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ORIGINAL ARTICLE

Field accumulation risks of heavy metals in soil and vegetable crop irrigated with sewage water in western region of Saudi Arabia

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Abstract Wastewater irrigated fields can cause potential contamination with heavy metals to soil and groundwater, thus pose a threat to human beings . The current study was designed to investigate the potential human health risks associated with the consumption of okra vegetable crop contaminated with toxic heavy metals. The crop was grown on a soil irrigated with treated wastewater in the western region of Saudi Arabia during 2010 and 2011. The monitored heavy metals included Cd, Cr, Cu, Pb and Zn for their bioaccumulation factors to provide baseline data regarding environmental safety and the suitability of sewage irrigation in the future. The pollution load index (PLI), enrichment factor (EF) and contamination factor (CF) of these metals were calculated. The pollution load index of the studied soils indicated their level of metal contamination. The concentrations of Ni, Pb, Cd and Cr in the edible portions were above the safe limit in 90%, 28%, 83% and 63% of the samples, respectively. The heavy metals in the edible portions were as follows: Cr > Zn > Ni > Cd > Mn > Pb > Cu > Fe. The Health Risk Index (HRI) was >1 indicating a potential health risk. The EF values designated an enhanced bio-contamination compared to other reports from Saudi Arabia and other countries around the world. The results indicated a

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potential pathway of human exposure to slow poisoning by heavy metals due to the indirect utilization of vegetables grown on heavy metal-contaminated soil that was irrigated by contaminated water sources. The okra tested was not safe for human use, especially for direct consumption by human beings. The irrigation source was identified as the source of the soil pollution in this study.

1. Introduction

The volume of sewage water generated by domestic, industrial and commercial sources has increased along with the increasing population, urbanization, improved living conditions, and economic development (Qadir et al., 2010). In the urban areas of many (developing) countries, urban and peri-urban agriculture depends, at least to a certain extent, on sewage water as a source of irrigation water. The quality of water and the conditions under which this water is used vary significantly. In poor countries, this water may, in extreme cases, take the form of diluted raw sewage, even if this practice is considered illegal (Huibers et al., 2004). However, the quality of the wastewater used and the nature of its use vary enormously, both between and within countries. In many low-income countries in Africa, Asia and Latin America, the wastewater tends to be untreated, whereas in middle-income countries, such as Tunisia and Jordan, treated wastewater is used (Al-Nakshabandi et al., 1997; Qadir et al., 2010).

Sewage water irrigation is also known to contribute significantly to the heavy metal content of soils (Mapanda et al., 2005). Plant species have a variety of capacities to remove and accumulate heavy metals; therefore, there are reports indicating that certain species may accumulate specific heavy metals, causing a serious risk to human health when plant-based foodstuffs are consumed (Fytianos et al., 2001). The disposal of sewage water and industrial waste is a significant problem. The sewage water and industrial waste are often drained to agricultural lands where they are used for growing crops, including vegetables. These sewage effluents are considered a rich source of organic matter and other nutrients, but they elevate the levels of heavy metals, such as Fe, Mn, Cu, Zn, Pb, Cr, Ni, Cd and Co, in the receiving soils (Rattan et al., 2005).

There is an increasing risk of public exposure to heavy metals because of the consumption of food grown in sewage wastewater (Chary et al., 2008). There are numerous reports in the literature supporting this assertion (Sharma et al., 2007; Khan et al., 2008; Srinivasan and Reddy, 2009; Tijani, 2009; Hani et al., 2010). The problem of heavy metals entering the food chain requires systematic assessments to make timely decisions to avoid severe health effects because of the invisible mode of heavy metal toxicity (Chary et al., 2008). Risk assessments have been performed using various risk assessment techniques, such as the hazard quotient (HQ) (Chary et al., 2008), the Health Risk Index (HRI) (Khan et al., 2008), the morbidity status (MS) (Srinivasan and Reddy, 2009), the enrichment factor (EF), the degree of contamination (C_{deg}), the uptake/transfer factor (UF) (Tijani, 2009), statistics, geostatistics and geographic information systems GIS (Hani et al., 2010).

Wastewaters are contaminated with trace elements, such as lead (Pb), copper (Cu), zinc (Zn), boron (B), cobalt (Co), chromium (Cr), arsenic (As), molybdenum (Mo) and manganese (Mn), many of which are non-essential and, over time, are toxic to plants, animals and human beings (Kanwar and Sandha, 2000). The long-term application of treated and untreated wastewater has resulted in a significant buildup of heavy metals in the soil (Khan et al., 2008; Ullah et al., 2012); as well as leachate to groundwater through dumpsites (Oyeku and Eludoyin, 2010) and in vegetables and cereals and their subsequent transfer to the food chain, causing a potential health risk to consumers (McGrath et al., 1994; Kumar Sharma et al., 2007). Heavy metal concentrations in plants grown in wastewater-irrigated soils were significantly higher than in plants grown in the reference soil. (Khan et al., 2008; Singh et al., 2010) have concluded that the use of treated and untreated wastewater for irrigation increased the contamination with Cd, Pb and Ni in the edible portions of vegetables, causing a potential health risk in the long term. (Sachan et al., 2007; Khan et al., 2012) have found that the bioaccumulation of Pb and Cr in vegetables was above the critical concentrations for plant growth, while Pb and Cd were above the prescribed limit for animal diets.

Although zinc is an essential element for plants, its elevated concentration is phytotoxic, directly affecting crop yield and soil fertility. Soil concentrations ranging from 70–400 mg/kg are classified as critical, above which toxicity is considered likely (Alloway, 1990). In addition it is an essential element required by the human body in small amounts. The average daily zinc intake through the diet ranges from 5.2 to 16.2 milligrams. Food may contain levels of zinc ranging from approximately two parts of zinc per million (2 ppm) parts food (e.g., leafy vegetables) to 29 ppm (meats, fish and poultry). Cadmium and its compounds might travel through the soil, but its mobility depends on several factors, such as pH and the amount of organic matter, which will vary depending on the local environment. Generally, cadmium binds strongly to organic matter, becoming immobile in the soil and is taken up by plant life, eventually entering the food chain.

Heavy metals are one of the important types of contaminants that can be found on the surface and in the tissues of fresh vegetables. The prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Vegetables, especially leafy vegetables grown in heavy metal-contaminated soils, accumulate higher amounts of metals than do those grown in uncontaminated soils because they absorb these metals through their leaves (Al Jassir et al., 2005). Leafy vegetables, such as cauliflower, cabbage and spinach, grow quite well in the presence of sewage water (Cobb et al., 2000), whereas other vegetables, such as radish, are sensitive to sewage water (Kapourchal et al., 2009). Vegetables grown using sewage water contain many heavy metals, which cause serious health hazards to the community and animals (Avci, 2013). This concern is of special importance in locations where untreated sewage is applied