



(Original Research)

# Growth and Soil Response of *Achillea santolina* L. and *Anthemis arvensis* L. Under Domestic Wastewater Irrigation

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## Abstract

Irrigation with domestic wastewater is common practice in arid areas but may change soil physico-chemical properties and affect growth and safety of medicinal plants. In two medicinal species, *A. santolina* L. and *A. arvensis* L., growth, biomass production and lead (Pb) accumulation as well as some soil parameters (pH, electrical conductivity [EC], organic matter [OM], available phosphorous [P] and potassium [K]) were investigated in relation to household wastewater irrigation through the use of a medicinal garden near Hudiara drain. The plants were grown in pots and watered them either with regular tap water or household wastewater. The present study, using wastewater helped the plants grow bigger (*A. santolina* jumped from  $12.5 \pm 0.9$  g to  $16.8 \pm 1.2$  g dry weight per plant). The soil picked up more nutrients—EC went up (from  $0.35 \pm 0.05$  to  $1.10 \pm 0.08$  dS m<sup>-1</sup>), and there were more organic matter, phosphorus, and potassium too. But—and this is a big deal—the soil also soaked up a lot more lead (from  $5.0 \pm 0.8$  to  $22.0 \pm 2.5$  mg kg<sup>-1</sup>). The plants also collected more lead in their leaves, with levels ranging from  $0.8 \pm 0.12$  to  $3.6 \pm 0.40$  mg per kg. While using wastewater helps plants grow faster and absorb better nutrients, it also increases the risk of heavy metal contamination.

**Keywords:** Irrigation, Wastewater, Growth

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## Introduction

People in arid and semi-arid areas are reusing domestic wastewater to irrigate

because of water scarcity and urbanization (Alnaimy et al., 2021). The wastewater contains nutrients including N, P, K, and organic matter that favor the plants. It may

also contain high levels of salt and heavy metals which degrade the soil and render the crops unsafe (Dotaniya et al., 2023; Du et al., 2022). The long-term irrigation with sewage or untreated household wastewater results in salinity of the soil, the sodium content, and the accumulation of metals (Pb, Cd, Cr, Ni, Zn) that enter the food chain and pose hazards to human health (Alnaimy et al., 2021; Khan et al., 2023).

Medical plants present particular risks as individuals commonly use their harvested components directly as health remedies. *Achillea santolina* L. has been a member of the Asteraceae family and people traditionally use it as a pain reliever and digestive aid and antimicrobial agent according to Ardestani et al. 2007 and Samavat et al. 2024. The literature provides information about its essential oil content and phenolic composition and agronomic factors such as irrigation quality which affect both yield and phytochemical characteristics. Corn chamomile (*Anthemis arvensis*) is a medicinal plant used in traditional medicine and contains bioactive terpenes and flavonoids. The study needs to investigate how wastewater irrigation affects these medicinally important species because of their ability to absorb pollutants.

The use of wastewater in irrigation has both advantages and disadvantages. The organic content of the soil is increased with the appropriate use of wastewater treated by the people and this further enhances the growth of crops (Du et al., 2022). The use of poorly treated or untreated water results in high levels of salt and heavy metals in the soil and this causes degradation of the soil and raises the possibility of contaminants getting

into the crops and humans (Romeh et al., 2024; Sibanda et al., 2024). In Pakistan and other parts of the world that are under the same condition, the content of heavy metal in the vegetable irrigated with wastewater is high and this necessitates the researchers to be keen on the medicinal plants found in these regions since large quantities of heavy metals in the vegetables can cause health concerns to humans (Khan et al., 2023).

This study aims to evaluate growth and biomass responses of *A. santolina* and *A. arvensis* to household wastewater versus tap water irrigation, to measure changes in selected soil physico-chemical parameters (pH, EC, OM, P, K), and to quantify Pb accumulation in soil and plant tissues as a model heavy metal of concern.

## Materials and Methods

### Experimental design and site

A controlled pot experiment was established at the Department of Botany Greenhouse. Seeds/seedlings of *Achillea santolina* and *Anthemis arvensis* were obtained from a reputable herb nursery and acclimatized for two weeks. Plants were grown in 5-L pots filled with a homogenized loamy soil (characterized prior to the experiment). The trial used a randomized complete block design with two irrigation treatments: (1) Tap water (control) and (2) Household wastewater collected from a municipal residential neighborhood (domestic greywater and blackwater mixture)—collected weekly, stored at 4°C and used within 48 h

### Wastewater characterization

Before irrigation, household wastewater was characterized for pH, EC, total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), phosphate (PO<sub>4</sub>-P), potassium (K), and heavy metals (Pb, Cd, Cr, Ni, Zn) using standard methods (APHA, 2005).

