

Heavy metal contamination from treated sewage effluents

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Abstract

Excessive exposure of heavy metals is known to have deleterious effects on health and has been shown to cause various diseases. The determination of heavy metals in sewage is important for monitoring environmental pollution caused by treated sewage effluents (TSE). Rare rainfall in Oman and lack of fresh water has led the authorities to recycle sewage effluents. However, the environmental impact related to heavy metals in sewage effluents is a serious health issue. Three sewage treatment plants (STPs) were used in this study. Water and sewage samples were analyzed for heavy metals; Al, As, B, Cd, Co, Cr, Cu, Fe, Hg, Mn, Mo, Ni, Pb, V and Zn using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) type Perkin Elmer 3300 DV ICP. Heavy metal concentration in the three STPs varied significantly and it was in correlation with heavy metals in sludge and soil irrigated with TSE. STPs used in industrial areas had higher concentration of heavy metals compared to STPs from residential communities, hospitals, and public institutions. In general, the highest concentration among the heavy metals from sludge was Pb, Hg, Cu, Cr, Ni, Zn and Cd. The results of this investigation indicates that there is a potential threat reusing recycled water and sludge which can infiltrate livestock, wildlife which impose the risk of spreading human diseases.

Keywords: *heavy metals, treated sewage effluent, sludge, contamination.*



1 Introduction

Heavy metal pollution is likely to produce widespread effects on terrestrial and marine wild life. Generally, heavy metals toxic to living organisms in the form of cations due to their ability to bind to biomolecules such as proteins [1]. In Oman during the last ten years, it was observed that there was a steady heavy metals accumulation in wild life specifically accumulation of Co, Hg, Pb and Sn [2]. It was reported that Co is an essential element for vitamin B₁₂ but can be toxic when it is in an inorganic form. It was found to be a carcinogenic element [3]. The main source of Co may be derived from anthropogenic input via run-off from ceramic industries which is commonly located on the coastal regions of Oman and may also contaminate the marine wild life. In addition, Hg is a very toxic element and it is a non-essential element to organisms. This element was found to accumulate in fish with up to a 10,000-fold bio-concentration factor [2]. The majority of mercury concentration in tissues occurs as methyl mercury. Bio-magnification of mercury through food chain occurs with age as a result of slow elimination in tissue [4, 5]. Mercury can be released to the environment through industrial and agricultural applications [5]. The major contributor of mercury pollution is from coal-burning power plants. Sn is essential element in many organisms but at blood concentrations can be highly dangerous to organisms [4]. Like mercury, lead is a non-essential element and its toxicity increases as a result of accumulation in tissues causing disabilities [2]. Lead was also found in plant tissue in Oman. Plants exposed to high lead concentrations expressed stress proteins and deformed roots [6].

Recent studies indicated that heavy metal pollution played a major role in the poisoning and decline of various populations [7–12]. Continuous contamination of living organisms to heavy metals overtime can lead to gradual accumulation in various tissues and ultimately fatal [13].

The current studies related to the effects of transformation, detoxification and excretion of heavy metals is insufficient. Further investigation on the effects of heavy metals is urgently needed for wild life and public health protection. Heavy metals Co, Cu, Mn, and Zn are essential elements important for the enzymatic activities but still can be toxic at high concentrations. On the other hand, non-essential metals are not involved in any metabolic process but its accumulation in tissues is an indication of environmental pollution of heavy metals [11]. Heavy metals are known to cause serious diseases especially when they are found excessively in animals and plants [3, 14, 15] found 15 heavy metals in marine fish and bivalves in the Gulf of Oman and Arabian Gulf. Al-Rawahi *et al.* [2] reported the presence of 12 different heavy metals in eggs and hatchlings of green turtles in Oman which is resulted from contaminated effluent.

Food safety is of an international concern. Vegetables subjected to heavy metal contamination when irrigated by wastewater. Mapanda *et al.* [16] reported accumulation of heavy metals in vegetables irrigated by contaminated recycled water. Solid waste and wastewater was also reported in underground water beds and was a cause of health concern [17]. We found heavy metals from treated and untreated sewage effluents penetrated well-water. Some of the wells exceeded the allowed minimum permissible levels in Oman (data not shown).

It is essential to indicate that sewage effluents may play a major role in spreading and consequently contaminating environment and wild life. Its accumulation in food chain can be detrimental to human health. Consumption of food and drinking water contaminated with high concentration of heavy metals cause a variety of chronic diseases such as chronic anaemia, liver cirrhosis, renal failure and cancers [18, 19].

The aim of this study is to investigate the role of sewage in spreading and contaminating environment and wild life by heavy metals.

2 Materials and methods

2.1 Sample collection

Three sewage treatment plants (STPs) were selected in this study in Muscat, Oman. TSE generated from these plants are available for public usage including irrigation of public greeneries. The selected STPs were as follows: A = Industrial STP only, B = Industrial and residential STP, C = Hospital STP. Samples were collected weekly over a period of two months. Samples were collected and analysed following the standard methods [20]. 1L sterile, labelled glass bottles were used to collect the effluent samples for heavy metal analysis [21]. Samples were preserved in a cooler at 10°C [20].

