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LOW COST AND ENERGY SAVING TECHNOLOGIES FOR WATER AND WASTEWATER TREATMENT

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Key words :

ABSTRACT

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INTRODUCTION

Safe collection, treatment and disposal of wastewater in developing countries are a major challenge before planners. The inherent drawbacks of end-of-pipe conventional technologies for wastewater treatment have led to serious thinking on alternate, low cost, natural and energy saving technologies on water treatment. Considerable research is going on all over the world in this area. Present talk shall focus on many of these technologies. The spectrum of these technologies is very wide starting from simple waste stabilization

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ponds to land application of industrial wastes, UASB, root zone technology, vermifiltration to recently developed living machine. Most of these technologies excluding vermifiltration and UASB shall be discussed in this talk. A brief over view of these promising systems is described here.

Waste stabilization ponds

Considered among the most primitive technologies for wastewater treatment, the waste stabilization ponds or oxidation ponds can deliver excellent results if operated in ideal conditions. According to WHO (1987), These ponds offer a low cost method for the developing world as construction and operational cost are low and they place no strain on technical resources or labour. Since the released effluent can be used directly for irrigation in semi-arid and other water scarce region, they should be ideal choice for developing world (Mara & Pearson, 1998). Not only a high degree of BOD & SS removal is obtained but excellent reduction is also obtained in pathogen removal, which is attributed to high pH and UV radiation

Following types of oxidation ponds are in operation (Rose, 1999)

Type	Characteristic features
Facultative Treatment Ponds	Large shallow ponds to retain wastewater for several days surface loading 100-400kg BOD/ha/d
Anaerobic Ponds	Deep ponds devoid of dissolved oxygen surface loading >3000kg/ha/d for a depth of 3m
Aerated Facultative Pond	They are small in surface area, mechanical aerators supply oxygen, which increases treatment efficiency and reduces land requirement.

Waste stabilization ponds can attain 99.99% faecal coliform reduction and are capable of attaining a 100% removal of helminthes, thus facilitating the recovery of wastewater for irrigation.

Some advancements have recently been made in stabilization pond technology like Zhas & Wang (1996) have used an attached growth media in stabilization ponds and found them to be increasing the number of total biospecies in the system and total hydraulic retention time was also reduced to just 7.5 days.

Advanced integrated ponds system (Mara and Pearson, 1998) is a 4-5 m deep facultative pond containing a digester pit which functions much like an anaerobic pond, but in this case within the facultative pond rather than preceding it. The facultative pond effluent is discharged into a stirred high rate pond, and thence into maturation ponds for biological disinfections. Recirculation of some of the high rate pond contents back to the surface layers of the facultative pond ensures odourless conditions in the latter.

The factors which affect stabilization pond performance are fluctuation in wastewater characteristics like radiation, light and temperature, algal growth

patterns and their diurnal and seasonal variations, bacterial growth patterns and decay rates, hydraulic transport patterns, evaporation and seepage, solid settlement, upward diffusion and sludge accumulation, gas transfer at interface etc.

Duckweeds

Duckweeds are very small sized angiosperms with a leaf like frond, a few millimeters in width and short root, usually less than a centimeter in length. Trivedy (2000) has described application of duckweeds in wastewater treatment. A lot of interest is recently generated in duckweeds as efficient wastewater treatment macrophytes. Duckweeds can be preferred under certain conditions over water hyacinth due to profitable post harvest uses. According to Oron (1994) duckweed value in terms of protein content is similar to soybean at US $0.20/kg (1990 figures). If grown on domestic wastewater free of heavy metals, duckweeds can be used as animal fodder and green fertilizer. According to Zirschikly and Reed (1988) duckweeds have superiority over water hyacinth in TSS reduction and nutrient removal. In duckweeds the nutrients are absorbed by plant biomass and are removed by harvesting. Algal growth is suppressed by duckweed because of competition for both sunlight and nutrients but allelopathic killing of algae can also not be ruled out.

Unlike water hyacinth, the plant uptake of metals has been reported to be less in these systems. Rose (1999) have reported 90-99% reduction in BOD and COD. 74-77% reduction in TKN and phosphorus levels at a BOD loading rate of 80-90 kg BOD/m2/day. Skilicorn *et al*. (1993) where the wastewater generated by Kumandini Medical complex in Mirzapur is treated in a 0.793 ha area. The project is undertaken by PRISM- Bangladesh by using *Lemna* where 0.5 million liters of raw sewage is treated in a 0.7 ha duckweed system. The primary treatment is carried out in a waste stabilization pond (24 hrs. detention), followed by secondary treatment and tertiary treatment by duckweeds where most of the organic pollutants and nutrients are removed. The treated wastewater from this system is directed to three fish production ponds of 0.2 ha each. Almost complete removal of pathogens was observed in this system.

