

HYDROPONIC CROP PRODUCTION USING HOTEL GREYWATER: GROWTH AND SAFETY ASSESSMENT

PRODUCTION HYDROPONIQUE À PARTIR D'EAUX USÉES D'HÔTEL : ÉVALUATION DE LA CROISSANCE ET DE LA SÉCURITÉ

Josephine Vosse^{1,2}, Sofia Semitsoglou Tsiapou¹, Lúcia Helena Santos³, Lucas Alonso¹,
Esther Mendoza¹, Joaquim Comas^{1,4}, and Gianluigi Buttiglieri¹

ABSTRACT

The reuse of greywater for hydroponic crop production may contribute to reducing freshwater demand in water-scarce regions while supporting local food production. This study assessed the suitability of source-separated light greywater from bathroom sinks and showers at Hotel Samba in Lloret de Mar, Spain, for growing lettuce (*Lactuca sativa*) and mint (*Mentha sativa*) in a hydroponic system. Two experimental cycles were conducted during high and low tourist seasons. Plants were grown for four weeks under controlled environmental conditions using three treatments: a conventional hydroponic nutrient solution prepared with deionized water, raw greywater, and greywater supplemented with the same hydroponic nutrients as the control.

Raw greywater supported plant survival and biomass increase without visible disease or acute phytotoxicity. However, compared with the control, lettuce and mint grown in unamended greywater showed reduced leaf area and dry mass, smaller and thicker leaves, and greater biomass allocation to roots, indicating nutrient limitation. In contrast, nutrient-amended greywater produced lettuce plants larger than the control and mint plants of comparable size, confirming that light hotel greywater can substitute freshwater in hydroponic nutrient solutions when nutrients are adequately supplied.

Although organic micropollutants were detected in greywater, transfer to edible tissues was limited, and the calculated dietary risk for detected compounds remained negligible under the assessed high-consumption scenario. Overall, the results indicate that light greywater is a promising alternative water source for hydroponic production of leafy vegetables and aromatic herbs, provided that nutrient management, disinfection, salt accumulation, and effluent treatment or recirculation are addressed.

Keywords: Greywater reuse; Hydroponics; Water scarcity; Source-separated greywater; Sustainable agriculture.

RÉSUMÉ

La réutilisation des eaux grises pour la culture hydroponique peut contribuer à réduire la demande en eau douce dans les régions souffrant de pénurie d'eau, tout en soutenant la production alimentaire locale. Cette étude a évalué l'aptitude des eaux grises légères, collectées à la source au niveau des lavabos et des douches de l'hôtel Samba à Lloret de Mar, en Espagne, à la culture de la laitue (*Lactuca sativa*) et de la menthe (*Mentha sativa*) dans un système hydroponique. Deux cycles expérimentaux ont été menés respectivement pendant la haute et la basse saison touristique. Les plantes ont été cultivées pendant quatre semaines dans des conditions environnementales contrôlées selon trois traitements : une solution nutritive hydroponique conventionnelle préparée avec de l'eau désionisée, des eaux grises brutes, et des eaux grises enrichies des mêmes nutriments hydroponiques que le témoin. Les eaux

¹ Catalan Institute for Water Research (ICRA-CERCA), 17003 Girona, Spain

² University of Girona, Girona, Spain

³ Institute of Natural Resources and Agrobiological Sciences of Salamanca, Spanish National Research Council, C/ Cordel de Merinas 40-52, 37008 Salamanca, Spain

⁴ LEQUIA, Institute of the Environment, University of Girona, 17001 Girona, Spain

grises brutes ont permis la survie des plantes et l'augmentation de leur biomasse sans aucune maladie visible ni phytotoxicité aiguë. Cependant, par rapport au témoin, la laitue et la menthe cultivées dans des eaux grises non enrichies présentaient une surface foliaire et une masse sèche réduites, des feuilles plus petites et plus épaisses, ainsi qu'une plus grande allocation de biomasse vers les racines, ce qui indique une limitation en nutriments. En revanche, les eaux grises enrichies en nutriments ont permis d'obtenir des plants de laitue plus grands que ceux du témoin et des plants de menthe de taille comparable, confirmant que les eaux grises légères issues d'hôtels peuvent se substituer à l'eau douce dans les solutions nutritives hydroponiques lorsque les nutriments sont fournis en quantité suffisante.

