SOIL BIOTECHNOLOGY FOR THE TREATMENT OF WASTEWATER : A REVIEW

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Abstract : Treatment process of water and wastewater and also its reuse for domestic, agricultural or industrial purposes, helps to conserve and to enhance water in both quality & quantity. Green technologies nowadays provide good water quality without contributing to global warming. There are various conventional treatment technologies which are effective in removing various pollutant and impurities from wastewater but required many external sources, manpower and pumping system and also required more maintenance and operation cost. Due to many problems in conventional treatment technologies, Soil Biotechnology (SBT) was bring into operation to achieve pollution free environment for both municipal wastewater and industrial effluent. The present study reviews about the SBT that it is a system for water treatment which consists of soil, formulated granular filter media and selected culture of macro and micro organisms such as earthworms. The sludge is not formed at the end of the process and useful vermi compost is being generated.

Index Terms- **Wastewater, Green technologies, conventional treatments, Soil Biotechnology, Earthworms.**

I. INTRODUCTION

The availability and quality of water resources is one of the major environmental challenges facing the increasing demands of domestic and industrial sectors of India [Saravanane 2014]. Water is made up of two main components i.e. two molecules of hydrogen and one molecule of oxygen. These components are not generally found in pure water therefore they may be considered as impurities. In potable water also there are many such impurities present which we drink day to day in our life. Almost 71% of earth's surface is covered by water, out of which only 2.5% of fresh water is available on surface. Rapidly growing of industrialization and population, all releases huge amount of wastewater which in return is utilized as a valuable source for irrigation in urban and pre-urban agriculture and is also significantly contributing to human welfare nowadays and eradication of natural resources around the world [Mohammadreza Kamali. 2019]. There are various laws and regulations made for proper usage of water and for discharging it into the natural water bodies. The characteristics of wastewater and how it is to be properly treated can be known from its source. For example, wastewater from homes and businesses (domestic wastewater) typically contains pollutants such as; faecal and vegetable matter, grease and scum, detergents, rags and sediment. On the other hand, wastewater from an industrial process (industrial effluent) may include; toxic chemicals and metals, very strong organic wastes, radioactive wastes, large amounts of sediment, high temperature waste or acidic/caustic waste. Wastewater could even come from streets and parking lots during a rainstorm (storm wastewater) that could contain; motor oil, gasoline, pesticides, herbicides and sediment [Moran 2018].

The most important challenge for the treatment of wastewater in to select the appropriate the technology for the treatment. Factors like capital cost, operation and maintenance costs, and land requirements are few important factors that are to be kept in consideration while selecting of the technology. It is also necessary to develop a decision-making framework that incorporates sustainability indicators to help developing countries, such as India, in selecting the appropriate technologies for wastewater management. The concept of appropriate technology (AT) was introduced by E. F. Schumacher, a British economist, in his famous book "Small Is Beautiful". The definition of AT expands on the conventional concept of appropriateness and suggests that AT is always contextual and situational. Thus it has become important to protect water from getting polluted or to develop cost effective technologies [Kalbar, 2012]. The two major chemical pollutants in water is nitrogen and phosphorus. Although there are many other chemical pollutants present in water such as heavy metals, detergents, pesticides, insecticides, nitrogen, phosphorus are the main or the most frequent limiting nutrients in eutrophication which are harmful. The various conventional treatment technologies are present from ancient times but are many costly and are not at all economic [P. Rajasulochana, 2016].

II. Wastewater Technologies:

To treat wastewater is for purpose of reducing or eliminating the problem of pollution on receiving water bodies. The degree and type of pollution is related to the type of waste discharged. Waste discharges can be categorized into two broad categories: organic wastes and inorganic wastes.

Organic Wastes are those substances that contain the element carbon and are derived from something that was once living. Examples include: vegetable and faecal matter, grease, proteins, sugars and paper.
Inorganic Wastes are those substances that do not contain carbon and are not derived from something that was once living. Examples include: metals, minerals, salts, acids and bases.