Soil and sludge samples were dried at 105°C for 3 h. Dried samples (0.2 g) were weighed in perfluoroalkoxy polymer container and treated with 4ml of concentrated nitric acid and 0.5ml of hydrofluoric acid. The samples treated in a microwave for 40 min. Then the samples were diluted to 100 ml with water. Sample solutions were diluted with water to give a final concentration of 1 g/l [22]. TSE samples were filtered and analysed for Al, As, B, Ba, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Sc, Se and Zn using inductively coupled plasma optical emission spectrometer (ICP-OES) type Perkin Elmer 3300 DV ICP (USA). Blank and certified reference materials were used as controls. Heavy metal concentrations were compared to the Omani Standard of Wastewater Reuse, [23] (Table1). Unrestricted irrigation TSE is used for irrigation of vegetable and salad, crops eaten uncooked, sports fields and public parks. Restricted irrigation TSE is used for Cereal crops, industrial crops, fodder crops, pasture and trees. Minimum Permissible Levels (MPL) for SB and Sc are unavailable [24].



Table 1: Heavy metal standards of wastewater reuse in Oman.

Metal	Symbol	Minimum Permissible Levels (MPL)	
		Unrestricted irrigation (ppb)	Restricted irrigation (ppb)
Aluminum	Al	5	5
Arsenic	As	0.1	0.1
Barium	Ba	1	2
Boron	B	0.5	1
Cadmium	Cd	0.01	0.01
Chromium	Cr	0.05	0.05
Copper	Cu	0.05	1
Iron	Fe	1	5
Mercury	Hg	0.001	0.001
Manganese	Mn	0.1	0.5
Nickel	Ni	0.1	0.1
Lead	Pb	0.1	0.2
Antimony	Sb	-	-
Scandium	Sc	-	-
Selenium	Se	0.02	0.02
Zinc	Zn	5	5

3 Results

Sludge samples at three localities in Muscat, Oman were analyzed in 2010. Heavy metals Pb, Hg, Cu, Ni, Zn, Cr and Cd were generally found at high concentrations. At medium concentrations were Sb, Al, As, B and Ba; at lower concentrations were Fe, Mn and Se (Figure 1).

Heavy metal concentration in TSE from the three localities demonstrated a wide variation in values without any specific patterns. The highest heavy metal concentrations were Pb, Zn, Cd, but only in localities A and B while C was significantly low. Locality C is where the hospital was located. B, Cr, Cu, Fe, Hg and Sb were next in concentrations and again in localities A and B were generally with dominant values. The third group Al, As, Ba, Ni, Sc and Se were at low levels in the three localities (Figure 2).

The soil heavy metal contamination was from the samples were taken from each locality demonstrated a close pattern to the STP values in the three localities. Many of the levels of the heavy metal surveyed from the sludge in the three localities, STP sludge and soil surpassed Omani standards safety levels (Figures 1–3).

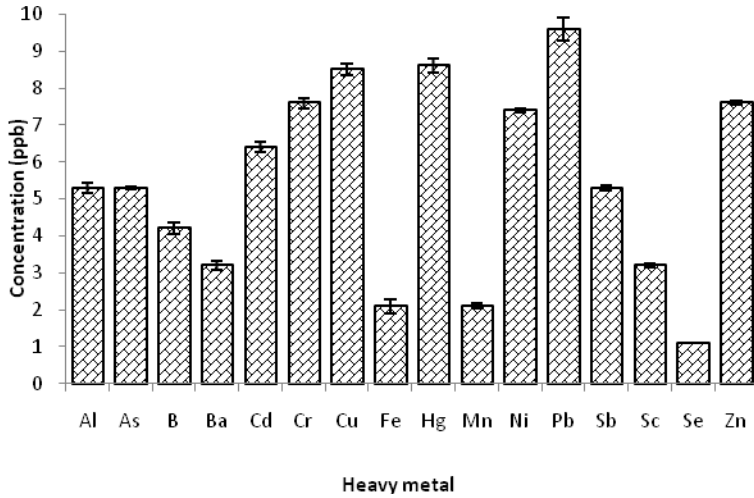


Figure 1: Heavy metals from sludge.

