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Heavy Metals Infiltration from Sewage Treated Effluent into Soil and Tomato Plants

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Abstract. Treated sewage effluent (TSE) in arid regions is a valuable water source used in agriculture. However, heavy metals in TSE, especially of industrial origin, are not removed by the bioengineering processes and remain a serious threat to food safety. A survey was conducted from three sources, TSE, soil and tomato plant (root, stem and leafs). Samples were analyzed for heavy metals using inductively coupled plasma optical emission spectrometer (ICP-OES). Heavy metal values were compared to the standards for wastewater reuse. The highest heavy metal values in TSE and soil were Al and Zn. In soil, Cu and Fe were significantly higher compare to the rest of the samples. In plant tissues, Zn values were significantly higher than the rest of the metals. Although other metals were at low concentrations, some of the values exceeded the Minimum Permissible Levels (MPL). In TSE, all heavy metal values exceeded MPL except B, Ba, Hg and Mn. In soil, Al, As Cd, Cr, Cu, Fe, Ni, Pb and Zn exceeded MPL. In root (Cd and Pb) and in leaf (Cr) exceeded MPL standards. Based on this data, apparently infiltration of heavy metals from TSE origin has contaminated soil but only a few reached tomato plants.

Keywords: Bioengineering, sewage-treated-effluent, contamination, heavy metals, soil, plants.

1. Introduction

The lack of rainfall in arid countries remains a serious concern to the authorities specifically in food security. Many of the arid zone countries depend on desalination of sea and brackish water as a source of drinking water. The modern bioengineering technologies used in treatment of raw sewage are important to reclaim valuable water used for many purposes. Most of sewage is from industry and residential sources. However, treated sewage effluent and sludge reuse extensively in irrigation of agricultural products such as vegetables. Most organic matters and pathogenic microbes are removed from sewage treatment process. Great efforts are being implemented to reduce threats of heavy metals from sewage effluents. However, mainly heavy metals from industrial sources remain unchanged after the treatment [1]-[4]. This raises concerns on food safety and food quality [5]. Different types of heavy metals were reported in terrestrial and marine wild life in Oman and believed to be from the sewage origin [1] and [2]. The infiltration of heavy metals from the sewage treated effluent (TSE) source into the environment is a serious problem facing arid regions like Oman and the rest of the Gulf region.

Heavy metals such as Cu, Cd, Pb and Zn cause the greatest environmental concern from sources including sewage water which has been reclaimed [2] and [3]. The heavy metals are inheritably persistent in bioaccumulating throughout the ecosystem and can be found at high levels, eventually reaching the food chain [3] and [4]. It was found that after efforts to reduce trace metal, municipal waste water still carried high amounts of trace metals into the environment [2]. Toxicity of heavy metals in organisms is because of its ability to bind to biomolecules. Many of the heavy metals are well known to be a mutagen causing cancer [5].

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Heavy metals in food are of a great concern to the community and its detection is important for the food safety and human health. The aim of this study is to investigate the heavy metal contamination levels of sewage treated effluent from industrial sources and its effect on soil and vegetables.

2. Materials and Methods

Tomato seeds were germinated on moist tissue paper in the laboratory. Seedlings were transferred to pots containing soil and were irrigated with TSE for two months. The plants were supplemented with 25 ml of Hogland's nutrient solution twice a week. The pots were kept in a greenhouse. Soil, root, stem and leaf were analyzed after two months.

TSE samples were collected weekly for a period of two months. All samples were stored in a cooler at 10℃. TSE samples analyzed according to APHA, AWWA and WEP methods [6]. Soil and plant components (root, stem and leafs) samples were dried at 105 oC for 3 h and were weighed (0.2 g) in perfluoroalkoxy polymer containers separately. Dried samples were then treated with 0.5ml of hydrofluoric acid solution and mixed with 4ml of concentrated nitric acid. All samples were heated in a microwave for 40 min. The samples were diluted to 100 ml with Milli-Q water to a final concentration of 1 g/l [7]. The treated samples were filtered and analysed for Al, As, B, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se and Zn using Perkin Elmer model 3300 DV ICP ICP-OES (USA). Blank and certified reference solutions were used as controls. The concentrations of heavy metal were compared to the Omani Standard of Wastewater Reuse for unrestricted irrigation which was adapted from FAO guidelines for trace metals in irrigation (Table.1). Unrestricted irrigation TSE is used for irrigation of uncooked vegetable crops [8]. Minimum Permissible Levels (MPL) for Sb and Sc are absent in the Standard.

