Annexure-IX

UNIVERSITY GRANTS COMMISSION

BAHADUR SHAH ZAFAR MARG

NEW DELHI – 110 002

PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. Title of the Project:	**Foliar transfer of airborne toxic heavy metals: Implication for heavy metal pollution management in air**
2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR	**Dr. Sudhir Kumar Pandey, Department of Botany, Guru Ghasidas Vishwavidyalaya (A central University) Bilaspur, C.G., 495009**
3. NAME AND ADDRESS OF THE INSTITUTION	**Guru Ghasidas Vishwavidyalaya (A central University) Bilaspur, C.G., 495009**
4. UGC APPROVAL LETTER NO. AND DATE	**F. No.-43-311/2014 (SR), 09-09-2015**
5. DATE OF IMPLEMENTATION:	**01/07/2015**
6. TENURE OF THE PROJECT:	**01/07/2015 to 30/06/2018**
7. TOTAL GRANT ALLOCATED:	**14,70,000**
8. TOTAL GRANT RECEIVED:	**9,70,000**
9. FINAL EXPENDITURE:	**9,34,686**
10. TITLE OF THE PROJECT	**Foliar transfer of airborne toxic heavy metals: Implication for heavy metal pollution management in air**

11. OBJECTIVES OF THE PROJECT

(1) To study the levels of toxic heavy metals in air in affected areas.

(2) To investigate the partitioning of these airborne heavy metals in different size fractions

(3) To investigate the foliar uptake of these toxic metals by native plant species

(4) To develop an effective methodology for control of airborne heavy metals through plants

12. WHETHER OBJECTIVES WERE ACHIEVED

In order to achieve the proposed objectives, a number of case studies were performed including location of diverse source activities. In initial screening, total 19 metals were quantified in foliar dust. Out of these, six metals (Pb, Cd, Cu, Cr, Co, and Ni) were found under toxic metals category based on the criteria laid down by United States Environmental Protection agency (US-EPA). Pb, Cd, and Cu were found as the most abundant metals at most sites. There were considerable variations in concentration of selected metals (Pb, Cd, and Cu) in different sample types (soil, road dust, foliar dust, and leaf samples of both plants) across all months. The results of different enrichment factor (EF) showed significant anthropogenic influence at sites other than control site.

Scanning electron microscopy combined with electron dispersive spectroscopy (SEM-EDS) study was conducted to analyse both surfaces (adaxial and abaxial) leaf of selected plants. The accumulation patterns of PM in different size ranges (Fine: 0.2 to 2.5 µm, Coarse: 2.5 to 10 µm, and 10–100 µm) were seen by SEM study combined with a novel image-based approach. EDS study confirmed the presence of toxic metals in deposited/accumulated PM. Airborne PM bound toxic metals were deposited in distinct size ranges from respirable suspended particulate matter (RSPM) to ultra-fine particles (UFPs: $PM_{0.1}$: less than 100 nm) range. Moreover, SEM-EDS study confirmed the presence of Pb, Cd, and Cu along with other metals (e.g., Co, Al, Zr, and As) in UFP. SEM images showed that PM was deposited all over abaxial surfaces especially in lactic glands and midrib portion. Moreover, EDS confirmed that PM (as small as 1.20 µm) were deposited inside the stomata with Pb, Cd, and Cu with other metals. Based on the concentrations of Pb, Cd and Cu in different matrices, comparing the EF in different samples, and strong correlation between foliar dust and leaf, it is evident these toxic metals were mainly accumulated in leaf through airborne route. As such, final confirmation of foliar uptake of these airborne toxic metals was done. Based on

the above observations, evergreen tree species native to the area were found to be effective bio-monitors for toxic metals in environment. They can also be used as a control means to reduce airborne particulate matter pollution (and metals). In this way, all the objectives were achieved as proposed in the project.

13. ACHIEVEMENTS FROM THE PROJECT

The results of the study are published in peer reviewed reputed high impact journals in the field of environmental science (based on journal citation report such as Science of the total Environment (6.551) and Ecological indicators (4.229)) which is the first of its kind from India to the best of our knowledge. Utilizing the funds of this project, the research facility is created to conduct such studies and well-trained manpower has been produced. The experiments done in this study were demonstrated to the postgraduate students that immensely helped them to generate their interests in the area and specialized. It eventually helped them to complete their projects assigned in the specialization of the Master degree and joining the Ph.D. We were able to develop strong national and international collaborations in the area to further extend such studies.

