



Assessment of Municipal Treated Wastewater Quality for Irrigation in Orathanadu Block of Tamil Nadu, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: The current study focuses on the threats to the environment and human health that relate to using treated wastewater produced from the municipal sewage treatment plant of Orathanadu for irrigation purposes.

Study Design: For this purpose, samples were taken monthly from the outflow wastewater and grouped into seasons.

Place and Duration of study: Municipal sewage treatment plant located at Orathanadu, Tamil Nadu, during 2019.

Methodology: The treated wastewater quality parameters such as pH, EC, total dissolved solids, total suspended solids, five days biological oxygen demand, chemical oxygen demand, and sodium adsorption ratio were measured monthly and grouped season-wise.

Results: In treated wastewater, the minimal mean electrical conductivity values, total dissolved solids, five days biochemical oxygen demand, chemical oxygen demand, and sodium adsorption

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ratio were 0.81 dS m^{-1} , 515.20 mg L^{-1} , 25.50 mg L^{-1} , 14.85 mg L^{-1} , and 1.59, respectively. The suitability for irrigation based on the Sodium Adsorption Ratio (SAR) was calculated with standard equations and found experimentally as 1.59, 1.62, 1.59 and 1.56 during winter, summer, monsoon and post-monsoon seasons, respectively. To assess water suitability for irrigation, irrigation water classes are utilized for salinity hazard (EC) and sodium hazard (SAR), and samples were C3-S1 class in all four seasons. Furthermore, the data indicated a slight to moderate restriction on using this treated wastewater in irrigation due to chloride hazards.

Conclusion: The results showed that treated wastewater meets national and international irrigation criteria and that treated wastewater can be used without restriction in light and medium-textured soils and in clay soils with leaching and drainage.

Keywords: Municipal treated wastewater; irrigation water quality; salinity hazard; sodium absorption ratio.

1. INTRODUCTION

Water is one of the critical inputs in agriculture. It determines the effect on the eventual yield. Over the years, increasing population, growing industrialization, expanding agriculture and rising living standards have pushed up the water demand. So, it drives to 'finding more water' and learning to use it more efficiently for the long run. Dams and reservoirs have been built to collect and conserve water and create groundwater structures such as wells. Recycling and desalination of water are other options, but the cost involved is very high. In Independence (1947), India's per capita water availability was 6,008 cubic metres a year. It came down to 5,177 cubic metres in 1951 and 1,820 cubic metres in 2001 [1]. During 2011, it has been assessed as 1545 cubic metres of available water. Further, based on the report, the average annual per capita water availability may reduce to 1486 cubic metres by 2021 [2].

The rising realization of water resource scarcity, competition for water resources, and the deleterious effect of contaminated water on humans and the environment demand adequate water.

Apart from freshwater management strategies, the issue of treating and recycling wastewater will play an essential role in tackling the existing and occurring problems.

Using treated wastewater (TWW) for irrigation can have both good and negative environmental consequences. The use of treated wastewater in agricultural crops can be helpful to the environment with careful planning and management. Nevertheless, unfortunately, it contains unfavourable chemical elements and microorganisms hazardous to the environment and human health [3]. Simultaneously, a variety

of risk factors in wastewater reuse have been found; some have short-term effects (e.g., microbial infections), while others have longer-term impacts that worsen with ongoing wastewater use (e.g., salinity effects on soil [4].

A quantity assessment is required to guarantee proper collection, conveyance, treatment, disposal, and reuse of sewage, as per the census of 1971, 142 class I cities and 190 class II towns were identified. In that, sewage generation for the year 1978 for class I cities was estimated as 7,006 million litres day⁻¹ (MLD), whereas treatment capacity was 2,755 MLD. In the case of class II towns, treatment capacity was only 5% of the total wastewater generation of 61 MLD. In 1988-89, the sewage generation from 212 class-I cities was estimated as 12,145 MLD, whereas treatment capacity was only 2,633 MLD. Similarly, in 241 class II towns, treatment capacity was 21 MLD against sewage generation of 1,279 MLD [5].