Table 1: Heavy metal standards of wastewater reuse in Oman (1996)

		Minimum Permissible Levels (MPL)
Metal	**Symbol**	**Unrestricted irrigation (mg/L)**
Aluminium	Al	5
Arsenic	As	0.1
Antimony	Sb	-
Boron	B	0.5
Barium	Ba	1
Cadmium	Cd	0.01
Chromium	Cr	0.05
Copper	Cu	0.05
Iron	Fe	1
Mercury	Hg	0.001
Manganes	Mn	0.1
Nickel	Ni	0.1
Lead	Pb	0.1
Selenium	Se	0.02
Zinc	Zn	5

3. Results

The highest heavy metal concentrations in TSE were Al and Zn. The rest were at a low level (Fig. 1). Similarly, Al and Zn values were in soil. However, the values of Cu and Fe were significantly higher than the values in TSE (Fig. 2). With the exception of Zn in plant tissue (root, stem and leaf) all heavy metal values were at low level (Fig. 3).

In terms of MPL value, the heavy metal concentration in TSE was mostly above the heavy metal standards of waste water reuse in Oman with the exception of B, Ba, Hg and Mn(MEMWR, 1996) (Table 2). In soil Al, As, Cd, Cr, Cu, Fe, Ni, Pb and Zn value exceeded the MPL while B was at the maximum MPL value. In plant roots, only Cd and Pb were above the MPL levels. In stem, none of the metals exceeded the MPL. However in leaf sample, Cr exceeded the values and Mn was at the maximum MPL value.

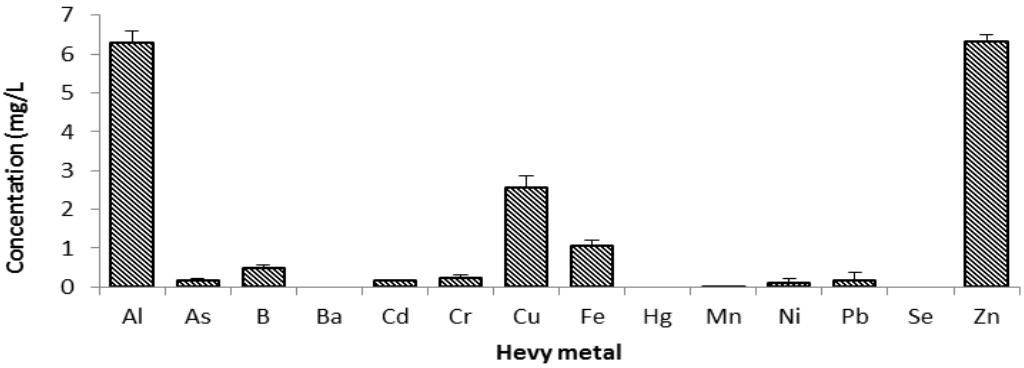

Fig. 1: Heavy metal in TSE

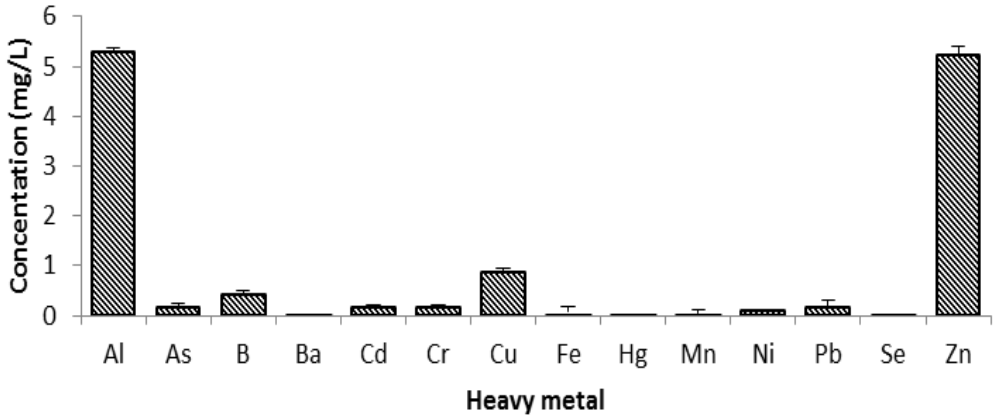

Fig. 2: Heavy metal in soil.

