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Land Treatment as Viable Solution for Waste Water Treatment and Disposal in India

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Abstract

The enormous increase in the generation of waste water on account of rapid growth of industrialization and urbanization has posed serious threat on human and natural resources. Wastewater has become a significant issue in urban areas especially in developing countries. Developed countries have the capacity to bear the water purification cost but developing countries don't have that capacity in as much as that they dispose untreated wastewater in to the open source water bodies. The authors of the present paper thus focus on land treatment of wastewater which is economical among other conventional methods which is viable solution for the treatment and disposal of water particularly for the developing countries including India.

Keywords: Waste water; Treatment; Land application; Hydraulic loading

Introduction

Urban water supply and sanitation are important basic needs for the improvement of the quality of life and enhancement of productive efficiency of the people. In urban areas, water is tapped for domestic and industrial uses from rivers, streams, wells and lakes. Almost 80% of the water supplied for domestic use, comes out as wastewater. In most of the cases wastewater is let out untreated and it either sinks into the ground as a potential pollutant of ground water or is discharged into the natural drainage system causing pollution in downstream areas Municipal sewage may be defined as "waste (mostly liquid) originating from a community; may be composed of domestic wastewaters and/or industrial discharges". It is major source of water pollution in India, particularly in and around large urban centers. In India about 78% of the urban population has access to safe drinking water and about 38% of the urban population has access to sanitation services.

Discharge of untreated sewage in water courses both surface and ground waters is the most important water polluting source in India. Out of about 38000 million litres per day of sewage generated treatment capacity exists for only about 12000 million litres per day. Thus, there is a large gap between generation and treatment of wastewater in India. Even the treatment capacity existing is also not effectively utilized due to operation and maintenance problem. Operation and maintenance of existing plants and sewage pumping stations is not satisfactory, as nearly 39% plants are not conforming to the general standards prescribed under the Environmental (Protection) Rules for discharge into streams as per the CPCB's survey report. There are 35 metropolitan cities (more than 10 Lac Population), 15,644 Million Liter per Day (MLD) of sewage is generated from these metropolitan cities. The treatment capacity exists for 8040 MLD i.e., 51% is treatment capacity is created. There are projected 498 Class-I Cities (having more than 1 Lac Population). Nearly 52% cities (260 out of 498) cities are located in Andhra Pradesh, Maharashtra, Tamilnadu, Uttar Pradesh and West Bengal. The sewage generated in class-I cities estimated 35558.12 MLD [1-3]. Total Sewage treatment Capacity of class-I cities is reported 11553.68 MLD, which is 32% of the sewage generation. Out of 11553.69 MLD sewage treatment capacities, 8040 MLD is treated in 35 Metropolitan cities i.e. 69%. This indicates that other than metropolitan cities, the capacity of 462 Class-I cities is only 31%. This tends to indicate that only part of the waste water is being treated and remaining disposed of without any treatment posing threat to natural environment and human health, thus requires low cost treatment like land treatment.

Land Treatment

Land treatment is defined as the controlled application of waste water onto the land surface to achieve a specified level of treatment through natural physical, chemical, and biological processes within the plant soil-water matrix. An effort has been made in the present paper to describe land treatment of wastewater including the selection and design of system for land treatment having minimum impact on the environment and minimum cost of operation. Such a treatment would be applicable where sufficient land is available. Waste water treatment is usually consists of conventional Physical, chemical, biological and combination thereof but such treatments involve high capital and recurring cost including sensitivity in maintenance and operation. However, Land Treatment of waste water is comparatively low cost and of least sophistication. Land treatment is the controlled application of waste-water to the land at rates compatible with the natural physical, chemical and biological processes that occur on and in the soil. The three main types of land treatment systems used are slow rate (SR), overflow (OF), and rapid infiltration (RI) systems. Waste water is a recyclable commodity [4]. Organic matter in the form of nitrogen, phosphorus, and micronutrients in waste water are generally harmful when discharged to lakes and streams, but these constituents have a positive economic value when applied under properly controlled conditions to vegetated soils. However, the wastewater may be classified as strong, medium and weak, the details of which is reflected in Table 1 below.

