Agricultural Water Management 171 (2016) 153–161

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Heavy metals in soil and plants after long-term sewage irrigation at Tianjin China: A case study assessment

Weiqing Meng[a,b], Zuwei Wang[a,*], Beibei Hu[a], Zhongliang Wang[a,b], Hongyuan Li[c], Robbin Cole Goodman[d]

[a] College of Urban and Environment Science, Tianjin Normal University, Tianjin 300387, China
[b] Tianjin Key Laboratory of Water Resources and Environment, Tianjin Normal University, Tianjin 300387, China
[c] College of Environment Science and Engineering, Nankai University, Tianjin 300071, China
[d] College of Science and Engineering, Texas A&M University—Corpus Christi, Corpus Christi, TX 78412, USA

ARTICLE INFO

Article history:
Received 1 April 2015
Received in revised form 17 March 2016
Accepted 22 March 2016

Keywords:
Sewage irrigation
Heavy metal
Soil
Wheat
Vegetables
China

ABSTRACT

Due to the constraints of freshwater for agricultural irrigation, sewage water has been used in farmland irrigation as an important supplement and alternative water resources during the past three decades in China, especially in northern areas. However, there is increasing concern about food safety and health risks, hence, a case study was undertaken to understand the long-term effect of sewage irrigation on heavy metal concentrations in soil and plants. Sewage sludge, soil and plant samples were collected and analyzed for heavy metals concentrations. Results showed that sewage irrigated soil contained much higher concentrations of Cd, Cu, Pb, Zn, Ni, Cr, As and Hg compared to clean water irrigated soil. The heavy metal content of the topsoil (0–20 cm) was much higher than that of the subsoil. Significant heavy metal (Cd, Zn and Hg) pollution has occurred in soils of areas that had been using untreated waste water irrigation in Tianjin, China. There were significant accumulations of heavy metals in wheat that used sewage irrigation. Compared with the other parts of the wheat plants, the higher contents of Cd, Cr, Pb and As in the roots indicated that roots had a strong absorption ability and maybe cause an obvious barrier effect. Based on the soil to plant transfer factor of heavy metals, there is a strong accumulation effect of Cd in vegetables. Overall, the concentrations of Cd, Pb, Ni, Cr and As were lower than the national permitted safety limits in soil. Mean Cd, Pb and As concentrations in vegetables were higher than the national safety limits, whereas the mean concentrations of Cu, Zn and Cr were below Chinese national safety limits. Therefore, in order to ensure food safety and use of sewage for irrigation, continuous monitoring and pollution control is needed.

1. Introduction

Due to rapid economic development, increasing population growth and accelerated urbanization, water resource scarcity has become a major factor restricting the sustainable development of agriculture during the past three decades in China, especially in northern areas. Rapid urbanization and industrialization requires enormous amounts of fresh water, and releases large volumes of wastewater. To make up for the shortage of water, sewage irrigation has been widely used in China since 1972 as an important supplement and alternative water resources (Yang and Abbaspour, 2007).

Industrial and domestic effluents were used in agricultural irrigation, which brings benefits and problems. The benefits of sewage water irrigation are that it not only reduces freshwater demand (USEPA, 1992), but also adds a certain amount of nutrients and organic matter into the soil (Horswell et al., 2003). However, wastewater may contain heavy metals like Cu, Pb, Zn, Cd, Ni, Cr, Mn, Hg. As a result of long term sewage irrigation, heavy metal accumulation in the agricultural ecosystems is almost inevitable (Singh et al., 2004; Liu et al., 2005; Sharma et al., 2007; Yang et al., 2008). This accumulation may cause potential risks to human health (Mapanda et al., 2005; Muchuweti et al., 2006; Al-Lahham et al., 2007; Singh et al., 2012). As long-term sewage irrigation often used untreated sewage and reclaimed wastewater, soil quality decline has become a critical issue. According to previous investigations (EPC, 2014), the total area of soil with heavy metal pollution

* Corresponding author at: 393 Binshui West Road, Tianjin 300387, China.
E-mail address: mengweiqing03@126.com (Z. Wang).