Similarly, the green gold corporation (www.ntrnet.net) has developed an integrated system of aquaculture and wastewater treatment. Here a helical production unit for duckweeds is installed, the wastewater flows through the channels with a continuously harvested duckweed system. The duckweeds are harvested daily to produce a continuous crop of protein rich duckweed plants for animal feed

The Mysara project of Jordan (Rose 1999) is also an ideal example of recycling the waste for profitable uses. Canadian International Development Agency (CIDA) have identified Jordan for a pilot project where the trucked sewage from the community shall be first treated in UASB reactors followed by duckweed technology for recovery of nutrients. The treated waste is used to produce terrestrial crops and use the recovered duckweeds as fodder in the production of poultry, sheep etc.

The Living Machine

A living machine system was tried in University of Waterloo, Canada. The aim was to develop an onsite wastewater treatment system for a part of University building with an objective of not only reducing the load on centralized wastewater management facility but also to create an aesthetically pleasant environment near the university building. A living machine uses mainly bacteria but also employs other organisms such as plants and gastropods to aid in the mineralization and removal of contaminants from water.

The first stage is an anaerobic tank; the sludge from here is removed and used in agricultural operations. The second stage is a closed aerobic reactor. Pumps are used tom bubble air through the tank to maximize oxidation, which decreases BOD. In the tank aerobic bacteria convert ammonia to nitrates in the process of nitrification. Gases may escape from the water at this point and are absorbed by the plants at the surface of the water. The third stage is the most aesthetically pleasing and generally receives the most public attention and educational endorsement (Living Technologies Ltd. 2004). Plants, bacteria, fish, snails and other aquatic organisms are present in the third stage. These organisms either help to clean the water or act as a substrate for bacterial growth as bacteria continue to breakdown the organics.

A number of living machines are in use in Europe and U.S.A. since 1995. There is no standard design of a living machine. Its characteristics are almost completely determined by the treatment needs and requirements of the clients. Many workers have put many extras, e.g. an anoxic tank between the aerobic and anaerobic tank. In many cases the final effluent is polished by a constructed wetland. A number of floating, submerged and emergent plants are used in the living machine including water hyacinth. However, their population is to be maintained and these plants should cover not more than 70% area of the ponds. Numerous animal species are also part of living machine. Common fish used in the living machine are goldfish.

ROOTZONE TECHNOLOGY

Root zone technology is an emerging cleanup technology for wastewater treatment, The technology can be defined as engineered use of green plants, including grasses and woody species to remove, to contain, or to render harmless the various environmental contaminants in the soil or water. Trivedy (1997, 2000) has discussed the technology in detail.

This technology incorporates all plant-influenced biological, chemical and physical processes that aid in uptake, sequestration, and metabolism of contaminants, either by plants or by free-living organisms that constitute the plants rhizosphere. Root zone technology takes the advantage of the unique and selective uptake capabilities of the plant root system, together with the translocation, bioaccumulation and contaminant storage/degradation abilities of the entire plant body.

The concept of root zone technology is based upon the well-known ability of plants and their associated rhizosphere to concentrate and/or degrade highly dilute contaminants. Certain wetland plants have nature's gift of a bio pump. Their leaves and stems absorb oxygen from the atmosphere and transfer them down through their hollow stems and roots. The tender portions of the roots, through their weak membranes, transfer this oxygen to the soil. The oxygen thus released is very active and is available for microorganisms in the soil to thrive and multiply. If the effluent containing organic matter is passed by percolation through this zone, the bacterial population consumes this organic matter and purifies the effluent. This action goes on in natural wetlands, but less efficiently.

Root zone technology system is actually an engineered effluent treatment plants. Plants transpire water to move nutrients from the soil to leaves and stem, where photosynthesis occurs. During this process the contaminants present in the soil are also taken up, sequestered, metabolized or vaporized out of the leaves along with the transpired water. Some plants that's are notoriously poor at water conservation, because they grow in moist environments, can considered to be good candidates for the root zone technology as they take up and process large volumes of water. For example, a single willow tree, on a hot summer day transpires about 19000 liters of water, and one hectare herbaceous plants transpire as much as 8000 liters of water.