In recent years, a number of technologies have been made available, especially using biological treatment methods for sewage wastewater and industrial effluent such as Membrane bioreactor (MBR), Fluidized aerobic bed, Fluidized aerated bed reactor, Submerged aeration fixed film reactor, Biological filter oxygenated reactor, Anaerobic filter, Expanded granular sludge blanket, Sequencing batch reactor, Up-flow anaerobic sludge blanket (UASB), etc [Saravanane 2014].

There are various types of options that can implement for treatment, reuse and recovery of wastewater. Nowadays natural treatment technologies are becoming more effective at a particular level by environmentalists. These technologies are considered feasible because they have low capital costs, they are easy in maintenance, have longer life-cycles and have great ability to recover a variety of resources which includes treated effluent for irrigation, organic humus for soil amendment and energy in the form of biogas [Jayshree Dhote, Sangita Ingole and Arvind Chavha, 2012]. There are various types of industrial effluent treatment processes. In total three types of treatment process that are aerobic, anaerobic and combination of both processes. He concluded that anaerobic treatment was one of the best among various treatment technologies. If the treatment plant is bigger, aerobic treatment like trickling filter, stabilization ponds and activated sludge process can be used in combination which in turn proves to be the economical treatment for the effluent. The frequently used anaerobic digester for treating complex organic solid waste like sludge generated from primary and secondary wastewater [David Moses Kolade, 2016].

The variety of chemicals such as biocides and stain repellents used in industry for softening, brightening, ant creasing, sizing, and wetting of the fabric or yarn. These chemical are present in wastewater. High concentrations of dyes can cause water borne diseases and increase BOD of receiving waters. The pH was controlled by adding either strong acid (HCl) or strong base (NaOH). The quantity of wastewater from textile industries has been increasing together with growing demand for textile products. The release of textile industry wastewater into the environment can cause serious health and environmental problems [M. A. Boda, S. V. Sonalkar, M. R. Shendge, 2017].

III. Natural Technologies for Wastewater Treatment:

The high cost of some conventional treatment processes has produced economic pressures and has caused engineers to search for creative, cost effective and environmentally sound ways to control water pollution. Application of ecological principles is found to be effective in treatment of wastewater. One technical approach is to construct artificial ecosystems as a functional part of wastewater treatment. The high cost of some conventional treatment processes has produced economic pressures and has caused engineers to search for creative, cost effective and environmentally sound ways to control water pollution. Application of ecological principles is found to be effective in treatment of wastewater. One technical approach is to construct artificial ecosystems as a functional part of wastewater treatment. There are two categories of aquatic treatment systems:
1. Natural Wetlands
2. Constructed Wetlands [Samar Kamtekar, 2016]

Constructed wetlands (CWs), also known as treatment wetlands, are engineered systems that are designed and constructed to improve water quality with relative low external energy requirements and easy operation and maintenance. Thus, CWs have been set up all over the world as an alternative to conventional mechanical systems for treatment of wastewater from small communities [wu, 2015].

Constructed wetland has been used for Grey water and domestic wastewater treatment. It utilizes wetland plants, soils, and their suitable microorganisms to suits natural wetland ecosystems processes for the treatment of wastewater. As the wastewater flows through the bed, it gets treated through natural processes; pollutants in the wastewater are mechanically filtered, chemically transformed, and biologically consumed. With respect to the direction of wastewater flow constructed wetlands are divided into reed beds, also known as horizontal flow constructed wetlands (HFCW), and vertical flow planted gravel filters (VFPGF), also referred to as vertical flow constructed wetlands (VFCW) [Samar Kamtekar, 2016].

According to Oren Shelef, Amit Gross and Shimon Rachmilevitch, the plants have a generally positive effect on wastewater treatment in CWs, the practical planning and maintenance of plantations is still premature as there is some lacking in the appropriate knowledge to direct these endeavours. The recommendation given by few scientists were (1) concentrating on specific species and their mechanisms in CW dynamics and (2) in practice, use of plants should be done appropriately. Such a plan should include choosing the species, their composition, the order of planting and their spatial arrangement, as well as the practice of a harvest plan. The use of CW plants for commercial purposes should also be taken into considerations. These new perspectives expand the potential use of plants in CWs and add more factors to consider when planning vegetation and management practices for CWs [Oren Shelef, Amit Gross and Shimon Rachmilevitch, 2013]. Oxidation pond is one of the best treatment options in terms of BOD removal efficiency, energy consumption and cost effectiveness but it also had some disadvantage of emission of foul odors, large land requirements, breeding place for mosquitoes. The treated effluent through oxidation pond can be further used for agricultural purposes and recreational activities. The main economic advantage is methane generation treatment as well as the generation of bio- fuel obtained from the regular harvesting of plants of wetlands [Nadeem Khalil, Umer Mujtaba Khan 2017].