Bien que des micropolluants organiques aient été détectés dans les eaux grises, leur transfert vers les tissus comestibles était limité, et le risque alimentaire calculé pour les composés détectés restait négligeable dans le scénario de consommation élevée évalué. Dans l'ensemble, les résultats indiquent que les eaux grises légères constituent une source d'eau alternative prometteuse pour la production hydroponique de légumes-feuilles et d'herbes aromatiques, à condition que la gestion des nutriments, la désinfection, l'accumulation de sel et le traitement ou la recirculation des effluents soient pris en compte.

Mots-clés : Réutilisation des eaux grises; Hydroponie; Pénurie d'eau; Eaux grises collectées séparément; Agriculture durable.

INTRODUCTION

Water reuse has long since been acknowledged to be a necessary measure to counter water scarcity, especially in the Mediterranean region, where touristic activities put additional pressure on decreasing natural freshwater resources. Here decentralised nature-based water treatment and reuse applications (e.g., in hydroponic systems) have been found to be a suitable solution to decrease the fresh water demand in tourist facilities (Estelrich et al., 2021, Zraunig et al., 2019).

The agricultural sector has been identified to have the highest potential for water reuse applications (Regulation (EU) 2020/741). An interest to quantify the circularity of water reuse regarding more resources than just the water, by looking into the potential benefit of recovered nutrients from wastewater for plant growth, is rising. Hereby is source separated greywater (GW) an interesting source, as it contains less microbiological contamination than wastewater (Sangare et al., 2021).

There is little literature assessing the sufficiency of nutrients in different GW sources to grow crops. Sangare et al. (2021) found more dry weight production in dishwasher GW irrigated lettuces compared to fresh well water. Conversely, Sawadogo et al. (2014) found that GW constitutes like washing detergent at concentrations <1g/l may negatively affect plant growth. Da Silva Cuba Carvalho et al. (2018) found that treated wastewater only grows plants of comparable size to conventionally grown hydroponic lettuces, if supplemented with nutrients. Similarly due to the lack of essential nutrients, especially nitrogen, for plant growth in treated GW, Eregno et al. (2017) increased their hydroponic lettuce production by using source-separated urine as nutrient solution.

On the other hand, the European water reuse regulation regulates a rather small number of pathogens and standard parameters, it recognizes the consumer health risk potential stemming from different groups of (organic) micropollutants (OMP), including pharmaceuticals and personal care products, that are commonly found even in treated wastewater and therefore might accumulate in with reclaimed water irrigated produce. OMP are listed for potential future regulation upon assessing sufficient evidence of potential human health or environmental risk. This study aims to assess the suitability of hotel light GW (i.e., from bathroom sinks/showers) to grow lettuce and mint plants of marketable size in a hydroponic system. Moreover, it determines OMP that may present themselves concentrated in this GW stream during low and high touristic seasons, hereby focusing on pharmaceuticals and transformation products covering the different toxicological classes, as well as EDCs. Finally, it aims to assess which OMP accumulation in plant tissues (i.e., leaves, stems, roots), and whether those accumulated in the edible part of the crops are likely to pose a potential health risk to the consumer upon chronic ingestion.

MATERIAL AND METHODS

Experimental setup

The suitability of source-separated light greywater (GW) from hotel guestrooms for hydroponic crop production was assessed in two experimental cycles representing high (HS) and low tourist (LS) seasons. Lettuce (*Lactuca sativa*) and mint (*Mentha sativa*) were grown for four weeks under controlled environmental conditions in a hydroponic system designed to minimize soil and external environmental effects. Lettuce was selected because it is widely used as an experimental crop due to its rapid growth and high tendency to accumulate micropollutants, while mint was included as a higher-value leafy crop with a comparable growth period.

The hydroponic system consisted of 15 individual PVC channels supplied with full-spectrum LED light for 14 h per day in an otherwise dark room (Figure 1). Temperature, relative humidity and light intensity were monitored every 30 min using HOBO data loggers and HOBOWare® software. Light distribution and edge effects were minimized through reflective surfaces and by leaving the first and last channel positions unplanted.

Three water treatments were tested in each cycle, with five channels per treatment: a control hydroponic nutrient solution prepared with deionized water; raw hotel GW collected weekly from Hotel Samba in Lloret de Mar, Spain; and nutrient-amended greywater (GW+), prepared by adding the same commercial hydroponic nutrient stock solutions used in the control. GW+ was included because raw GW was not expected to provide sufficient nutrients for optimal plant growth (Eregno et al., 2017; Mendoza et al., 2023; Mendoza et al., 2024). Fresh GW was sieved, homogenized and used immediately after weekly collection, then stored at 4°C and reused after 3.5 days, corresponding to the shortest feasible hydraulic retention time in the static experimental system.

