PLANT GROWTH AND POTENTIAL CONSUMER HEALTH RISK OF FOOD CROPS GROWN IN HYDROPONICS FED WITH REAL LIGHT GREYWATER

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Introduction

The European water reuse regulation (2020/741) recognized a knowledge gap about the potential human health risk related to agricultural irrigation in water reuse applications concerning the accumulation of micropollutants, including pharmaceuticals, in the edible part of crops irrigated with reclaimed water.

Decentralized nature-based greywater treatment and reuse applications (e.g., hydroponic systems) have been found suitable to decrease the freshwater demand in tourist facilities (Estelrich et al. 2021). Greywater (GW) has been discussed as a preferable source for water reuse, due to its lower organic pollution, turbidity, and suspended solids compared to black water (Zraunig et al., 2019). However, due to its decentralized collection, GW tends to have a more concentrated, source specific load of micropollutants.

This research aimed to study the fate of pharmaceuticals contained in real, light GW (sinks and showers) from hotel guest rooms, when reused in a decentralized hydroponic system for food crop production (lettuce and mint), with special focus on effects on the plant's growth and potential human health risk.

Materials and methods

Experimental set-up

The experiment was conducted during low tourist season (October/November 2022). Light GW (BOD: 22 mgO_2/L; COD: 55 mgO_2/L; TOC: 9 mg/L; TSS: 35 mg/L; Turbidity: 22 FNU; EC: 713 µS/cm; TN: 7.7 mg/L; TP 0.9 mg/L) from hotel guestrooms sinks and showers was collected weekly from a storage tank directly onsite of Hotel Samba located in Lloret de Mar (Spain). Lettuce and mint planters were fixated in hydroponic channels situated in controlled environmental conditions (21ºC; 68% relative humidity; 14 light hours, LED lamps) using mash pots filled with inert expanded clay substrate. Three different experiments (i.e., waters) were tested simultaneously:

1) Serving as a control (CTRL), two channels of mint and two channels of lettuce containing six plants per channel, as well as one additional abiotic channel, were fed with commercial hydroponic nutrient solution (average concentrations measured in CTRL: TN: 195 mg/L; $N\text{-}NO_3$ 181 mg/L; $P\text{-}PO_4$: 41 mg/L; Cl: 0.4 mg/L; $S\text{-}SO_4$: 53 mg/L; Na: 7.7 mg/L; $N\text{-}NH_4$: 27 mg/L; K: 181 mg/L; Mg: 36 mg/L; Ca: 126 mg/L) prepared with clean deionized water.

2) Similarly, two channels of each crop and one abiotic channel were fed with the light GW from the hotel.

3) Finally, the last set of channels (4 biotic and 1 abiotic) were fed with GW amended with nutrients (GW+) by adding the same volume of commercial hydroponic nutrient stock solutions used to prepare the CTRL.

While containing more nutrients than freshwater, in fact, GW on its own was expected to not contain enough nutrients to support optimum plant growth. Water in channels was renewed twice per week and the plants were harvested after 4 weeks of experiment.

Evaluation methods

Plant growth assessment. The effect of greywater compared to freshwater on the plant growth/morphology was assessed in duplicate for both crops in each treatment by means of traditional plant growth parameters including "relative growth rate (RGR)", "specific leaf area (SLA)", "net assimilation rate (NAR)", and "leaf weight ratio (LWR)" as described in relevant guidelines (e.g., Pérez-Harguindeguy et al., 2013).

Fate of pharmaceuticals. The presence of 62 pharmaceuticals was assessed by UPLC-QqLIT in water and in the plant material (leaves and roots). For the evaluation of the accumulation of pharmaceuticals plant material was freeze-dried, the extraction, and clean-up was done according to Montemurro et al., (2020). Quantification could be performed for 51 and 44 compounds in the lettuce leaves and roots respectively, using the Analyst software 1.6.3.

Human health risk assessment: To assess the risk of chronic ingestion of the produced crops throughout a human's life, the estimated daily intake (EDI) of the accumulated compounds in the edible part of the plants calculated for an average consumer was compared with reference values which indicates whether health risk is expected. These reference values were generated using either the lowest daily therapeutic dose (LDTD; obtained from drugs.com, last accessed October 2023, with default safety factors by Snyder et al., (2010)) or the threshold of toxicological concern (TTC; defined by Kroes et al., (2004); Cramer class obtained from apps.ideaconsult.net/data/ui/toxtree, last accessed October 2023)).

Results and discussion

Presented are the results for lettuces, analogous results for mint will follow in the conference.

Plant growth assessment

GW did support plant growth. However, by itself it did not provide enough nutrients to achieve comparable plant growth (lower #leaves, produced dry weight, and leaf area) to commercial hydroponic nutrient solution (CTRL). There was, in fact, a depletion of essential nutrients for plant growth (i.e., TN and TP) in the GW effluent after the 3.5 days retention time in the system. Plants grown in GW showed a typical nutrient stress response by growing a higher mass proportion of roots (LWR) as well as smaller but thicker leaves (lower SLA) to maximise assimilation activity/growth per unit area (same NAR and RGR as CTRL). On the other hand, plants grown in GW+ produced bigger (higher RGR, dry weight, and leaf area, same # leaves) and structurally stronger leaves with higher photosynthetic efficiency (NAR), than those grown in CTRL.

Accumulation of pharmaceuticals in plants

The potential accumulation of a total of 51 and 44 pharmaceuticals was assessed in edible and non-edible parts (i.e., leaves and roots) respectively. Out of them, 4 pharmaceuticals were detected in the roots of the lettuce plants grown in the GW and GW+ condition: atenolol (GW: 32.95 & GW+: 21.06 ng/g, dw), sotalol (GW: 15.28 ng/g, dw & GW+: <LOQ), and the transformation products 2OH-ibuprofen (GW: 34.26 & GW+: 125.78 ng/g, dw) and metoprolol acid (GW: 381.62 & GW+: 476.59 ng/g, dw). Only levamisole was detected in the edible part (i.e., leaves & stems) of the GW (143.61 ng/g, dw) and GW+ (111.45 ng/g, dw) lettuces.

Human health risk assessment

The estimated daily intake (EDI) of levamisole was correlated to a daily per capita consumption of 50 g (Eregno et al., 2017) of lettuce leaves grown in both GW and GW+ by an average adult person with 70 kg body weight (BW). As a result, EDI lay below both reference values generated from the TTC as well as the LDTD approach. And is consequently far below levels that would indicate potential concern for human health, even if the lettuces were consumed over the average span of a whole human lifetime.

Conclusions

The reuse of light greywater from hotel bathroom sinks and showers to prepare hydroponic nutrient solution for crop irrigation did not lead to any significant signs of phytotoxicity. However, it did result in subtle morphological changes in plants, while overall enhancing plant growth.

Pharmaceutical accumulation from real, untreated light greywater was minimal, with only a few compounds detected, primarily concentrated in the roots. The potential health risk from chronic ingestion of the single pharmaceutical levamisole, which accumulated in the edible parts of lettuce, was assessed and found to be negligible for human health. Similar data on pharmaceutical accumulation and related risks in mint plants will be presented at the conference.

These findings suggest that reusing light greywater is a promising alternative to freshwater for agricultural irrigation, offering a sustainable solution for water resource management.

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