Land Treatment Methods

Land treatment of waste water is called as land application of

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wastewater or natural treatment of waste water which involves the basic concept using vegetation cover, soil surfaces and geological materials to remove certain pollutants. The following three main types of land treatment systems are used.

- Slow rate (Irrigation) – SR
- Rapid Infiltration (Infiltration) – RI
- Over Flow – OF

Slow rate

Slow Rate (SR) systems are the predominant form of land treatment for municipal and industrial waste-water. Such a technology incorporates waste-water treatment, water reuse, crop utilization of nutrients and waste-water disposal. It involves the application of waste-water to vegetated land by means of various techniques, including sprinkling methods or surface techniques such as graded-border and furrow irrigation. Water is usually applied intermittently (every 4 to 10 days) to maintain aerobic conditions in the soil profile. The applied water is either consumed through evapotranspiration or percolated vertically and horizontally through the soil system [5]. Any surface runoff is collected and reapplied to the system. Treatment occurs as the wastewater percolates through the soil profile (Table 2). In most cases, the percolate will enter the underlying groundwater, or it may be intercepted by natural surface waters or recovered by means of under drains or recovery wells.

SR systems can be classified into two categories based on design objectives. Category 1 systems are designed with waste-water treatment itself, rather than crop production, as their main objective. Accordingly, in this system, the maximum possible amount of water is applied per unit land area. However in the second category, the system is designed mainly with a view to water reuse for crop production, and consequently the amount of water applied is just enough to satisfy the irrigation requirements of the crop being grown. SR systems have the highest treatment potential of all natural treatment systems.

Major Constituents	Strong (mg/l)	Medium (mg/l)	Weak (mg/l)
Total Solids	1200	700	350
Dissolved Solids (TDS)	850	500	250
Suspended Solids	350	200	100
Nitrogen (N)	85	40	20
Phosphorous (P)	20	10	6
Chloride	100	50	30
Alkalinity ($CaCO_3$)	200	100	50
Grease	150	100	50
BOD_5^2	300	200	100

Table 1: Major suspended of strong, medium and weak waste-waters.

Parameter	Removal Mechanism
BOD	Soil adsorption and bacterial oxidation
SS	Filtration through the soil
Nitrogen	Crop uptake, denitrification, ammonia volatilization, soil storage
Phosphorus	Chemical immobilization (precipitation and adsorption), plant uptake
Metals	Soil adsorption, precipitation, ion exchange, complexation
Pathogens	Soil filtration, adsorption, desiccation, radiation, predation, exposure to other adverse environmental factors
Trace Organics	Photodecomposition, volatilization, sorption, degradation

Table 2: Mechanisms of waste-water constituent removal by SR systems.

Parameter	Percentage Removal
BOD	90 to 99+ Percent
TSS	90 to 99+ Percent
TN	50 to 90 percent
TP	80 to 99+ Percent
Fecal Coliform	99.99+ Percent

Table 3: Removal capacity of suspended and organic matters by slow rate treatment.

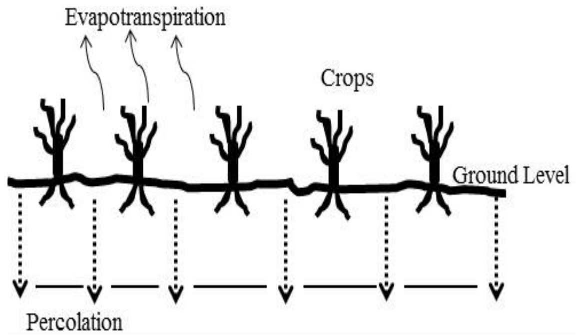

Figure 1: Slow rate land treatment.