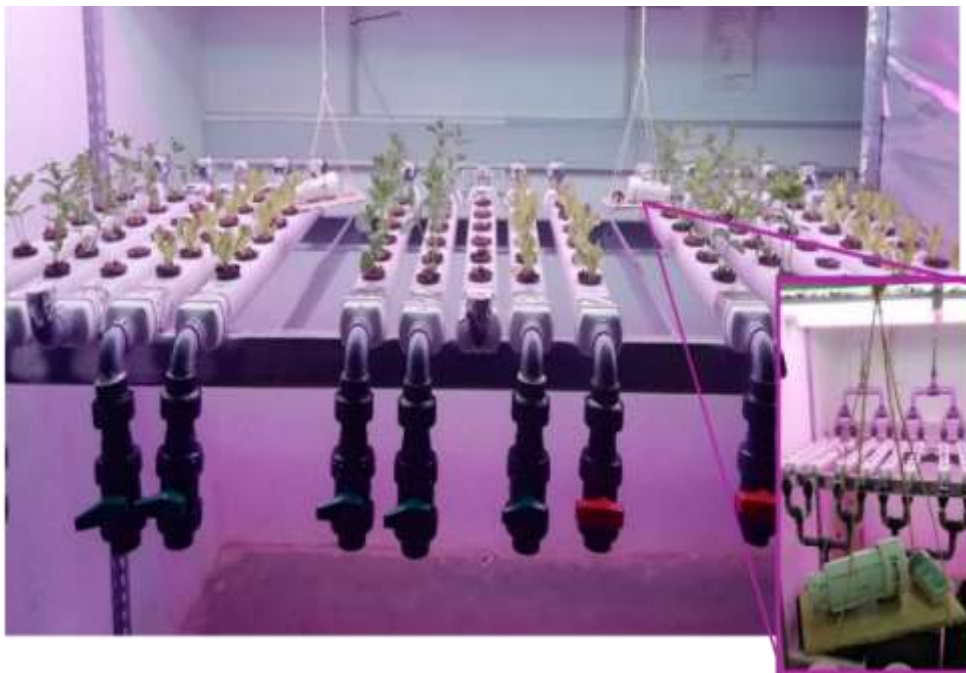


Figure 1. Hydroponic system set-up

Water quality, OMP analysis, and plant growth

Water quality was monitored through weekly influent and effluent sampling during the first half of each week. Standard parameters included BOD, COD, TOC, TSS, TN, TP, turbidity, electrical conductivity and pH, alongside ion and organic micropollutant/endocrine-disrupting compound analyses.

To evaluate OMP uptake by plants, lettuce and mint were sampled at the beginning and end of each experiment. Plant material was rinsed, separated into functional groups, freeze-dried and stored at -20°C until analysis. Extraction followed an adapted QuEChERS protocol with dSPE PSA-C18 clean-up (Montemurro et al., 2020), and extracts were analysed by ultraperformance liquid chromatography coupled to tandem mass spectrometry. OMP data were acquired and processed using Analyst 1.5.1 software.

Plant growth was assessed using representative plants from each treatment. Plants were cleaned, separated into functional groups and analysed for leaf number, leaf area, fresh weight and dry weight. Leaf area was measured using the Easy Leaf Area Free mobile application, and plant parts were oven-dried at 70°C for 48 h. Growth was further evaluated using standard growth parameters reported in plant functional and growth-analysis literature: relative growth rate, leaf weight ratio, specific leaf area, and net assimilation rate (van Holsteijn, 1980; Hunt et al., 2002; Pérez-Harguindeguy et al., 2013; Pandey et al., 2017).

Relative growth rate was calculated following recommendations for logarithmic biomass transformation before averaging (Poorter & Garnier, 1996; Hunt et al., 2002). These parameters allowed comparison of biomass accumulation, allocation to photosynthetic tissues, leaf morphology and photosynthetic productivity between treatments.