According to suggestion given by I.H. Farooqi, Farrukh Basheer and Rahat Jahan Chaudhar, the removal of pollutants in constructed wetland type of systems relies on a combination of physical, chemical and biological processes that naturally occur in wetlands and are associated with vegetation, sediment and their microbial communities. Subsurface flow system - create subsurface flow keeping treated water below the surface. Free water surface systems-simulate natural wetlands, water flowing over the soil surface. Constructed wetland is one of the effective treatments for the wastewater [I.H. Farooqi, Farrukh Basheer and Rahat Jahan Chaudhar, 2016]. The CW is of great potential for the treatment of wastewater. These systems consist of beds or channels which have been planted with helophytes, which rely upon physical, chemical and biological processes to remove contaminants from wastewater. CWs are generally classified into two categories: surface flow and subsurface-flow. CW can efficiently remove variety of inorganic, organic and biological contaminants from domestic and industrial wastewaters. Helophytes and microorganisms are the active agents in the treatment process. Reduction in faecal Coliform populations was reported up to 99% by CW [Ashutosh Kumar Choudhary, Satish Kumar and Chhaya Sharma 2011].

IV. Decentralized water management:

Due to increasing population the natural resources are exhausting which destroys the wastewater reuse planning and emphasizes on the decentralized wastewater treatment, especially in rural areas where high cost wastewater collection and treatment does not permit the conventional sewage treatment plants. Decentralized wastewater treatment involves the collection, treatment, disposal and reuse of water from individual homes, clusters of homes, isolated communities at or near the point of generation. Vermifiltration has great potential to reduce the pollutants from wastewater. In vermifiltration, the earthworm's body act as a bio-filter and extends the microbial metabolism by increasing their population. The resulting effluent becomes highly nutritive and can be reused for irrigation purposes. Earthworms have characteristics of decomposing and are waste eaters. They promote the growth of beneficial decomposers bacteria and biological simulator. The two processes- microbial process and vermi process simultaneously work in the treatment of wastewater using earthworms. Earthworms further simulate and accelerate microbial activity by increasing the population of soil microorganisms and also through improved aeration [Renu Bhargava].

Decentralized Wastewater Treatment Systems (DEWATS) is rather a technical approach than merely a technology package. In general, DEWATS are locally organized and people-driven systems that typically comprise a settler, anaerobic baffled tanks, filter beds of gravel and sand, and an open pond. The open pond or the polishing tank recreates a living environment for the wastewater to clean itself, naturally.

The system operates without mechanical means and sewage flows by gravity through the different components of the system. Up to 1,000 cubic meter of domestic and non-toxic industrial sewage can be treated by this system. DEWATS applications are based on the principle of low-maintenance since most important parts of the system work without technical electrical energy inputs and cannot be switched off intentionally [DEWATS DELHI]. Wastewater management includes wastewater collection, transport, treatment and reuse or disposal. Wastewater management in India has mainly focused on centralized approaches. Although this approach allows for the treatment of greater quantities of wastewater and consequent economies of scale, it has numerous drawbacks. A centralized approach incurs high capital and operation and maintenance costs. It also requires skilled manpower in order to ensure sustainability

