

Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer

N. Sridhara Chary^{a,*}, C.T. Kamala^a, D. Samuel Suman Raj^b

^aAnalytical Chemistry and Environmental Sciences Division, Indian Institute of Chemical Technology, Hyderabad-500 007, India

^bCenter for Environment, Institute of Science and Technology, Jawaharlal Nehru Technological University, Hyderabad-500 072, India

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Abstract

Heavy metal pollution of soils resulting from sewage and wastewater irrigation is causing major concern due to the potential risk involved. In the present study Musi River and its environs were assessed for heavy metal contamination. The study area was assessed for Zn, Cr, Cu, Ni, Co and Pb in soils, forage grass, milk from cattle, leafy and non-leafy vegetables. Partitioning pattern of soil revealed high levels of Zn, Cr, and Cu associated with labile fractions, making them more mobile and plant available. The associated risk was assessed using hazard quotient (HQ). Human risk was assessed in people known to consume these contaminated foods by analyzing metals concentrations in venous blood and urine. Results showed high amounts of Pb, Zn, Cr, and Ni compared to permissible limits. HQ was found to be high for Zn followed by Cr and Pb with special reference to leafy vegetables particularly spinach and amaranthus. © 2007 Elsevier Inc. All rights reserved.

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1. Introduction

Land spreading of untreated sewage effluents is practiced all over the world because of the economic advantage it offers over effluent treatment. Heavy metals can also accumulate in the soil at toxic levels as a result of long-term application of untreated wastewaters. Soils irrigated by wastewater accumulate heavy metals such as Cr, Zn, Pb, Cd, Ni, etc in surface soil. When the capacity of the soil to retain heavy metals is reduced due to repeated application of wastewater, heavy metals leach into ground water or soil solution available for plant uptake. For the metals derived from anthropogenic sources, this can strongly influence their speciation and hence bioavailability. However, the heavy metal content in plants can also be affected by other factors such as the application of fertilizers, sewage sludge or irrigation with wastewater (Devkota and Schmidt, 2000; Frost and Ketchum, 2000; Mangwayana, 1995). Studies have shown that heavy metals are potentially toxic to crops, animals and humans when contaminated soils are

used for crop production (Xian, 1989). Heavy metals may enter the human body through inhalation of dust, consumption of contaminated drinking water, direct ingestion of soil and consumption of food plants grown in metal-contaminated soil (Cambra et al., 1999; Dudka and Miller, 1999). Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, as well as vitamins, minerals, and trace elements. It is known that serious systemic health problems can develop as a result of excessive accumulation of dietary heavy metals such as Cd, Cr, and Pb in the human body (Oliver, 1997). One important dietary uptake pathway of metals could be through crops irrigated with contaminated wastewater.

In suburban parts of India, the use of industrial or municipal wastewater for irrigation purpose is a common practice (Singh et al., 2004). To face the growing demand for irrigation water, non-conventional resources are often used. Important sources of heavy metals in wastewater are urban and industrial effluents and deterioration of sewerage pipelines. Irrigation with wastewater is known to contribute significantly to the heavy metal content of soils (Mapanda et al., 2005; Nan et al., 2002; Singh et al.,

*Corresponding author.

E-mail address: sreedharacharya@rediffmail.com (N. Sridhara Chary).

2004). In India, total wastewater generated per annum from 200 cities is about 2600 Mm³ (Kaul et al., 1989) and also the use of sewage effluents for irrigating agricultural lands is on the rise especially in the peri-urban areas. Although the concentration of heavy metals in sewage effluents are low, in many cases these are contaminated with industrial wastes and long-term use of these wastewaters often results in the build-up of the elevated levels of these metals in soils (Rattan et al., 2002). Since food chain contamination is one of the major routes for entry of metals into the animal system, monitoring the bioavailable pools of metals in contaminated soils has generated a lot of interest (Datta et al., 2000; Yadav et al., 2002).