14. SUMMARY OF THE FINDINGS

A general survey of study area was conducted and spot testing of toxic metals in PM was done at diverse locations. Study sites, target plants, and target toxic metals were selected based on three different case studies, source characteristics and micro-meteorological conditions. Soil, foliar dust, road dust, and leaf samples were collected from selected sites. The concentrations of toxic metals in these matrices were determined for consecutive two years at regular intervals. For final confirmation of foliar uptake of airborne toxic metals, plants leaves were analysed by Scanning electron microscopy coupled with energy dispersive spectroscopy (SEM-EDS).

At first, Foliar dust was collected and analysed for maximum possible number of metals by inductively coupled plasma mass spectroscopy (ICP-MS). Total 19 metals were quantified in foliar dust. Out of these, six metals (Pb, Cd, Cu, Cr, Co, and Ni) were found under toxic metals category based on the criteria laid down by United States Environmental Protection agency (US-EPA). Pb, Cd, and Cu were found as the most abundant metals at most sites.

The concentrations of target metals (Pb, Cd, and Cu) in different samples were compared on annual basis (two-year average). Variations in the concentration of Pb, Cd, and Cu in different samples (soil, road dust, foliar dust, and soil samples of both plants) were tested by ANOVA. The variations within soil samples across different sites were not significant. However, in other samples (road dust, foliar dust and leaf samples of both plants), variations were statistically significant.

EF gives an idea about the degree of enrichment by anthropogenic influence. Three diverse types of EF factor were derived (1) conventional enrichment factor (EF), (2) modified enrichment factor (MEF), and (3) simple enrichment factor (SEF). The results of different EF showed significant anthropogenic influence at sites other than control site. Based on the concentrations of Pb, Cd and Cu in different matrices, comparing the EF in different samples, and strong correlation between foliar dust and leaf, it is evident these toxic metals were mainly accumulated in leaf through airborne route.

SEM-EDS study was conducted to analyse both surfaces (adaxial and abaxial) of selected plants.The accumulation pattern of PM in different size ranges were seen by SEM study. EDS study confirmed the presence of toxic metals in deposited/accumulated PM. Airborne PM bound toxic metals were deposited in distinct size ranges from respirable suspended particulate matter (RSPM) to ultra-fine particles (UFPs: $PM_{0.1}$: less than 100 nm) range. Moreover, SEM-EDS study confirmed the presence of Pb, Cd, and Cu along with other

metals (e.g., Co, Al, Zr, and As) in UFP. In this way, final confirmation of foliar uptake of these airborne toxic metals was done and recommendations were made.

15. CONTRIBUTION TO THE SOCIETY

The outcome of this project would provide an understanding toward the levels, sources, and partitioning of the toxic PM bound metals in various matrices. Moreover, the study revealed accumulation of toxic metals (with PM) from airborne route in leaves of target plants which is a less common route considered for accumulation of toxic metals. The accumulation of these toxic metals on leaf surfaces may be affected by morphology and structural property of leaves; orientation and size of leaves, thickness of cuticle, roughness, existence of surface waxy layers, specific leaf area, stomatal and trichome density, and stomatal pore size. The evergreen tree species naturally growing and studied in this project can be used as effective bio-monitors for toxic metals in environment. They can also be used as a control means to reduce airborne particulate matter pollution (and metals). As such, it would provide a basis for development of plans for management of these toxic species in air. On the other hand, the manpower trained through this project would be certainly beneficial for extending and disseminating the new knowledge to the society in various ways.

16. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT

Yes, a

partial help was provided through this project to complete the Ph.D. of Dr. Triratnesh Gajbhiye.

17. NO. OF PUBLICATIONS OUT OF THE PROJECT: **Three (03)**

1. Gajbhiye, T., **Pandey, S.K.***, SS Lee, KH Kim. **2019.** Size fractionated phytomonitoring of airborne particulate matter (PM) and speciation of PM bound toxic metals pollution through *Calotropis procera* in an urban environment. ***Ecological Indicators***. 104, 32-40 **(IF= 4.229).**

2. Gajbhiye, T., **Pandey, S.K.***, Kim, K.-H, Szulejko, Jan E. **2016.** Airborne foliar transfer of PM bound heavy metals in *Cassia siamea*: A less common route of heavy metal accumulation. ***Science of the total environment***. 573, 123-130 **(IF = 6.551).**

3. Gajbhiye, T., Kim, K.-H, **Pandey, S.K.***, Brown, RJC. **2016.** Foliar transfer of Dust and Heavy Metals on roadside Plants in a subtropical Environment. ***Asian Journal of Atmospheric Environment***. 10, 137-145 (Indexed in SCOPUS and EBSCO)

(PRINCIPAL INVESTIGATOR)

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24.02.21

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