STUDIES ON HEAVY METAL CONTAMINATION IN SOILS AND SEDIMENTS OF AN URBAN INDUSTRIAL CLUSTER USING ENVIRONMETRIC METHODS AND RISK ASSESSMENT APPROACH

by

MAYURI CHABUKDHARA

Department of Civil Engineering

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New Delhi- 110016, India

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To

Sensei

Certificate

This is to certify that the thesis entitled "**Studies on Heavy Metal Contamination in Soils and Sediments of an Urban Industrial Cluster using Environmetric Methods and Risk Assessment Approach**", being submitted by Ms Mayuri Chabukdhara, to the Indian Institute of Technology Delhi, for the award of 'Doctor of Philosophy' in Civil Engineering is a record of the bonafide research work carried out by her under my supervision and guidance. She has fulfilled the requirements for the submission of this thesis, which to the best of my knowledge has reached the requisite standard.

The material contained in the thesis has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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(Prof. Arvind K. Nema)
Professor
Civil Engineering Department
Indian Institute of Technology Delhi
New Delhi- 110016, India

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Mayuri Chabukdhara

New Delhi

Mayuri Chabukdhara

Abstract

Present study is an attempt to assess the soil and sediment contamination in an urban-industrial region with respect to heavy metal pollution. Effort has also been made to understand the spatio-temporal variations of heavy metals distributions in various environmental components including surface and groundwater, aquatic macrophytes, vegetables and crops. Environmetric multivariate analysis been explored to identify the possible sources of contamination while fuzzy-logic and geochemical approaches have been exploited to assess the level of pollution. Health risk assessments due for heavy metals exposure via different pathways have been estimated. Ecological risk assessment has been carried out for soils and sediments.

Results indicated that in river water, NO_3^-, TA, TH and BOD were above the desired limits and DO value was lower than the required limit for inland surface water. Metal concentrations in river water samples followed the order of: Fe > Zn > Pb > Mn > Ni > Cr > Cu > Cd. Environmetric analysis indicated Pb, Zn and Ni may have come from industrial and urban discharges while Cu, Cr and Cd may have natural sources and Fe and Mn may have come from mixed sources. Overall, the water quality of Hindon was relatively poor with respect to its use for domestic purposes and may even pose threat to the aquatic life. Wastewater drains carrying dominant industrial discharges *viz.* D-2, D-3, D-4 and D-5 showed higher levels of pollutants. For groundwater, except for NO_3^-, all other parameters showed relatively higher levels in urban site as compared to peri-urban region indicating the influence of urbanization and industrialization in the groundwater quality of Ghaziabad. Mean concentrations of Pb, Cd, Fe and Ni in groundwater exceeded the safe limits in both the season except Cd in post-monsoon. Order of sites based on total metal concentrations of all metals in Hindon sediments was of S-3 > S-4 > S-2 > S-5 > S-6 > S-1 and total heavy metal concentrations in the sediment samples from the river followed the order: Fe > Mn > Zn > Ni > Pb > Cr > Cu > Cd. When compared to the eco-toxic threshold values it is found that Hindon river is seriously polluted and concentrations Cu, Cr, Pb, Cd, Ni and Zn in sediments are likely to result in harmful effects on sediment-dwelling organisms which are expected to occur frequently. Metal fractionation indicated that the metals studied can be ranked as follows according to the percentage of each in the exchangeable fraction (the most mobile and bioavailable): Cd > Ni > Cu > Pb > Zn > Cr > Mn.

