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Investigation of Heavy Metals Concentration in Wastewater Reused for Agriculture Irrigation in Isfahan

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Background & Aims of the Study: The use of urban wastewater in agriculture is receiving renewed attention with the increasing scarcity of freshwater resources in many arid and semiarid areas, despite its associated health and environmental risks. Long term wastewater usage for irrigation results in accumulation of heavy metal in soils and plants. So, due to the environmental and health risks associated with wastewater irrigation, this study was carried out to investigate heavy metals in the Wastewater Treatment Plant effluent in Isfahan.

Materials & Methods: A duplicate sample of treated wastewater was taken from Isfahan's North wastewater treatment plant (WWTP) in winter season. Then, examination was accomplished according to Standard Methods for the Examination of Water and Wastewater. Results compared with Iran standard for wastewater reuse in irrigation.

Results: In this study, there was no cadmium (Cd) and chromium (Cr) in the effluent, and the mean concentration of lead (Pb), nickel (Ni), zinc (Zn) and copper (Cu) content was 0.008 and 0.004, 0.028 and 0.018 mg/L, respectively. The Iranian standard content of Cd, Cr, Pb, Ni, Zn, and Cu for irrigation are 0.05, 1, 1, 2, 2 and 0.2 mg/L.

Conclusions: The results of this study indicate that the mean contents of Cd, Cr, Pb, Ni, Zn, and Cu in the effluent of Isfahan North WWTP was in safe range for use in agricultural irrigation. All of them were lower than the allowable limit suggested by the standard of Iran.

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Background

Millions of families in developing world cities and towns improve their access to food and raise income through agricultural activities in urban and peri-urban areas (1,2). However, in many cases, untreated or partially treated wastewater is used to irrigate crops, that it can endanger consumers' health (3,4).

However, wastewater irrigation provides water, N, P, and organic matter to the soils, but there is a concern about the accumulation of potentially toxic elements, especially heavy metals in soil and plants. When wastewater is used in agricultural fields, heavy metals enter the soil and get fixed to the soil components.

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Therefore, constant application of wastewater for growing vegetables, fodders and other major crops tends to accumulate large amount of heavy metals in soil, which persists there for an indefinite period and has long term effects on the soil environment (5,6). Also, repeated irrigation of crops with wastewater has significant effects on the physical and chemical properties of soil (7-9).

Application of untreated or treated wastewater to irrigate urban vegetable gardens is raising serious concern about possible health risks associated with the consumption of these vegetables, especially with regard to the concentrations of heavy metals in their edible parts (10,11). Heavy metals are a special group of trace elements, which have been shown to cause definite health hazards when taken up by plants. These heavy metals include zinc (Zn), cadmium (Cd), copper (Cu), and nickel (Ni), lead (Pb), manganese (Mn), iron (Fe), mercury (Hg), and chromium (Cr). These are called heavy metals because in their metallic form, their densities are higher than 4 g/cc (12,13).

Excessive accumulation of heavy metals in agricultural soils because of irrigation with treated wastewater may not only lead to soil contamination, but also affect food quality and safety. Important sources of heavy metals in wastewater are urban and industrial effluents. (14-16)

High concentrations of heavy metals in fruits and vegetables are related to high prevalence of upper gastro-intestinal cancer (17). The genetic and epigenetic effects of these elements are associated with an increased risk of different types of cancer (18).

Arsenic and its inorganic compounds are considered to be “carcinogenic to humans” by the International Agency for Research on Cancer. Cadmium is absorbed into the body, accumulate in liver and kidney, although it can be found in almost all adult tissues. Trivalent arsenite (As+3) has more carcinogenic properties than pentavalent (As+5) arsenate (19,20). In the body, lead not only accumulates in tissues, especially bone, but also in the liver, kidneys, pancreas, and lungs. Pregnant women and young children are particularly vulnerable, since lead can easily cross the placenta and enter the fetal brain (21). Trivalent chromium is an epigenetic carcinogen factor because it can form stable compounds with macromolecules, such as DNA and cysteine residue of proteins and glutathione (22).

