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Biomonitoring of heavy metals by pollen in urban environment

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Abstract Abstract Industrial development and consumption of petroleum products leads to increase air pollution levels especially in urban and industrial areas. Heavy metal components associated with air pollutants have far reaching effects with respect to economic and ecological importance of pollens. The pollens are male reproductive organs of the plant and travel through air from flower to flower for pollination purpose. During this period they are exposed to air pollutants. Present investigation thus pertains to study of effect of air pollutants on pollens especially biosorption and bioaccumulation of heavy metals. The pollens of three commonly occurring plants namely *Cassia siamea*, *Cyperus rotundus*, *Kigelia pinnata* have been studied from the NH-6 of Nagpur city, India. The pollens exposed to polluted air showed the presence of higher concentrations of Ca, Al and Fe as compared to unexposed pollens. Higher concentration of these metals was observed in *Cyperus rotundus* followed by *Cassia siamea* and *Kigelia pinnata*. These results indicate that pollens act as good indicator of air pollution giving results in short time of exposure of 5–10 h. Apart from this, it is also reported that some of these metals play crucial role in the metabolic activity in pollens for example Calcium is necessary for growth of pollen tube and other metabolic activities in pollens. The presence of these metals in pollens may also enhance the allergenicity of the pollens. Similarly accumulation of heavy metals may also deteriorate the quality of pollen for their economical use. The viability of pollen is also affected by these pollutants in sensitive species leading to impairment of their fertility.

Keywords Pollens · Air pollutants · Metals · Bioaccumulation · Allergenicity

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Introduction

Since last few decades air pollution has increased to significant levels due to anthropogenic activity, especially industrial development, transport and urbanization. These air pollutants are responsible for impacts on biodiversity and public health (Awofolu 2003). Among these impacts, the pollens also accumulate heavy metals and acts as indicators of air pollution (Xiong and Peng 2001). Based on literature survey the accumulation of different concentration of heavy metals such as Cadmium (Cd^{2+}), Cobalt (CO^{2+}), Copper (Cu^{2+}), Iron (Fe^{2+} and Fe^{3+}), Mercury (Hg^{2+}), Manganese (Mn^{2+}), Zinc (Zn^{2+}) and Aluminium (Al^{3+}) in pollen grain was investigated. Cd^{2+}, Cu^{2+} and Hg^{2+} showed the greatest toxicity in pollen germination and pollen tube growth, whereas

germination and growth rate may also affected by Mn^{2+} (Sawidis 1997; Zhang et al. 1999). Similarly Cd^{2+} was only metal which produced effect at the intracellular level and organelle distribution within the tip regions and appeared to be disorganized (Sawidis and Reiss 1995; Strickland and Chaney 1979). Such heavy metal accumulated pollens acts as an allergen and causes various allergic problems in the human beings (Polovic et al. 2004; Navazio et al. 1998). There is some evidence confirming that air pollution may be responsible for the increase in pollen-induced allergies and asthma in highly polluted areas (Ishizaki et al. 1987; Ruznak et al. 1994; Behrendt et al. 1992, 1997). Pollen grains accumulated heavy metals i.e. Lead and Cadmium but also nitrate, sulphur and other compounds. This chemical alteration of pollens may be responsible for aggravating clinical problems. (Nilsson and Nybom 1975; Colladha and Carlsson 1968; Calladha and Nilsson 1973; Chehregani et al. 2004).

Nagpur City is very well known as second *Green City* in India. Plantations are actively carried out every year in the city with the active participation of local administration and non-governmental organizations (NGOs). The Nagpur city is situated in between 20° 30′ and 21° 30′ N latitude and 78° 30′ and 79° 30′ E longitude. The strategic situation of the Nagpur City in the central part of India has lead a rapid expansion of city and ever increasing environmental problems with reference to pollution of air, water and soil.

Present study reports the bioaccumulation of trace metals (As, Pb, Ni, Cd, Fe, Al, Ca, Cu) by the male reproductive organs i.e. pollen grains of plants namely *Cyperus rotundus, Cassia siamea* and *Kigelia pinnata*. This is with the view of exploring bioaccumulation of contaminating species in the environment and investigation of impacts of pollution on living being for the future planning of economical and social development as well as one of the important parameter in environmental impact assessment studies.

