# A Wastewater Reclamation Using Soil Aquifer Treatment (SAT) Technology to Enhance Groundwater Recharge

**L. Chandrakanthamma and K. Prasanna**

**Abstract** Soil aquifer treatment (SAT) is a water purification technique that involves a combination of physical, chemical, and biological processes (American Public Health Association (APHA) in Standard Methods for The Examination of Water and Wastewater. American Public Health Association, Washington, DC, 1998) to improve the quality of wastewater effluent as it seeps through layers of soil. This technology is particularly useful in developing countries like India due to its affordability and ease of operation, as it does not require specialized expertise from wastewater treatment plant operators. SAT (Bahgat et al. in Water Res 33:1949–1955, 1999) is a dependable method that consistently produces high-quality treated wastewater that meets accepted standards. Furthermore, it provides supplementary treatment for primary, secondary, and tertiary effluents from wastewater treatment plants (Arye et al. in Chemosphere 82(2):244–252, 2011). The utilization of wastewater effluent for soil aquifer treatment (SAT) (Bahgat et al. in Water Res 33:1949–1955, 1999) has emerged as a promising solution to address water scarcity in arid and semi-arid regions. However, further investigations are necessary to evaluate the impact of various factors on SAT performance, including organic micro pollutants, pathogens, nutrients, organic matter, suspended solids, rate of hydraulic loading, type of soil, temperature changes, redox conditions, pre-treatment of wastewater, biological activity, and wetting and drying cycles. This research involves analyzing data from laboratory-scale soil columns, horizontal subsurface flow constructed wetlands, and on-site soil analyses. By obtaining a comprehensive understanding of SAT performance, treated municipal wastewater can be considered a feasible option for providing water to communities in such areas. In the present study, the

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water from STP is filtered through a medium of sand and Biochar. The filtered water is checked for its characteristics, before recharging the ground water.

**Keywords** Leachate · Alum coagulation · Floc · Phyto-remediation · Hydraulic loading rate (HLR) · Biological activity

## 1 Introduction

In present scenario of water scarcity everywhere, with the SAT technology if ground water is recharged, sufficient water will be available to meet the needs of human kind. Life is dependent on the availability of fresh water (Table 1), but the world is currently encountering a widespread issue of ensuring a consistent and safe water supply for its inhabitants. This challenge arises from various factors, such as population expansion, climate change, and pollution of freshwater sources. Currently, about one-third of the global population (2.5 billion individuals) resides in regions where water scarcity is a pressing concern, according to the United Nations.

The disposal of untreated wastewater and improperly treated water into bodies of water and land is becoming a widespread issue globally, more specifically in developing countries [1] due to reasons like population growth, urbanization, and inadequate investment in (conventional) wastewater treatment plants [2]. Furthermore, the majority of current wastewater treatment plants are outdated and over whelmed, intended to serve only a small percentage of the population they are meant to serve. This issue is exacerbated by rising water scarcity and competition for water resources across various sectors. To address the problem of surface water pollution and achieve efficient water resource management [3] through water reuse, it is necessary to establish and implement various treatment technologies [3] with low energy consumption and a minimal chemical footprint. One possible solution is to plan for the use of effluents in soil aquifer treatment (SAT) [4] to treat wastewater effluents for subsequent reuse.

**Table 1** As per recent studies, the global water distribution (*Source* Internet)

| S. No. | Source | Availability (%) |
|---|---|---|
| 1 | Salt water | 97.5 |
| 2 | Fresh water | 2.5 |
| 3 | Glaciers, permanent snow cover | 68.9 |
| 4 | Fresh groundwater | 29.9 |
| 5 | Fresh water lakes an river storages | 0.3 |
| 6 | Others | 0.9 |

### 1.1 Feasibility Analysis and Design of SAT System

After identifying SAT as a potential solution, to achieve the established goals, it is important to conduct a comprehensive feasibility analysis that considers various factors like legal, economical, technical, institutional, social, and environmental aspects [5]. Once all the requirements in these areas are met, the preliminary design can then be developed.

