434	-0.9148	-0.2528	0.7418	0.7631	0.8481	0.6733	0.9026	0.4166	0.6102	0.8171
Mn			1	0.9937	-0.8261	-0.3280	0.9506	0.9497	0.9994	0.8089	0.9805	0.6235	0.8913	0.9866
Cu				1	-0.7737	-0.4294	0.9726	0.9218	0.9896	0.8051	0.9897	0.6536	0.8502	0.9980
Pb					1	-0.1194	-0.6421	-0.8356	-0.8345	-0.6713	-0.8042	-0.3355	-0.7518	-0.7346
Cd						1	-0.5144	-0.0868	-0.2993	-0.1664	-0.4455	-0.3549	-0.0062	-0.4726
Ni							1	0.8974	0.9429	0.8600	0.9549	0.7913	0.7924	0.9785
Cr								1	0.9556	0.8982	0.8963	0.7051	0.9251	0.9054
As									1	0.8059	0.9740	0.6127	0.9047	0.9816
Co										1	0.8078	0.9202	0.6817	0.7892
Na											1	0.6463	0.7851	0.9836
K												1	0.4671	0.6563
Ca													1	0.8419
Mg														1

Table 13: Correlation matrix for the elemental concentration of different plant samples collected in June 2018 from the surroundings of Thermal Power Plant, Hisar.

	Zn	Fe	Mn	Cu	Pb	Cd	Ni	Cr	As	Co	Na	K	Ca	Mg
Zn	1	0.7253	0.9975	0.9970	-0.7951	0.3265	0.9735	0.9472	0.9623	0.8115	0.9895	0.6341	0.8620	0.9868
Fe		1	0.7351	0.6959	-0.8704	0.7223	0.6007	0.6972	0.6488	0.5311	0.7892	0.2637	0.5318	0.6429
Mn			1	0.9894	-0.8293	0.3571	0.9616	0.9623	0.9628	0.7874	0.9825	0.6168	0.8907	0.9746
Cu				1	-0.7473	0.2859	0.9850	0.9299	0.9615	0.8383	0.9889	0.6628	0.8327	0.9961
Pb					1	-0.6460	-0.6565	-0.8538	-0.7438	-0.4480	-0.7890	-0.2681	-0.8375	-0.6873
Cd						1	0.2568	0.5025	0.4241	0.3946	0.3900	0.3520	0.3010	0.2328
Ni							1	0.9211	0.9763	0.9006	0.9618	0.7726	0.8046	0.9934
Cr								1	0.9761	0.7881	0.9225	0.6942	0.9286	0.9103
As									1	0.8941	0.9485	0.7996	0.8577	0.9587
Co										1	0.8406	0.9321	0.5420	0.8619
Na											1	0.6385	0.7919	0.9777
K												1	0.4769	0.6986
Ca													1	0.8065
Mg														1

4. Conclusions

The present study reports determination of concentration of zinc, iron, manganese, copper, lead, cadmium, nickel, chromium, arsenic, cobalt, sodium, potassium, calcium and magnesium in different plant samples collected from the surroundings of thermal power plants (TPP) at Panipat, Yamuna Nagar and Hisar Districts of Haryana, India. The atomic absorption spectrometry (AAS) and inductively coupled plasma atomic emission spectrometry (ICP-AES) techniques were used for determination of elemental concentration. From the results, it is found that potassium, calcium, sodium and magnesium were the major elements present in all the plant samples. Elemental concentration in different sample locations varied significantly in the plant samples. It has been demonstrated that AAS and ICP-AES techniques with multi-elemental characterization over a wide range of concentration, are user-friendly instruments and require minimum sample for such studies.

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