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Health risk assessment of heavy metals through consumption of vegetables irrigated with reclaimed urban wastewater in Algeria

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ABSTRACT

Municipal wastewater reclamation and reuse provides a valid and effective way to face water crisis in many countries around the world. In this paper, a performance survey on the urban wastewater treatment plant (UWWTP) of the city of Boumerdes has been conducted in order to assess the potential of reuse of its treated waters. The study reveals that the plant is operated efficiently and complies with the related discharge standards in terms of organic matter and heavy metals. Three vegetable species (potato, tomato and cucumber) were planted and irrigated with treated waters issued from Boumerdes plant and subsequently analyzed for the purpose of assessing their heavy metals content. The concentrations of Cu, Zn, Pb and Cr were observed in range of 2.5–3.0, 0.5–0.6, 1.8–12.5 and 0.9–6.2 mg/kg (dry wt.), respectively. The survey showed, paradoxically, that all vegetables irrigated with reclaimed waters are much less contaminated with metals than similar vegetables purchased in different Algerian markets. Furthermore, the assessing of the potential health risk for consumers has showed that irrigation with treated waters can reduce the estimated daily intake (EDI) and the target hazard quotient (THQ) for all metals by more than 85%. This study reveals that no adverse effects on resident's health could be expected from consumption of vegetables irrigated with treated wastewaters.

1. Introduction

Reclamation and reuse of wastewaters offer nowadays a valid and effective alternative to meet the demands for water while helping to conserve limited high-quality freshwater supplies. Many countries around the world with limited freshwater resource due to the extreme climate, growth of the population and economical development have opted for this way to face the water crisis (Angelakis et al., 1999; Xu et al., 2014; Zhang et al., 2011).

However, the safety of reclaimed water (e.g., municipal effluent from the Wastewater Treatment Plant (WWTP)) is source of concern; toxic chemicals are one of dominant hazardous components in wastewater (Asano et al., 2007; Xu et al., 2014). These residual toxic chemicals in WWTP effluents would accumulate and cause long term potential risks on human health (Asano et al., 2007). Considering the non-biodegradability and the persistent nature of heavy metals, the control of their levels in reclaimed water intended for irrigation is of vital concern. Indeed, such trace-elements may enter the human body via consumption of food crops and can cause various toxic effects (Khan et al., 2013; Li et al., 2012; Liu et al., 2011); they can damage the nervous, skeletal, circulatory, enzymatic, endocrine, and immune systems; some

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are harmful for liver, kidney or lung while others are carcinogenic (Brewer, 2010; Jarup, 2003; Martin and Griswold, 2009). As a result, more and more attention has been paid to this area while national and international regulations have lowered the discharge standards for heavy metals in treated water intended for irrigation.

Crops and vegetables are important components of human diet across the world both in terms of quantities consumed and nutritional value (Khillare et al., 2012); therefore, information about heavy metal accumulation in food crops and their dietary intake are necessary for assessing their risk to human health. More importantly, the assessment of the accumulation of toxic heavy metal in food crops which are irrigated with WWTP effluents is of prime interest. Many previous studies have assessed the health risks of heavy metals via the consumption of food crops: grown on reclaimed tidal flat (Li et al., 2012), cultivated in mining area (Hu et al., 2014), and irrigated with wastewater and treated wastewater (Christou et al., 2014; Chung et al., 2011; Kalavrouziotis et al., 2008; Kiziloglu et al., 2008). The average concentrations of heavy metals in different crops and the total daily intake of crops have been used in these assessments. To our knowledge, no such survey has yet been carried out in Algeria.

In many areas in Algeria, untreated wastewater flows freely through channels into little rivers, where local farmers draw their irrigation water. Crops and vegetables irrigated may include carrots, lettuce, cabbage, green onion and others which are easily consumed raw as salad. The public health risks of using such contaminated streams for irrigation are obvious as we have highlighted in a previous study (Cherfi et al., 2014). Hence, the government has legalized the reuse of WWTP effluents for irrigation under controlled conditions to minimize the transfer of pathogenic and toxic contaminants into the agricultural products, soils, surface and groundwater (Official Journal of the Algerian Republic, 2005, 2007, 2012). In so doing, the government's objective was to eliminate the problem with wastewater disposal while dealing with the water crisis afflicting the agricultural field especially.

