# Comparative Impact of Clean Municipal water and Domestic Wastewater Irrigation on Mineral Composition and Morphological Traits of *Ocimum sanctum*L

**Anjali Varshney[1], Nikki Nikam[2], Hitesh Solanki[3]**

[1]Head Department of Botany, [2]Student, [3]Professor and Head
[1, 2]Sir P T Sarvajanik Collegeof Science, Veer Narmad South Gujrat University - Surat
[3]Department of Botany, Bioinformatics and Climate Change Impacts Management, Gujarat University – Ahmedabad

**Abstract**

**This study presents a comparative analysis of the effects of clean municipal water and domestic wastewater with high salinity on the growth and mineral content of *Ocimum sanctum* (commonly known as Tulsi), a widely used medicinal plant. Two sets of plants were cultivated under controlled pot conditions using standard agricultural soil: one irrigated with clean municipal water and the other with high-salt-content domestic wastewater, including borewell water. Over an 81-day period, morphological observations and mineral content analysis were conducted to assess the influence of irrigation type. Key parameters such as sodium (Na), potassium (K), calcium (Ca), and iron (Fe) concentrations were analyzed in the plant tissues. Results indicated comparable levels of these essential nutrients in both treatments. However, variations were observed in morphological traits, suggesting that while wastewater can serve as an alternative irrigation source without significantly altering the plant's nutrient uptake, it may influence plant development. These findings align with prior research demonstrating the potential of treated wastewater in irrigation without compromising crop quality (Toze, 2006; Qadir et al., 2007). The study supports the reuse of treated wastewater in sustainable agriculture, with considerations for plant-specific morphological responses.**

**Keywords: Tulsi, Domestic Wastewater, Mineral Composition, Soil**

**Introduction:**

Water pollution, particularly from heavy metals, poses a significant environmental threat globally. These pollutants are primarily introduced into aquatic systems through industrial activities such as mining, mineral processing, and metallurgical operations. Heavy metals are persistent, non-biodegradable, and highly soluble in water, making them easily absorbed by living organisms. Once incorporated into the food chain, they can undergo bioaccumulation and biomagnification, posing severe ecological and health risks (Alloway, 2013).

In this context, the use of medicinal plants for both phytoremediation and agricultural productivity under wastewater irrigation is of growing interest. *Ocimum sanctum* L. (syn. *Ocimum tenuiflorum*), commonly known as Tulsi or Holy Basil, is a medicinal plant of the Lamiaceae family, indigenous to the Indian subcontinent and widely cultivated across tropical and subtropical regions (Govaerts, 2014; USDA-ARS, 2014). Renowned in Ayurveda as “The Incomparable One” and “Queen of Herbs,” Tulsi is traditionally revered for its therapeutic, spiritual, and ecological benefits. It has been extensively used to treat ailments such as respiratory disorders, inflammation, cardiovascular diseases, and infections, with proven antioxidant, anti-inflammatory, adaptogenic, and immunomodulatory properties (Pattanayak et al., 2010).

Modern science has begun to validate Tulsi’s medicinal applications while also highlighting its environmental utility. Notably, Tulsi has been planted in pollution-sensitive zones such as around the Taj Mahal to mitigate air pollution impacts. Given its resilience and wide range of bioactive compounds, O. sanctum presents a promising candidate for studying plant responses to irrigation with treated or untreated wastewater.

Conventional methods for removing heavy metals from wastewatersuch as chemical precipitation, ion exchange, reverse osmosis, and membrane filtrationare often costly, energy-intensive, and inefficient at low contaminant concentrations. In contrast, adsorption-based techniques offer a cost-effective and practical alternative, particularly for trace-level metal removal (Ali et al., 2012). Exploring the growth, mineral uptake, and physiological response of *O. sanctum* under different water qualities can contribute valuable insights into sustainable irrigation practices and wastewater reuse in agriculture.

**Materials and Methods:**

**Experimental Site and Soil Characteristics**

A controlled pot experiment was conducted to evaluate the effect of clean municipal water and domestic wastewater on the growth and mineral composition of *Ocimum sanctum*. The experiment was performed in an open area with ambient environmental conditions in Surat, Gujarat, India, beginning on 3rd December and continued for 81 days (Photo plate1).

