Article

Effects of heavy metals/metalloids present in fly ash from coal fired thermal power plant on photosynthetic parameters of *Mangifera indica*

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Abstract
In the present work heavy metals/metalloids present in the fly ash emitted from a coal fired thermal power plant was estimated. The effects of heavy metals/metalloids present in the ash on various photosynthetic parameters (fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc.) were estimated. Heavy metals/metalloids were estimated using atomic absorption spectrophotometer (AAS, 7000 Shimadzu) for Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co and Ni and the standard solution was prepared using standard metal solution of Inorganic Ventures. Various photosynthetic parameters were estimated using JUNIOR-PAM, Chlorophyll Fluorometer, Heinz Walz GmbH, Germany. It was clear from the observed value of Fv/Fm (0.717) that the heavy metals/metalloids present in the fly have negative effects on plants because for a healthy plant Fv/Fm should not be less than 0.75. Similarly other parameters were also adversely affected by the presence of heavy metals/metalloids present in the fly ash that were deposited on the plants leaves. Therefore, the issue of fly ash emitted from thermal power plants need to be addressed in a proper way.

Keywords heavy metals; fluorescence; ETR-Factor; Fv/Fm.

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1 Introduction

Environmental pollution in recent years has increases manifolds due to rapid growth of industries and anthropogenic pressure worldwide (Zhang et al., 2011; Jean-Philippe et al., 2012; Al-Farraj et al., 2013; Su et al., 2014). Out of the different types of environmental pollutants the problem, heavy metal pollution is of serious concern to the environmentalists since they persist in the environment and may have serious repercussions to the biotic world. There are various sources of heavy metal coming in the environment such as mining industries, electroplating industries, thermal power plants, textile, and leather and tanning industries etc. Out of the above fly ash coming from thermal power plants are also important sources. Huge amount of fly ash is generated in India from the coal fired thermal power plants leading to environmental pollution (TERI, 2000). The fly ash contains several heavy metals/metalloids such as As, Mo, Se, Cd and Zn (el-Mogazi et al., 1988). Presence of these metals/metalloids and other components may make the fly ash toxic which may have deleterious impacts on flora and fauna surrounding the power plants. Environmentally released metals are mainly deposited in soils and are mobilized either by leaching or by uptake into plants (Prajapati et al., 2012).

Various researches have established that there is a clear cut relationship between the exposure of heavy metals/metalloids and the physiological responses in plants (such as changes in chlorophyll content and photosynthesis activities). Usually metals/metalloids exposure of low levels does not lead to any visible effects on the plants, but it is only after a threshold limit of metals/metalloids (Rodríguez et al., 2007). Fly ash contaminated by metals/metalloids causes stresses that limit plant growth and development (Liphadzi and Kirkham, 2006). Studies have shown that plant species growing in polluted environments may be stressed in various ways viz. bioaccumulation of metals to toxic concentrations may disturb normal physiological processes of plants (Dahmani-Muller et al., 2000; Monni et al., 2001; Plekhanov & Chemeris, 2003; Liphadzi & Kirkham, 2006). For example, studies have shown that growth and photosynthetic activities are adversely affected by cadmium (Nagel et al., 1996). However, metal pollution of plants growing in the polluted environments may exhibit toxicity simultaneously and interactively at different levels (Walker et al., 2003; Vάzquez et al., 2006; Rodríguez et al., 2007).

2 Materials and Methods

Present experiments were performed in the vicinity of a super thermal power plant (NTPC, Sipat, Chhattisgarh, India) located at 22°07' N and 82°16' 43 E with an installed capacity of 2980 MW. *Mangifera indica* (mango plant) commonly growing in the area was selected for the present stusy. The ash deposited on the leaves of *Mangifera indica* was taken for the analysis of heavy metals/metalloids. Analysis of fly ash for heavy metals/metalloids (Fe, Zn, Pb, Cd, Mo, Cu, Cr, Co and Ni) were performed with the help of atomic absorption spectrophotometer (AAS) model: AA 7000, SHIMADZU and the standards were prepared using standard metal solution of Inorganic Ventures. Various photosynthetic parameters (fluorescence, Fv/Fm, fluorescence quenching coefficients, relative electron transport rate, photosynthetic active radiation, ETR-Factor absorptance of photons by photosynthetic pigments etc.) were measured using JUNIOR-PAM, Chlorophyll Fluorometer, Heinz Walz GmbH, Germany.