Criteria	Range
Field Area	56 to 560 acres/MGD
Application Rate	2 to 20 ft./yr. (0.5 to 4.0 in/wk
Bod Loading	0.2 to 5 lb/acre/d
Soil Depth	At least 2 to 5 ft
Soil Permeability	0.06 to 2.5 in/r
Lower Temperature Limit	25 deg F
Application Method	Sprinkler or surface
Pre-treatment Required	Preliminary and secondary
Particle Size (For Sprinkler Applications)	Solid less than 1/3 sprinkler nozzle

Table 4: Applicable design criteria for slow rate system.

As the primary system water is applied to agricultural lands or vegetation either by sprinkling or by surface techniques, nutrients contained in wastewater are utilized by crops and vegetation while BOD and suspended solids are removed through water infiltration. It is not suitable to apply for consumption of crops. This method can further sub divide in to two categories as Normal Rate Irrigation and High Rate Irrigation based on Annual Loading Rate and land requirement. Annual Loading Rate of Normal Rate Irrigation varies from 0.3 to 1.5 m/yr. Agricultural sites using this Normal Rate Irrigation are generally with less slope. The Annual Loading Rate of High Rate Irrigation systems are 3.0 m/yr. This rate can vary according to the environment and suitable only for permeable soil. The System is very operative at removing harmful wastewater constituents. Table 3 shows the removal capacity of suspended and organic matters at slow rate treatment. Table 4 shows applicable design criteria for Slow Rate system and land treatment system depicted in Figure 1 below:

Rapid infiltration

Rapid infiltration (RI) is the most intensive of all land treatment methods. In this method usually high hydraulic and organic loadings are applied intermittently to shallow infiltration or spreading basins as reflected in Figure 1. The RI process uses the soil matrix for physical, chemical, and biological treatment. Physical straining and filtering occur at the soil surface and within the soil matrix [6]. Chemical precipitation, ion exchange and adsorption occur as the water percolates through the soil. Biological oxidation, assimilation and reduction occur

Criteria	Slow Rate	Rapid Infiltration	Over Flow
Grade	< 20% on cultivated land < 40% on non-cultivated land	Not critical, excessive grades require much earth work	Finis slope 2% to 8%
Soil Permeability	Moderately slow to moderately rapid	Rapid (Sands, sandy, loams)	Slow (clay, silt and soils with impermeable barriers)
Pth to Ground Water	0.6 – 1 m (minimum)[b]	1 m during flood cycle, 1.5 – 3 m during dry cycle	Not critical
Climatic Restriction	Storage often needed for cold weather and during heavy precipitation	None possibly modify operation in cold weather	Storage usually needed for cold weather
Treatment Goal	Secondary or Advance water treatment	Secondary, Advance water treatment or ground water	Secondary removal
Climate Needs	Warmer seasons	None	Warmer seasons
Vegetation	Yes	No	Yes
Area (Ha)*	23-280	3-23	6-40
Hydraulic Loading (M/L)	0.5-6	6-125	3-20

Table 5*:* Applicable design criteria for rapid infiltration system.

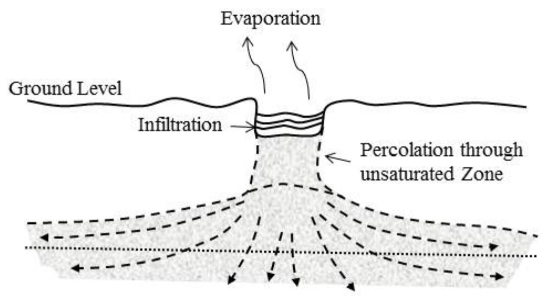

Figure 2: Rapid filtration of land treatment.

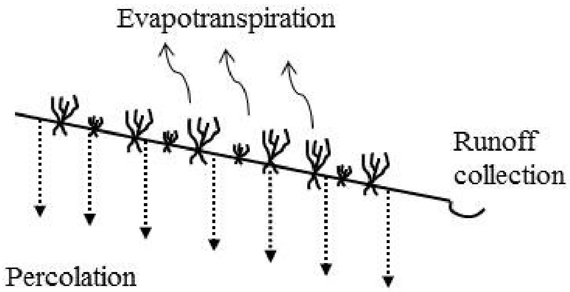

Figure 3: Overflow land treatment.

within the top few feet of the soil. Vegetation is not applied in systems of this kind. The RI system is designed to meet several performance objectives including the following:

- Recharge of streams by interception of groundwater;
- Recovery of water by wells or underdrains, with subsequent reuse or discharge;
- Groundwater recharge;
- Temporary storage of renovated water in the local aquifer.