In that context, this paper presents original data on the impact assessment of the reuse of an UWWTP's effluent for irrigation. The study was undertaken with the aim to (1) study the performance of the UWWTP of the city of Boumerdes in order to assess the potential of reuse of its treated waters, (2) investigate the concentration of lead (Pb), chromium (Cr), copper (Cu) and zinc (Zn) in some selected vegetables irrigated with reclaimed water and figure out whether they meet the agreed international requirements, and (3) assess the health risks through the estimated daily intake (EDI) and the target hazard quotient (THQ) of these metals via consumption of these vegetables.

2. Experimental

2.1. *Performance survey of the UWWTP of the city of Boumerdes*

The urban wastewater treatment plant (UWWTP) of the city of Boumerdes (50 km east of Algiers) is an activated sludge biological treatment system with a design capacity of 15,000 m^3/day (equivalent population: 75,000). It is located along the Mediterranean Sea shoreline and discharges most of its effluent to the sea; only a small part is reused occasionally in irrigation by two local farmers.

As shown in Fig. 1, the Boumerdes UWWTP is devoid of primary and tertiary treatment; the wastewaters are processed in two main steps: preliminary treatment including coarse screening, grit removal and oil separation, and secondary treatment by activated sludge.

During the present study, water sampling and experimental analyses from both the influent and effluent of the treatment plant were accomplished and the UWWTP was evaluated based on the effluent composition and the reuse potentials. Sampling was performed every day over a one-year period and the measurements were realized on average daily or weekly samples, depending on the measure (daily sample: temperature, pH, total suspended solid (TSS); weekly sample: chemical oxygen demand (COD), 5-day biochemical oxygen demand (BOD_5), NO_3^-–N, TKN, PO_4^{-3}–P, NH_4^+–N, NO_2^-–N).

The analysis of trace metals contents was made from Mars to Mai on average daily samples. The targeted metals: lead (Pb), zinc (Zn), chromium (Cr) and copper (Cu) were analyzed in every flux entering and leaving the UWWTP (sewer incoming, treated-water outgoing, removed grit and evacuated sludge).

2.2. *Impact assessment of irrigation with treated water from Boumerdes UWWTP*

2.2.1. *Sampling, preparation and analysis*

The study was conducted in the city of Boumerdes, in an agricultural land of a local farmer accustomed to using reclaimed water to irrigate his crops, as regulated by the Algerian guideline for the reuse of treated water.

Three vegetable species (potato, tomato and cucumber) were planted and irrigated with treated water of Boumerdes UWWTP during the period of Mars to June. The crops were grown under a greenhouse and drip-irrigated twice per week over 8 h.

After the harvest, samples of about 4 kg of each vegetable were randomly collected in order to determine the Pb, Zn, Cu and Cr contents in their edible parts. These vegetable samples were washed and cleared of rotten and damaged parts, grinded and homogenized in a mixer grinder and then oven-dried at 105 °C for 24 h to get the moisture content.

Two grinded samples (3 g, each) for each food item were dry-ashed for 3 h in porcelain crucibles at 450 °C in a muffle furnace. The ash was then digested with concentrated nitric acid solution until the transparent solution was achieved. The digested solution was then filtered using Whatman filter paper, diluted to 50 mL and analyzed by a flame atomic absorption spectrophotometer (Unicam model Solar-929. Cambridge, UK). All measurements were made under the following conditions: air–acetylene flame, spectral bandwidth: 0.5 nm, lamp current: 10 mA, air flow rate: 6 L/min, acetylene flow rate: 2.5 L/min. Five separate readings were made for each solution at the wavelengths (nm): 217.0 for Pb, 213.9 for Zn, 324.8 for Cu and 357.9 for Cr. The means of these measurements were used to calculate the concentrations.

All chemical reagents used were of analytical grade. Stock solutions of diverse metals were prepared from the high purity compounds (99.9%) purchased from Sigma-Aldrich (St. Louis, MO, USA).

2.2.2. *Health risk assessment: Estimated daily intake (EDI)—Target hazard quotient (THQ)*

In order to evaluate the health risks through consumption of vegetables irrigated with treated water, the estimated daily intake (EDI: μg of the selected heavy metal/day. kg body wt.)