Wastewater Renovation using Soil Aquifer Treatment (SAT) System : Case Study of Latur District (Marathwada)

Aniket V. Patil[1], Tejaswini S. Mankar[2], Shilpa S. Motegaonkar[3]

[1] *BE. Student, Dept. of Civil Engineering, PCCOE, Pune, Maharashtra, India*
[2] *BE. Student, Dept. of Civil Engineering, PCCOE, Pune, Maharashtra, India*
[3] *Associate Professor, Dept. Of Civil Engineering , PCCOE, Pune, Maharashtra, India.*

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Abstract - *Land treatment of wastewater has risen as a promising substitute to the conventional wastewater treatment advances. In soil aquifer treatment, preliminary treated wastewater is permitted to pervade through the aerated vadose soil zone where it undergoes decontamination through unit operations and processes viz. filtration, sedimentation, absorption, adsorption and biodegradation. The objective of this study was to establish a Soil Aquifer Treatment (SAT) system for attenuation of pollutants in wastewater and limiting the degradation of groundwater resources and it's reuse for Marathwada region. Aquifer material of less than 2.36 mm was used to have homogeneous soil column fill material, reduce flow distortions, minimize unrepresentative effects of earthworms and debris, use grain sizes that contribute to expulsion in the SAT procedure. From the study maximum removal of most nutrients was observed at 114 mm/hr hydraulic loading rate accompanied with highest removal efficiencies of BOD, COD and TDS. The quality of the treated wastewater deteriorated with amplified collective loading in bulk of the class parameters. A prominent feature of the study is the introduction of temperature variation conception assisting the overall treatment process. The study explains the effect of Variation of temperature of preliminary* treated wastewater from 30 °C to 45 °C on the system performance. BOD and COD removal efficiencies of the process were as high as 99.12% and 92.53% respectively. The SAT system is found to be more competent, robust and sustainable than the ordinary wastewater treatment frameworks and consequently recommended for implementation.

Key Words: Land treatment, preliminary treated, vadose, Soil Aquifer Treatment, groundwater resources, hydraulic loading rate, temperature variation, robust, sustainable.

1.INTRODUCTION

Numerous urban communities and agricultural territories depend on the consolidated utilization of surface water and groundwater. At the point when request expands, groundwater is frequently the most monetary wellspring of supply, however overexploitation can prompt the deterioration of water quality or a diminishing groundwater level. Managed Aquifer Recharge (MAR) alludes to various recharge techniques that discharge the recycled water from over the ground, permeating through unsaturated soil, or from beneath the ground, by infusion or recharge wells. The additional benefit of this technique is that recycled water, for example, treated black water, storm water or grey water is not quite recently released into other surface waters, but rather reused as water for irrigation in agribusiness or to purposefully energize groundwater aquifers by means of MAR. Soil Aquifer Treatment (SAT) is one of many MAR strategies, which is getting developing consideration since it highlights advantages viz. characteristic natural treatment, inbuilt capacity ability to cradle seasonal varieties of supply and demand and in addition mixing with natural water bodies, which advances the acknowledgment of further uses, especially indirect potable reuse. Treatment advantages are at first accomplished amid vertical invasion of wastewater effluent through the vadose zone by filtration, sedimentation, adsorption, biodegradation and eventually during its horizontal movement in the saturated zone by dispersion and dilution before it is abstracted again from a reclamation well.

Unplanned disposal of untreated or deficiently treated wastewater to lakes, streams and land is expanding at staggering volumes, particularly in Latur district of Marathwada region (Maharashtra) because of rapid population growth, urbanization, excessive utilization of groundwater and absence of funds to build, operate and maintain conventional wastewater treatment plants (WWTPs) has influenced us to undertake this project for arid and semi-arid locales of Maharashtra. Our review's concentration is to observe the variety in purification proficiency of SAT with relating variety of temperature for recovery of groundwater for purpose of irrigation.

2. LITERATURE REVIEW

A few field examines have exhibited the practicability of SAT method for reclamation of wastewater. Primary and secondary effluents have been utilized as influent to SAT frameworks and the expulsion component of various contaminants, viz. organics, supplements, microscopic organisms, infections and overwhelming metals has been accounted for. A significant part of the work on SAT innovation can be credited to Bouwer and his colleagues.