Human health risk assessment

A human health risk assessment was performed for pharmaceuticals detected in the edible parts of lettuce and mint grown in hotel GW. Exposure was estimated using the estimated daily intake under a high-consumer scenario, based on the 95th percentile of lettuce and mint consumption from dietary survey data. The hazard quotient was calculated as the ratio between estimated daily intake and a compound-specific reference value. A hazard quotient below 1 was interpreted as indicating no expected adverse health effects under the assessed exposure scenario, whereas values above 1 indicated that potential risk could not be excluded without further assessment.

Reference values were derived using three approaches: lowest daily therapeutic doses (LDTD) combined with default safety factors (Snyder et al., 2010), threshold of toxicological concern (TTC) values assigned through Cramer structural classification and structural alerts (Kroes et al., 2004), and, where available, toxicological reference values based on NOAEL or LOAEL data. The most conservative value available for each compound was selected. Cramer classifications and structural alerts were generated using Toxtree, while lowest therapeutic doses were obtained from Drugs.com dosage recommendations.

Reference values were normalized to a default European adult body weight of 70 kg. For compounds detected in roots, daily consumption values were additionally calculated to estimate the theoretical quantity of roots that would need to be accidentally consumed to reach the reference value, using reference values based on the same approaches (Snyder et al., 2010; Kroes et al., 2004).

RESULTS AND DISCUSSION

Water quality and reuse suitability

Raw hotel GW did not fully comply with the water-quality requirements for the intended agricultural reuse application (Table 1). The main exceedances were related to TSS and BOD in the high-season GW and TP in the low-season GW, although these values remained within the same order of magnitude as the

regulatory limits. After 3.5 days in the hydroponic system, the unamended GW showed improved quality, with unplanted channels meeting TSS and BOD limits, suggesting that simple pre-treatment, storage or aerated retention could be sufficient to reach class B–D agricultural reuse quality, provided that disinfection is included.

In contrast, nutrient-amended greywater (GW+) exceeded several limits because nutrient addition increased TN, TP, ions and EC. Faster plant growth also concentrated some parameters through higher water uptake. Therefore, GW+ would be better suited to a recirculating hydroponic system with targeted treatment for accumulated salts, particularly Na⁺ and Cl[−], before reuse or discharge.

Table 1. Experimental GW and GW+ in- & effluent from channels containing M: Mint, L: lettuce or A: unplanted (HRT: 3.5 days)

In- & effluent	HS_GW				HS_GW+				LS_GW				LS_GW+			
	IN	M	L	A	IN	M	L	A	IN	M	L	A	IN	M	L	A
COD [mg O ₂ /L]	68	66	48	54	N/A	83	82	N/A	55	40	49	49	N/A	92	95	N/A
BOD ₅ [mg O ₂ /L]	36	8	9	11	N/A	14	12	N/A	22	16	13	11	N/A	23	23	N/A
TSS [mg/L]	47	20	16	26	N/A	63	39	N/A	35	24	24	22	N/A	73	64	N/A
TN [mg/L]	6	2	2	5	184	198	186	177	8	2	2	8	199	222	205	196
TP [mg/L]	0.6	0.3	0.3	0.8	39	40	36	36	0.9	0.4	0.5	0.8	43	48	43	38
Turbidity [NTU]	20	6	6	10	33	29	21	28	23	14	15	31	27	39	29	54
Legend		Does not comply with UWWTD (baseline)														
		Complies with UWWTD; Spanish & EU water reuse regulation quality class B-D														
		Complies with UWWTD; Spanish & EU water reuse regulation quality class A-D														

Plant growth

Unamended GW supported the survival and biomass increase of both lettuce and mint, but growth was generally lower than in the control. Lettuce and mint grown in GW produced fewer and smaller leaves, lower leaf area and lower water content, while allocating a higher proportion of dry biomass to roots (Figure 2). This suggests adaptation to nutrient limitation, particularly N and P deficiency, through increased root investment and possibly enhanced nutrient-searching capacity. Despite lower total biomass, some GW plants showed relatively high net assimilation rates, indicating intensified productivity per unit leaf area. By contrast, GW+ plants showed no clear signs of phytotoxicity and often performed similarly to or better than the control. GW+ lettuces produced higher leaf area and dry weight than controls in both seasons, while GW+ mint matched or approached control performance. However, the higher water content and larger but less dense leaves in GW+ plants could affect post-harvest quality and shelf life, as reported for hydroponic lettuce with high water content (Lei & Engeseth, 2021; Sublett et al., 2018).