Materials and methods

Samples and sampling protocol

Samples of fresh pollen grains of *Cassia siamea*, *Cyperus rotundus* and *Kigelia pinnata* were picked up from unburst anther of the plants in clean petriplates. They were divided in two groups first group called fresh pollens which were not exposed to air and the second group was exposed to polluted air for 5–10 h during day time. Both the groups of pollen samples were analyzed for the metal content and the Bio-concentration Potential (Concentration of metal species in exposed pollen X 100/Concentration of metal species in unexposed pollen) of the pollen of different plant species was calculated with respect to different metal pollutants in air.

Acid digestion of pollen grains

The 1:1 proportion of nitric acid (HNO_3) and water was added to previously weighed pollen samples and solution were prepared by making up the volume to 10 ml. These samples were kept overnight to soak the heavy metals and exinic mineral elements adsorbed on the surface of pollen grains. Then the sample solution is filtrated for further analysis.

Instrumentation

Quantitation of metallic content of digested samples was carried out with the Inductively Coupled Plasma Emission Spectrophotometer (Model: Optima 4100DV).

Results and discussion

The Results of the metal concentration in exposed and fresh pollens are shown in the Tables 1, 2 and 3. In fresh pollens, As and Cd were not recorded but Pb was observed in *Kigelia pinnata* in traces i.e. 0.0003 mg/g. The trend of occurrence of metals in pollens of three plant species is shown below:

Ca>Fe>Al>Ni>Cu ———— *Cyperus rotundus*
Ca>Al>Fe>Cu>Ni ———— *Cassia siamea*
Ca>Al>Fe>Ni>Cu>Pb ——— *Kigelia pinnata*

Among all the metals, Calcium (0.1512–0.7102 mg/g) was present in highest concentration in all the pollens. Aluminium (0.0066–0.1114 mg/g) and Iron (0.0018–0.1651 mg/g) were at the next highest level of concentration. Other metals were obtained in traces.

In case of fresh pollen grains of *Cyperus rotundus*, the metals viz. As, Pb, Cd were not recorded in the pollens while other metals were observed to be present in decreasing order of Ca (0.2306 mg/g), Fe

Table 1 Metal contents in pollens of *Cyperus rotundus*

Metal	Fresh pollens (mg/g)	Exposed pollens (mg/g)	Bioconcentration (%)
As	0.0000	0.0014	∞
Pb	0.0000	0.0117	∞
Ni	0.0022	0.0087	395.4
Cd	0.0000	0.0000	–
Fe	0.0363	0.1651	454.8
Al	0.0285	0.1114	390.8
Ca	0.2306	0.7102	307.9
Cu	0.0009	0.0782	8,688.8

(0.0363 mg/g), Al (0.0285 mg/g), Ni (0.0022 mg/g) and Cu (0.0009 mg/g). Cu was present in traces while all other metals were present in significant amounts. When metal concentration in exposed pollens was compared with that of fresh pollens (Fig. 1), it was observed that Ca (0.7102 mg/g), Fe (0.1651 mg/g), Al (0.1114 mg/g), Cu (0.0781 mg/g), Pb (0.0117 mg/g), and As (0.0014 mg/g) were accumulated considerably. As and Pb were recorded as new species in pollens as a result of air pollution. The bioconcentration potential (Concentration of metal in exposed pollen x 100 / Concentration of metal in fresh pollen) was observed to be highest in case of As (∞), and Pb (∞), Cu (8688.8 %), which are highly toxic for biotic components, followed by Fe (454.8 %), Al (390.8 %), Ni (395.4 %), Ca (307.9 %) (Table 1 and Fig. 1).

