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ORIGINAL ARTICLE

Microbial contamination of vegetable crop and soil profile in arid regions under controlled application of domestic wastewater

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Abstract Increasing lack of potable water in arid countries leads to the use of treated wastewater for crop production. However, the use of inappropriate irrigation practices could result in a serious contamination risk to plants, soils, and groundwater with sewage water. This research was initiated in view to the increasing danger of vegetable crops and groundwater contamination with pathogenic bacteria due to wastewater land application. The research was designed to study: (1) the effect of treated wastewater irrigation on the yield and microbial contamination of the radish plant under field conditions; (2) contamination of the agricultural soil profile with fecal coliform bacteria. Effluent from a domestic wastewater treatment plant (100%) in Jeddah city, Saudi Arabia, was diluted to 80% and 40% with the groundwater of the experimental site constituting three different water qualities plus groundwater as control. Radish plant was grown in two consecutive seasons under two drip irrigation systems and four irrigation water qualities. Upon harvesting, plant weight per ha, total bacterial, fecal coliform, fecal streptococci were detected per 100 g of dry matter and compared with the control. The soil profile was also sampled at an equal distance of 3 cm from soil surface for fecal coliform detection. The results indicated that the yield increased significantly under the subsurface irrigation system and the control water quality compared to surface irrigation system and other water qualities. There was a considerable drop in the count of all bacteria species under the subsurface irrigation system compared to surface irrigation. The bacterial count/g of the plant shoot system increased as the percentage of wastewater in the irrigation water increased. Most of

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the fecal coliform bacteria were deposited in the first few centimeters below the column inlet and the profile exponentially decreased with increasing depth.

1. Introduction

About 1.2 million people in developing countries live in water scarce areas and by 2025, the number is expected to increase to 1.8 million due to the lack of undependable policies or suitable management strategy for reuse of treated wastewater in crop production (FAO, 2007). In the arid areas, there is an increasing need for water which resulted in the emergence of wastewater application in agriculture to reduce the demand on freshwater resources. Approximately 70% of treated wastewater is used for agriculture (Cytryn, 2010) and may have detrimental environmental and health effects. Transmissions of intestinal nematode (*Ascaris lumbricoides* and *Trichuris trichiura*), pathogenic bacteria and diseases, including diarrhea, dysentery, typhoid and cholera to farmer working in the wastewater irrigated fields and/or vegetable consumers were the major risks of the use of treated wastewater (WHO, 1989).

Determination of different microbial pathogen numbers in a partially treated wastewater samples is imperative and can allow an effective assessment of the treatment process. There are always worries and precautions about the reverse effect of treated wastewater use in the irrigation of edible crops (Toze, 2005). Thus, international and local organizations have concerns about putting standards for reuse of treated wastewater in agriculture. Plant production of corn, potato, lettuce, olive trees and alfalfa irrigation with treated wastewater was increased compared to plants irrigated with natural water resources which may be due to the presence of plant nutrients (mainly nitrogen and phosphorus) in the treated wastewater but the risk due to the presence of some pathogens is still under consideration (Mandi and Abissy, 2000; Kouraa et al., 2002; Munir and Mohammad, 2004; Lopez et al., 2006).

Fecal coli bacteria are present in human and animal feces and are relatively harmless to humans' intestines and *Escherichia coli* is the most common species of fecal coli bacteria. Furthermore, species of the genus Streptococcus cause pneumonia, ear infection and meningitis. Like fecal coli bacteria, fecal streptococci are applied as indicators of water pollution and have been used for many years to determine the quality and safety of water for irrigation and human consumption (WHO, 1989; Ashraf, 2015.). In treated wastewater, detection of these bacteria means a failure in the disinfection process but their absence does not necessarily guarantee the absence of pathogens. In practice, the desire goal is to obtain zero fecal coliform in water to be used for irrigation of raw eaten crops. To prevent transmission of many diseases, efficient treated wastewaters that comply with the microbiological quality guidelines should be used for crop irrigation.

The fate and transport of bacteria in soils is essential for assessing the risks for groundwater contamination by land-applied wastewater. Contaminant transport experiments can be very useful tools for the quantitative assessment of microbial transport in soils and to explicate the important factors and processes that control microbial transport. Many investigators have examined the transport of microorganisms in soil after land application of wastewater. These studies focused on the removal of bacteria (Schaub and Sorber, 1977; Smith et al., 1985) or viruses (Schaub and Sorber, 1977; Lance et al., 1982; Lance and Gerba, 1984) under conditions of saturated or unsaturated flow in soil columns or in field tests. Many others have investigated bacterial transport through soils (Aislabie et al., 2001; McLeod et al., 2003; Guber et al., 2005). Some have modeled bacteria transport through undisturbed soils (McGechan and Vinten, 2003; Pang et al., 2008). Transport of fecal coliform has been reported in many studies as well (McCoy and Hagedorn, 1980; Jamieson et al., 2002; Unc and Goss, 2003). Contamination of groundwater resources with fecal bacteria or viruses from wastewater poses a threat to the portability and the use of water resources (Crane and Moore, 1984; Kadam et al., 2008).

In the western region of Saudi Arabia, many local farmers use treated and untreated wastewater to grow vegetable crops under no regulation or legislation. The main objective of this research was to exploit and identify microbiological risks associated with the use of treated domestic wastewater in the irrigation of a radish plant under field condition as well as the contamination of the soil profile exposed to wastewater application containing fecal coliform bacteria. To achieve this aim, chemical analysis and some pathogenic bacteria were investigated in the effluent of the wastewater treatment plant, which was used to irrigate radish plant for two successive seasons under two drip irrigation systems. Transport experiment of wastewater through soil column was also investigated to quantify the distribution of fecal coliform.

2. Material and methods

2.1. Experimental design

The experimental site (1 km × 1 km in size) which is the Agricultural Research Station of King Abdulaziz University, Saudi Arabia is located at Hada Al-Sham village; about110 km northeast of Jeddah city on the mainstream of Usfan basin; or about 72 km east of the red sea coast. The soil of the experimental site was classified as sandy loam, pH 7.9, EC 2.4 dS/m, and organic matter 0.55%, heavy metals (mg/kg): Pb 0.9, Cd 0.001, Cr 0.001, and Ni 0.03. Ground water is the main source of irrigation in this region. During this study, the temperature ranged from 30 to 45 °C.

White Radish plant (*Raphanus sativus* L. cv. Smart Selection Indian) was grown under two different drip irrigation systems and four water qualities. Seeds were obtained from the local markets of Jeddah, washed and soaked in 2% Na hypochlorite for four hours. A split block design arranged in strips subplots with two irrigation systems (surface and subsurface- drip irrigation) and four different treated wastewater qualities (100%, 60% and 40% in addition to