Root Zone Treatment Systems are planted filter beds consisting of sand/gravel/soil. The Root Zone Treatment System uses a natural way to effectively treat domestic & industrial effluents. This Technology originated in Germany but was developed in 1970's is successfully running in different countries, mainly in Europe, India and America. The process incorporates the self-regulating dynamics of an artificial soil eco-system.

The term 'Root Zone' encompasses the life interactions of various species of bacteria, the roots of reed plants, soil, sun and water. They are also known as constructed wetlands or sub-surface flow systems. In this system, these plants conduct oxygen through their stems into their root systems and create favorable conditions for the growth of bacteria. The wastewater flow through the root zone in a horizontal or vertical way where the organic pollutants are decomposed biochemical by the bacteria present in the rhizosphere of root plants .The filter media are selected carefully to provide favorable conditions for both plants & bacterial growth and to avoid clogging. Organic pollutants are removed drastically from wastewater and are reduced to their elemental forms.

Theoretically there are over 400 wetland species, which can be used for wastewater treatment, however following species, have been successfully tried

- Phragmites australis (reed)
- Phragmites Karka (reed)
- Arundo donax (Mediterranean reed)
- Typha latifolia (cattail)
- Typha angustifolia (cattail)
- Iris pseudacorus
- Schoenopletus lacustris (bulrush)
- Scirpus Lacustris

ADVANTAGES OF ROOT ZONE TREATMENT SYSTEMS

1. RZTS is a decentralized wastewater treatment facility and can be set-up within the premises of residential areas and colonies no unhygienic condition created. Sanitation of even single house is also possible.
2. Removal of bacteria and parasite is very effective, recycling and reuse of wastewater for secondary purposes (toilets, gardening) can be done effectively, especially in the water-scarce region.
3. RZTS requires low construction, operational and maintenance cost. Besides routine checks, only harvesting of the reeds is required once in 3-5 years. The reeds can also be used for commercial purposes.

RZTS are tolerant against shock loading or interrupted use. In temperate climates such as in India, this technology is being tried since last one decade. A number of RZTS plants have been set-up at different locations in India by various organizations for e.g. Auroville, Chennai (Anna University), Pune, Tekkadi (Kerala), Bhopal, Gurgaon (TERI), Bilaspur (MP) etc., for treatment of both domestic & industrial effluents. But the performance efficiency of these plants is yet to be known. To collect more data on RZT Plants, CPCB has sponsored a project to Center for Scientific Research (CSR), Auroville to monitor performance efficiency of a few plants located in the Auroville for a period of one year. The initial analytical results of BOD & COD removal are appreciable.

APPLICATION OF ROOT ZONE TREATMENT TECHNOLOGY

1. Treatment of domestic wastewater especially for small towns (Class-II & III), village resorts, hotels, hostels, etc., is easily possible & affordable because it involves low capital, operation & maintenance cost.
2. RZTS can also treat Biodegradable Industrial Effluents specially effluents from agro based industries as the same can be seen at Kids Leather (Tannery effluent), Chennai, Industrial effluent of Proctor & Gamble at Bhopal & CPCB project at Mother Dairy, Delhi.

RZTS Technology can be applied in Urban Watershed Management (UWM) by treating the open nallah in decentralized way and receiving the treated waste either for irrigation or dilution purposes

Water hyacinth technology

Water hyacinth eco-technology has shown a great promise in providing cost effective solutions to waste water problem in many specific areas (Trivedy 1998; Trivedy 2001). Water hyacinth based waste treatment was tried only in US, India, Japan, Singapore, Malaysia and India for initial 25 yrs with maximum number of studies coming form US. Successful pilot projects are documented (Brix and Schierup1989; Mandi 1994; Trivedy and Nakate 2000). Wastewater treatment by water hyacinth has been successfully implemented by the city of san Diego, U.S.A. to produce a treated effluent attaining quality standards that would be expected from advanced secondary treatment process.recent researches have shown that water hyacinth use for wastewater treatment in spreading worldwide

- Traditionally it was used only for sewage treatment and few industrial wastes different types, of wastes and chemical species are employed for treatment by using water hyacinth.