Cassia siamea is a tree usually present in avenue plantation. It was observed that fresh pollens of *Cassia siamea* did not show the presence of the metals As and Pb, while other metals were observed to be present in decreasing order of Ca (0.2115 mg/g), Al (0.0066 mg/g), Fe (0.0018 mg/g), Cu (0.0013 mg/g),

Table 2 Metal content in pollens of *Cassia siamea*

Metal	Fresh pollens (mg/g)	Exposed pollens (mg/g)	Bioconcentration (%)
As	0	0.0004	∞
Pb	0	0.0006	∞
Ni	0.0011	0.0030	272.7
Cd	0	0	–
Fe	0.0018	0.0158	877.6
Al	0.0066	0.0179	269.6
Ca	0.2115	0.4589	216.9
Cu	0.0013	0.0017	130.7

Table 3 Metal content in pollens of *Kigelia pinnata*

Metal	Fresh pollen (mg/g)	Exposed pollen (mg/g)	Bioconcentration (%)
As	0.0000	0.0004	∞
Pb	0.0003	0.0006	200
Ni	0.0011	0.0013	118.1
Cd	0.0000	0.0000	–
Fe	0.0049	0.0127	259.1
Al	0.0097	0.0126	129.8
Ca	0.1512	0.2298	151.9
Cu	0.0004	0.0005	125

and Ni (0.0011 mg/g). All the metals were present in traces except Ca and Al. When metal concentration in exposed pollens was compared with that of fresh pollens (Fig. 2), it was observed that Ca (0.4589 mg/g), Al (0.0179 mg/g), Fe (0.0158 mg/g), Cu (0.0017 mg/g), Pb (0.0006 mg/g), and As (0.0004 mg/g) were accumulated considerably. As and Pb were recorded as new species in pollens as a result of air pollution. The bioconcentration potential was observed to be highest in case of As (∞), and Pb (∞), which are highly toxic for biotic components, followed by Fe (877.7 %), Ni (272.7 %), Al (269.6 %), Ca (216.9 %), and Cu (130.7 %) (Table 2 and Fig. 2).

Kigelia pinnata is a commonly occurring large deciduous tree. Leaves are pinnately compound. Flowers in a panicle, dark purple with yellow stripes. It is a fast growing, multipurpose tree used for ornamental and roadside planting. It was observed that fresh pollens of *K. pinnata* did not show the presence of the metals As and Cd, while other metals were observed to be present in decreasing order of Ca (0.1512 mg/g), Al (0.0097 mg/g), Fe (0.0049 mg/g), Ni (0.0011 mg/g), Cu (0.0004 mg/g), and Pb (0.0003 mg/g). All the metals were present in traces except Ca, Al and Fe. When metal concentration in exposed pollens was compared with that of fresh pollens (Fig. 3), it was observed that Ca (0.2298 mg/g), Fe (0.0127 mg/g), Al (0.0126 mg/g), Pb (0.0006 mg/g), Cu (0.0005 mg/g), and As (0.0004 mg/g) were accumulated considerably. As was recorded as new species in pollens as a result of air pollution. The bioconcentration potential was observed to be highest in case of As (8), which is highly toxic for biotic components, followed by Fe (259.1 %), Pb (200 %), Ca (151.9 %), Al (129.8 %), and Cu (125 %), Ni (118.1 mg/g) (Table 3 and Fig. 3).