Many factors may influence the release of metals from sediments including pH, OM (organic matter), redox potential etc. Heavy metals of anthropogenic origin are found predominantly as labile fractions in sediments. This is because heavy metals are easily adsorbed on surfaces of sediment particles through relatively weak physical and chemical bonds. The order of sites in terms of I_{geo} was: S-4 > S-3 > S-6 > S-2 > S-5 > S-1. Based on I_{geo} values of these metals followed the sequence Cd > Pb > Ni > Zn > Cu > Fe > Cr > Mn. Overall order of sites based on metals concentrations in sediments was: D-5 > D-4 > D-3 > D-1 > D-6 > D-2. Cluster analysis showed that soil samples collected from 14 major sites fell into three major groups. Relatively higher concentrations of all metals in group 1 could be due to its proximity to industrial and commercial locations, highways and waste dumpsite. Cu, Pb and Zn in group 1 sites of urban soils may have come from industrial sources such as induction and foundries, electroplating and galvanizing industries, lead reprocessing industries etc. Cluster analysis was performed for sampling sites and results indicated two major groups. Group 1 sites lying in urban region are more polluted as compared to group 2 sites that were in peri-urban region in terms of metal contamination. Overall MTF sequence in pre and post-monsoon season in aquatic macrophytes was: Cd > Mn > Ni > Pb > Cr > Zn > Cu and Cd > Zn > Pb > Cu > Mn > Ni > Cr, respectively. Overall ecological risk index (*RI*) accounting for the contamination caused by Cu, Cr, Pb , Cd, Zn, and Ni in river sediments indicated considerable pollution at S-2, S-4, S-5 and S-6 while S-3 showed high level of contamination. Based on *RI* value, contamination in sediments for the different sampling sites can be ranked in the following order: S-3 > S-6 > S-4 > S-2 > S-5 > S-1. Based on *RI* value, contamination in urban soils for the different sampling sites can be ranked in the following order: US-3 > US-8 > US-7 > US-4 > US-13 > US-11 > US-9 > US-1 > US-10 > US-5 > US-2 > US-12 > US-14 > US-6. Overall order of sites was: AS-6 > AS-13 > AS-2 > AS-3 > AS-1 > AS-5 > AS-7 > AS-12 > AS-4 > AS-14 > AS-10 > AS-8 > AS-9 > AS-15 > AS-11. Metal pollution were: mildly high for US-3, quite high for US-4, high for US-7 and absolutely high for US-8. Thus the sources affecting urban soil at these sites need attention. The fuzzy evaluation sets for groundwater was quite high for peri-urban groundwater and absolutely high for groundwater in urban region of Ghaziabad district. Pb and Cd were higher than both the safe limits in all the vegetables/cereals. Similarly, Zn and Ni concentrations were much above the permissible limits in all crops/vegetables except for Zn in rice. Except for rice, Health risk index (HRI) of adult and children was more than 1 for all metals in all vegetables. Non-cancer risk due

to exposure to urban soils indicated that Cr (HI =2.21 and 1.96) exhibit Hazard Indexes (HI) larger than 1 (safe level) for children. For non-cancer risk HIs to adult and children decreased in the order of Cr > Pb > Mn > Ni > Cu > Cd. Though, HI for Pb (0.667 and 0.622) in children is lower than the safe level (1), if contacted by children in large enough doses can trigger neurological and developmental disorder. The carcinogenic risk levels of Cr, Pb, Cd and Ni for adults and children obtained in this study are all within acceptable range. Non-cancer risk and cancer risk are within acceptable limit for agricultural soils. However, for children, health risk due to Pb and Cd exceeded the safe limits at several sites particularly in pre-monsoon. Present study demonstrates that the assessment of soils and sediments using various approaches (multivariate, geochemical, risk assessment and fuzzylogic) can be used as a suitable tool to do monitoring studies and to assess the contaminants of concern and identify exposure pathways. The study suggests that a complementary approach that integrates environmetric analysis, soil and sediment quality criteria, geochemical investigation, risk and fuzzylogic approach should be considered in order to provide a more accurate appraisal of the heavy metal pollution in soil and sediments and associated environmental components. Consequently, it can serve to undertake and design effective strategies and remedial measures to prevent further deterioration of the soils and river ecosystem in future.

Key words: Soil; Sediments; Heavy Metals; Environmetric analysis; Geochemical; Risk Assessment; Fuzzy logic

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