In 2008-09, it was estimated by the Central Pollution Control Board (CPCB) that out of 38,254 MLD of sewage generated in Class I cities and Class II towns, only 11,787 MLD was treated. In 2014, CPCB carried out the inventorization of Sewage Treatment Plants (STPs) in the country. As a result, as per information received from State Pollution Control Boards and Pollution Control Committees, 816 STPs were installed in different States/UTs in the country and sewage treatment capacity developed during that period was only 23,277 MLD. The sewage generation increased from 7,067 MLD in 1978-79 to 62,000 MLD in 2014-15 whereas treatment capacity augmented from 2,758 MLD to 23,277 MLD only.

In seven States /UTs namely Delhi (405 MLD - 12.5%), Gujarat (60 MLD - 1.55%), Haryana (192

MLD - 16%), Madhya Pradesh (84 MLD - 4%), Tamil Nadu (211 MLD - 6.6%), Chandigarh (27 - 40 MLD - 10 -16%) and Puducherry (15.3 MLD - 26%), domestic wastewater was collected, treated and reused for different purposes. The percentage of reuse of treated sewage is maximum in Haryana (80%), followed by Puducherry (55%), Delhi (50%), Chandigarh (35%), Tamil Nadu (25%), Madhya Pradesh (20%), Andhra Pradesh (5%).

Estimated sewage generation for the State of Tamil Nadu is 6,421 MLD and the total treatment capacity is 1,492 MLD (63 STPs). Based on the data analysis, the following observations are made: 1. Installed capacity is 1,492 MLD (23.23%) against the sewage generation of 6421 MLD. Therefore, it shows a gap of 4,929 MLD (76.77%) in treatment capacity. 2. Out of 1,492 MLD of installed capacity developed, operationalized capacity is 1,492 MLD (100%) and actual utilized capacity is 995 MLD.

The research work was aimed to focus on the environmental concerns of using treated wastewater (TWW) from a municipal sewage water treatment plant (MSWTP), Orathanadu, Thanjavur District (WWTP), for irrigation and assessment its acceptability as a non-conventional water resource for irrigation.

2. MATERIALS AND METHODS

2.1 Site Description

Orathanadu is one of the leading agriculture production areas under the old Cauvery delta irrigation scheme of Tamil Nadu, India. Orathanadu is a town panchayat with a population of 1.60 lakhs (2011 census) and 40,383 residencies. Daily, the town panchayat supplies 14.2 lakh litres of water for household purposes through 18 numbers of groundwater pumping systems. Initially, all the wastewater used to be discharged directly into the natural waterways with the degradation of organic matter by existing microorganisms. However, increased population leads to more quantity of domestic wastewater and polluting the surrounding environment. In this background, the sewage water treatment plant was established in Orathanadu, Tamil Nadu (10.62° N latitude and 79.26° East longitude) and started working in December 2017. This plant receives 8 MLD of domestic wastewater through an underground pipeline. The collected domestic wastewater was

treated with the primary and secondary processes by the Orathanadu town municipality. This treated wastewater was utilized for irrigation purposes.

2.2 Analysis and Data Collection

Orathanadu MSTWP provided the data used in this study during 2018-19. Samples were collected at monthly intervals using clean polyethylene containers before the discharge. Samples of treated wastewater were analyzed for chemical and physical properties and grouped into seasonal. The chemical parameters like, electrical conductivity (EC), and pH by [6], total dissolved solids (TDS), total suspended solids (TSS), biological oxygen demand (BOD), chemical oxygen demand (COD) by [7], Potassium (K), Sodium (Na), Calcium (Ca), Magnesium (Mg) by [8] turbidity and bicarbonate (HCO_3) [9] was analysed as per the procedure of Standard Method for Examination of Water and Wastewater. In addition, calculation of some descriptive statistics, data analyses of variance and means comparison (at 5 % statistical level) were carried out using SPSS 27.0 package [10].