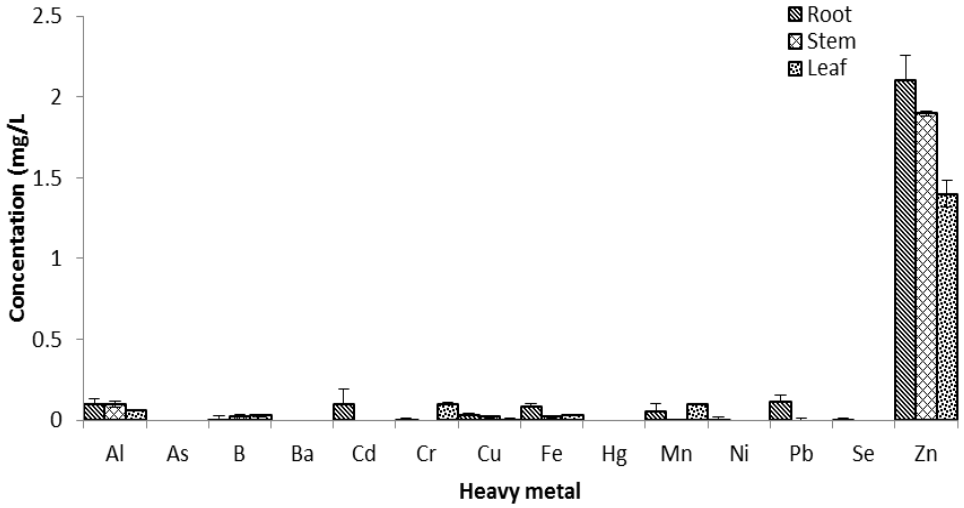

Fig. 3: Heavy metal in plant tissue.

4. Discussion

In this study, the use of TSE as the water source for plants irrigation contains heavy metals which consequently infiltrate the soil reaching the plants. Other studies in Oman, contaminated TSE was found in sediments affecting the environment and the food chain [3]. The use of heavy metal contaminated TSE is therefore a serious health issue in the food safety. The current bioengineering processes for treatment of contaminated sewage effluent are not successful in removing heavy metals [9], [10]. Based on these facts,

the result the reuse of sewage effluents is required to meet the international standards for reclaimed wastewater and its reuse specifically for agricultural purposes. Many governmental authorities and international organizations such as Food and Agriculture Organization (FAO) of the United Nations have set specific standards to reduce infiltration of heavy metals into the soil, consequently affecting environment, plants and food chain. The Omani Standard was set to limit such effect from reclaimed water and its reuse in agriculture [8]. Safe levels of heavy metals in food and drinking water were also recommended by some investigators [11], [12].

Table 2. Heavy metal exceeded MPL for Omani standard 1996.

Heavy metal	TSE	Plant tissue			
		Soil	Root	Stem	leaf
Al	Y	Y	N	N	N
As	Y	Y	N	N	N
B	N	M	N	N	N
Ba	N	N	N	N	N
Cd	Y	Y	Y	N	N
Cr	Y	Y	N	N	Y
Cu	Y	Y	N	N	N
Fe	Y	Y	N	N	N
Hg	N	N	N	N	N
Mn	N	N	N	N	M
Ni	Y	Y	N	N	N
Pb	Y	Y	Y	N	N
Se	Y	N	N	N	N
Zn	Y	Y	N	N	N

Y = Yes; N = No; M = Maximum.

The TSE reuse in countries of arid zone, such as Oman has become a necessity. However, TSE reuse has led to several public health and environmental problems resulted from accumulation of toxic compounds [2].

Heavy metals are very dangerous when consumed. For example, Cd, Ni, Pb and Zn are known to be cumulative toxins. Heavy metals toxicity is subject to biomagnification leading to accumulation in the food chain and causing serious chronic diseases such as renal failure, liver cirrhosis and chronic anemia. It is well documented that some heavy metals cause DNA mutation which lead to different types of cancers [13].

In this study, several heavy metals exceeded the MPL Omani Standard, for sewage water discharge. There was a clear trend in increasing heavy metal values from the TSE in soil. Similar results were reported previously [3]. Some of the heavy metals were reported to contaminate marine environment resulted from sewage disposal [1].

Contamination of heavy metals is mainly related to industries [14]. Released heavy metal contaminates soil and infiltrates underground water through sewage and industrial effluents [15]. Such water, if used for drinking and irrigation of farms may be detrimental to health.

In this study, the most common heavy metals, such as Cr, Cu, Ni Zn were detected. These heavy metals have major industrial uses. Stringent regulations in many countries have been made and were found to reduce heavy metal contamination significantly, and consequently, its effect on the food chain. New cleaning technologies are being introduced to improve industrial activities and to reduce heavy metals pollution and its anthropogenic emissions in wastewater. Surface treatment from industrial discharge has been introduced to reduce its effect on the environment and the food chain [10].

Data form this study indicates a serious food chain contamination by heavy metals which may affect human health. Stringent regulations and enforcement are needed to reduce heavy metals contamination.

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