The factors to consider in the design of SAT systems [4]:

(i) The pre-treatment requirements must be considered, including the level of wastewater treatment necessary and any additional treatment required for successful operation of the system.
(ii) The rate of infiltration, measured in hydraulic loading, should be determined based on the characteristics of the soil and the amount of water that can be effectively absorbed.
(iii) The amount of land required should take into account wet and dry cycles to ensure that the system can function effectively throughout the year.
(iv) The number of wells required and their production capacity must be determined based on the expected water demand and the characteristics of the groundwater resources in the area.
(v) The spacing between wells should be optimized to maximize the water recovery while minimizing the potential for contamination.
(vi) The distance between the wells and the infiltration pond or injection well must be carefully considered to ensure that the water is effectively treated and can be safely injected or infiltrated into the ground.
(vii) The pumping rate should be optimized to ensure that groundwater flow and velocity are not disrupted, which could impact the quality of the water recovered.
(viii) The percentage of native groundwater present in the reclaimed water must be monitored to ensure that the quality of the water meets regulatory standards.
(ix) The quality of water obtained from the SAT system must be regularly monitored to ensure that it meets the required standards for its intended use.
(x) Any post-treatment requirements, operation and maintenance requirements, and monitoring protocols must be established to ensure the long-term viability and success of the system.

The initial stage in assessing the possibility and creating designs for Subsurface Absorption Technology (SAT) systems is choosing a suitable site with hydrogeological conditions that are appropriate. To do this, a comprehensive site investigation must be conducted, including various tests such as boreholes, infiltration tests, test pits, groundwater wells, and soil and groundwater quality sample analyses.

### *1.2 Selection of Site and Soil Requirements*

The selection of site is a critical factor for the successful implementation of a soil aquifer treatment (SAT) system. Several key factors should be considered during site evaluation and selection, including the depth of the soil, permeability, depth to groundwater, and aquifer thickness (i.e., depth from the water table to the bedrock [1]). These factors play a crucial role in determining the effectiveness of the SAT system in treating wastewater and preventing contamination of groundwater resources. Therefore, careful consideration of these factors is essential when selecting a site for a SAT system.

The use of effluent [6] for soil aquifer treatment (SAT) is a potential solution to alleviate water scarcity in arid and semi-arid regions. However, further research is required to assess the impact of various factors on SAT performance, such [7] as organic micropollutants, pathogens, nutrients, organic matter, suspended solids, rate of hydraulic loading, type of soil, different temperature fluctuations, redox conditions, wastewater pre-treatment, biological activity, and wetting and drying cycles. This study involves analyzing data from laboratory-scale soil columns, horizontal subsurface flow constructed wetlands, and on-site soil analyses. A comprehensive understanding of SAT performance will enable treated municipal wastewater to be considered a viable option for supplying water to communities in the area of Ramapuram, Chennai.

## 2 Materials and Methods

### *2.1 Treatment Methods*

In order to investigate multiple parameters using SAT, there are two systems followed, one is a specialized soil-column system (as shown in Fig. 1) that mimics aquifer conditions using three columns, each measuring 55 cm in length and 10 cm in inner diameter. The columns, made of acrylic, will be capped with rubber gaskets at the top and bottom. A screen will be positioned at the base of each column to provide support for a layer of 2.5 cm of sand, followed by a depth of 2.5 cm of gravel, and 50 cm of soil.

Second one is tank model of 10 m*3 m with various details as given below also in progress to check various parameters along with vertical columns (Fig. 2).

Before starting the experiments, the soil columns and the horizontal tanks are to be biologically prepared by infiltration of feed water for 6 months.