2.3 Assessment Methods

The data gathered during laboratory analysis was utilized to evaluate a variety of indices for classifying wastewater pollution and determining its suitability for irrigation. Many academic researchers have established various water quality criteria for use in irrigation under various settings. However, the US Salinity Laboratory (USSL) classification is the most often used. The appropriateness of wastewater was assessed using parameters such as electrical conductivity (EC), total dissolved solids (TDS), sodium (Na^+), Sodium Adsorption Ratio (SAR), and salinity hazards.

3. RESULTS AND DISCUSSION

3.1 Environmental Risk

Irrigation with treated wastewater might add specific contaminants, such as carbonates, bicarbonates, chlorides, etc., to the groundwater [11]. In addition, irrigation with treated wastewater causes land salinity, also causes land sealing and sodium accumulation, which could cause increased runoff and land erosion. Thus, one particular concern of the environmental problems is long-term

sustainability (e.g. the increase in salinity and sodium content in soil). Therefore, in total, 70 regulations and guidelines, including the Environmental Protection Agency (EPA), International Organization for Standardization (ISO), Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO) etc. were developed the quality criteria for treated wastewater for irrigation purposes. In addition, the Government of India has prescribed standards (Table 1) for the reuse of treated sewage for different purposes like horticulture, irrigation, non-contact impoundments and washing [12].

The qualitative parameters viz., pH, EC, TDS, TSS, BOD₅, COD, turbidity and SAR of descriptive statistics of treated wastewater based on seasonal average are shown in Tables 2, 3, 4 and 5. Electrical conductivity and pH values are not considered primary parameters in the reuse guidelines.

The outlet of treated wastewater had a pH in the range of 7.30 to 7.76. Thus, it lies between the standard ranging of 6.5 and 8.3. The minimum means pH 7.38 was observed during the winter season and the maximum in the summer season

7.60 each. Therefore, the pH of treated wastewater value is within the safe criteria [13] and can be used for irrigation purposes.

The EC should play a more significant part in the rule because it will affect and eventually modify the salinity of irrigated land. Therefore, treated wastewater with an average EC value of 0.7 to 3.0 mS cm⁻¹ should be used cautiously [14,15]. The mean EC recorded in the TWW was 0.89, 0.93, 0.96 and 0.81 in winter, summer, monsoon and post-monsoon seasons, respectively. However, the increased EC of 0.93 was observed during monsoon season in the treated wastewater should be regarded as a direct effect of the MSWTP septage overload during the summer period, as supported by [16]. As a result, the salinity level of indirect wastewater irrigation could exceed the directly consumed crop's tolerance level, so additional treatments are needed. Although in all the seasons, the EC value is a slight to moderate level, it indicates that preventive measures are to be taken when the TWW is used for long-term irrigation purposes or adopt alternate strategies like leaching during rainy periods.

Table 1. Recommended norms of treated sewage quality for specified activities at the point of use [12]

| Parameter | Landscaping, Horticulture & Agriculture | | Crops | |
|------------------------------|---|------------------|-----------------------------|------------|
| | Horticulture, Golf course | Non edible crops | Crops that are eaten edible | |
| | | | Raw | Cooked |
| Turbidity (NTU) | < 2 | AA | < 2 | AA |
| SS | Nil | 30 | Nil | 30 |
| TDS | ----- 2100 ----- | | | |
| pH | ----- 6.5 to 8.3 ----- | | | |
| Temperature °C | ----- Ambient ----- | | | |
| Oil & Grease | 10 | 10 | Nil | nil |
| Minimum Residual Chlorine | 1 | Nil | Nil | Nil |
| BOD | 10 | 20 | 10 | 20 |
| COD | AA | 30 | AA | 30 |
| Total Kjeldahl nitrogen as N | 10 | 10 | 10 | 10 |
| Dissolved Phosphorous as P | 2 | 5 | 2 | 5 |
| Nitrate N | 10 | 10 | 10 | 10 |
| Faecal coliform in 100 ml | Nil | 230 | Nil | 230 |
| Helminthic eggs per litre | A | < 1 | < 1 | < 1 |
| Colour | Colourless | AA | Colourless | Colourless |
| Odour | Aseptic, which means not septic and no foul smell | | | |