Bouwer et al. (1974a, b) [5] explored the execution of a pilot quick infiltration framework in the Salt riverbed. A great renovated wastewater with for all intents and purposes nil BOD, SS and fecal coliforms and generous elimination of phosphate and substantial metals joined by change of smelling salts to nitrate was obtained. Bouwer et al. (1980), demonstrated that a entry of secondary effluent through 3.3m of unsaturated zone brought about COD and BOD decreases of very nearly 100%, nitrogen of around 30–65% and phosphate expulsion around 40–80%. Viruses and fecal coliforms expulsion was practically total. The normal hydraulic loading on the framework was 121 m/yr with flooding and drying periods being 2–3 weeks and 10–20 days, separately.

C. S.P. Ojha and P. Nema et al. (2000) [6] had contemplated Techno-Economic Evaluation of Soil-Aquifer Treatment utilizing Primary Effluent at Ahmedabad, India. A pilot study was completed in Sabarmati River bed at Ahmadabad, India for renovation of primary treated municipal wastewater through soil aquifer treatment (SAT) system. The foundation for the pilot SAT framework contained two essential settling basins, two infiltration basins and two production wells situated in the centre point of infiltration basins for pumping out reclaimed wastewater. The execution information demonstrated that SAT has a decent potential for expulsion of natural toxins, supplements and microbes and infections. The SAT framework was observed to be more proficient and practical than the ordinary wastewater treatment frameworks and subsequently suggested for selection. A striking element of the review is the presentation of biomat idea and its commitment in the general treatment process.

Abrham Abebe (2010) [2] investigated the Removal Efficiency of Black Cotton Soil in Attenuation of Pollutants from Wastewater for Reusing Wastewaters for Aquifer Recharge at Kality Treatment Plant Water and Textile Treatment Plant Water, Addis Ababa, Ethiopia. The goal of this review was to survey soil capability in weakening of toxins from wastewater and to reuse it for aquifer energize with sign of ground water security. Wastewater from material treatment plant and sewage treatment plant was utilized. Undisturbed soil core of dark cotton soil was utilized as a part of the initial 50cm of soil layer which is put in 20 PVC plastics to recreate soil segment test. Dark cotton soil is the prevailing soil sort in the review zone which has high in cation trade limit and low electric conductivity this element is critical for maintenance of supplements. Three pressure driven stacking rates was chosen 136mm/d, 181 mm/d and 226mm/d for recognizable proof of ideal water powered stacking rates. Through the framework there was an expansion drift watched which ascend to 1.92 and 2.64 for the separate water sorts at 226mm/d and these HLRs where the slightest expulsion productivity was acquired for the two water sorts demonstrating improvement of penetration issue because of sodium impact which is one of the component for decrease evacuation effectiveness

Chol D. T. Abel et al. (2013) [1] analyzed the Impact of Hydraulic Loading Rate and Media Type on Removal of Bulk Organic Matter and Nitrogen from Primary Effluent in a Laboratory-Scale Soil Aquifer Treatment System. The impact of pressure driven stacking rate (HLR) and media sort on the expulsion of mass natural matter and nitrogen from essential emanating amid soil aquifer treatment was researched by directing lab scale soil segment contemplates. Two soil sections stuffed with silica sand were worked at HLRs of 0.625 and 1.25 m/d, while a third segment was pressed with rise separating material and worked at HLR of 1.25 m/d. Mass natural matter was viably expelled by 47.5±1.2% and 45.1± 1.2% in silica sand sections worked at 0.625 and 1.25 m/d, separately and 57.3± 7.6% in hill sifting material segment worked at 1.25 m/d. Ammonium-nitrogen diminishment of 74.5±18.0% was accomplished at 0.625 m/d contrasted with 39.1±4.3% at 1.25 m/d in silica sand segments, while 49.2± 5.2% ammonium-nitrogen decrease was achieved at 1.25 m/d in the hill separating material segment. Ammonium-nitrogen diminishment in the initial 3 m was thought to be commanded by nitrification handle confirm by comparing increment in nitrate.

3. REGION OF STUDY : LATUR DISTRICT, MARATHWADA, MAHARASHTRA

Latur district in the Marathwada region in the state of Maharashtra, India, is located between 17°52' North to 18°50' North and 76°18' East to 79°12' East on the Deccan plateau. The whole area of study is categorized as a "draught prone region". In significant parts of the locale, falling/declining water level patterns have been seen in practically whole Nilanga, Ausa, Latur and Renapur talukas and northern piece of Ahmadpur and southern piece of Udgir taluka. These zones additionally match with more profound pre rainstorm water levels in the scope of 10 to 20 m below ground level. The taluka classified as "Semi-Critical" viz., Latur and Ausa, Nilanga, Chakur and Renapur, talukas where the phase of ground water advancement has as of now came to around at least 70% additionally agree with the more deep water level and declining pattern zones.