The water is release to the land at higher rates by spreading in basing and allow to treatment of water when it move through the soil matrix by percolation. This system is most suitable for high permeable soil and need good natural or constructed drainage. The annual loading rate may be varying from 3.0 to 150.0 m/yr. Availability of vegetation cover is not a component of this system. At the end of the RI process BOD, suspended solids, and faecal coliforms are almost removed. Table 5 shows the applicable design criteria for rapid infiltration system along with its indicative diagram in Figure 2.

Overland flow

Overland flow (OF) is a treatment process in which waste-water is treated as it flows down through a system of vegetated sloping terraces where waste-water is applied intermittently to the top portion of each terrace and flows down the terrace to a runoff collection channel at the bottom of the slope as shown in Figure 2. Application techniques include high-pressure sprinklers, low-pressure sprays, or surface methods such as gated pipes used with relatively impermeable surface soils in which infiltration through the soil is limited in contrast to SR and RI systems [7]. The effluent waste-water undergoes a variety of physical, chemical and biological treatment mechanisms as it proceeds along surface runoff path. Overland flow systems can be designed for secondary treatment, advanced secondary treatment or nutrient removal, depending on requirements.

Over flow is a biological treatment process. This system is suitable for relatively impermeable soil. BOD and Suspended Solids are removed by the process of Biological Oxidation, Sedimentation, and Filtration. Removal mechanisms for Nitrogen (typically removes 75% to 90%) are Plant uptake, Denitrification and Ammonia volatilization. Effluent is collected in to drainage and can be reused or discharged to a surface water body. The schematic diagram of over flow land treatment is shown in Figure 3 below.

Process Design

Hydraulic loading rates based on soil permeability

Hydraulic loading rates should be within measured soil capabilities. Loading is to be based on a water balance that includes precipitation, evapotranspiration, and wastewater percolation. The total monthly loading should be distributed uniformly, taking into consideration planting, harvesting, drying and other periods of no application.

The basic steps in the procedure are as follows:

- Determine the design precipitation for each month based on a 10-year return frequency analysis for monthly precipitation.
- Estimate the evapotranspiration rates (ET) of the selected crop for each month.
- Determine the overall saturated vertical hydraulic conductivity of the site using the soil evaluation.
- Establish a maximum daily design percolation rate that does not exceed the designed rate of the overall saturated vertical hydraulic conductivity measured at the site, taking into consideration suggested hydraulic loading rates based on soil morphology.

- Calculate the monthly hydraulic loading rate using the following equation:

$L_{W} = E_t - P + W_p$

Lw = Wastewater hydraulic loading rate, inches per month.

P = Design precipitation, inches per month.

Et = Evapotranspiration (or crop consumptive use of water), inches per month.

Wp = Percolating water, inches per month (use a percentage of the minimum saturated vertical hydraulic conductivity).

• Calculate the loading rates for each month with adjustments for those months having periods of non-application. Periods of non-application may be due to wet weather, cold weather, vegetation management or maintenance.

Hydraulic loading rate based on nitrogen limit

Nitrogen management for the SRI process principally involves crop uptake with some denitrification. Aerobic nitrification involves the breakdown of organic nitrogen to ammonia and ammonium. Through the action of bacterial organisms such as *Nitrosomonas*, the ammonium ion is broken down to nitrite-nitrogen. This is further broken down through the action of *Nitrobacter* bacteria to nitrate-nitrogen. Denitrification involves the biological reduction of nitrate to nitrite and finally nitrogen gas [8]. Such biological denitrification requires bacteria (*Pseudomonas, Micrococcus, Bacillus,* and *Acomobacter*), anoxic conditions and a source of organic carbon.