*All units in mg L⁻¹ unless specified; AA-as arising when other parameters are satisfied;
A tolerance of plus 5% is allowable when yearly average values are considered.*

Table 2. Results of descriptive statistics of treated wastewater sample during the winter season (2019)

| Parameters | pH | EC | TDS | TSS | COD | BOD | Turbidity | SAR |
|--------------------|------|------|--------|-------|-------|-------|-----------|------|
| Mean | 7.38 | 0.89 | 566.4 | 18.75 | 14.85 | 25.55 | 2.75 | 1.59 |
| Std. Error of Mean | 0.04 | 0.08 | 48.0 | 0.65 | 0.55 | 3.05 | 0.05 | 0.01 |
| Std. Deviation | 0.05 | 0.11 | 67.8 | 0.92 | 0.78 | 4.31 | 0.07 | 0.01 |
| Variance | 0.00 | 0.01 | 4608.0 | 0.84 | 0.61 | 18.61 | 0.00 | 0.00 |
| Range | 0.07 | 0.15 | 96.0 | 1.30 | 1.10 | 6.10 | 0.10 | 0.01 |
| Minimum | 7.34 | 0.81 | 518.4 | 18.10 | 14.30 | 22.50 | 2.70 | 1.58 |
| Maximum | 7.41 | 0.96 | 614.4 | 19.40 | 15.40 | 28.60 | 2.80 | 1.60 |

Table 3. Results of descriptive statistics of treated wastewater sample during the summer season (2019)

| Parameters | pH | EC | TDS | TSS | COD | BOD | Turbidity | SAR |
|--------------------|------|------|--------|-------|-------|-------|-----------|------|
| Mean | 7.60 | 0.93 | 595.2 | 21.23 | 15.77 | 31.87 | 2.93 | 1.62 |
| Std. Error of Mean | 0.04 | 0.07 | 44.3 | 2.30 | 1.61 | 1.32 | 0.22 | 0.02 |
| Std. Deviation | 0.08 | 0.12 | 76.8 | 3.98 | 2.80 | 2.29 | 0.38 | 0.04 |
| Variance | 0.01 | 0.01 | 5898.2 | 15.84 | 7.82 | 5.26 | 0.14 | 0.00 |
| Range | 0.15 | 0.24 | 153.6 | 7.70 | 5.30 | 4.20 | 0.70 | 0.09 |
| Minimum | 7.53 | 0.81 | 518.4 | 16.80 | 12.60 | 30.30 | 2.50 | 1.58 |
| Maximum | 7.68 | 1.05 | 672.0 | 24.50 | 17.90 | 34.50 | 3.20 | 1.66 |

Table 4. Results of descriptive statistics of treated wastewater sample during the monsoon season (2019)

| Parameters | pH | EC | TDS | TSS | COD | BOD | Turbidity | SAR |
|--------------------|------|------|--------|-------|-------|-------|-----------|------|
| Mean | 7.60 | 0.96 | 612.8 | 27.20 | 21.10 | 33.30 | 3.65 | 1.59 |
| Std. Error of Mean | 0.06 | 0.06 | 35.8 | 1.19 | 0.61 | 1.46 | 0.33 | 0.01 |
| Std. Deviation | 0.12 | 0.11 | 71.7 | 2.38 | 1.21 | 2.91 | 0.66 | 0.02 |
| Variance | 0.01 | 0.01 | 5143.8 | 5.69 | 1.47 | 8.49 | 0.43 | 0.00 |
| Range | 0.28 | 0.25 | 160.0 | 5.00 | 2.60 | 6.90 | 1.50 | 0.05 |
| Minimum | 7.48 | 0.87 | 556.8 | 25.10 | 19.70 | 29.40 | 3.00 | 1.56 |
| Maximum | 7.76 | 1.12 | 716.8 | 30.10 | 22.30 | 36.30 | 4.50 | 1.62 |