Over the most recent two years, the average precipitation in Marathwada was under 50 percent that has prompted becoming scarce of open wells and in addition bore wells. There emerges need of effectively advancing water education and planning at the grassroots of individuals. Marathwada, an area known more for its normal and extreme dry seasons in the current years, now indicative of the most astounding precipitation deficiency in the nation at 42%. A series on Marathwada's fight with three successive years of dry season is deficient without understanding the effect of ecological and climatic changes. The ascent in the nation's yearly temperature by 0.7 °C and unpredictable climatic trends are certain to influence the area's farming being categorized under arid zones.

4. WORKING OF SOIL AQUIFER TREATMENT (SAT) SYSTEM

SAT is utilized to enter either storm water or pre-treated wastewater through an infiltration basin or an infusion well. As the emanating travels through the soil and the aquifer, it can experience noteworthy quality changes through physical, substance and organic procedures. The water is put away in the basic unconfined aquifer for the most part for resulting reuse, for example, water system or notwithstanding to drink water purposes (by and large after a water filtration step). To put it plainly, SAT has benefits both in treatment in the overwhelmed unsaturated zone, which acts like a characteristic channel and capacity inside the immersed zone. Later, the sewage which is treated in section through the vadose zone, has come to the groundwater it is typically permitted to stream some separation through the aquifer before it is gathered. This extra development through the aquifer can create encourage cleaning (expulsion of microorganisms, precipitation of phosphates, adsorption of engineered organics, and so on.) of the sewage. Since the soil and aquifer are utilized as characteristic treatment, frameworks, for example, those in Figure 1 are called soil-aquifer treatment frameworks or SAT frameworks. Soil-aquifer treatment is basically a low-technology, propelled wastewater treatment framework. It likewise has a tasteful preferred standpoint over customarily treated sewage in that water recuperated from a SAT framework is clear and odour free as well as it originates from a well, deplete, or by means of common waste to a stream or low zone, as opposed to from a sewer or sewage treatment plant. Consequently, the water has lost its implication of sewage and the general population see water more as leaving the ground as groundwater than as sewage gushing. This could be an essential figure the general population acknowledgment of sewage reuse plans.

During SAT, treated wastewater is irregularly ponded in the infiltration basins to recharge groundwater. The ponded wastewater permeates through an unsaturated soil or vadose zone to a fundamental, unconfined aquifer for capacity. At that point, the revived water is accessible for reuse through recuperation wells. Past reviews demonstrated that the execution of SAT frameworks is

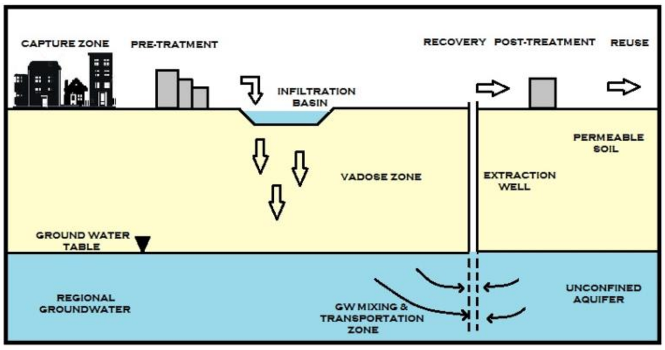

Fig 1- Layout depicting various Components of SAT

principally controlled by soil sort, gushing pre-treatment and wet and dry process durations (Quanrud, 1996; AWWA Exploration Establishment, 1998; Houston, 1999). Contingent upon these components, critical upgrades in water quality can be acquired. The real water quality concerns related with reuse of wastewater subjected to SAT incorporate broke down organics, nitrogen species, and pathogens. These contaminants show in the wastewater gushing are evacuated or changed by physical, chemical or potentially organic procedures in the vadose zone, basically, and hence in the aquifer. SAT has demonstrated exceptionally compelling in evacuating all out nitrogen and infections while applying optional emanating.

5. SOIL COLUMN SIMULATIONS OF SAT SYSTEM (LAB-SCALE)

5.1 Method of soil sampling

To obtain undisturbed and intact soil layers which represent soil layer samples hand digging applied from the study area. Representative soil samples were collected from 3 taluka's of the Latur district viz. Deoni, Udgir and Nilanga. All columns were filled with 70 cm of aquifer material while tapping gently on the surface of the column using a mallet rubber hammer to ensure homogeneous media packing in the column. Aquifer material of less than 2.36 mm was used to have homogeneous soil column fill material, reduce flow distortions caused by larger soil material, minimize unrepresentative effects of earthworms and debris, use grain sizes that contribute to removal in the SAT process. This better simulated the subsurface SAT process, independent of soil type.