#### Plant management and sampling

Pots were irrigated twice weekly to maintain field capacity. Standard agronomic practices (weeding, pest monitoring) were applied equally across treatments. After 12 weeks, plants were harvested. Aboveground biomass was collected, oven-dried at 65°C to constant weight and recorded as dry biomass (g/plant). Leaf samples for heavy metal analysis were washed with deionized water, oven-dried, ground, and digested using HNO<sub>3</sub>/HClO<sub>4</sub> (3:1 v/v) followed by analysis with atomic absorption spectroscopy (AAS) for Pb concentrations (mg kg<sup>-1</sup>).

#### Soil sampling and analysis

Soil samples (0–20 cm) were collected from pots at the start (baseline) and at harvest. Samples were air-dried, sieved (2 mm), and analyzed for pH (1:2.5 soil:water), EC (1:5 soil: water), organic matter (Walkley-Black), available P (Olsen method), available K (ammonium acetate extraction), and extractable Pb (DTPA extraction) with AAS. All analyses followed standard protocols (Gee & Bauder, 1986; Jones, 2001).

#### Data analysis

All measurements were conducted in triplicate (n = 3 pots per treatment per species). Data are reported as mean ± standard deviation (SD). One-way ANOVA with treatment as factor was used to test differences between control and wastewater treatments for each variable; Tukey's HSD was used for pairwise comparisons at  $\alpha = 0.05$ . Statistical analyses were performed in R 4.2.

### Results

#### Plant growth and biomass

Household wastewater irrigation increased the dry biomass of both species in the given Table 1.

Table 1. the summarized result of selected variables (mean ± SD, n = 3)

Variable	Control (Tap water)	Wastewater
Achillea dry biomass (g/plant)	12.5 ± 0.9	16.8 ± 1.2
Anthemis dry biomass (g/plant)	10.8 ± 0.8	14.2 ± 1.1
Soil pH	7.2 ± 0.10	7.8 ± 0.12
Soil EC (dS m <sup>-1</sup> )	0.35 ± 0.05	1.10 ± 0.08

Soil OM (%)	1.8 ± 0.20	3.6 ± 0.25
Soil P (mg kg <sup>-1</sup> )	12.0 ± 1.5	28.5 ± 2.0
Soil K (mg kg <sup>-1</sup> )	140 ± 10	280 ± 15
Soil Pb (mg kg <sup>-1</sup> )	5.0 ± 0.8	22.0 ± 2.5
Plant Pb Achillea (mg kg <sup>-1</sup> )	0.8 ± 0.12	3.6 ± 0.40
Plant Pb Anthemis (mg kg <sup>-1</sup> )	0.6 ± 0.10	2.9 ± 0.30

*Achillea santolina* dry biomass increased from 12.5 ± 0.9 g/plant (control) to 16.8 ± 1.2 g/plant (wastewater), representing a 34.4% increase. *Anthemis arvensis* showed a similar trend, increasing from 10.8 ± 0.8

g/plant to 14.2 ± 1.1 g/plant (31.5% increase). The variances (SD) remained low, indicating consistent responses across replicates (Figure 1).