Table 5. Results of descriptive statistics of treated wastewater sample during the post-monsoon season (2019)

| Parameters | pH | EC | TDS | TSS | COD | BOD | Turbidity | SAR |
|--------------------|------|------|-------|-------|-------|-------|-----------|------|
| Mean | 7.40 | 0.81 | 515.2 | 20.90 | 15.57 | 25.97 | 4.08 | 1.56 |
| Std. Error of Mean | 0.07 | 0.01 | 8.4 | 0.21 | 0.50 | 0.44 | 0.39 | 0.01 |
| Std. Deviation | 0.11 | 0.02 | 14.6 | 0.36 | 0.86 | 0.76 | 0.68 | 0.02 |
| Variance | 0.01 | 0.00 | 215.0 | 0.13 | 0.74 | 0.57 | 0.47 | 0.00 |
| Range | 0.23 | 0.04 | 28.8 | 0.70 | 1.70 | 1.40 | 1.35 | 0.05 |
| Minimum | 7.30 | 0.79 | 502.4 | 20.60 | 14.80 | 25.10 | 3.35 | 1.53 |
| Maximum | 7.52 | 0.83 | 531.2 | 21.30 | 16.50 | 26.50 | 4.70 | 1.58 |

As far as TSS (Tables 2- 5) are concerned, the treated wastewater recorded values with an average of 18.75, 21.23, 27.20 and 20.90 mg L⁻¹ in winter, summer, monsoon and post-monsoon season, respectively. The highest value, 27.20 mg L⁻¹ is recorded in the monsoon season. However, it was established that TSS limits of 50 mg L⁻¹ (no restriction on use) and >100 mg L⁻¹ (severe restriction on use) when the treated wastewater is used in drip irrigation systems [14].

The reuse quality limits for the surface irrigation of orchards (e.g. olive tree cultivation) suggested by the EPA are 80 mg L⁻¹ of Chemical Oxygen Demand (COD) and 30 mg L⁻¹ of TSS. The COD of the wastewater ranged from 12.6 mg L⁻¹ to 22.3 mg L⁻¹. The mean values of COD were 14.85 ± 0.78, 15.77 ± 2.86, 21.10 ± 1.21 and 15.57 ± 0.86 mg L⁻¹ for winter, summer, monsoon and post-monsoon periods, respectively. The Biological Oxygen Demand (BOD) of the

wastewater varied from 22.5 mg L⁻¹ to 36.3 mg L⁻¹. The mean value of COD was 25.55 ± 4.31, 31.87 ± 2.29, 33.3 ± 2.91 and 25.97 ± 0.76 for winter, summer, monsoon and post-monsoon seasons, respectively. The results showed that almost all indices were located in the range of use of treated wastewater for irrigation. Based on the average value of COD and BOD₅ of treated wastewater in seasonal medium and low risk, respectively, for sustainable irrigated plantations [17].

Regarding turbidity, the minimum of 2.75 nephelometric turbidity unit (NTU) to the maximum value of 4.08 NTU was registered during the study period. The post-monsoon period recorded the highest value of 4.08 NTU compared to other seasons. However, in all the seasons, the turbidity value is more than the recommended level < 2 NTU [12]. A high level of turbidity can affect the performance of the irrigation facility. It can lower the

hydraulic conductivity of the soil and, in turn, pollute the soil surface through surface flow [18].

3.2 Salinity Hazard

Salinity is the result of all dissolved anions and cations in water. It is an essential parameter in determining the suitability of water for irrigation use. It is generally measured as the electrical conductivity (EC) of water or the concentration of total dissolved solids (TDS). It causes an increase in the osmotic pressure of soil solutions, harming the ability of plants to absorb water and nutrients [19]. In addition, high soil salinity and SAR values cause soil structure deterioration, decrease soil permeability, and reduce crop yields due to toxic and osmotic effects [20]. The criteria used to evaluate the quality of wastewater for use in irrigation are listed in Table 6.