5.2 Method of water sampling

Preliminary treated wastewater from relevant location was used as an influent for the soil column simulation. Wastewater sampling technique and preservation followed the standard methods of sample preservation and sampling. Water samples were collected using plastic bottles and storage cans preserved using refrigerator and transported to laboratory analysis and the rest to undertake simulation in soil columns within few hours. Distilled water was allowed to run in the soil profiles for a few days to keep soil moisture until laboratory simulation started. Influents are applied at normal room temperature of around 25 degree Celsius initially before beginning with the temperature variation phase.

5.3 Experimental set-up

To study Soil Aquifer treatment for possible ground water recharge, soil columns of transparent acrylic material were set-up in the laboratory. The transparent acrylic pipes used for experimentation were 1000 mm long and 94 mm internal diameter each. A ponding head space (free-board) of 30 cm was provided at the top of each column. At the bottom of the column, perforated plates were provided to discharge the treated effluent into a beaker and prevent the entry of finer sediments into the beaker. A cylindrical storage tank was provided at certain elevation which served the purpose of influent holder (preliminary effluent) facilitating downward flow under the action of gravity with controlled flow rates by control valves. Designed HLR of 114 $mm^3/mm^2/hr$ was adopted and frequently checked at influent points of each column using a measuring cylinder and a stopwatch.

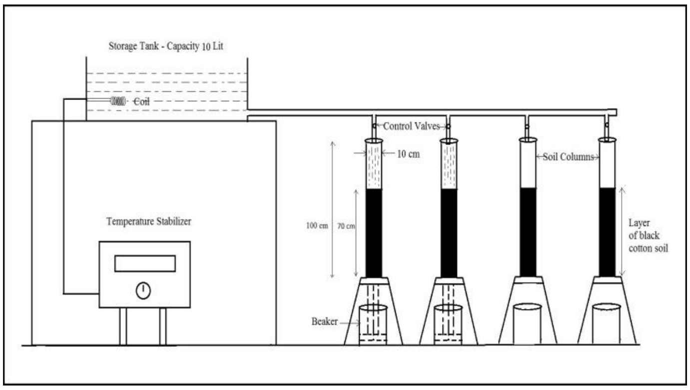

Fig 2- Proposed Setup of Soil Column Simulation of SAT Process

5.4 Water quality analysis and soil test

Test for the intended major physical, chemical and biological parameters for the collected samples of the sewage treatment plant, and from the outflow of laboratory simulation was done at Pimpri Chinchwad COE in Environmental Engineering laboratory. The water quality parameters tested before and after the process simulation includes: PH determination by PH meter, EC by conductivity meter and the determination of DO, Biological oxygen demand (BOD) (mg/l) and Chemical Oxygen Demand (COD) (mg/l) by Titration method.

Removal efficiency was calculated based on the following formula:

$$\% \text{ Removal efficiency } = \frac{\text{Cinf} - \text{Ceff}}{\text{Cinf}} \text{ x } 10$$

where,

C_{inf} = Initial Parameter concentration
C_{eff} = Final Parameter concentration

5.5 Effect of temperature variation on system performance

The performance of SAT mainly depends on wastewater effluent quality, hydro-geological conditions at site and process conditions applied. Temperature and redox conditions are reported as key parameters influencing the removal of contaminants during soil passage. A series on Marathwada's battle with three consecutive years of drought is incomplete without understanding the impact of climate change. The study explains the effect of Variation of temperature from 30°C to 45 °C (+5°C for each cycle) on the system performance. Results obtained in this study demonstrated that the efficiency of SAT system to remove bulk organic matter. BOD and COD indicators improved significantly at high temperature as depicted in Chart-3 and Chart-4 respectively. The charts show inlet and outlet concentrations (mg/l) of BOD and COD and corresponding increase in removal efficiency with varying samples.

6. RESULTS AND DISCUSSION

- The removal efficiencies followed a pattern of continuous ascend until saturation level was reached for most of the quality parameters (BOD, COD, etc).
- The observed average quality of the renovated wastewater was: BOD<5mg/l; COD<100mg/l; SS<100mg/l along with EC as low as 0.34.
- The BOD and COD removal efficiencies of the process were as high as 99.12% and 92.53% respectively
- Removal of bulk organic matter in aerobic soil columns was significantly higher at high temperature.
- The SAT system was found to be more competent, robust and sustainable than the ordinary wastewater treatment frameworks and consequently recommended for implementation.