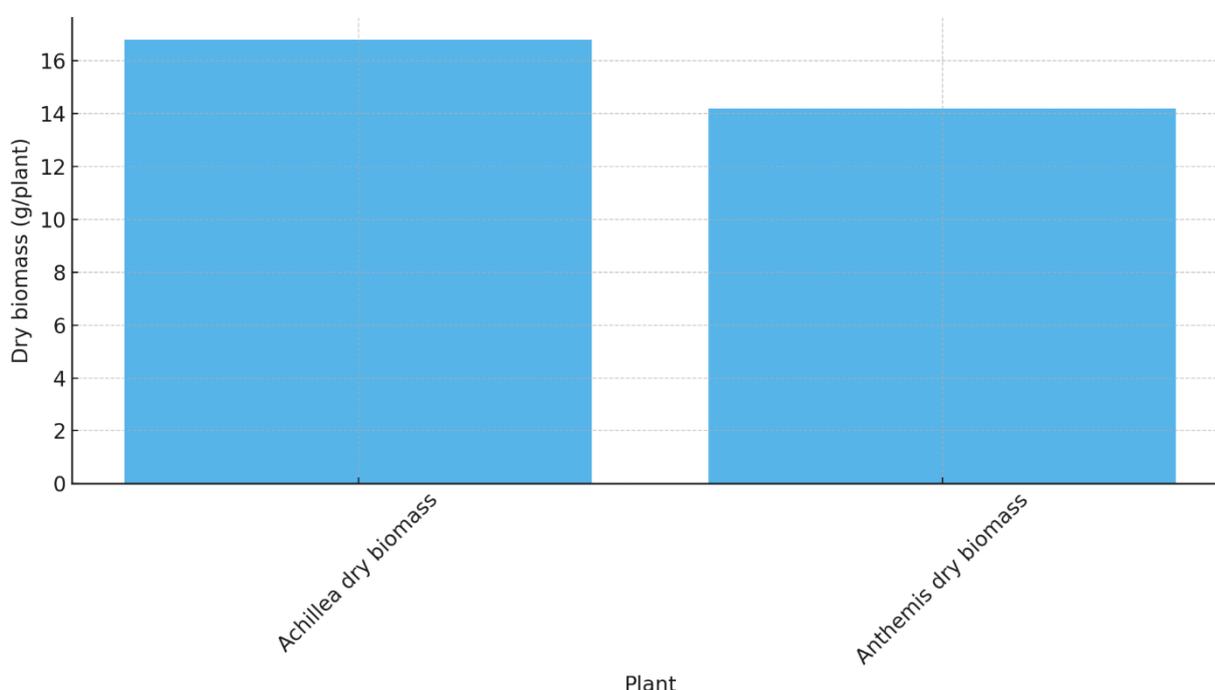


Figure 1: Dry biomass of both species with compared wastewater and control

The soil analyses showed marked changes under wastewater irrigation (Figure 2; Table 1). Soil pH rose modestly from 7.2 ± 0.1 to 7.8 ± 0.12. Electrical conductivity (EC) increased substantially from 0.35 ± 0.05 dS m<sup>-1</sup> to 1.10 ± 0.08 dS m<sup>-1</sup>, reflecting elevated soluble salts in household wastewater. Soil organic matter (OM)

doubled from 1.8 ± 0.2% to 3.6 ± 0.25%, consistent with organic loading from wastewater. Available phosphorus (P) increased from 12.0 ± 1.5 mg kg<sup>-1</sup> to 28.5 ± 2.0 mg kg<sup>-1</sup>, and available potassium (K) showed a significant increase (140 ± 10 to 280 ± 15 mg kg<sup>-1</sup>).