Table 6. Degree of restriction on use for agriculture irrigation [14]

| Parameters | None | Slight to moderate | Sever |
|--------------------------------------|------|--------------------|-------|
| EC, $\mu\text{S cm}^{-1}$ | <700 | 700–3000 | >3000 |
| TDS, mg L^{-1} | <450 | 450–2000 | >2000 |
| Na ⁺ , mg L^{-1} | <100 | >100 | >100 |
| SAR, mg L^{-1} | <3 | 3–9 | >9 |

The treated wastewater sample of EC and total dissolved solids results lie in between 700 – 3000 $\mu\text{S cm}^{-1}$ and 450–2000 mg L^{-1} , and it was classified as slight to moderate restrictions usage.

Table 7. Irrigation water classes for Salinity hazard and Sodium hazard [22]

| Salinity hazard class | EC, ($\mu\text{S cm}^{-1}$) | TDS (mg L^{-1}) | Irrigation water classification | Characteristics |
|-----------------------|-------------------------------|----------------------------|---------------------------------|---|
| C1 | 0–250 | <200 | Excellent | Low-salinity water can be used for irrigation on most soil with the minimal likelihood that soil salinity will develop. |
| C2 | 251–750 | 200–500 | Good | Medium-salinity water can be used for irrigation if a moderate amount of drainage occurs. |
| C3 | 751–2250 | 501–1500 | Permissible | High-salinity water is not suitable for use on soil with restricted drainage. Even with adequate drainage, special management for salinity control may be required. |
| C4 | >2250 | 1501–3000 | Unsuitable | Very high-salinity water is not suitable for irrigation under normal conditions. |

| Salinity hazard class | EC, ($\mu\text{S cm}^{-1}$) | TDS (mg L^{-1}) | Irrigation water classification | Characteristics |
|-----------------------|-------------------------------|----------------------------------|---------------------------------|---|
| Sodium hazard class | SAR (meq L^{-1}) | Water-suitability for irrigation | Characteristics | |
| S1 | 0–10 | Low | | Suitable for all types of soils except for those crops which are highly sensitive to Sodium. |
| S2 | 10–18 | Medium | | Suitable for coarse-textured or organic soil with good permeability. Relatively unsuitable in fine-textured soil. |
| S3 | 18–26 | High | | Harmful for almost all types of soils. Requires good drainage, high leaching, and gypsum addition. |
| S4 | >26 | Very high | | Unsuitable for irrigation. |

3.3 Sodium Hazard

Sodium content is an essential factor in irrigation water quality evaluation. Excessive sodium leads to the development of alkaline soil that can cause soil physical problems and reduce soil permeability. Therefore, sodium represents another important element within the soil-plant system after TSE application, especially when the treated wastewater has a high sodium adsorption ratio (SAR). After using these effluents for plant irrigation, provided evidence of increasing Na concentrations in the soil and the plants [21]. The permissible limit and restriction were given in Table 7. Soil permeability is reduced by irrigation with water high in sodium; therefore, the best measure of irrigation water of soil permeability character is the water SAR considered together with its EC.

In this respect, Tables 2 - 5, which is based on the integrated effect of EC (Salinity hazard) and SAR (Sodium hazard), has been used to assess the water suitability for irrigation. It is found that treated wastewater samples categorized in class C3-S1 indicate high salinity and low sodium water, which can be used for irrigation on almost all soil types except for those susceptible crops to sodium. Although this water is ideal for plants with high salt tolerance, it is not suitable for irrigation, especially in soils with poor drainage [23].

4. CONCLUSION

The irrigation water classes for Salinity hazard and Sodium hazard found that samples in all the seasons were in C3-S1, indicating high salinity and low sodium water. In addition, data obtained indicated a slight to moderate degree of restriction on using this treated wastewater in irrigation due to salinity hazards. Although this

sort of water is acceptable for plants with high salt tolerance, it is not suitable for irrigation, especially in soils with poor drainage. Irrigation with treated wastewater, if not adequately treated, may result in a reduction in yield in sensitive crops and a decrease in soil quality as salinity in long-term irrigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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