- Water hyacinth has shown promise in removal of toxic organic wastes, almost all the heavy metals (Trivedy, 2000) and radioactive wastes it appears the plant has remarkable capacity to remove an exceptionally wide range of substances a large number of them are yet to be tested.
- It is being used in combination with other plants to obtain better performance. Fish culture is being increasingly used in hyacinth treated water; algal control in water after secondary treatment is also achieved by water hyacinth.
- In extremely poor countries where water scarcity is acute and sanitation is abysmally low especially in rural areas water hyacinth can be used to provide clean water points in waste drains. It is also proposed not only as a water purifier but also a mean to generate income for rural poor (Trivedy and Thomas, 2005).
- Biomass utilization should be an integral part of the hyacinth based systems. It is important to identify low cost methods for the disposal and/or utilization of the large amounts of solids that can be generated by water hyacinth treatment process.
- Microbial ecology of hyacinth based system especially the role of suspended and attached growth needs to be investigated in detail.
- Design parameters developed so far need to be validated in different conditions for different kinds of wastes.
- Role of algae in water hyacinth systems needs to be studied.
- Higher efficiency through microbial augmentation/higher growth of the plant or through other processes should be achieved to reduce area requirements.

Water hyacinth has shown a great promise as a low cost and efficient water purifier and its application is increasing worldwide. Traditionally it was used only for sewage treatment but its great potential in now displayed in treatment of wide range of chemical substances. It is now considered to be a great provider, which can be a solution of several needs like water supply, environment protection, energy, fertilizer and raw material for several industries especially for rural poor. It appears most of the potential of this plant is yet to be tapped.

Novel technologies in water treatment

According to a latest third world Academy of Sciences report, of the 6 billion people on earth, more than one billion (one in six) lack access to safe drinking water. About 2.5 billion (more than one in three) do not have access to adequate sanitation sources. These shortcomings are responsible for more than 6 millions children's death every year. Today 31 countries representing 2.8 billion people including China, India, Kenya, Ethiopia, Nigeria and Peru confront chronic water problems. Within agebneration the world population will be close to 8 billion people, the quantity of water, however, will be the same. We have to find newer ways to save treat and recycle the water.

Some of the new approaches are:

1. Now affordable reverse osmosis for desalination.
2. Protecting presently available water resources and devising effective ways to reduce water consumption for different human uses.

3. Effective water harvesting.
4. Recycling like the gray water can be used to recharge groundwater's to help curb the salinity levels and to improve the health of wetlands.

The TWAS report (www.ictp.trieste.it) cites some innovative examples of water/wastewater treatment. For example 30 million liters of effluents from a rubber factory complex in Sri Lanka is recycled by an innovative method. The wastewater is first subjected to anaerobic digestion with coconut fiber as supporting media, followed by an aerated tank and a circular conical floored clarifier, followed by a sand filter consisting of sand at the top and metal gravels of increasing size at the bottom. The filtered water is subsequently discharged for reuse.

Another example is provided from Chile- the sewage is first passed through a biofilter, which consists of several layers with large stones at the bottom, smaller stones and gravel above, followed by a layer of saw dust- all of which is topped by 20 to 30 cm of humans containing a large number of microorganisms and 5000-10000 earthworms per sq meter. COD and BOD were found to be drastically reduced. The treated water is then subjected to UV treatment 30-watts/sq meter/sec. This system is extremely good for small communities.

NASA (USA) has developed a UV protected granulated activated charcoal bed. Charcoal is an effective water purification material that can adhere to diverse classes of inorganic, organic or biological contaminants, the larger the surface area of charcoal, more effective it is. Thus the experts have used powdered or granulated charcoal instead of charcoal lumps. The process extends the active life of the charcoal through the use of UV light that inhibits the growth of microbes on the carbon surface while disinfecting and purifying the water passing through these tubing's.

The use of titanium oxide for photocatlytic treatment of wastewater has also emerged a low cost and effective method of water purification. Twenty years ago Japanese scientists showed that anatase a naturally occurring mineral that is a form of titanium oxide or TiO_2 is an effective disinfectant when subjected to UV radiation. Under such conditions TiO_2 produces reactive oxygen and free radicals that kill bacteria fungi and viruses ion a brief time. Thus the water is purified through photo catalysis. Adding Fe2) 3 with TiO_2 allowed the use of sunlight directly for better absorption of light.

Electrochemical oxidation

In electrochemical oxidation energy rather than sunlight is used. The catalyst here is not $Ti0_2$ but a mixture of oxides of various metals.

CONCLUSION

The low cost, natural and energy saving technologies are attracting a lot of attention these days due to their low installation cost, their ease of maintenance and less dependence on external inputs like power and chemicals, their potentially longer life cycles and their ability to recover a variety of resources including treated effluent for irrigation, organic humus for soil amendment and biogas etc. However, intensive research is needed in this area especially in developing countries to perfect the design factors and test the technologies

at pilot and field level.

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