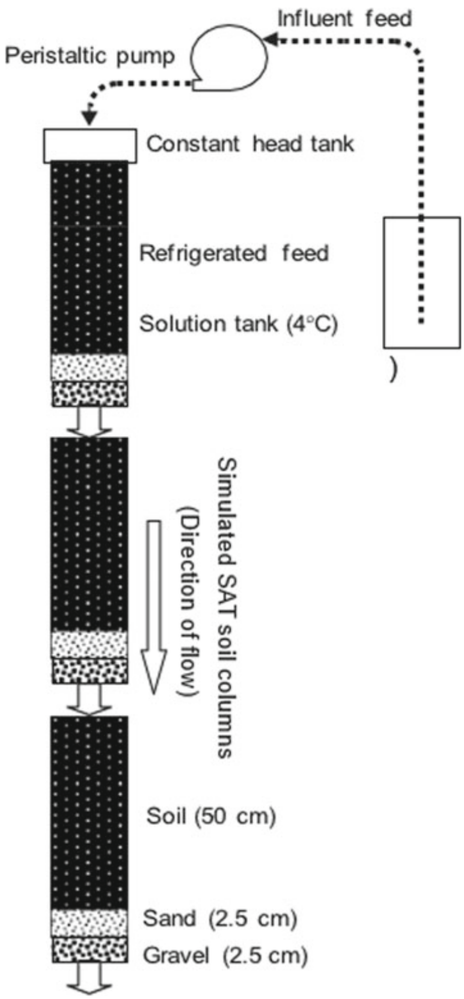


**Fig. 1** Laboratory model soil aquifer treatment system (*Source* Water Research [4])

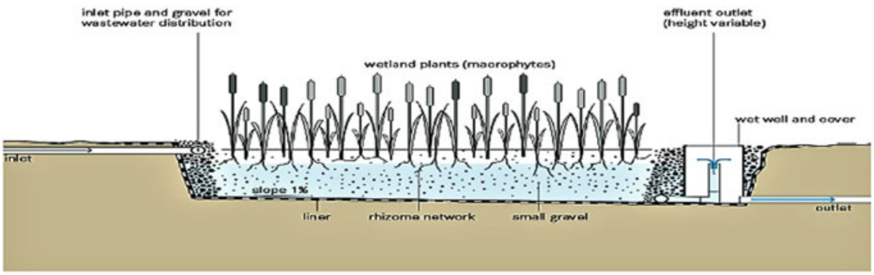


**Fig. 2** Diagram of the horizontal subsurface flow constructed wetland [1] (*Source* http://www.mdpi.com/journal/water)

**Table 2** Various soil tests were conducted before applying the methods mentioned above to know the soil characteristics

| S. No. | Parameter | Value |
|---|---|---|
| 1 | Specific gravity of soil | 2.6 |
| 2 | Sieve analysis of soil | |
| | (i) % of gravel (> 4.75 mm) | 1.4% |
| | (ii) % of coarse sand (4.75–2.00 mm) | 0.1% |
| | (iii) % of medium sand (2.00–0.425 mm) | 78% |
| | (iv) % of fine sand (0.425–0.075 mm) | 6.5% |
| | (v) Fineness modulus | 0.418 |
| | (vi) Uniformity coefficient Cu | 4.454 |
| 3 | Liquid limit of the soil | 35.67% |
| 4 | Plastic limit of the soil | 23.3% |
| 5 | Density of soil | 1.43 gm/cc |
| 6 | Coefficient of permeability of the soil | 0.015 cm/s |
| 7 | pH of soil | 8 |
| 8 | Water quality data for the STTP | |
| | pH | 7.5 |
| | COD | 52 mg/l |
| | Nitrate | 4.3 mg/l |

## 3 Results and Discussions

Various tests were conducted to find the soil characteristics (the preliminary tests done are field based and further work will be carried under controlled conditions).

Knowing the parameters of the reference sample, further tests will be conducted on the water filtered through the test columns which are provided with a bioindicator and a check well. Preliminary tests are conducted to know the soil structure.

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