3 Results and Discussions

Dust in the vicinity of the coal fired thermal power plant arises mainly because of two reasons. First, due to emissions from the power plant and second from the re-suspension of fly ash present in the fly ash dykes due to wind and other atmospheric conditions. The dust deposited on the mango leaf were analysed by AAS. The analysis of dust deposited on *Mangifera indica* leaves showed the presence of various heavy metals/metalloids and in varied concentration as shown in Table 1. It is clear from the table that Fe was present in maximum amount followed by Mo>Zn>Cr>Co>Ni>Cd. Lead and copper were absent in the dust. Presence of these metals/metalloids in dust deposited on leaves may have serious repercussions for the various physiological processes of plants including the photosynthetic parameters. These contaminants are also harmful for the general public, terrestrial flora and fauna and as well aquatic flora and fauna of the area.

Table 1 Heavy metals/metalloids concentration (μg g^{-1} dry wt. of dust) present on leaves of *Mangifera indica*.

Metal/metalloids	Fe	Zn	Pb	Cd	Mo	Cu	Cr	Co	Ni
Concentration	33.02	1.402	0.00	0.082	4.49	0.00	0.213	0.176	0.127

Dust deposited on plant leaf surfaces may impede with gas diffusion between the leaf and atmosphere. Sedimentation of dust particles affects the upper surfaces of leaves more (Thompson et al., 1984; Kim et al., 2000) while finer particles affects lower surfaces (Ricks and Williams 1974; Krajickova and Mejstrik, 1984; Fowler et al., 1989; Beckett at al., 2000). The adverse effects of dust contaminated by heavy metals/metalloids on the various photosynthetic parameters have been shown in the Table 2. The Fv/Fm values which is an indication of the maximum and effective photochemical quantum yield of PS II is below 0.75. If the value of Fv/Fm is below 0.75 (0.717, 0.639 and 0.684 in present study), it means that the plant is under stress condition and accordingly other photosynthetic parameters are also adversely affected. Dust deposition affects the light available for photosynthesis and blocks the stomatal pore for diffusion of air and thus put stress on plant metabolism (Eller, 1977; Hope et al., 1991; Keller and Lamprecht, 1995; Anthony, 2001).The ETR-F values correspond to the ratio of photons absorbed by photo-synthetic pigments to incident photons which is 0.84 in present case. The PAR value in present case is 429 (in µmoles/(m^2·s) and the relative electron transport rate (ETR) varies during the experiments which is provided in the Table 2. Variation of other photosynthetic parameters can also be observed from the given table.

Table 2 The deatiled report of the various photosysnthetic parameters.