Tulsi plants were grown in pots filled with medium-heavy, loamy-sandy topsoil. The soil was analysed before planting and was found to have neutral pH (6.8–7.2), medium humus content, high calcium and potassium levels, and adequate magnesium. Phosphorus content was classified as very high based on standard soil nutrient evaluation guidelines (Brady & Weil, 2010). The soil exhibited good drainage capacity, which is essential for optimal growth of *Ocimum sanctum* (Siddiqui et al., 2017).

**Water Sources and Irrigation Treatment**

Two types of irrigation water were used:

- **Control treatment (T1):** Clean municipal water (referred to as "sweet water").
- **Test treatment (T2):** Domestic wastewater with high salt content obtained from the Surat municipal wastewater treatment facility. The wastewater was characterized prior to use, and its physicochemical parameters (e.g., pH, EC, TDS, $Na^+$, $K^+$, $Ca^{2+}$) were consistent with common domestic effluents (Metcalf & Eddy, 2014).

Water was applied using a lysimetric method to simulate field conditions. Irrigation was scheduled to maintain soil moisture at 80% of the total water-holding capacity of the pots, leaving 20% capacity for potential rainwater retention. This approach minimizes leaching of nitrates and other solutes, as recommended in controlled pot experiments (Allen et al., 1998).

**Plant Material and Experimental Design**

Uniform and healthy *Ocimum sanctum* seedlings were procured from a certified local nursery. Each plant was grown in a separate pot (30 cm diameter, 25 cm height) filled with 10 kg of pre-characterized soil. A total of six pots were used, with three replicates per treatment (T1 and T2). The pots were arranged in a completely randomized design (CRD) and placed with adequate spacing to avoid shadowing.

**Growth Monitoring and Data Collection**

Plant growth was monitored weekly for both treatments. Plant height was measured every Sunday using a standard meter scale. Photographic documentation was conducted weekly to visually assess changes in morphology, pigmentation, and overall plant health.

**Mineral Analysis**

On the 81st day, plants were harvested and sent to an accredited analytical laboratory for mineral content analysis. Leaf samples were washed with deionized water, oven-dried at 65°C to constant weight, and ground to fine powder. Concentrations of sodium (Na), potassium (K), calcium (Ca), and iron (Fe) were determined using flame atomic absorption spectrophotometry (FAAS), following digestion in a nitric-perchloric acid mixture (AOAC, 2016).

**Statistical Analysis**

Data were statistically analysed using descriptive statistics and t-tests to compare mineral content and morphological traits between treatments. Statistical significance was set at $p < 0.05$ using IBM SPSS Statistics version 25.

**Results and Discussion:**

**Statistical Analysis of Mineral Content in *Ocimum sanctum* Leaves**

**Table 1: Data Summary**

| Mineral | T2 Wastewater Treated (mg/100g) | T1 Clean Water Treated (mg/100g) |
|---|---|---|
| **Sodium (Na)** | 3.826 | 4.000 |
| **Potassium (K)** | 301.843 | 295.000 |
| **Calcium (Ca)** | 154.126 | 177.000 |
| **Iron (Fe)** | 2.830 | 3.170 |

**Percentage Difference Calculation**

To assess the practical differences between treatments, we calculate the percentage difference using the formula:

Percentage Difference=(Clean Water – Wastewater) /Average of the two×100

**Table 2: Difference calculation of minerals**

| Mineral | % Difference (Clean vs Wastewater) | Interpretation |
|---|---|---|
| **Na** | +4.44% | Slightly higher in clean water treatment |
| **K** | -2.30% | Slightly higher in wastewater treated plant |
| **Ca** | +13.65% | Notably higher in clean water treated plant |
| **Fe** | +10.66% | Higher in clean water treated plant |

**T-Test:**

Descriptive statistics and observational insights:

- Potassium is slightly higher in the wastewater-treated plant. This could be due to increased $K^+$ ions in the wastewater, which is often enriched with nutrients from domestic sources.
- Calcium and Iron show noticeable reductions in the wastewater-treated plant. This may suggest reduced uptake or altered bioavailability of these minerals in saline or high-EC conditions (Qadir et al., 2007).
- Sodium levels are slightly higher in the clean water-treated plant, which may reflect soil variability or plant physiological adjustments, though the difference is minimal.