In recent years, one potential problem that has been recognized concerning the disposal of wastewater to agricultural lands is the accumulation of heavy metals in the soil and their uptake by plants and finally endangering consumers’ health. Long term wastewater usage for irrigation results in heavy metal accumulation and can exceed the maximum permissible limits for human or livestock consumption. So, due to the environmental and health risks associated with wastewater irrigation, the present study was carried out in Isfahan with the aim of investigation of heavy metals in the Wastewater Treatment Plant (WWTP) effluent.

Aims of the study: The objective of this study was to investigate of heavy metals in the wastewater treatment plant (WWTP) effluent of Isfahan in Iran.

Materials & Methods

This study was carried out in Isfahan, Iran. Isfahan's North WWTP (Fig. 1) has 65 hectare area with activated sludge treatment process. This plant treats 180000 m^3 wastewater per day. There is extended area for agriculture in downstream of the WWTP.

Isfahan has shortage of water and most of the farmers have problem to irrigate their product.

Unfortunately, some of the farmers use the

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effluent illegally for irrigation. So, this survey was performed to specify the suitability of Isfahan's North WWTP effluent for irrigation in terms of heavy metals. In this study, the standard of Iranian Environment Department was selected as leading criteria. Sampling had been done with duplicate frequency in winter season. All the examinations were done according to Standard Methods for the Examination of Water and Wastewater (23). Considering health risks associated with wastewater reuse for agriculture, health of consumers, and effects on soil and environment, heavy metal test, including Cd, Cr, Pb, Ni, Zn, and Cu was accomplished.

Results

Table 1 shows the mean heavy metal concentrations in Isfahan's North WWTP effluent and proposed national wastewater reuse standard of heavy metal for irrigation in Iran.

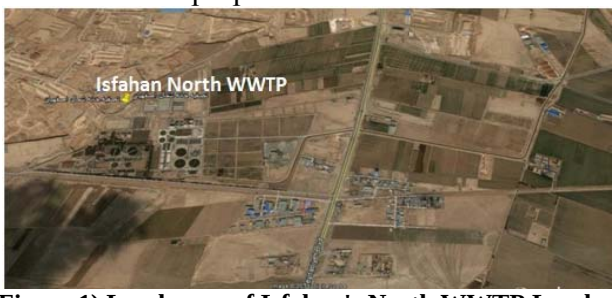

Figure 1) Landscape of Isfahan's North WWTP Land.

Table 1) amount of heavy metal concentration in Isfahan's North wastewater treatment plant effluent & Iran standards for agricultural reuse

Parameter	Unit	Mean amount in WWTP effluent	SD	Approved standard for agricultural reuse in Iran
Cadmium (Cd)	mg/L	٠	٠	0.05
Chromium (Cr)	mg/L	٠	٠	1
Lead (Pb)	mg/L	0/008	0.001	1
Nickel (Ni)	mg/L	0/004	0.001	2
Copper (Cu)	mg/L	0.018		0.2
Zinc (Zn)	mg/L	0.028		2

Discussion

In this study, there was not any Cd and Cr in the effluent, also the mean content of Pb, Ni, Zn, and Cu) was 0.008, 0.004, 0.028 and 0.018 mg/L, respectively. The proposed national wastewater reuse standard of heavy metal for irrigation in Iran are 0.05, 1, 1, 2, 2 and 0.2 mg/L for Cd, Cr, Pb, Ni, Zn, and Cu, respectively. Results show that Cd, Cr, Pb, Ni, Zn and Cu contents of Isfahan North WWTP effluent were in safe range for use in agricultural irrigation.