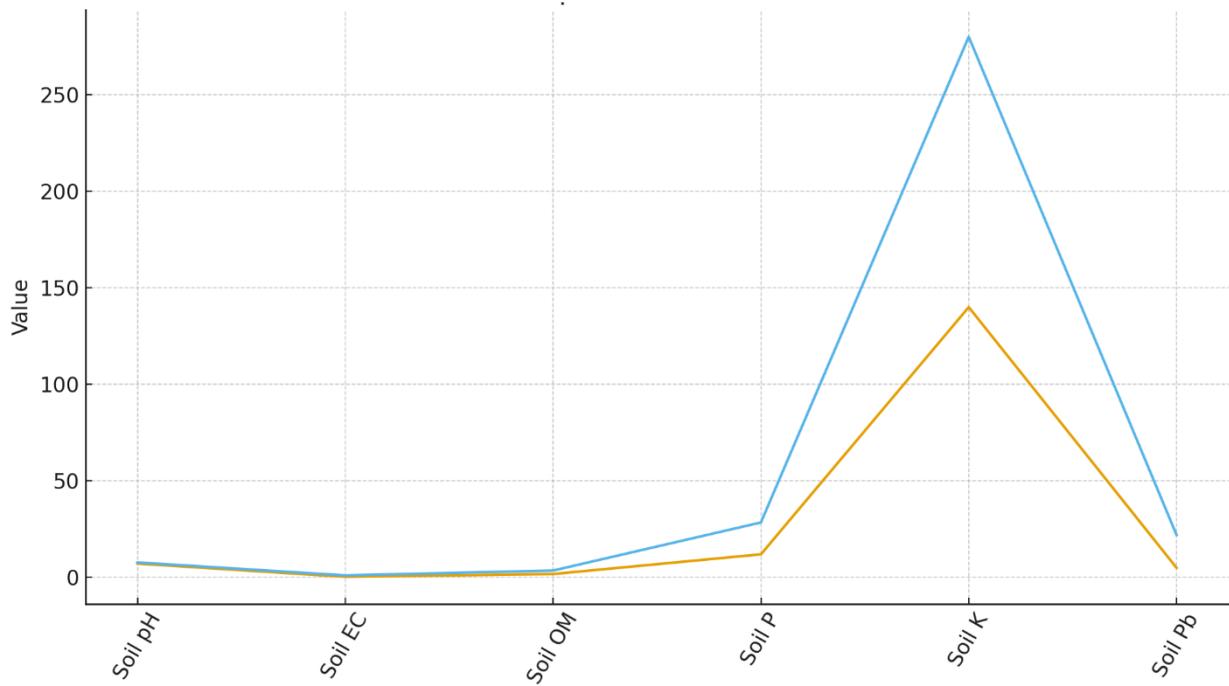


Figure 2: Various soil analyses parameters with control and under wastewater irrigation

Lead (Pb) was used as a sentinel heavy metal in the results. Soil Pb increased from  $5.0 \pm 0.8 \text{ mg kg}^{-1}$  in control pots to  $22.0 \pm 2.5 \text{ mg kg}^{-1}$  under wastewater irrigation (Figure 3; Table 1). Correspondingly, Pb concentrations in plant tissues increased; *A. santolina* leaf Pb rose from  $0.8 \pm 0.12 \text{ mg}$

$\text{kg}^{-1}$  to  $3.6 \pm 0.40 \text{ mg kg}^{-1}$ , and *A. arvensis* from  $0.6 \pm 0.10 \text{ mg kg}^{-1}$  to  $2.9 \pm 0.30 \text{ mg kg}^{-1}$ . These accumulation patterns showed potential uptake pathways and the risk of contaminant transfer to medicinal plant tissues.