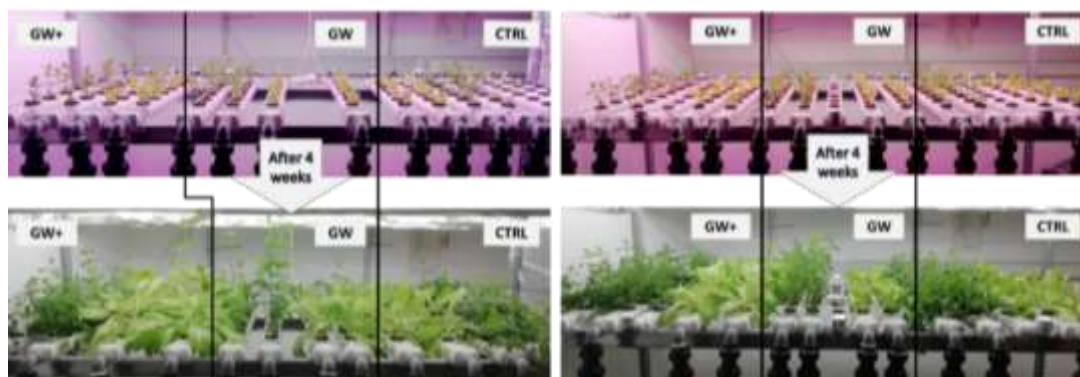


Figure 2. Plant growth for the HS (on the left) and LS experiments (on the right), of lettuces and mints grown in GW+ (left), GW (middle) and CTRL (right) conditions.

OMP in greywater

A total of 84 OMP, including pharmaceuticals and endocrine-disrupting compounds, were monitored in GW. Of these, 40 compounds were not detected, 8 were detected below the limit of quantification, and 36 were quantified in at least one influent sample. Twenty compounds were detected in both seasons, including acetaminophen, valsartan, 2OH-ibuprofen, diclofenac, naproxen, 1OH-ibuprofen, clindamycin, metoprolol acid, hydrochlorothiazide, ibuprofen, codeine, levamisole, metoprolol, metronidazole, BPA, carbamazepine, losartan, venlafaxine, propranolol and estrone. Several additional compounds were detected only during the high tourist season, including antibiotics, transformation products, benzotriazole, sulfamethoxazole, fluoxetine, ethinylestradiol and others, while trazodone and lorazepam were detected only during LS.

Although more compounds were detected during the high tourist season, individual compound concentrations were often higher during the low season. This indicates that seasonal tourist load influenced the diversity of detected compounds, but not necessarily their maximum concentration. Compared with previous studies at the same site, concentrations were highly variable between seasons and campaigns.

Literature values from the same GW system showed higher average concentrations for several common pharmaceuticals, especially acetaminophen, diclofenac, ibuprofen and naproxen. In the present study, the highest average concentrations were lower and corresponded mainly to acetaminophen, valsartan, 2OH-ibuprofen, diclofenac and naproxen. Some compounds previously reported at the site, such as iopromide, atenolol, TBEP, gemfibrozil, ofloxacin and diltiazem, remained below detection limits in the present influent samples. Conversely, several newly analysed compounds and transformation products were quantified, highlighting the importance of broad analytical screening when assessing GW reuse.

OMP accumulation in plants

Only three compounds were detected in edible leaf tissues: levamisole, hydrochlorothiazide and codeine. Levamisole was detected in leaves from several conditions, including low-season mint and lettuce grown with GW or GW+, and high-season GW lettuce. Hydrochlorothiazide was consistently detected in mint leaves in both GW and GW+ treatments and in both seasons, but not in lettuce leaves. This absence in lettuce may partly reflect analytical limitations, since the detection limits in lettuce leaves were similar to or higher than the concentrations measured in mint. Codeine was found only in low-season GW lettuce leaves, while detection in mint was limited by a high detection limit.

Several additional compounds were detected in roots, indicating that root tissues retained more micropollutants than edible leaves. Acetaminophen and metoprolol were found in high-season lettuce and mint roots, while metoprolol acid occurred in roots in both seasons. Propranolol, triclosan and citalopram were detected in low-season mint roots, and venlafaxine was found below quantification limits

in GW mint roots across seasons. Other compounds were detected sporadically in roots, but not consistently in edible tissues. Overall, the results suggest that although GW contains a complex mixture of micropollutants, transfer to edible lettuce and mint leaves was limited under the tested conditions. The higher frequency of detection in roots also indicates that belowground tissues may act as a relevant sink for some compounds.

