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Potential ecological risks of metal(loid)s in riverine floodplain soils

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ABSTRACT

The quality of soils under different land uses is getting deteriorated throughout the world due to various anthropogenic activities. This deterioration is highly complex in riverine floodplain areas due to contamination by multiple point and non-point sources and change in seasons. Therefore, a study was conducted to analyze seasonal (pre and post-monsoon) variations in physico-chemical characteristics, contents of metal(loid)s (Al, As, Cd, Cr, Co, Cu, Fe, Mn, Mo, Ni, Pb, Sb and Zn) in riverine floodplain soils under three land uses (agricultural, riverbank and roadside) from areas around the rivers Beas and Sutlej in Punjab, India. Further, analysis was done to assess the ecological and genotoxic risks (*Allium cepa* genotoxicity assay) posed by metal(loid)s in these soils. It was observed that soil samples under the three land uses were slightly alkaline (pre-monsoon) to acidic (post-monsoon) in nature with sandy texture and low soil organic matter. The levels of most metal(loid)s increased in post-monsoon soil samples under the three land uses, which was attributed to increase in soil organic matter, silt and clay contents in post-monsoon samples due to precipitation, flooding and sedimentation. The ecological Risk Index (58.3–104.5) and Modified Risk Index (145.2–178.9) calculated to analyze the level of ecological risks of metal(loid)s revealed that As, Cd and Sb posed moderate to considerable ecological risks in the agricultural and roadside soils in both seasons. *Allium cepa* genotoxicity assay indicated that the metal(loid)s in studied soils can cause genotoxic effects in biological systems. Therefore, various steps such as reduction in use of agrochemicals, promotion of organic agricultural methods and decontamination of soils using techniques such as phytoremediation etc must be taken to ensure reduction and containment of metal(loid)s in such riverine floodplain areas.

1. Introduction

The soil environments worldwide are under threat of metal(loid) contamination due to human activities such as industrialization, urbanization, intensive agriculture, wastewater irrigation, vehicular traffic etc. (Brady and Weil, 2008; M. Kaur et al., 2014; Chandrasekaran et al., 2015). But, the metal(loid) contamination risk is far more complex in riverine floodplain areas because a conglomeration of metal(loid)s brought and deposited by rivers from distant areas can occur in the soils (Rennert et al., 2017; Iwegbue et al., 2018). The metal contents in riverine floodplain soils under different land uses are further impacted by changes in climatic conditions, because events like precipitation during rainy seasons (as monsoon season in India) causes flooding which significantly changes the soil characteristics and deposits metal (loid)s brought from various upstream sources. The soil characteristics such as pH, soil organic matter (SOM), soil texture etc. significantly affect the mobility, availability and toxicity of metal(loid)s in soils (Troeh and Thompson, 2005; Boluda et al., 2011). Therefore, the regular analysis of soil characteristics and metal(loid)s contents is necessary for determining their impacts on plants, animals and humans. But, analysis of metal(loid) contents alone does not indicate their potential risks in soil. Further different factors and indices such as Contamination Factor (CF) and Enrichment Factor (EF), Ecological Risk Index (RI) and Modified Risk Index (MRI) should be calculated to determine the potential ecological impacts of metal(loid)s in soils (Trujillo-González et al., 2016; Duodu et al., 2016; Tian et al., 2017; Bhatti et al., 2018). In order to examine the impact of contaminants (such as metal(loid)s) in soil on biological systems, rapid, sensitive and widely applied plant assays such as *Allium cepa* root chromosomal assay can be used (Rank et al., 2003; M. Kaur et al., 2014).

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Considering the risks posed by metal(loid)s in riverine floodplain soils, a seasonal study was conducted in floodplain areas of Punjab, India around its two main rivers Beas and Sutlej, to analyze a hypothesis that "Metal(loid)s pose ecological and genotoxic risks in soils under different land uses in riverine floodplain soils". The area selected for study was around Harike wetland which is a Ramsar site where Beas and Sutlej rivers merge. Although previous studies have been done on heavy metal(loid) contamination of soils around rivers from the study area and other parts of world (Bhatti et al., 2016, 2017; Rennert et al., 2017; Iwegbue et al., 2018), but few reports have depicted the seasonal changes in soil characteristics and ecological impacts of metal(loid)s contents in riverine floodplain areas. Therefore, in the present study soils under three land uses i.e. agricultural, riverbank and roadside were selected for analysis of soil characteristics, metal(loid)s contents, ecological risks posed by metal(loid)s and genotoxic potential (using *Allium cepa* genotoxicity assay) in two seasons i.e. pre-monsoon (April to June) and post-monsoon (October to January).

2. Material and methods

2.1. Study area

The study area comprised of six villages situated around the rivers Beas and Sutlej in Punjab in areas around Harike wetland. Fig. 1 shows the map of the studied area having the six villages and Supplementary Table 1 shows the details of villages. These villages have fertile lands with sandy loam and calcisolic soils. The annual rainfall in this area is 435.6 mm and has semiarid to sub-humid climate. Agriculture is the main occupation of this area and has two main crop seasons Rabi (pre-monsoon) and Kharif (post-monsoon). Wheat and rice are the two main crops grown in Rabi and Kharif season, respectively. Significant industrial and urban activities are prevalent in upstream areas like Ludhiana, Jalandhar, Kapurthala (J. Kaur et al., 2014).