V. Soil Biotechnology:

Soil Biotechnology (SBT) is a process for processing of organic and inorganic matter. In these system fundamental chemical reactions of nature such as respiration, mineral weathering and photosynthesis takes place. As per carbon cycle, water supports around three to four billion tons live carbon while soil and land support 800 billion tons live carbon. Life evolved in water two billion years ago but moved out on to land impelled by the thermodynamic logic - that life longs for itself and evolution is about minimizing energy needs - that it takes roughly 500 kJ/g live carbon per year to support life in water, 26 kJ/g live carbon per year in soil compared to 3 kJ/g live carbon per year on land. But conventional waste processing uses water as medium contrary to the design of carbon cycle. So in SBT, processing is carried out in soil. In SBT, respiration serves to bring about oxidation of organic and inorganic and thereby substantially reduce oxygen demand, mineral weathering serves to regulate the environment to enable these reactions to occur at the desired rates while photosynthesis serves as a bio-indicator of process performance. In warm climates the system is open to atmosphere while in very cold climes suitable closures may be needed. If space is a limitation then multi-staged bioreactor system (bio tower) can be used. [Umesh Yeole].

"*SBT is a wastewater treatment process, which is based on a bio-conversion process where fundamental reactions of nature, namely respiration, photosynthesis and mineral weathering take place in a media housing micro & macro organisms which bring about the desired purification. SBT is an oxygen supplying biological engine and so the process can treat all types of water – domestic, municipal and industrial*" (Vision Earth care, 2013).

Since then, SBT has been installed in more than 20 locations, treating wastewater volumes between 5-10 MLD in industries, housing societies, resorts, schools, universities, ashrams, hotels and municipal corporations.

These are part of the process that cleans organic waste through oxidation and releases carbon dioxide. Nitrification followed by de-nitrification convert the nitrogen load in the wastewater to elemental nitrogen gas. Primary minerals, which form the base media in the bioreactors within which the purification processes take place, create a pH buffering effect. Whilst earthworms serve to aerate and regulate bacterial populations, trees and shrubs planted on the surface of the bioreactor act as bio-indicators to signal a properly functioning plant. SBT houses an engineered ecology of formulated media containing selected micro and macro organisms such as geophagus earthworm *Pheretima elongate,* bio indicator plants. Bioconversion takes place by bacterial processing of organics and in-organics wherein geophagus worms regulate bacterial population. It contains media, culture and additives. COD, BOD, suspended solids, colour, odour, bacteria, and coliforms are removed all in a single all green facility open to atmosphere. It is unlike land treatment which is space intensive and unlike constructed wetlands which engages aquatic ecology [SBT manual]. SBT is an oxygen supplying biological engine and so the process can treat all types of water – domestic municipal & industrial. CAMUS-SBT is suitable for treating water with salinity <2500 mg/L. For higher salinity special designs are available [Prof H S Shankar].

5.1 Suitability of macro or micro-organisms:

The mass production of earthworms in waste material has been termed as vermiculture and the valorisation of waste material by earthworm technology is known as vermicomposting [Bhatt, 2018]. Vermifiltration of wastewater using earthworms is a newly conceived technology. Earthworm's body works as a biofilter and they have been found to remove the 5 days BOD, COD, total dissolved solids (TDS), and the total suspended solids (TSS) from wastewater by the general mechanism of ingestion and biodegradation of organic wastes, heavy metals, and solids from wastewater and also by their absorption through body walls. In vermifiltered, the earthworms facilitate up the microbial activity by increasing the population of soil microorganisms [186-190]. Vermi compost behaves as a strong buffer and natural adsorbent for reducing transition metals, Biological oxygen demand (BOD) and chemical oxygen demand (COD) from industrial effluents. Column studies provide the most practical application in the treatment of industrial effluent. The solution continuously enters and leaves the column so that complete equilibrium is never established at any stage between the solute in solution and amount adsorbed [Singh, 2015].

From around 600 million years earthworms are being used for the treatment of wastewater and in protecting the environment. Charles Darwin called them as the "unheralded soldier of mankind", and the Greek philosopher Aristotle called them as the "intestine of earth" which means digesting a wide variety of organic materials including the waste organics from earth [Samal, 2018]. Earthworms are long, cylindrical, narrow, bilaterally symmetrical, segmented animals without bones. The body is dark brown, glistening, and covered by all of delicate cuticle. They weigh around 1,400–1,500 mg after 8–10 weeks. On an average, 2,000 adult worms weigh 1 kg and one million worms weigh approximately 1 ton. Usually the life span of an earthworm is practically 3–7 years depending upon the type of species and the ecological situation. Earthworms nourish millions of nitrogen-fixing and decomposer microbes in their gut. They have chemoreceptors which help in search of food. The distribution of earthworms in soil depends on factors like availability of organic matter, soil moisture and pH of the soil. They develop in different habitats especially those which are dark and moist [186-190].