21-12-2013	17:51:33	WinControl (rev 700) report file																		
Date	Time	Type	No.	1:F	1:Fm'	1:PAR	1:Temp	1:Y (II)	1:ETR	1:Fo'	1:ETR-F.	1:qP	1:qN	1:qL	1:NPQ	1:Y (NO)	1:Y (NPQ)	1:Fo	1:Fm	1:Fv/Fm
		D		Device Nr: #1, Mini-PAM																
07-09-2013	08:11:19	SCHS		Chart Start																
07-09-2013	08:11:27	FO	462	808	2853	0	86.3	0.717	0	-	0.84	-	-	-	-	-	-	808	2853	0.717
07-09-2013	08:12:45	F	463	1352	1607	429	86.3	0.159	28.6	~663	0.84	0.27	0.538	0.132	0.775	0.474	0.367	808	2853	0.717
07-09-2013	08:13:34	F	464	1303	1559	429	86.3	0.164	29.5	~654	0.84	0.283	0.557	0.142	0.83	0.456	0.38	808	2853	0.717
07-09-2013	08:14:19	F	465	1269	1519	429	86.3	0.165	29.7	~647	0.84	0.287	0.574	0.146	0.878	0.444	0.391	808	2853	0.717
07-09-2013	08:15:15	F	466	1269	1510	429	86.4	0.16	28.8	~645	0.84	0.279	0.577	0.142	0.889	0.444	0.396	808	2853	0.717
07-09-2013	08:15:27	SCHS		Chart start																
07-09-2013	08:15:37	FO	467	680	1883	0	86.3	0.639	0	-	0.84	-	-	-	-	-	-	680	1883	0.639
07-09-2013	08:15:49	F	468	1536	1826	429	86.4	0.159	28.6	~672	0.84	0.251	0.041	0.11	0.031	0.815	0.026	680	1883	0.639
07-09-2013	08:16:20	F	469	752	1521	0	86.3	0.506	0	~626	0.84	0.859	0.256	0.715	0.238	0.399	0.095	680	1883	0.639
07-09-2013	08:16:52	F	470	704	2083	0	86.3	0.662	0	~704	0.84	1	-0.146	1	-0.096	0.374	-0.036	680	1883	0.639
07-09-2013	08:17:23	F	471	743	2440	0	86.3	0.695	0	~741	0.84	0.999	-0.412	0.996	-0.228	0.394	-0.089	680	1883	0.639
07-09-2013	08:17:54	F	472	767	2595	0	86.3	0.704	0	~755	0.84	0.993	-0.53	0.977	-0.274	0.407	-0.111	680	1883	0.639
07-09-2013	08:17:57	SICS		Induction Curve start																
07-09-2013	08:18:01	FO	473	814	2574	0	86.3	0.684	0	-	0.84	-	-	-	-	-	-	814	2574	0.684
07-09-2013	08:18:41	F	474	2041	2290	429	86.3	0.109	19.6	~783	0.84	0.165	0.144	0.063	0.124	0.793	0.098	814	2574	0.684
07-09-2013	08:19:02	F	475	1276	1520	429	86.4	0.161	29	~668	0.84	0.286	0.516	0.15	0.693	0.495	0.344	814	2574	0.684
07-09-2013	08:19:24	F	476	1232	1480	429	86.3	0.168	30.3	~660	0.84	0.302	0.534	0.162	0.739	0.478	0.354	814	2574	0.684
07-09-2013	08:19:43	F	477	1208	1461	429	86.4	0.173	31.2	~656	0.84	0.314	0.543	0.171	0.762	0.469	0.358	814	2574	0.684
07-09-2013	08:20:04	F	478	1191	1447	429	86.3	0.177	31.9	~653	0.84	0.322	0.549	0.177	0.779	0.462	0.361	814	2574	0.684
07-09-2013	08:20:26	F	479	1176	1440	429	86.4	0.183	33	~652	0.84	0.335	0.552	0.186	0.788	0.456	0.361	814	2574	0.684
07-09-2013	08:20:47	F	480	1168	1429	429	86.4	0.183	33	~649	0.84	0.335	0.557	0.186	0.801	0.453	0.364	814	2574	0.684
07-09-2013	08:21:08	F	481	1158	1424	429	86.4	0.187	33.7	~648	0.84	0.343	0.559	0.192	0.808	0.449	0.364	814	2574	0.684
07-09-2013	08:21:28	F	482	1149	1418	429	86.4	0.19	34.2	~647	0.84	0.349	0.562	0.197	0.815	0.446	0.364	814	2574	0.684
07-09-2013	08:21:49	F	483	1139	1414	429	86.4	0.194	35	~646	0.84	0.358	0.564	0.203	0.82	0.442	0.364	814	2574	0.684
07-09-2013	08:22:10	F	484	1129	1409	429	86.4	0.199	35.9	~645	0.84	0.366	0.566	0.209	0.827	0.438	0.363	814	2574	0.684
07-09-2013	08:22:31	F	485	1121	1408	429	86.4	0.204	36.8	~645	0.84	0.376	0.566	0.216	0.828	0.435	0.361	814	2574	0.684
07-09-2013	08:22:52	F	486	1119	1401	429	86.3	0.201	36.2	~644	0.84	0.373	0.57	0.215	0.837	0.434	0.365	814	2574	0.684
07-09-2013	08:23:03	F	487	268	176	0	86.3	-	-	-	0.84	-	-	-	-	-	-	814	2574	0.684

F_o Basic fluorescence yield (relative units) recorded with low measuring light intensities. **F_m** Maximal chlorophyll fluorescence yield when photosystem II reaction centers are closed by a strong light pulse (relative units). **$F_v/F_m = (F_m-F_o)/F_m$** maximum photochemical quantum yield of photosystem II. **qP and qL** Coefficients of photochemical fluorescence quenching. **qN** and **NPQ** Parameters of non-photochemical quenching.**Y(NO) and Y(NPQ)** Yields of non-photochemical quenching. **PAR** Photosynthetic active radiation. **ETR** Relative electron transport rate. **ETR-Factor** Absorptance of photons by photosynthetic pigments.

4 Conclusions

The present study was conducted in the vicinity of a coal fired thermal power plant. In order to ensure whether the fly ash emitted from the thermal power plants have any adverse effects on the flora of the surrounding areas the present experiments were performed. The analysis of dust deposited on the leaves of *Mangifera indica* (mango plant) that was common in the area for heavy metals/metalloids was performed. The analysis showed that dust was contaminated by the presence of several metals/metalloids. At the same time, the adverse effects of these contaminants on the various photosynthetic parameters of the leaves were also studied. The study clearly indicated that presence of heavy metals/metalloids have negative effects on photosynthetic parameters that will ultimately lead to reduction in the net productivity of the plants and ultimately the entire ecosystem. Henceforth, the issues of fly ash emitted from coal fired thermal power plants needs to be addressed seriously using modern day emission control technologies.

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