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Faecal pollution on vegetables and soil drip irrigated with treated municipal wastewaters

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ABSTRACT

A three-year study was carried out to evaluate the effects of three different types of municipal treated wastewater distributed by drip irrigation on the microbial quality of some vegetable crops. The three different treated wastewater were: a secondary effluent originated from the municipal treatment plant after screening and grit removal, primary clarifiers followed by activated sludge process and partial aerobic stabilization of the sludge, finally the chemical precipitation of phosphorus, denitrification and chlorination; the second source, a tertiary-treated wastewater is originated after that the secondary effluent is first treated through granular media sand filtration and then it is pumped into the second phase of treatment represented by ultra-filtration module equipped with hollow fibre membranes (nominal porosity 0.2 μm). The third water source was a simplified lagooning treatment in which part of the secondary effluent is pumped outside of the municipal plant and it is collected in a big reversed pyramid-shaped land pit, in this tank the water resided for a 4–5 days before being distributed to crops. In an experimental field in southern Italy (Apulia region) the physico-chemical and microbiological characteristics of the irrigation waters and faecal pollution on typical vegetable crops of southern Italy environment were determined. Total and Faecal Coliforms, *Escherichia coli*, *Salmonella* and protozoa *Giardia* and *Cryptosporidium* were monitored in the irrigation water, on plants and on soil at harvesting time. The different quality of irrigation water affected yields. For microbial results, however, in spite of the water contained high levels of microbial load (248, 1713 and 123429 *E. coli* cfu 100 mL^{-1} in Tertiary filtered Wastewater, Lagoon treated Wastewater and Secondary treated Wastewater, respectively), exceeding the values of law (10 *E. coli* cfu 100 mL^{-1}), on crops and on soil, at harvesting time revealed no pollution. *Salmonella* and *Cryptosporidium* were never found in water, soil and crops. These data show that it is possible to irrigate with municipal treated wastewater and how despite they have higher values than those imposed by Italian law, crops quality and soil do not present any problems of faecal pollution and therefore do not cause risks for human health.

1. Introduction

Clean freshwater is a limited resource and its use for crop irrigation is in competition with the demand for household and industrial consumption. Lack of clean freshwater have already forced agriculture, especially in Central Europe and in the Mediterranean area, to search for alternative water sources and irrigation strategies to sustain food production as stated by the European Water Framework Directive (EC, 2000). Hence, low quality water, e.g., treated/untreated wastewater or surface water run-off, will be increasingly used for irrigation in agriculture. Already today, low quality waters are used to irrigate food crops in Australia, Mediterranean countries and elsewhere, e.g., Israel has for decades used treated wastewater in irrigated agriculture (Lazarova et al., 2000). Irrigation of agricultural land with low quality water, in particular drip and subsurface irrigation, can potentially also lead to contamination of groundwater when irrigation water contains high numbers of faecal microorganisms and human pathogens like *Salmonella*, *Campylobacter*, *Shigella*, enteric viruses, and protozoan parasites (Calci et al., 1998; Nwachuku and Gerba, 2008; U.S. EPA, 2004). However, soil application of treated wastewater, which often still contains human pathogens, may potentially increases pathogen survival by preventing their exposure to the harmful effects of UV-light and desiccation (Forslund et al., 2011). Pathogens in protected soil environments may subsequently be transferred to root and could therefore pose a food safety risk for consumers, in particular when such products are consumed raw, e.g., radishes and

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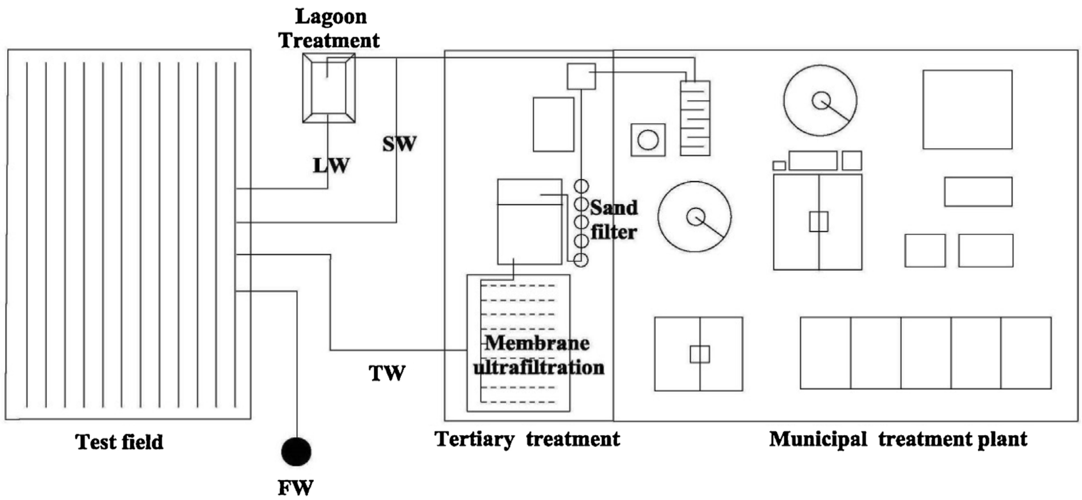