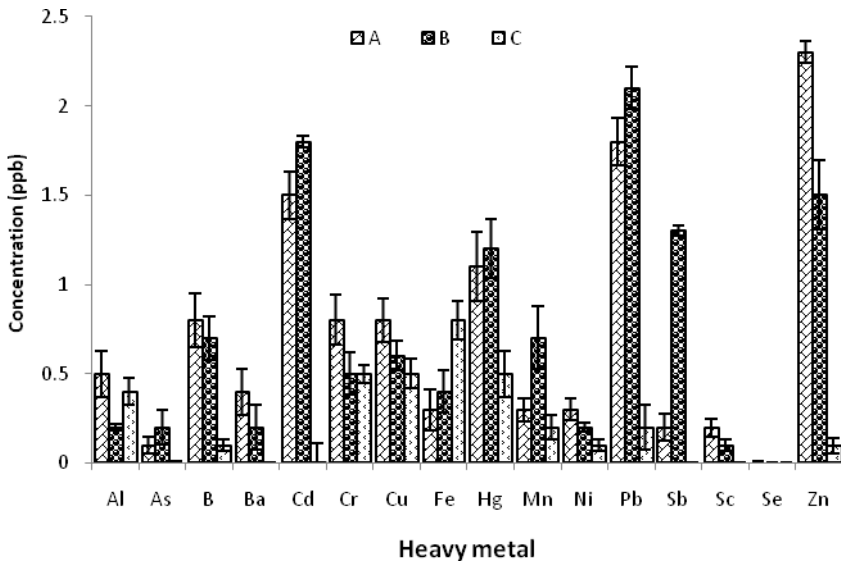


Figure 2: Samples of heavy metal concentrations (ppb) taken from STP at three different localities in Muscat, Oman. Zn, Pb and Cd were found at high concentrations in localities A and B.

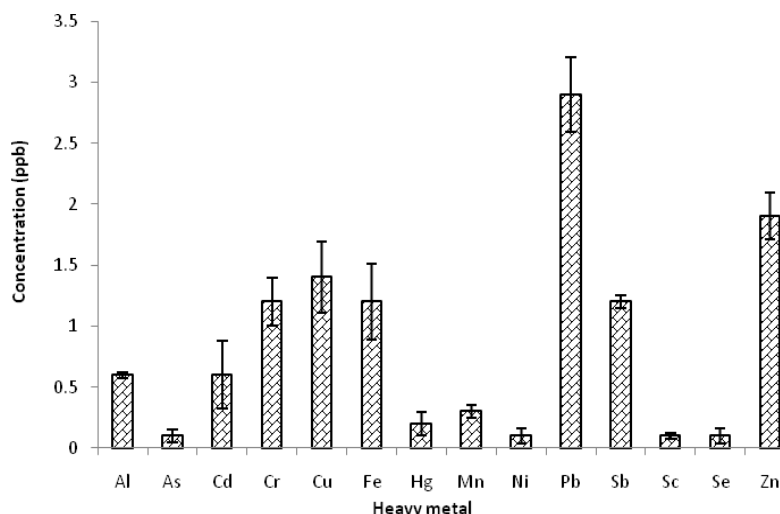


Figure 3: Heavy metals in soil samples irrigated by TSE from STP localities in Muscat, Oman.

4 Discussion

Due to low annual rainfall and arid conditions in Oman, reuse of TSE has become a necessity. However, several environmental and public health problems are now facing the country. Specifically, the reuse of TSE and sludge which resulted in accumulation of toxic compounds in soil and rapid infiltration into underground water affecting public health, animals and plants.

In this study, the detection of heavy metals in sludge and treated sewage effluents were evidently found to contribute to pollution of soil affecting the environment. As a result, heavy metals infiltration into the soil occurring very rapidly and consequently contaminates water and the whole food chain. Heavy metals in drinking water and food were found to be responsible for a several chronic diseases such as chronic anemia, liver cirrhosis, renal failure and cancers [18, 19].

In this study, throughout the three localities, several heavy metals exceeded the MPL levels set by the Omani authorities [23, 24]. Several international organizations recommended safe levels of heavy metals in food and drinking water [25–29]. However, many of the heavy metals in this study exceeded the safety levels which made food and drinking water not suitable for consumption. Heavy metal values from localities A and B surpassed MPL. The STPs from these localities are fed by water from industrial sources. It was reported that most of heavy metals contamination are related to industries [30, 31]. It is well documented that heavy metals in underground water is also contributed by a lithology of rocks and quantity of infiltrating rainfall. However, water composition also affected by human activities [32]. Heavy metal impurities penetrate the soil to reach underground water through sewage and industrial

effluents were also reported [33]. Such water, if used for drinking and irrigation of farms may be detrimental to health. The use of sludge in soil has to pass standard safety conditions before reused. Sludge must be kept at a minimum of 3 weeks before grazing or harvesting crops. The use of sludge is prohibited in soils when fruits or vegetables are growing [24]. The results of this investigation show that there is an alarming condition facing human health, ecology and environment in Oman. There is a steady increase in the levels of heavy metals throughout the three study areas. Unless there is a stringent enforcement, the danger of heavy metals infiltration might be harmful in the future affecting wild life and human health.

5 Conclusions

Soil contained heavy metals probably resulted from contaminated TSE and sludge. The highest concentrations of the heavy metals in all samples were Pb and Zn. The data indicate that the major source of the heavy metal concentrations originated from STP used for industrial effluents and the lowest was from the hospital. Several heavy metals have surpassed the MPL levels.

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