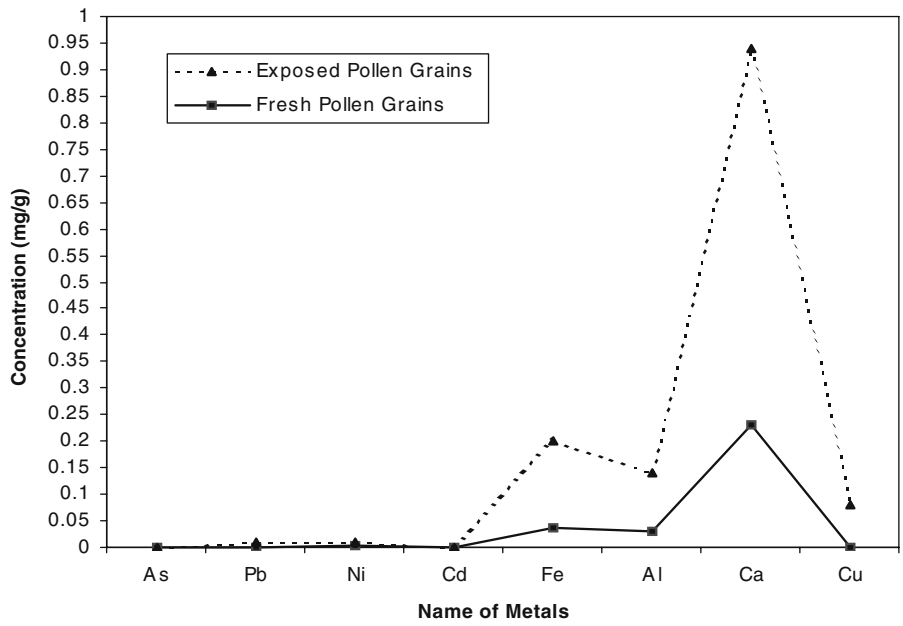

Fig. 1 Concentration of metals in fresh and exposed pollen grains of *C. rotundus*

Arsenic and Lead were not present in fresh pollens but were observed in exposed pollens showing their presence in the air and particulates of Nagpur city. Therefore their bioconcentration was observed to be infinity. Apart from Arsenic and Lead, other metals like Iron, Calcium, Nickel, Aluminium, Copper were observed to be biosorbed and bioconcentrated in significant amounts in pollens. Thus these pollens act as indicators of presence of metal species in air as pollutants. Pollens of *Cyperus rotundus* were observed to be the best indicator of air pollution as highest bioconcentration of metals is observed in them. Pollens of *Cassia siamea* were observed to be the next best indicator of air pollution, which showed