The earthworms are tireless tillers of our soils and their castings are richest and best of all fertilizers. They are very useful in treatment of wastewater as well as sludge. They are also useful for treatment of waste water from industries as well as domestic and residential sewage. Their removal efficiency is about 80-90% for BOD and 70-80% for COD. They stabilized organic matter and converted to stable product. Among all earthworms *Eisenia Fetida* is best suited for treatment of waste water from different fields [Himanshu Gupta, 2015].

5.2 Physical Structure of SBT:

The physical structure of SBT basically consists of raw water tank, a bioreactor type structure, a treated water tank and pumping equipments and its electrical installations only if required. The process is meant to handle domestic sewage and industrial sewage containing primarily organic effluent. Treated water quality of various levels can be obtained, from river discharge quality up to near drinking-water quality, from an SBT depending on the requirement and investment potential.

5.3 Components:

a. Media: It is formulated from soil with primary minerals of suitable size and composition.

b. Culture: Geophagus worms (*Eisenia Fetida*), nitrifying and denitrifying organisms and bacteria capable of processing cellulose, lignin, starch, protein and anaerobic bacteria for Methanogenesis. The bacterial culture is extracted from excreta of ruminant animals.

c. Additives: Formulated from natural materials of suitable particle size and mineral compositions to provide sites for respiration and CO2 capture.

d. Plants: Green plants particularly with tap root system act as bio-indicators and add aesthetic value.

e. Under drain: Stone rubble of various sizes ranging from fine sand to gravel.

5.4 Treatment Process:

The wastewater is first collected in a holding tank after which it is pumped into a trapezoidal-shaped bioreactor. The bioreactor is constructed by excavation and made waterproof. The under drain is laid at the base. The tank is then filled with layers of media and culture. The surface of the bioreactor contains rows of plants. A network of perforated pipes is constructed on the surface that spreads the incoming wastewater evenly over the surface of the bioreactor. Another set of pipes is also laid vertically extending into the bioreactor for aeration.

Water is pumped over the bioreactor through the perforated pipe network and begins to trickle down the filtering media. The suspended solids in the wastewater are held back by the top media. As the water seeps through the rest of the layers, dissolved pollutants are removed, and finally treated water passes through an outlet at the bottom of the tank and is collected in a treated water storage tank constructed alongside. If required, recirculation pumps can be added to transport the water back into the bioreactor. This creates a second round of purification, obtaining the desired hydraulic retention and improved output water quality to the desired level. Shrubs and trees are planted on top of the bioreactor to act as bio-indicators, organisms used to monitor the health of the environment. In this case the growth of these plants will determine their ecological health thereby indicating the quality of the recirculated water [Arghyam, 2013].