The Musi River flows into Hyderabad, capital of Andhra Pradesh, India as a clean resource until it reaches the T-main sewer where 25 million liters per day (mld) of untreated sewage is released. It is from this point that the river serves as little more than a sewer drain. Even during monsoon, runoff inflows are very low in comparison to the quantity of sewage discharged into the river. During monsoon the Musi River catchment area receives 700–800 mm of rainfall, but because of the large inputs of domestic sewage and industrial wastewaters, self-purification within the river and dilution are minimum (EPTRI, 1997; Sircar, 2000). Due to the rapid unplanned development of the city of Hyderabad, the quantity of sewage generated is many times more than the design capacity of the Amberpet Sewage Treatment Plant (STP). This results in a high percentage of under-treated and untreated sewage entering the river. The capacity of the Amberpet STP is 115 mld, but the plant typically receives 350 mld, which includes industrial effluents (Sircar, 2000; Musi River, 2001; CPCB, 2002). This drainage water which is from both domestic and industrial sources, is channeled to several contiguous plots of land or some times supplemented by water pumped from the river for irrigation.

Organic pollutants in the river are partially eliminated by self-purification and accessible dilution. The inorganic pollutants (heavy metals) are the fraction of greatest concern due to their persistence in sewage sludge, which later becomes a potential source of risk to the nearby soils and vegetation. Episodes of heavy metal pollution of the Musi River and its surroundings have been reported (Chandra Sekhar et al., 2005; Kumari et al., 1991; Venkateshwarulu and Sampath Kumar, 1982; Bansal, 1998). Along the banks of the Musi intensive cultivation of fodder grass (para grass) and food crops occurs in the sewage sludge, and the concentrations of heavy metals are reported to be very high (Kumari et al., 1991; Venkateshwarulu and Sampath Kumar, 1982; Bansal, 1998; Anjaneyulu, 2001; Chandra Sekhar et al., 2005). Grass raised along the river is the fodder for most of the cattle in and around Hyderabad (Buechler et al., 2002; Sircar, 2000). A variety of vegetable crops are also cultivated on the banks of the river and sold in the nearby market.

Earlier studies by authors on river Musi reported concentrations of metals in soils and corresponding

accumulation in nearby vegetation (Chandra Sekhar et al., 2005). These studies can only be regarded as base line data since there exists no explanation regarding the metal accumulation status and also possible mobility into nearby plants of the Musi River stretch. Further there are no reported studies on the assessment of possible health risk linked with consumption of these contaminated foods (milk, vegetables). Thereby a study was conducted along the stretch of Musi River to assess the concentration of heavy metals in soils, resulted uptake by the plant and elevated transfer to human food chain that helps in assessing the related health hazard associated with it. The metal concentrations in soil and vegetables are compared with established permissible limits. Also a dietary intake of vegetables by human were calculated and compared with the recommended dietary intakes.

2. Experimental

2.1. Study site and sampling

2.1.1. Soil

Soil sampling was carried out at 12 different locations along and across 8 km stretch of the Musi River, including 2 km on either side of the river. Soils were mainly red sandy loam and brownish sandy soil with black clay subsoil. Geologically the Musi basin is covered by granites of Archean age and intercalated with quartz veins here and there and is at an altitude of 500 m above mean sea level (M1) and 470 MSL (M12). The location map of the Musi River stretch along with the 12 sampling sites (M1–M12) is shown in Fig. 1. The study area consists of approximately 23.33 km² under residential use, 4.95 km² with plantations and harvested land, and 18.12 km² land with scrub (Anjaneyulu, 2001).

Sampling was carried out using standard protocols (USEPA, 1992). An 8 cm diameter stainless steel auger capable of retrieving a cylindrical plug of soil 2 inch in diameter and 2 inch deep was used for soil collection. Twelve points where the surface was free of plant material and debris were selected for soil sampling on each plot. Samples were taken from surface till the depth of 20 cm with a composite of 10–15 subsamples taken across a 1 × 1 m square pit. Samples were placed in plastic bags and sealed for transport and storage. In the laboratory, the samples were air-dried, mechanically ground and sieved to obtain <2 mm fraction. A 20–30 g subsample was drawn from the bulk soil (<2 mm fraction) and reground to obtain <200 µm fraction using a mortar and pestle. Soil samples were digested using HF/HClO₄ for total metals (Zn, Cr, Cu, Ni, Pb and Cu). The extracts were analyzed using a Varian Ultra Mass 700 ICP-MS.

2.1.2. Vegetation

A diversity of crops are grown along the Musi River in the study area. The predominant crop is forage grass/para

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