Fig. 1. Layout of treatment plant, experimental field and irrigation systems.

other vegetables (Natvig et al., 2002). The survival of microorganisms in soil depends on parameters such as temperature, moisture content, pH, soil composition and inhibitory competition from the indigenous microflora (Abu-Ashour et al., 1994; Chu et al., 2003; Mawdsley et al., 1995), as well as the time the microorganisms are able to survive outside a natural host. Pathogen numbers will show a temporal decrease even at low temperatures, if the conditions are unfavorable (Maule, 1999). Survival of bacterial pathogens in soil have been reported for up to one month after they were applied to grassland soils (Nicholson et al., 2005), while several studies have reported prolonged survival of viruses in soil (Feachem et al., 1983; Rzezutka and Cook, 2004).

Municipal wastewater, if properly treated, can be used for irrigation and they represent an attractive alternative to conventional waters, in arid and semi-arid countries. However, the irrigation reuse of treated municipal wastewater can lead both hygienic and agronomic problems.

Treated effluent can be used for irrigation under controlled conditions to minimize hazards from pathogenic and toxic contaminants of the agricultural products, soil, surface and ground waters. The use of treated wastewater in irrigation is associated with some health risks due to the possibility of the presence of a wide spectrum of pathogens, such as, coliforms, hence, contaminated water or wastewater has a great potential for transmitting a wide variety of diseases and illnesses (Al-Nakshabandi et al., 1997; Al-Lahham et al., 2003).

To contain microbial risk to human health is necessary to submit secondary effluents to tertiary treatment (flocculation–filtration–disinfection). The risks related to the use of wastewater for irrigation purposes are several and essentially attributable to two factors: the first is the contamination of agricultural soils and/or contamination of the food chain, the second is water contamination subsurface (Leoni et al., 1985).

Hence, the objective of this paper was to study the effect of irrigation by treated wastewater (tertiary filtered wastewater, lagoon treated wastewater and secondary treated wastewater), as compared to conventional water, on the pathogenic contamination of vegetable crops.

2. Materials and methods

A field experiment investigation was carried out at Trinitapoli (Apulia region, South Eastern Italy) to evaluate the feasibility of adopting the effluent of the local municipal wastewater treatment plant for agricultural reuse (irrigation of vegetable crops) after appropriate treatment. Three different treated wastewater were adopted: a secondary effluent (secondary-treated municipal wastewater, SW) originated from the municipal treatment plant after screening and grit removal, the raw sewage flows to primary clarifiers followed by activated sludge process and partial aerobic stabilization of the sludge, finally the chemical precipitation of phosphorus, denitrification and chlorination (usually 10 ppm dosing, without dechlorination step). The second source, a tertiary-treated wastewater (TW) is originated after that the secondary effluent is first treated through granular media sand filtration (tanks with the following filling materials: anthracite, quartz sand and gravel support with different diameters) and then it is pumped into the second phase of treatment represented by ultra-filtration module equipped with hollow fibre membranes (nominal porosity 0.2 μm) with cellulose triacetate double wall (0.8 mm diameter) at an internal pressure of 0.8–1.0 bar. Periodically all the membranes are automatically cleaned by back wash flushing. Part of the secondary effluent is pumped outside of the municipal plant and it is collected in a big reversed pyramid-shaped land pit, measuring 25×7 m at the bottom and 33×12 m at the top, 1.8 m deep, coated by a black polyethylene film. In this tank the water resided for a 4–5 days before being distributed to crops. This water source constitutes a simplified lagooning treatment (LW), originating the third source of water. All these treatment (SW, TW and LW) were compared with fresh water source (FW) from the Marana Capacciotti dam which served as the control (Fig. 1).

The experimental field was located immediately outside the treatment plant where vegetables were grown for testing irrigation with different water sources. The results reported in this paper refer three years of irrigation on six vegetable crops in succession.

2.1. Field characteristics, agronomic conditions and experimental design

The experimental field was located near the wastewater treatment plant of Trinitapoli (41°21′00″N 16°06′00″E; altitude 5 m a.s.l.). The trials were carried out in a sandy loam soil (USDA classification) with a field capacity (−0.03 MPa) of 35.8% dry weight (dw), a wilting point (−1.5 MPa) of 11.1% dw and a bulk density of 1.7 t m^{-3}. The main characteristics of the soil layer of the experimental site (0–0.4 m) characterized once, before trial, are as follow: sand 52%; loam 35%; clay 13%; organic matter 1.90%; P_2O_5 (Olsen) 30.75 mg kg^{-1}; extractable K_2O ($BaCl_2$) 820 mg kg^{-1}; total N (Kjeldahl) 0.885‰; pH 7.79; electrical conductivity 0.69 dS m^{-1}. The site