Human health risk assessment

The health risk assessment focused on the three compounds detected in edible leaves: levamisole, hydrochlorothiazide and codeine. Estimated daily intake was calculated using high-consumer scenarios based on the 95th percentile of lettuce and mint consumption. An example is provided in Figure 3. For compounds detected below the limit of quantification, the LOQ was used as a conservative worst-case concentration. Reference values were derived using conservative approaches based on lowest daily therapeutic doses (LDTD), threshold of toxicological concern (TTC) and, where available, toxicological reference values (Snyder et al., 2010; Kroes et al., 2004).

Hazard quotients were below 1 for all detected compounds and crop conditions. They also remained below the more conservative threshold of 0.1 sometimes applied to account for additional exposure pathways such as drinking water, other foods, dermal contact or inhalation. Therefore, chronic consumption of the tested lettuce and mint is not expected to cause adverse health effects under the assessed exposure scenario.

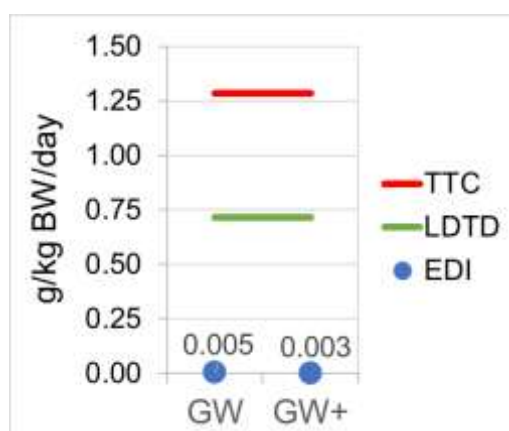


Figure 3. Comparison of EDI for levamisole accumulated in edible part of lettuces grown in GW/GW+ and TTC and LDTD reference values.

CONCLUSIONS

This study showed that source-separated light greywater from hotel sinks and showers can be used as an alternative water source for hydroponic lettuce and mint production. Raw greywater supported plant survival and biomass increase without visible disease or acute phytotoxicity, but it did not provide sufficient nutrients for optimal growth. Plants grown in unamended greywater showed typical nutrient-stress responses, including reduced leaf area and dry mass, smaller and thicker leaves, and greater biomass allocation to roots.

When supplemented with hydroponic nutrients, greywater performed as well as or better than the conventional control solution prepared with deionized water. GW+ plants showed no clear phytotoxicity and often achieved higher growth performance, particularly in lettuce. This confirms the main hypothesis that light hotel greywater can be reused productively in hydroponic systems if nutrient supply is properly adjusted.

The chemical safety results were also encouraging. Although greywater contained a complex mixture of organic micropollutants, transfer to edible lettuce and mint leaves was limited. Only a small number of compounds were detected in edible tissues, while more compounds accumulated in roots. The calculated dietary risk remained negligible under the assessed high-consumption scenario, with hazard quotients below relevant concern thresholds.

ACKNOWLEDGMENTS

Authors acknowledge funding from the Spanish State Research Agency of the Spanish Ministry of Science and Innovation for G Gsolutions (PID2024-161596OB-C21; MICIU/AEI /10.13039/501100011033 / FEDER, UE) as well as from Project PCI2024-153445 (NEWater), funded by MCIU/AEI/10.13039/501100011033/EU and Co-funded by the European Union.