The following procedure should be used to determine wastewater loading rates when nitrogen concentration in the groundwater is a concern.

- Calculate the allowable monthly hydraulic loading rate based on nitrogen limits and monthly design flow information using the following equation:

$L_n = (Cp)\ (Pr - E_t) + (U)\ (4.413)/((1\text{-}f)\ (C_n)\text{-}\ C_p)$

- Ln = Wastewater hydraulic loading rate, in/month.
- Cp = Nitrogen concentration in percolating water, mg/L.
- Pr = Precipitation rate, in/month.
- Et = Evapotranspiration rate, in/month.
- U = Crop nitrogen uptake, lb. /acre month.
- Cn = Nitrogen concentration in applied wastewater, mg/L.
- f = Fraction of applied nitrogen removed by denitrification and volatilization.
- Compare the value of the hydraulic loading rate based on nitrogen to the hydraulic loading rate based on the saturated vertical hydraulic conductivity of the soil for each month of the year.
- After the appropriate loading rate is determined, the area of the absorption field can be calculated.

Storage requirements

The storage area should be calculated based on the minimum storage requirement for all land treatment systems that distribute wastewater effluent onto the ground surface. Local climatic records as well as nationally available climatic data, should be evaluated to estimate the number of days each month wastewater will not be applied to the site due to weather conditions. Wastewater should not be applied if any of the following site conditions exist:

- Amount of snow on the ground is greater than one inch.
- Rainfall in the previous 24-hour period exceeds one half inch.
- Soil temperature measured one inch below the soil surface is less than 32°F.

Phosphorus removal

Phosphorus is removed from solution by fixation processes in the soil, such as adsorption and chemical precipitation. Removal efficiencies are generally very high for slow rate systems and more dependent on the soil properties than on the concentration of phosphorus applied. Phosphorus retention can be enhanced by the use of crops such as grass with large phosphorus uptake. Field determination of levels of free oxides, calcium, aluminium, and soil pH will provide information on the type of chemical reaction that will occur. Determination of phosphorus absorption capacity of the soils requires laboratory testing of field samples [9]. Systems with strict phosphorus limits in the percolate should include monitoring for nutrient soil phosphorus to verify retention in the soil.

Removal of trace elements and other parameters of concern

The concentrations of trace elements and other parameters of concern vary significantly, depending on wastewater characteristics. Trace elements include metals, pesticides, volatiles, and acid extractable and base neutral organics. Trace element assessments are necessary to assure that levels will not be toxic to cover vegetation or impair groundwater quality. In some cases, where applied concentrations of trace metals are excessive, it may be necessary to maintain soil pH at 6.5 or higher.

Other constituents of concern include greases, emulsions, and salts [10]. These may clog soils, plug nozzles, coat vegetation, be persistent or non-biodegradable/non-exchangeable with soil materials, or be toxic to vegetative cover. Effluent that exhibits these properties should not be applied to the land surface.

Microorganism removal

The potential for public health risks from microorganism contamination as a result of land treatment of wastewater varies greatly depending upon site-specific conditions. The factors include type of application, pre-application treatment, and public access to the site, population density, adjacent land use, climate, type of on-site buffer zones, and type of vegetative cover. The evaluation of these variables should be done to achieve the goal of minimizing public health risks from land treatment of wastewater. All wastewater that contains pathogens must be disinfected prior to application

Conclusion

Land treatment of waste water is economically viable and easy to handle. Such a treatment restricts waste water to be discharged into rivers, lakes, and water bodies thus prevent them for being polluted. It also prevents ground water to pollute in case of indiscriminate discharge of waste water on land. Waste water is a resource and usable and should not be considered as a waste and in this context Land Application as specified in paper can be treated as usable resource management. Its applicable where sufficient land is available and water scarcity exists particularly in the state of Rajasthan and other such areas. It will not have negative impact if recommended hydraulic loadings on a specified soil is applied. Its application domestic waste water is recommended along with some industrial waste waters of easily biodegradable in nature. However, more research in this area needs to be taken.

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