http://dx.doi.org/10.1016/j.agwat.2016.03.013
0378-3774/

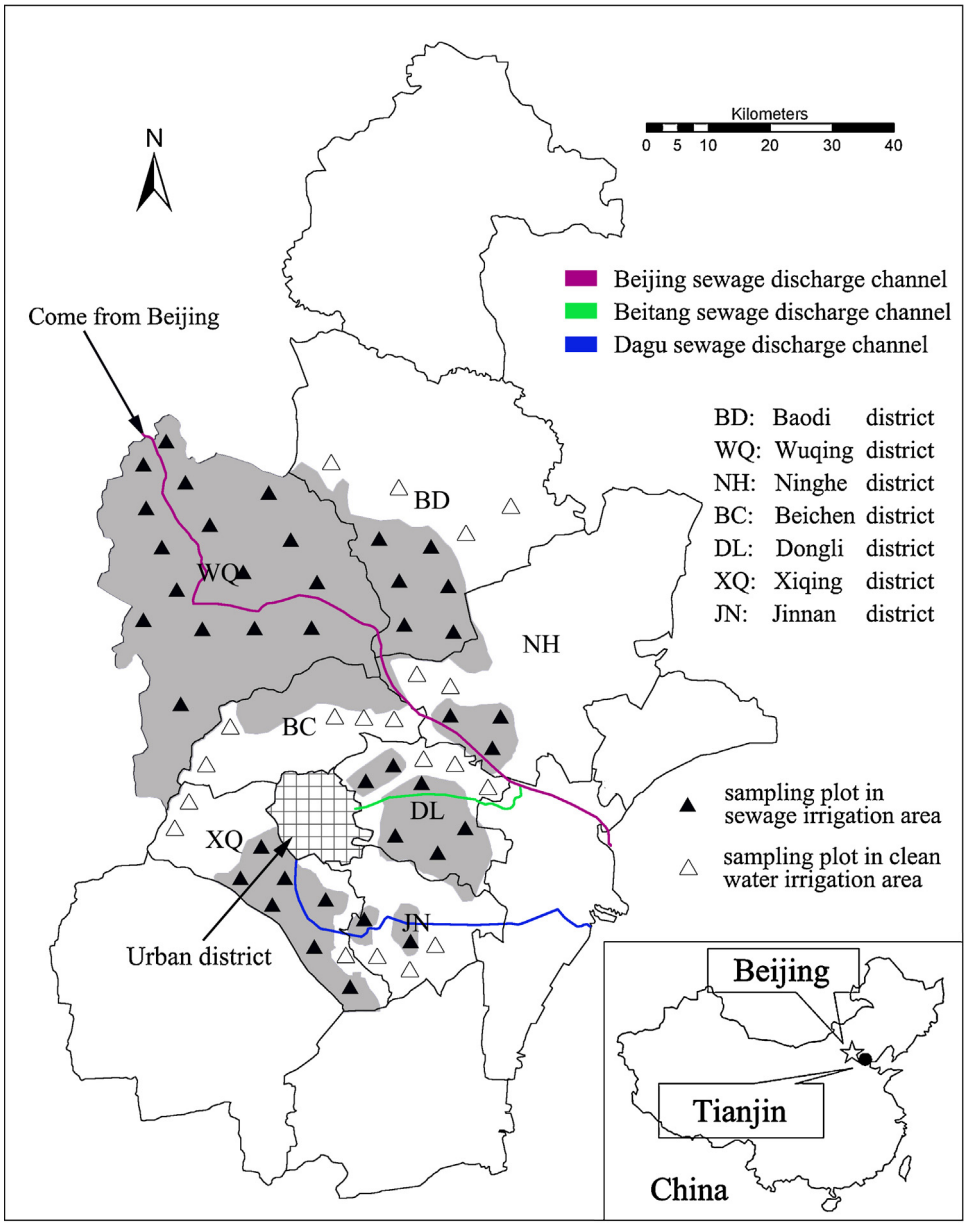

Fig. 1. Location of Tianjin and its sewage irrigation areas.

in China is more than 20 million ha, and 26.4% of sewage irrigation soil areas were polluted.

Tianjin, the biggest sewage-irrigation region of China, has a history of more than 35 years of wastewater irrigation. The enrichment of heavy metals in soil and the food chain has caused much attention among researchers and managers, and some research has been done on soil contamination in China (Liu et al., 2005; Khan et al., 2008). Wang et al. (2005) assessed the health risks of heavy metals to the general public in Tianjin via consumption of vegetables and fish, but the data, which was collected in 1996 by Tianjin Environmental Protection Bureau, was too old. Furthermore, Wang et al. (2012) assessed the health risk of heavy metals in soils and vegetables of the Beijing-Tianjin city cluster (Wang et al., 2012). However, further research is needed regarding the soil, crops and vegetable contamination to constitute a complete investigation. The aim of this study was to investigate the sewage irrigation and the heavy metal contamination level of Tianjin city, then to assess the impacts of the long history of sewage irrigation on heavy metal contents through the transfer factor from soil to crops and vegetables. This study can provide the latest and most important information related to the impacts of long-term sewage irrigation on heavy metal content in Tianjin.

2. Materials and methods

2.1. Study area

Tianjin, lying near Beijing, is located in Northern China along the west coast of the Bohai Gulf (Fig. 1), which is the water scarce region in China. The annual rainfall is 600 mm, while annual evaporation is 1500 mm. The average annual per capita water resource availability is currently about 160 m^3 per capita (Zhang et al., 2008), which is approximately 6–7% of the world average, far below the internationally recognized minimum standard of 1000 m^3 per capita. The elevation of the Tianjin area is 2–5 m a.s.l. and the alkalinityof the soil is high with pH 7.5–8.7, and according to our investigation, the range of variation in soil salinity is 0.06–2.92%. Rapid economic growth, urbanization and changing lifestyles have imposed severe