2.2. Sampling and preparation

Soils were collected in the month of April 2013 (pre-monsoon) and October 2013 (post-monsoon). The monsoon season falls in the study area from July-September period in which precipitation occurs throughout north India. The precipitation causes high inflow of water in rivers from mountains and causes flooding and sedimentation in areas along almost all rivers of north India including Beas and Sutlej. Soil samples in triplicates were collected from each village as composite samples for each of the three land uses i.e. agricultural under wheat (pre-monsoon) and rice (post-monsoon) cultivation, river bank and roadside.

Five subsamples were pooled for each replicate to form the composite soil samples (approximately 2 kg) of the three land uses from

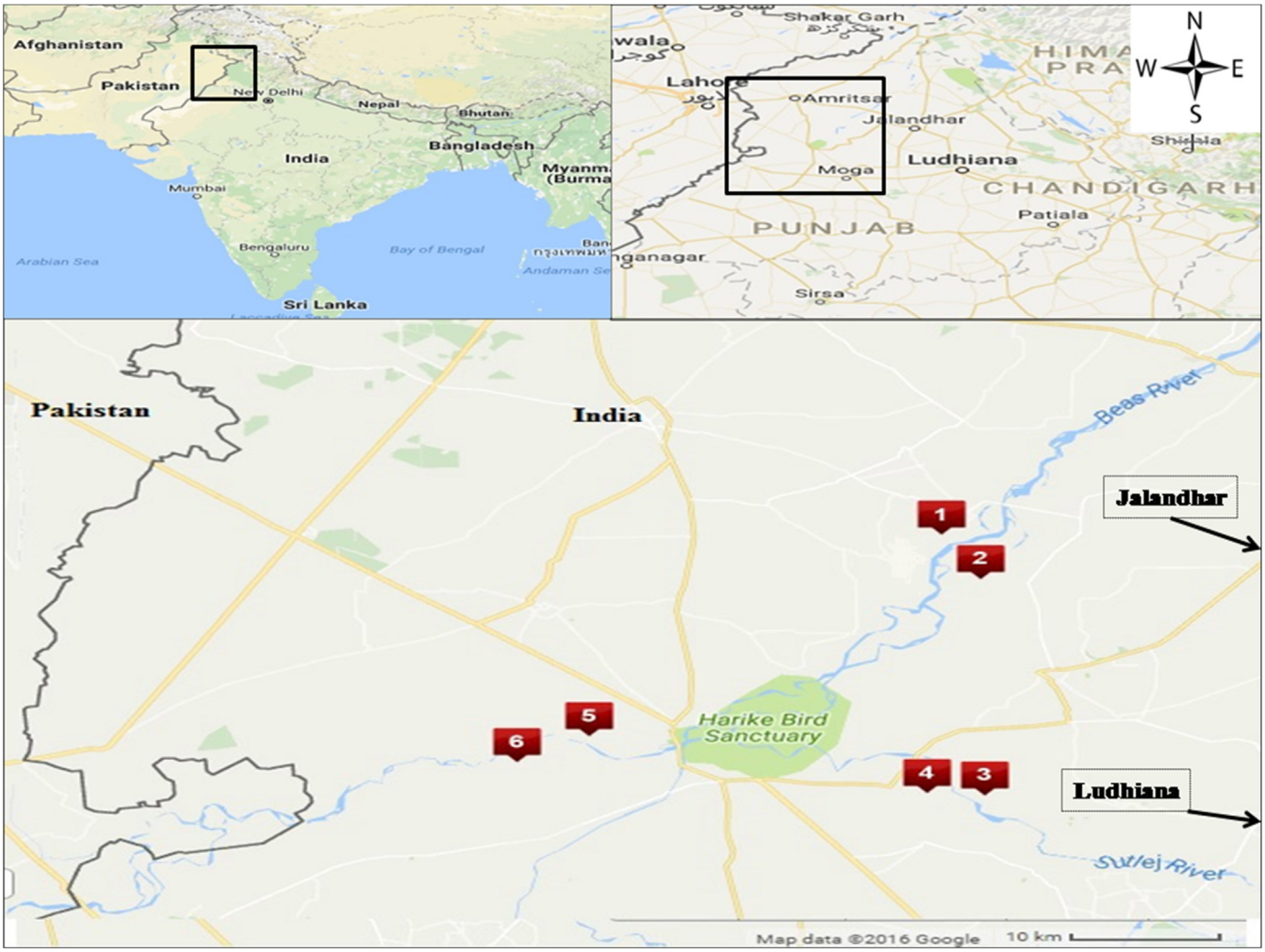

Fig. 1. Map of the sampling villages around Beas and Sutlej rivers, Punjab, India. *Six sampling villages are shown in red flags. Village names (full detail of villages given in Supplemetary Table 1): 1-Jalalabaad; 2-Rajewal; 3-Yousufpur; 4-Tibbi Taiba; 5-Doomniwala; 6-Gatta Badshah. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)