Toxic Metals Contamination

Subjects: Environmental Sciences

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Concentrations of potentially toxic metals including Cd, Cu, Pb, Cr, U, Th in surface water and sediment samples collected from a river were analyzed to assess the contaminations, distribution characteristics and sources of these metals. The contents of the metals were lower than the standard levels set by WHO for drinking water. However, U and Th contents were far beyond the background values of surface water. The concentrations of Cd, Cr and U in sediments were higher than the background values and the Probable Effect Level (PEL) of sediment quality guidelines (SQGs) which may result in high potential harmful biological effects to aquatic ecosystem. Based on the contamination factor (CF), geo-accumulation index (I_{geo}) and potential ecological risk index (RI), Cd, Cr and U were considered to be the metals that mainly contribute to the contamination of sediments. The calculation results also indicated that the sites adjacent to the uranium ore field were highly polluted. Results of cluster analysis, principal component analysis and correlation analysis revealed that Cr, Pb, U, Th were highly correlated with each other. These metals were mainly originated from both anthropogenic source and natural processes, especially emissions from uranium mining and quarrying, whereas Cd mostly came from anthropogenic source (agricultural activities) of the upper reaches of the river.

Potentially toxic metals | Uranium mining | Surface water | Sediment | Contamination indices | Source identification

1. Introduction

Heavy metals in aquatic environment have received considerable attention around the world owing to their wide availability, long incubation period, strong concealment and environmental toxicity [1][2]. Heavy metal is a common term used in the literature on geochemistry and environmental pollution. However, it is argued that the term is not clearly defined and describes music rather than science. In present study, the term “potentially toxic metals” is applied instead of “heavy metals” [3][4]. As a result of intensive human activities and the expansion of industrial and agricultural production, large quantities of potentially toxic metals have been discharged into rivers around the world. Moreover, potentially toxic metal residues in contaminated rivers may accumulate in sediment, microorganisms, aquatic plants and animals. In addition, these metals can easily produce “secondary pollution” due to changes in sedimentary environment and pose great potential harm to biological and human health through food chain or other migration pathways [5]. As an important type of environmental pollutants, toxic metals can enter water bodies through various natural or anthropogenic pathways and occur in the water phases, sediments and organisms, and exhibit different environmental geochemical behaviors and biological toxic effects. Human activities, such as mining and disposal of waste water containing toxic metals and industrial metal chelates from tanneries, steel mills, etc., are the main sources of metals in water and sediments, which lead to a decline in water quality [6][7][8].

Most of the toxic metal pollutants are adsorbed by the suspended particles in water. These sorbed metals undergo complex migration and transformation processes in the water-sediment-organism, such as adsorption, desorption, precipitation, biological absorption and other reactions [9][10]. Metal ions in water not only can generate hydroxides by hydrolysis, but also react with inorganic ions to form sulfide, carbonate and phosphate complexes. Due to the low solubility, persistence and subsequent accumulation, these metals and their complexes are easy to precipitate in sediments. Thus, sediments frequently act as the sinks of metal pollutants. However, when physico-chemical conditions of sediment-water interface change subjecting to biological action, disturbance or hydrodynamic scour, potentially toxic metal pollutants are released from the sediments into the water bodies. Studies have shown that sediment could act as an indicator for water pollution, the history and intensity of anthropogenic metal pollution and ecological changes [11]. Thus, the sediments played an important role in controlling the pollution sources [12][13][14]. Therefore, an evaluation of toxic metal pollution in river sediment is of great value for a study of river ecological environment, as well as prevention and control of river pollution.

Due to the poorly designed facilities, uranium mining activities, like open-pit mining, in situ leaching and heap leaching, have resulted in a considerable accumulation of toxic metals and radionuclides in environmental medium [15]. Under the action of precipitation infiltration, weathering and leakage, the tailing slags easily diffuse and migrate to the surrounding environment [16]. Finally, they enter the surrounding rivers via infiltration and surface runoff leading to serious contamination to water bodies and the associated ecosystems. In recent years, significant pollutions caused by potentially toxic elements (e.g. Pb, Cd, Cu, Zn, Hg, As) and radionuclides (e.g. U, Th, Ra, e.g.) in mining ecosystems have been widely reported [17][18][19][20]. Radionuclides pollution and toxic metals loading in shallow tailings, discharge water, surface water, groundwater and paddy soil around the study uranium mining area were found and recognized [21][22][23]. However, there is a lack of research focusing on the concentrations and distributions of radionuclides and potentially toxic metals in surface water and sediments, especially in the river downstream the uranium mining. The distributions of radionuclides and potentially toxic metals are worth to quantitative study. Therefore, the objectives of present study are to: (i) investigate the distribution and levels of potentially toxic metals in water and sediments; (ii) explore the pollution status and ecological risk levels of potentially toxic metals in sediments; (iii) determine the source apportionment of potentially toxic metals in study area.

2. Distribution Characteristics of Toxic Metals

Distribution characteristics of toxic metals (Cd, Cu, Pb, Cr, U, Th) in both surface water and sediments were investigated in this study. Concentrations of metals in water samples were lower than the recommended safe values. However, contents of radionuclides (U and Th) were much higher than the background values of surface water radionuclides in Jiangxi province. The maximum concentrations of most metals (except Cr, Cd and Pb) were observed at the site H3, downstream of the uranium mine. It showed that the concentration of potentially toxic metals in surface water might be affected by uranium mining activities.

High concentration levels of metals were found at H3 site adjacent to the uranium ore, indicating that there might have been potentially toxic metal emissions from the uranium mine. Concentrations of Cu, Pb, Th were lower than the background values, while Cd, Cr and U contents were higher than the background values. According to the sediment quality guidelines (SQGs) of USEPA, the Cr contents above PEL might pose high potential harmful biological effects to aquatic ecosystem. The analyzed contamination factor (CF), geo-accumulation index (I_{geo}) and potential ecological risk index (RI) revealed that Cd, Cr and U metals mainly contributed to the contamination and ecological risk of sediments along the studied river. Moreover, among the six sampling sites, the sediments taken from surroundings of uranium ore field were highly polluted. Results of CA, PCA and correlation analysis suggested that Cr, Pb, U and Th were highly correlated and originated from both anthropogenic source and natural processes, especially emissions from uranium mining and quarrying. Cd was mainly generated by anthropogenic source of agricultural activities.

Although all the metals for water are quite low, the river sediments were highly contaminated with metals (Cd, Cr and U) and the contamination is mainly correlated to the agricultural activities and uranium mining activities. These metals can be easily to released again into the water body through water flow, biological disturbance and chemical reaction, forming "secondary pollution". Hence, it is necessary to implement ecological risk and environmental monitoring of river sediments downstream the uranium deposits to ensure the downstream ecosystem safety of the uranium mine, as well as strengthening regional agricultural pollution prevention and control.

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