Heavy metals present in wastewater are an important concern for wastewater reuse irrigation, because they pose a health risk to plants' and crops' quality. Wastewater from factories often contains heavy metals. These metals have very adverse effects on human health. Evaporation of, and repeated irrigation by treated wastewater, which have heavy metals may cause build up of contaminants on

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crops or uptake of chemical constituents through root of plants. Also, daily intake of Cd, Cr, Pb, and Ni via consumption of sewage-fed vegetables exceeded the recommended oral dose of metal for both adult and children. Crops grown in these soils were contaminated by heavy metals (24,25). In this study, it was revealed that the Isfahan North WWTP effluent meets all standard levels approved by Iran (Table 1).

Dikinya et al.'s results showed that the Glen Valley soils are naturally high in some of these trace elements, and that crop cultivation under wastewater irrigation has actually lowered the trace element content of the soils (26). So, it is clear that if effluent has heavy metals, it can transit to plants and consequently endanger consumers' health. Fortunately, Isfahan effluent has good quality in terms of heavy metals.

Chromium may pose public health risks, such as dermatitis, especially if farmers irrigate without using protective clothing (27). Thus, in irrigation it is very important to pay attention to worker protection acts. Unfortunately, farm workers do not have any information about this matter. As motioned above, Isfahan effluent doesn't has no Cr content.

The concentrations of heavy metals in plants also depend on application rate, soil reactions, and plant species. This is partially evidenced by a study in India in 2008 that showed Cr elevated significantly in roots as the sludge application increased (28). Studies have shown that leafy type vegetables accumulated higher level of heavy metals than fruit type (29,30). Therefore, paying attention to this matter in selection of plant species for cultivation in Isfahan's farm lands near to WWTP is vital to decrease consumers' health risk in future. For example, vegetables such as cabbage (Brassica juncea, Brassica oleracea) cultivated in wastewater-irrigated soils take up heavy metals in large quantities and consequently can cause potential health risks to the consumers (31).

Surveys of wastewater use have shown that more than 85% of the applied heavy metals are likely to accumulate in the soil, most at the surface. Thus, it is important that farm lands be monitored annually to control characteristics of soil.

Table 2 shows some crops' water requirement, growing period, and amount of farm land that can be irrigated with treated wastewater (hectare) in Isfahan. So, using wastewater reuse can save a large amount of fresh water for agricultural purposes.

Table 2) Some crop water requirements and growing period (32)

Crop	Total water requirement (mm)	Approximate growing period (day)	Amount of farm land that can be irrigated with treated wastewater in Isfahan (hectare) *
Wheat	375	90	4316
Barley	360	90	4500
Cotton	1070	200	3364
Rice	1060	105	1783
Sun flower	875	120	2468

*375 mm/90 day=4.17 mm/Day. If this loading is applied over 1 hectare of land, it equals to 0.00417 m/day × 10000 m^2=41.7 m^3/ha/day, and for growing period is equal to 41.7 × 90 = 3753 m^3/ha. Isfahan's North WWTP effluent is 180000 m^3/day. For growing period is equal to 180000 m^3/day×90=16200000 m^3. At last, 16200000/3753= 4316 hectare.

Conclusion: Isfahan's North WWTP effluent does not have high level of heavy metals and all of them meet the standard of Iran, but it is clear that exceeded use of treated wastewater for irrigation pose some load of metals to soil. Thus, it is recommended that alternative irrigation by fresh water and treated wastewater should be used.

Studies revealed that long term wastewater use for irrigation results in heavy metal accumulation in soils and bioaccumulation in plants beyond maximum permissible limits for both humans and livestock consumption, so it is

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important to set up a very strong monitoring program for controlling soil and product quality over time.

To restrict heavy metals' loads on the soils, only treatment is not enough, it is important to prevent or limit the discharges of wastewater from industries into domestic wastewaters or WWTP.

Wastewater reuse program for irrigation in agricultural field results in saving large amount of water, and therefore, higher amount of farm lands can be under cultivation.

Footnotes

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Conflict of Interest:

The authors declare no conflict of interest.

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