5.5 Schematic diagram of SBT Process:

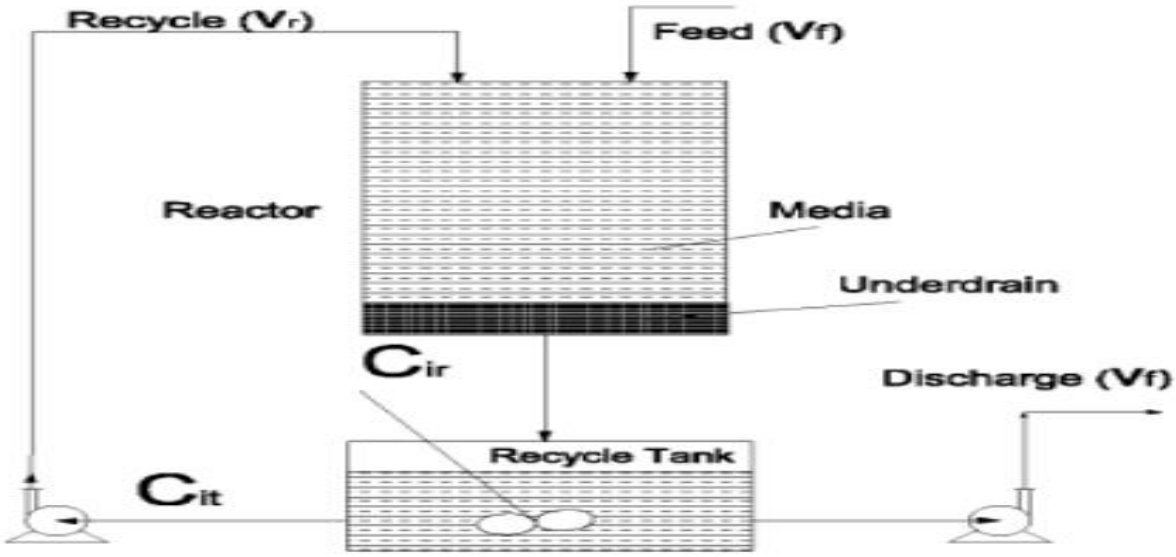

Figure 1: Schematic of experimental setup of SBT, where C_{ir} is the concentration of species at the exit of reactor, C_{it} is the concentration of species in recycle tank.

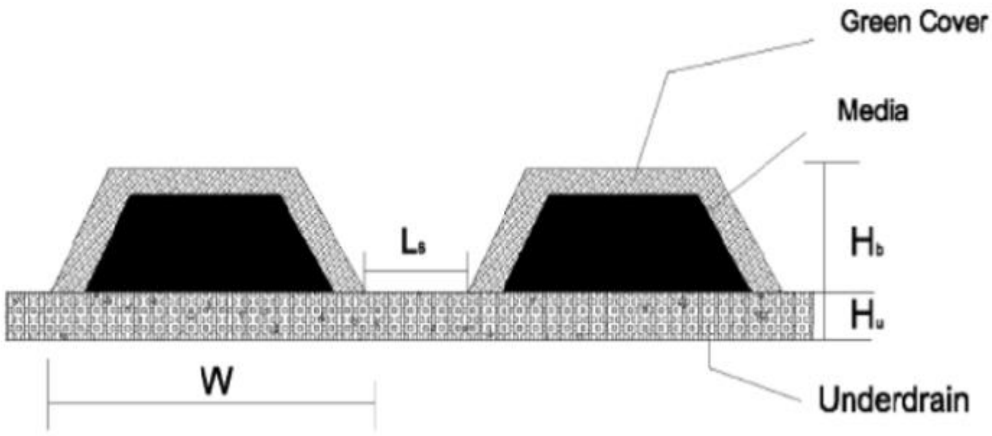

Figure 2: Schematic of cross section at field SBT, where W is the width of the media strench, H_b is the height of media; H_u is the height of under drain.
[Source: Umesh Yeole]

5.6 Salient features:

- The technology has the capacity to reduce rates of Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD),
- Total Suspended Solids (TSS), Turbidity, Nitrogen and Phosphorus.
- Tunable output quality

- No odour
- Very low energy use intensity due to high Natural oxygen transfer in process. (0.06 kWh/kL sewage).
- Very low space intensity of 0.8-1.0 sq.m/kL per day sewage.
- An engineered evergreen natural process with no moving parts except for pumps.
- No sludge due to ecology at work.
- Very high bacteria, BOD, COD, suspended solids, colour, odour, ammonia removal.
- Practically maintenance free.

5.7 Applications:

- Sewage treatment for reuse in construction, cleaning & gardening, ground water recharge, makes up water for swimming pools & industries etc
- Industrial wastewater treatment,
- Industrial air purification
- Applicable for societies, buildings, hospitals, commercial buildings, etc.

VI. Conclusion and Discussion:

From the literature surveyed it can be said that Soil Biotechnology is one of the environment friendly technology. SBT is having very high potential in minimal requirement of power; Power is needed only when pumping system is required to pump water in and out of the reactor. This requirement can be reduced further if the water is allowed to flow by gravity. Further, the plant does not require uninterrupted operation and is meant to be run for a few hours a day. Thus SBT is a strong technology where uninterrupted power supply is problematic or not possible. Also for operating SBT skilled manpower id not required.

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