**Mineral Content Comparison (per 100g of leaves):**

**Table 3: Mineral Comparison**

| Mineral | Wastewater Treated (mg) | Clean Water Treated (mg) | Absolute Difference (mg) | Percent Difference (%) |
|---|---|---|---|---|
| **Sodium (Na)** | 3.826 | 4.000 | -0.174 | -4.35% (↓) |
| **Potassium (K)** | 301.843 | 295.000 | +6.843 | +2.32% (↑) |
| **Calcium (Ca)** | 154.126 | 177.000 | -22.874 | -12.92% (↓) |
| **Iron (Fe)** | 2.830 | 3.170 | -0.340 | -10.72% (↓) |

**Sodium (Na)**: Slightly lower in the wastewater-treated plant (~4.35% decrease). The values are close, suggesting minimal difference in sodium uptake under both conditions.

**Potassium (K):** Slight increase (~2.32%) in wastewater-treated plants. This could suggest potassium availability in the wastewater supports uptake, but the change is marginal.

**Calcium (Ca):** A notable 12.92% decrease in calcium in the wastewater-treated plant, indicating that high salt content or ion antagonism might reduce calcium uptake.

**Iron (Fe):** A 10.72% decrease in iron under wastewater treatment, which may be due to changes in soil pH or competitive ion effects limiting availability.

The comparative analysis of mineral content in Ocimum sanctum leaves irrigated with domestic wastewater and clean municipal water over an 81-day period revealed modest variations in macro- and micronutrient uptake. Among the four elements studied - sodium (Na), potassium (K), calcium (Ca), and iron (Fe), the most pronounced differences were observed in calcium and iron concentrations, both of which were lower in plants irrigated with domestic wastewater.

The slightly reduced sodium content in wastewater-treated plants (3.826 mg/100g) compared to clean water-irrigated plants (4.000 mg/100g) suggests that while domestic wastewater contained a higher salt load, sodium accumulation in Tulsi leaves remained relatively low. This may be attributed to the plant's selective uptake mechanisms or possible sodium exclusion at the root level (Tester & Davenport, 2003).

Potassium levels were marginally higher (by 2.32%) in wastewater-irrigated plants. Potassium is known to be an essential nutrient for plant growth, and its presence in wastewater—often in the form of potassium salts—can contribute to its bioavailability (Toze, 2006). The data suggest that wastewater may serve as a supplementary potassium source without significantly affecting uptake regulation in *O. sanctum*.

The observed decrease in calcium content (-12.92%) in wastewater-treated plants is noteworthy. High concentrations of sodium in wastewater may compete with calcium ions for uptake due to similar ionic radii, leading to ion antagonism and reduced calcium transport (Maathuis, 2009). Calcium plays a crucial role in cell wall integrity and signalling; hence, prolonged exposure to saline wastewater might affect plant structural stability or stress responses.

Similarly, iron content was lower by approximately 10.72% in wastewater-irrigated plants. This reduction could result from altered soil pH or redox conditions caused by wastewater constituents, which can precipitate iron into unavailable forms (Alloway, 2013). Iron deficiency in plants may impair chlorophyll synthesis, although no visible chlorosis was reported during the experimental period.

Despite these differences, overall mineral concentrations remained within acceptable limits, and the growth pattern of the plants showed no signs of toxicity or nutrient deficiency. This indicates that Tulsi has a certain degree of tolerance to saline and nutrient-rich wastewater, aligning with findings from earlier studies that demonstrate the adaptability of medicinal plants to alternative irrigation sources (Singh et al., 2012; Jadia & Fulekar, 2008).

**Conclusion:**

This study demonstrates that *Ocimum sanctum* can be irrigated with domestic wastewater containing elevated salt concentrations without causing substantial alterations in mineral content. Although the mineral levels between treatments are relatively similar, clean water irrigation resulted in marginally higher uptake of calcium and iron, which are important for plant structure and metabolic processes. The potassium content was higher in the wastewater treatment, likely due to its presence in the effluent. Although there are some differences in mineral content between the two irrigation treatments, the differences are moderate and may not be biologically significant without replication or variance data. However, the observed decrease in calcium and iron under wastewater treatment may suggest a need to monitor long-term effects of saline irrigation on micronutrient uptake in *Ocimum sanctum*.The data suggests that domestic wastewater may be a feasible irrigation source for *Ocimum sanctum*, but further replicated studies are needed to confirm these trends statistically.However, long-term studies with replicated trials are necessary to assess the cumulative effects on plant health, medicinal quality, and soil sustainability.

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**Photo plate 1: Morphological difference of treated plants**

| **Sweet water treatment plant** | **Waste water treatment plant** |
|---|---|
| **December** | **December** |
|  |  |
| **January** | **January** |
|  |  |
| **February** | **February** |