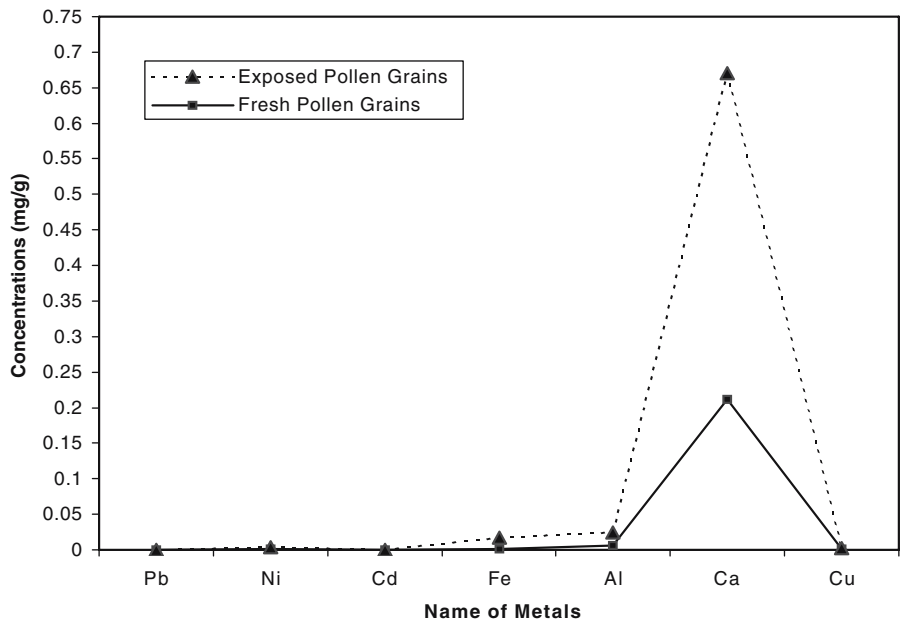

Fig. 2 Concentration of metals in fresh and exposed pollen grains of *C. siamea*

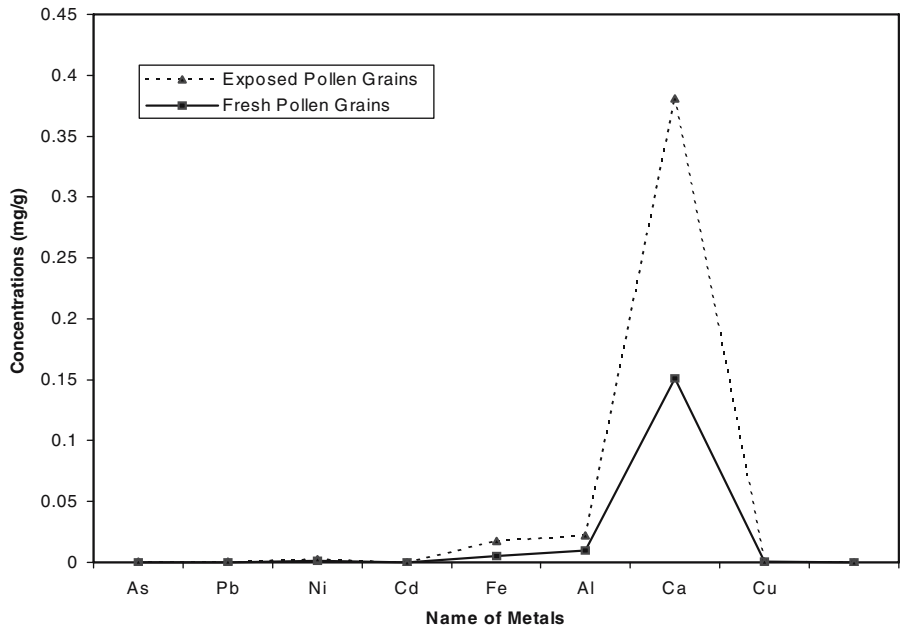

Fig. 3 Concentration of metals in fresh and exposed pollen grains of *K. pinnata*

mostly second highest bioconcentration of most of the metals in air. This is evident from following trend of bioconcentration.

C. rotundus>*C. siamea*>*K. pinnata* (for Arsenic, Lead, Nickel, Aluminium, Calcium, Copper)
C. siamea>*C. rotundus*>*K. pinnata* (for Iron)

Arsenic, Lead, Iron were observed to be bioconcentrated to a large extent while other metals to significant extent in the pollens of *Cyperus rotundus* and *Cassia siamea* and to marginally significant extent in the pollens of *Kigelia pinnata*. The trend of bioconcentration in the pollens of different plants is given below.

As>Pb>Cu>Fe>Al>Ni>Ca (*C. rotundus*)
As>Pb>Fe>Ni>Al>Ca>Cu (*C. siamea*)
As>Fe>Pb>Ca>Al>Cu>Ni (*K. pinnata*)

The types of the pollen that most commonly cause allergic reactions are produced by anemophilous or wind pollinated plants (trees, grasses and weeds) that do not have showy flowers. These plants manufacture small, light, dry pollen granules that are custom-made for wind transport. However it is now shown that the air also contains pollens from entomophilous plants, which are shed in the air due to wind currents, or during flight of insects attached pollens get shed in air.

According to the past experiments, polluted pollen grains are more effective than non-polluted pollen grains in inducing allergic symptoms. Air pollution can cause allergic symptoms, but when associated with allergen (pollen grains) their allergenicity power is increased. The allergenic potential may be reinforced through the presence of such airborne pollutants on the pollen grain surface. The pollen grains may be acting as carriers of pollutants from one area to another. The quality and composition of particles attached to pollen grains express theoretically a measure of the quality of local and regional environment. Therefore, one has to take into consideration that in regions with high pollution, air pollutant particles are not only a carrier of pollutants, but also carrier of allergens. Air pollutants induce allergen release and agglomeration of pollen material, including pollen proteins, on the surface of pollens. Releasing pollen allergens on the surface of pollen grains is one of the important reasons of allergy frequently in polluted areas. On the other hand, pollen allergens adsorbed by airborne particles alter their properties, and modification of these properties increases allergy symptoms in polluted cities.

Conclusion

Air quality is getting deteriorated in urban environment due to vehicular exhaust and dust pollution. The avenue plants and the vegetation in urban environment are exposed to air pollution. The pollens from flowers get exposed to air pollution and absorb from flowers get exposed to air pollution and absorb heavy metals. This has got undesirable impact on biochemical composition and viability of pollens having bearing on reduction of reproduction potential and consequent loss of biodiversity. However, the pollens may also be utilized as bioindicators of urban air pollution. More research work is needed on following aspects.

1. Heavy metal bioaccumulation potential of pollens
2. Reproductive potential of exposed pollens with respect to germination and fertilization
3. Bioindicator value of pollens to detect air pollution in urban environment
4. Exposed pollens and their allergenicity in comparison to unexposed pollens

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