

CONTAMINANTS OF EMERGING CONCERN IN FRESH PRODUCE IRRIGATED WITH TREATED WASTEWATER IN ISRAEL

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Abstract

Introduction. Pharmaceuticals and other contaminants of emerging concern (CECs) are ubiquitous in environmental niches such as rivers and streams, aquifers, and soils due to different management of treated wastewater. Once exposed to the agroecosystem via irrigation with treated wastewater, CECs can be taken up by plants which may introduce them into the food chain and lead to potential human exposure. The fate of CECs in the water-soil-plant continuum is affected by the CEC concentration in the irrigation water, the chemo-physical properties of the molecule, its environmental persistency, soil properties, and by plant uptake and translocation processes. These parameters and processes would determine the occurrence and concentration of the CECs in the grown produce. Today, data regarding the concentration of CECs on a wide range of commercially grown crops and on a state-level is scarce to non-existent. Here we report data on 65 CECs in irrigation water, soils, and fresh produce grown in commercial fields irrigated with TWW in Israel.

Methodology. For an assessment of CECs occurrence in fresh produce eight crops were selected: leafy greens, carrot, orange, tangerine, tomato, potato, avocado, and banana. For each edible organ (i.e., roots, leaves, and fruits), number of samples was calculated based on preliminary experiments with carbamazepine and published data to obtain a confidence interval of ~25%. The selected crops were sampled (stratified sampling method) from five geographical districts in Israel (from north to south): Galil-Golan, Amakim, Center, Shfela VeHar, and the Negev, according to the cultivated area irrigated with treated wastewater in each district. The sampling was conducted from only commercial fields irrigated with treated wastewater in Israel throughout 2017-2019. A total of 445 locations were visited once: Leafy greens- 64 fields; carrot- 43 fields; orange- 55 fields; tangerine- 63 fields; tomato- 43 fields; potato- 49 fields; avocado- 71 fields; and banana- 57 fields. At each field irrigation water, soil, and plant (i.e., edible part) samples were

collected. Crops were collected systematically from the center of the field a few days before harvest. For analysis of CECs, all samples were spiked with internal standards, extracted, and sent for LC-MS for analysis.

Main results. All field-collected irrigation water (i.e., treated wastewater) and soils exhibited traces of the analyzed CECs. The number of analyzed CECs ranged between 4 – 46 in irrigation water samples and 1 – 21 in soil samples. The concentrations of CECs ranged between low ng/L to tens of $\mu\text{g/L}$ and low ng/g range to tens of ng/g in irrigation water and soil samples, respectively; these ranges are similar to other studies that reported CECs in TWW and treated wastewater-irrigated soils. CECs were detected in all crops (i.e., edible parts), only 4 potato samples were free of the analyzed CECs. In total 24 contaminants were detected in the fresh produce. CEC concentrations in the sampled crops ranged from low ng/g to low $\mu\text{g/g}$ (dry weight). Leafy greens exhibited the highest number of detectable compounds and highest concentrations reaching up to $>2000 \text{ ng/g}$. A lower number and concentration of CECs were exhibited in fruit crops (banana, avocado, citrus, and tomato). The lower number of compounds detected in fruits and tubers as compared to leaves is expected as it was previously shown that uptake and translocation of non-ionic CECs in plants are governed by the transpiration stream, thus compounds are expected to be present in elevated concentrations in leaves and roots.

Carbamazepine (anticonvulsant) and venlafaxine (antidepressant), persistent, non-ionized, and lipophilic molecules ($\log K_{ow}$ 2.5 and 3.2, respectively), exhibited the highest detection frequencies in the fresh produce. Carbamazepine was detected in leafy greens (95%), citrus (100%), avocado (99%), banana (93%), tomato (79%), potato (53%) and carrot (21%). Venlafaxine was detected in leafy greens (99%), citrus (15%), avocado (37%), banana (7%), tomato (21%), and carrot (47%), but was not detected in potato samples. the lowest carbamazepine concentrations in leafy greens were obtained in the Negev district, this area is irrigated with high-quality treated wastewater (i.e., post-soil-aquifer treatment) exhibiting significantly lower carbamazepine (and other CECs) levels (mean concentration of $240 \pm 388 \text{ ng/L}$). This resulted in low carbamazepine concentrations in the receiving soils and consequently in the leafy green samples ($7.35 \pm 7.06 \text{ ng/g}$).

Main conclusions.

- Irrigation with treated wastewater exposes agroecosystem to CECs which in-turn accumulate in soils and taken-up into crops.
- Data from this study can be used to perform a reliable risk assessment and regulations concerning treated wastewater irrigation.