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ORAL PRESENTATIONS

Reuse of Wastewater in Agriculture: Risks or Benefits? A Pilot-scale Study on Durum Wheat (*Triticum durum* Desf.)

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Introduction

Over 70% of freshwater is used for agriculture in most parts of the world, with much higher figures in developing countries. Agriculture is constantly competing for limited availability of water for domestic, industrial and environmental uses. Population growth, rapid urbanisation and climate change contribute to increasing water demand, resource depletion and water pollution (Boretti and Rosa, 2019). This study aimed to investigate the presence and fate of emerging contaminants (antibiotics, anti-inflammatories, plasticisers, personal care products) in soil and durum wheat plants treated with treated municipal wastewater in Southern Italy. An experiment was designed with durum wheat plants grown in lysimeters and subjected to irrigation treatments with fresh water and contaminated wastewater. The study presents useful results on the distribution of contaminants of emerging interest between the various compartments and the degradation pathways.

Materials and Methods

The test was conducted at the experimental site of the Centro Ricerche Agrobiologiche ALSIA Metapontum, in the province of Matera (40.4029 N, 16.7944 E.), Italy. The sowing of the 'Saragolla' variety (*Triticum durum* Def.) took place on 13 January 2022, after the tomato harvest. On the same pots ofthe previous year, the same test was conducted on the tomato to assess the effect of crop succession. The experimental design involved the comparison of three irrigation treatments: (I) fresh water (FW) irrigation; (II) irrigation with secondary sewage effluent treated and refined with the addition of target contaminants in a dose comparable to the European average concentration (TWWx1); (III) irrigation with secondary sewage effluent treated and refined with emerging contaminants in a triple dose (TWWx3). The lysimeters allowed us to accurately monitor all elements of the water balance and to take drainage water samples to monitor any movement of ECs in the aquifer. In this regard, since the wheat test is carried out in a protected environment, four pre-flowering irrigation interventions were deliberately scheduled. The concentration of ECs in water samples was determined by an on-line solid phase extraction (SPE) method whose analytical conditions (UPLC-QTOF/MS/MS) have been described in detail elsewhere (Montagna et al., 2020). Extraction of ECs from soil was performed following the modified QuEChERS method reported by De Mastro et al. (2022). They were obtained using analytical standards (purity > 99%, provided by Lab Instruments, Italy) of clarithromycin; sulfamethoxazole; trimethoprim; carbamazepine; diclofenac; fluconazole; climbanazole; ketoprofen; metoprolol; naproxen; gemfibrozil and triclosan. Those compounds were specifically selected for their presence in wastewater, which is usually not completely removed during conventional treatment. In general, the concentration of EC in treated wastewater ranges from a few ng/L to a few µg/L (Mordechay et al., 2021). Standards were used to prepare the multi-compound standard solution (1000 ppm). The solution was added to the wastewater used for irrigation to obtain a concentration of 200 and 600 µg/L of each compound to obtain TWWx1 and TWWx3.

Results

The fate of ECs in the soil-plant water system varies depending on the specific contaminant. Naproxen, diclofenac, ketoprofen, metoprolol, trimethoprim, sulfamethoxazole, gemfibrozil, triclosan and clarithromycin introduced into the lysimeters with irrigation water were not found in plant tissue, soil and drainage water. Clarithromycin showed an average presence of 20% only in the soil. This should indicate that 100% of these ECs are rapidly degraded into by-products of different chemical composition. At the end of the growing cycle, climbanazole was observed in the soil, 85 % TWWx1 and 75 % in TWWx3, while no accumulation was observed in plant tissues and drainage water. It should be noted that the TWWx3 treatments were carried out to force the concentration of EC relative to the European wastewater average and to stimulate the soil-plant response. The ability of the soil to adsorb these ECs could also explain their absence in drainage water. Carbamazapine and fluconazole were detected in plant tissues, soil and drainage water; they were the least degraded ECs in the by-products. Very interestingly, both products were found to be present close to 45% in the plant compost in the TWWx3 thesis. These results seem to indicate a greater persistence of these two ECs in the soil-water system and longer degradation times than the other ECs analysed. Carbamazepine is one of the most frequently detected ECs in soils irrigated with reclaimed water (Beltrán et al., 2020) and that seems to indicate a high potential for soil and water pollution by this contaminants. However, the presence in our study of carbamazepine and fluconazole in plant tissues (roots, stems, leaves in TWWx1 and also in the grain in TWWx3) indicates a potential uptake and accumulation of those two contaminants also in the edible part of the grain and, consequently, a possible risk to human health. The results from an agronomic point of view showed a significant increase in yield in the theses treated with wastewater (TWWx1; TWWx3), which can be attributed to a higher presence of nutrients in this water.

Conclusions

In the present study, an analysis was conducted on the effects of wastewater reuse in agriculture, particularly for durum wheat production. The behaviour of several emerging contaminants (ECs) in the plant-soil complex was analysed and found to vary. Fluconazole and carbamazepine, in particular, were found to have higher uptake concentrations in the plant, with accumulation observed in the plant and grain especially in the TWWx3 treatment. However, some ECs (such as sulfamethoxazole, trimethoprim, ketoprofen, diclofenac, metoprolol and naproxen) showed high uncertainties in their fate, probably due to degradation in the soil and influential crop parameters. The results of this study contribute to the argument that reuse of treated wastewater for irrigation, if properly monitored, can be a safe approach in agriculture and can support policy makers in developing future legislative frameworks for sustainable water management. However, to obtain a definitive answer on the safety of wastewater reuse for irrigation, further studies are needed to provide more information on ECs, including the formation of metabolites and transformation products, in relation to agricultural systems.

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