REFERENCES

- da Silva Cuba Carvalho, R., Bastos, R. G., & Souza, C. F. (2018). Influence of the use of wastewater on nutrient absorption and production of lettuce grown in a hydroponic system. *Agricultural Water Management*, 203(April 2017), 311–321. <https://doi.org/10.1016/j.agwat.2018.03.028>
- Eregno, F. E., Moges, M. E., & Heistad, A. (2017). Treated greywater reuse for hydroponic lettuce production in a green wall system: Quantitative health risk assessment. *Water (Switzerland)*, 9(7). <https://doi.org/10.3390/w9070454>
- Estelrich, M., Vosse, J., Comas, J., Atanasova, N., Costa, J. C., Gattringer, H., & Buttiglieri, G. 2021. Feasibility of vertical ecosystem for sustainable water treatment and reuse in touristic resorts. *Journal of Environmental Management*, 294(June).
- Hunt, R., Causton, D. R., Shipley, B., & Askew, A. P. (2002). A modern tool for classical plant growth analysis. *Annals of Botany*, 90(4), 485–488. <https://doi.org/10.1093/aob/mcf214>
- Kroes, R., et al., 2004. Structure-based thresholds of toxicological concern (TTC): Guidance for application to substances present at low levels in the diet. *Food and Chemical Toxicology*, 42(1), 65–83.
- Lei, C., & Engeseth, N. J. (2021). Comparison of growth characteristics, functional qualities, and texture of hydroponically grown and soil-grown lettuce. *Lwt*, 150(March), 111931. <https://doi.org/10.1016/j.lwt.2021.111931>
- Mendoza, E., Magrí, A., Blandin, G., Bayo, À., Vosse, J., Buttiglieri, G., Colprim, J., & Comas, J. (2023). Second-generation magnesium phosphates as water extractant agents in forward osmosis and subsequent use in hydroponics. *Membranes*, 13(2), 226.
- Mendoza, E., Vosse, J., Azzellino, A., Santos, L. H. M. L. M., Semitsoglou-Tsiapou, S., Comas, J., & Buttiglieri, G. (2024). From shower to table: Fate of organic micropollutants in hydroponic systems for greywater treatment and lettuce cultivation. *Blue-Green Systems*, 6(1), 70–89.
- Montemurro, N., et al., 2020. Comparison of high resolution mrm and sequential window acquisition of all theoretical fragment-ion acquisition modes for the quantitation of 48 wastewater-borne pollutants in lettuce. *Journal of Chromatography A*, 1631.
- Pandey, R., Paul, V., Das, M., Meena, M., & Meena, R. C. (2017). Plant Growth Analysis. Manual of ICAR Sponsored Training Programme on “Physiological Techniques to Analyze the Impact of Climate Change on Crop Plants,” January. <https://doi.org/10.13140/RG.2.2.21657.72808>
- Pérez-Harguindeguy, N., Díaz, S., Garnier, E., Lavorel, S., Poorter, H., Jaureguiberry, P., Bret-Harte, M. S., Cornwell, W. K., Craine, J. M., Gurvich, D. E., Urcelay, C., Veneklaas, E. J., Reich, P. B., Poorter, L., Wright, I. J., Ray, P., Enrico, L., Pausas, J. G., De Vos, A. C., ... Cornelissen, J. H. C. (2013). New handbook for standardised measurement of plant functional traits worldwide. *Australian Journal of Botany*, 61(3), 167–234. <https://doi.org/10.1071/BT12225>
- Poorter, H., & Garnier, E. (1996). Plant growth analysis: An evaluation of experimental design and computational methods. *Journal of Experimental Botany*, 47(302), 1343–1351. <https://doi.org/10.1093/jxb/47.9.1343>
- Sangare, D., Coulibaly, L. S., Andrianisa, H. A., Coulibaly, J. Z., & Coulibaly, L. (2021). Investigating the capacity of hydroponic system using lettuce (*Lactuca sativa* L.) in the removal of pollutants from greywater while ensuring food security. *International Journal of Environment, Agriculture and Biotechnology*, 6(3), 123–131. <https://doi.org/10.22161/ijeab.63.13>
- Sawadogo, B., Sou, M., & Hijikata, N. (2014). Effect of Detergents from Greywater on Irrigated Plants : Case of Okra (*Abelmoschus esculentus*) and Lettuce (*Lactuca sativa*) *Journal of Arid Land Studies*, 24(1), 117–120.

- Snyder, S., Stanford, B., Bruce, G., Pleus, R., & Drewes, J. E. (2010). Identifying hormonally active compounds, pharmaceuticals, and personal care product ingredients of health concern from potential presence in water intended for indirect for direct potable reuse. In WaterReuse Research Foundation: Vol. WRF-05-005.
- Sublett, W. L., Barickman, T. C., & Sams, C. E. (2018). The effect of environment and nutrients on Hydroponic Lettuce yield, quality, and Phytonutrients. *Horticulturae*, 4(4). <https://doi.org/10.3390/horticulturae4040048>
- van Holsteijn, H. M. C. (1980). Growth of lettuce - II. Quantitative analysis of growth. 13.
- Zraunig, A., et al., 2019. Long term decentralized greywater treatment for water reuse purposes in a tourist facility by vertical ecosystem. *Ecological Engineering*, 138(June), 138–147.