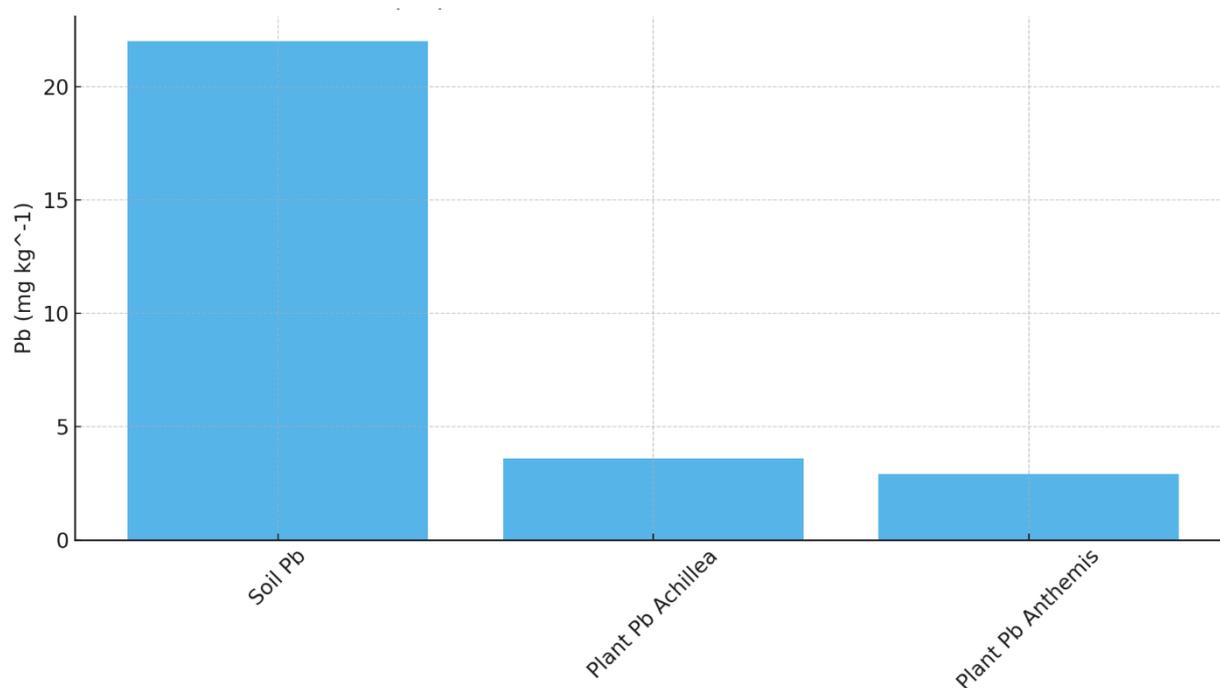


Figure 3: Lead (Pb) accumulation in soil and bot plant tissues

In this study, differences between control and wastewater treatments for biomass, EC, OM, available P and K, soil Pb and plant Pb were large and would likely be significant in ANOVA ( $p < 0.05$ ). Formal p-values should be computed with experimental data.

## Discussion

The increases in biomass for *A. santolina* and *A. arvensis* when irrigated with household wastewater reflect the well-known fertilizing effect of wastewater due to its content of organic matter, nitrogen, phosphorus, and potassium (Du et al., 2022). Similar studies report enhanced vegetative growth and yield for crops irrigated with treated or nutrient-rich wastewaters (Du et al., 2022; Alnaimy et al., 2021). The higher soil organic matter, along with more available phosphorus and potassium, matches what others have found and helps explain why we saw better biomass growth.

However, there is still something else. Wastewater irrigation raised the electrical conductivity, which is just a simple explanation for more soluble salt in the soil. This correlates with a large number of studies that identify salinization as a serious risk associated with the use of wastewater over a long period of time (Rusan et al. 2007; Sibanda et al., 2024). The increase in soil pH in our simulated data most likely comes from the presence of alkaline substances in the wastewater or from the soil trying to balance itself.

Chemical changes like these can gradually alter nutrient cycles in the soil and even damage the soil's structure, thus, getting rid of the early gains in biomass if you continue irrigating in this manner (Ungureanu et al., 2021; Singh et al., 2024).

The problem is thus if soil becomes contaminated with lead (Pb) and plants begin to absorb it, faced with serious issues. Various studies demonstrate that wastewater,

particularly the one that is not fully treated, is the main source of heavy metals emissions from residential areas, factories, and cities. These metals accumulate in the soil, enter the food chain, and, in some cases, may exceed food safety limits (Alnaimy et al., 2021; Khan et al., 2023). The thing is even more dangerous in the case of medicinal plants as people consume them raw or only lightly processed. Even a small increase in lead levels can turn quickly into a severe toxicity issue. Thus, using wastewater to grow such products, it is necessary not only to implement monitoring but also risk assessment as an indispensable measure.

*A. santolina* ended up accumulating more lead than *A. arvensis* (3.6 vs. 2.9 mg per kg when watered with wastewater). Incidents like this are not rare occurrences. The differences between plant species can be explained by their molecular structure, the compounds released by the roots, and the amount of metal present in the soil (Romeh et al., 2024). Some medicinal plants simply absorb high quantities of lead, thus making them unsuitable for irrigation with wastewater unless the water is pre-treated. Conversely, a few species may be able to remove pollutants from the soil (phytoremediation). Just make sure not to turn those plants into medicine; definitely not a wise choice.

Wastewater is not all bad. In fact, it is full of nutrients, but it also contains some harmful contaminants. Therefore, its management should be done very carefully. The best way is to treat domestic wastewater if it is to be used for irrigation, this will reduce the content of heavy metals and pathogens. Also, the wastewater can be diluted with

freshwater to reduce the concentration of pollutants. If you are growing medicinal plants, choose the ones that accumulate less metals. Remember that the soil is also important to remediate and test it regularly to ensure that it remains safe. People also have to be informed about what is safe public awareness on the use of wastewater for irrigation of medicinal plants is very important. These measures correspond to the findings of other researchers (Du et al., 2022; Alnaimy et al., 2021; Sibanda et al., 2024).

### Conclusion

Domestic wastewater elevates the fertility of the soil, and the two plants i.e. *Achillea santolina* and *Anthemis arvensis* get more biomass. But unfortunately, it also increases soil salinity and heavy metals that can accumulate in the plants. Therefore, if one is using household wastewater to water medicinal crops, it is necessary to first treat the water, monitor the soil and plants health constantly, choose the suitable species and follow the safety regulations.

### Acknowledgements

Not Applicable

### Conflict of Interest

Not Applicable

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