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Assessment of heavy metal concentrations in surface water sources in an industrial region of central India

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Abstract

Rapid industrialisation and resulting industrial solid waste from power plants and integrated iron and steel industries, have imposed an enormous environmental pressure on water resources of Chhattisgarh, a state in Central India. Rural population living nearby the study area is mainly depended on the available surface water in the form of lakes or pond in their vicinity. Therefore it is necessary to look after the surface water through leachate pollution caused by dumping and disposal of industrial solid waste. In the present study, ten surface water samples each for pre monsoon and post monsoon were collected for analysis from the surrounding areas of a major industrial region of Chhattisgarh. The AAS analysis of the surface water samples shows higher concentration of certain heavy metals above the permissible limits. In the pre monsoon samples the metals Mn and Cr resulted higher concentration and at the same time metals; Cu, Fe and Pb resulted in lower concentrations. Similarly, for the post monsoon samples, Mn, Cr and Fe found with higher concentration, while Cu and Pb resulted with lower concentration. The high amount of heavy metals were found in the analyzed samples shows that there is a real risk for population living in the nearby areas of the industrial region of Chhattisgarh. Therefore a huge amount of industrial wastes produced needs a proper disposal. Unscientific and poorly-managed disposal of industrial solid wastes containing heavy metals needs remediation before discharging into the environment.

Keywords: Industrial solid waste; Heavy metals; Leachate; Surface water; Water pollution

1. Introduction

Coal based thermal power plants, contributing to the 61.5 percent of total installed power capacity, are the major source of electricity generation in India [3]. Most of industries are using pulverized coal as the fuel, producing enormous quantities of coal fly ash every year. India has 211 billion tonnes of coal reserves. Indian coal used in thermal power plants is of low grade quality and has an ash content of 40–50% [18]. The power generation in India was about 200,000 MW in 2012 and it is expected to increase up to 300,000 MW by 2017. The present fly ash generation rate is about 131.09 million tonnes per year and the utilization rate of coal is 73.13 million tonnes per year [15].

One of the popular methods of disposal of fly ash is by wet sluicing in on-site fly ash ponds. This disposal

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in the form of dilute slurry has a high potential for leaching into the surrounding soil, surface waters, and groundwater. The varieties of trace elements, some of them, potentially toxic are transferred to the surrounding environment through different pathways [8]. These elements have a greater tendency to leach out from the solid phase (fly ash) and display subsequent enrichment in concentration from coal to bottom ash and to fly ash [2]. The coal fly ash contains trace metals like As, Be, Cd, Cr, Cs, Cu, Co, Ni, Pb, Sc, V, Zn and Zr etc. which are toxic in nature and due to this, the wet disposal of coal fly ash has raised serious environmental concerns. Indeed, the industrial solid waste disposal has created severe environmental problems in India [11,14]. Disposal of such huge quantity of fly ash is a major environmental issue, mainly due to the leaching of pollutants into surface and ground water sources. The impact of coal ash leachates on receiving waters, apart from increased elemental concentrations causes change in water pH with implications for trace element mobility [4]. It was observed that the leaching of heavy metals in ground water is very high near thermal power plants [1,16] and [13].

The objective of the study is to assess the contamination of surface water sources surrounding a major industrial region in Chhattisgarh, central India, subjected to large scale dumping of fly ash and steel slag waste, due to some heavy metals like Cr, Cu, Fe, Mn, Pb and Zn. These metals have been selected as per their common environmental concern along with health hazards to the human being, animals as well as to aquatic life.

2. Materials and methods

Ten surface water samples were collected before and after monsoons season from the areas surrounding to an industrial sector located near populated areas, having fly ash and steel slag dumping sites, using 1000 ml polyethylene terephthalate (PET) bottles. All the PET bottles were rinse with the surface water of each location before sampling and samples were taken from 100 mm below the surface, away from the edge of each surface water bodies. The samples were properly labelled for identification of sources on the site and immediately transported to the laboratory as soon as after sampling for preservation and analysis. The duration of preservation of the water samples was seven days at a temperature of 40 C (in a fridge) by adding HNO3 to maintain a pH < 2, according to the industrial waste resource guidelines [6]. All the sampled surface water sources were located at 500−1500 m away from the industrial waste dumping position.

3. Metal analysis

The concentration of selected trace metals, i.e. Cu, Cr, Fe, Pb, Mn and Zn, in all surface water samples, were analysed using Atomic Absorption Spectrophotometer (AAS) (VARIAN GTA-120, AA240). The Atomic Absorption Spectrometry (AAS) is a technique used mostly for measuring quantities of chemical elements present in samples by measuring the absorbed radiation by the chemical element of interest. The principle of Atomic Absorption Spectroscopy with graphite furnace (GFAA) and flame type measurement is the same [9]. In GFAA analysis, an electro thermal graphite furnace is used. The sample is heated stepwise (up to 3000 °C) to dry. The advantage of the graphite furnace is that the detection limit is about two orders of magnitude better than that of AAS [9,10]. The instrument facility available at CGCOST, Raipur laboratory having both options Graphite as well as flame type analysis but only one option of flame type analysis was available there at the time of analysis.Figs. 1−3.

The samples were diluted with 2% 1N nitric acid solution. 100 ml sample was taken and adjusted to pH > 2 with a standard pH meter at 27 °C for Cr. Standard solution of selected metals was used to prepare calibration series of Cr, Cu and Pb i.e. 0.2 mg/l to 0.8 mg/l with 0.5% $HNO_{3,}$ for Fe 6.0 mg/l to 24.0 mg/l with 0.5% $HNO_{3;}$ for Mn 2.0 mg/l to 8.0 mg/l with 0.5% $HNO_{3;}$ for Zn 0.3 mg/l to 1.2 mg/l with 0.5% HNO_3 respectively. Steps given in the standard operating procedure (SOP) were followed accordingly, then aspirate each standard and samples, and the readings were recorded Tables 1−3.

4. Effect of distance on surface water sources

The extent of contamination of surface water quality due to surface and sub-surface leachate transport depends upon the number of factors like chemical composition of leachate, rainfall, depth and distance of the water body from the pollution source (the industrial waste dumping site in the present case). Surface water samples at different distances from dump sites were analyzed in the present study to understand the level of contamination [12]. The concentrations of selected metals at 39 m and 350 m were found to be higher in the water samples which were situated near the disposal point and surface water bodies located at 120 m from the dumping site show less concentration