Table -1: Characteristics of Influent(before treatment) and Effluent (after treatment)

Parameter	Influent	Effluent	Standard range (for irrigation)
Ph	7.26	7.33	5.5-9.0
Total suspended solids(mg/l)	180	60	200
Total dissolved solids(mg/l)	500	400	2100
BOD(mg/l)	192	1.6	100
COD(mg/l)	388	32	250
Electrical conductivity	0.38	0.34	1.0

(Source for standard range : CPHEEO 2012)

Graphical Representation of Experimental Results :

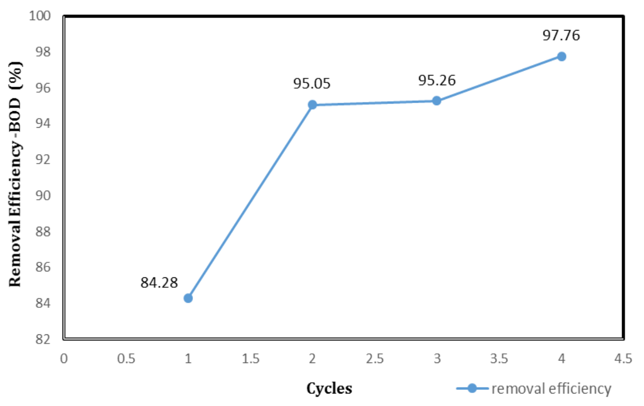

Chart – 1 : Graphical representation of cycles Vs. removal efficiency BOD

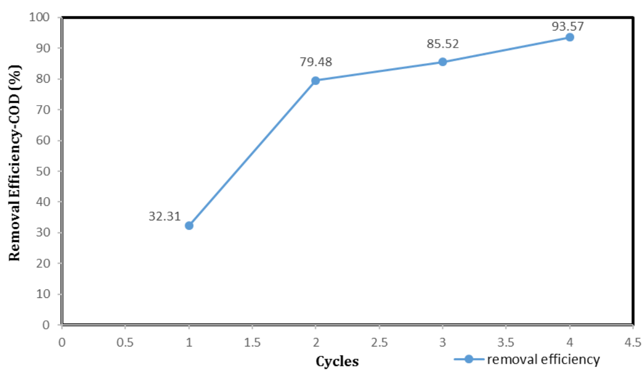

Chart – 2 : Graphical representation of cycles Vs. removal efficiency COD

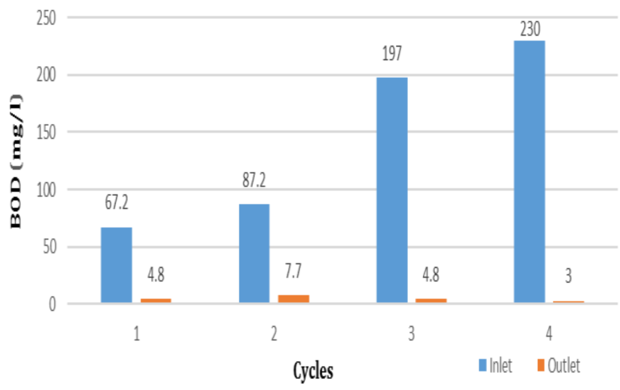

Chart – 3 : Graphical representation of cycles vs. BOD (temperature variation)

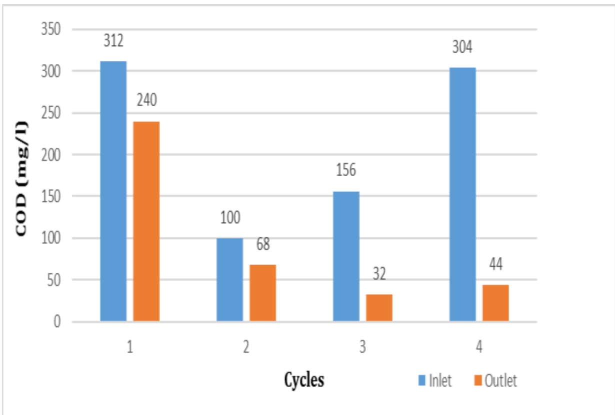

Chart – 4 : Graphical representation of cycles vs. COD (temperature variation)

7. CONCLUSIONS

The simulation of SAT system to be adopted using black cotton soil was found to provide the desired quality of renovated wastewater for unrestricted irrigation(OR indirect potable use). Black cotton soil gave satisfactory results for attenuation of pollutants from wastewater and hence can be adopted for proposed arid and semi-arid regions. Effluent quality deteriorated with increased cumulative loading in majority of the quality parameters. The shallow entrance of polluting influences might be an alluring element of SAT framework as the framework might be revived effortlessly through biodegradation of biomat. Efficiency of SAT system to remove bulk organic matter improved significantly at high temperature.

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