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Dr. Meenaksi Munjal
Department of Chemistry, DAV Collage Abohar, Punjab, India

Correspondence
Dr. Meenaksi Munjal
Department of chemistry, DAV Collage Abohar, Punjab, India

Waste water treatment technologies: A Review

Dr. Meenaksi Munjal

Abstract
Nowadays many water resources are polluted by anthropogenic sources including household and agricultural waste and industrial processes. Public concern over the environmental impact of wastewater pollution has increased. Several conventional wastewater treatment techniques, i.e. chemical coagulation, adsorption, activated sludge, have been applied to remove the pollution, however there are still some limitations, especially that of high operation costs. The use of aerobic waste water treatment as a reductive medium is receiving increased interest due to its low operation and maintenance costs. In addition, it is easy-to-obtain, with good effectiveness and ability for degrading contaminants. This paper reviews the use of waste water treatment technologies to remove contaminants from wastewater such as halogenated hydrocarbon compounds, heavy metals, dyes, pesticides, and herbicides, which represent the main pollutants in wastewater.

Keywords: Sewage, Aerobic, Treatment, Technologies

Introduction
A supply of clean water is an essential requirement for the establishment and maintenance of diverse human activities. Water resources provide valuable food through aquatic life and irrigation for agriculture production. However, liquid and solid wastes produced by human settlements and industrial activities pollute most of the water sources throughout the world.

Due to massive worldwide increases in the human population, water will become one of the scarcest resources in the 21st century (Day D., 1996) [14]. In the year 2015 the majority of the global population (over 5 billion) will live in urban environments (UN, 1997) [49]. By the year 2015, there will be 23 megacities with a population of over 10 million each, 18 of which will exist in the developing world (Black, 1994) [2]. Central to the urbanization phenomena are the problems associated with providing municipal services and water sector infrastructure, including the provision of both fresh water resources and sanitation services. Currently, providing housing, health care, social services, and access to basic human needs infrastructure, such as clean water and the disposal of effluent, presents major challenges to engineers, planners and politicians (Black, 1994; Giles and Brown, 1997) [2, 21].

As human numbers increase, greater strains will be placed on available resources and pose even greater threat to environmental sources. A report by the Secretary-General of the United Nations Commission on Sustainable Development (UNCSD, 1997….) concluded that there is no sustainability in the current uses of fresh water by either developing or developed nations, and that worldwide, water usage has been growing at more than three times the world's population increase, consequently leading to widespread public health problems, limiting economic and agricultural development and adversely affecting a wide range of ecosystems.

Although India occupies only 3.29 million km2 geographical area, which forms 2.4% of the world's land area, it supports over 15% of world's population. The population of India as of March 1, 2001 was 1,027,015,247 persons (Census, 2001) [10]. India also has a livestock population of 500 million, which is about 20% of world's total livestock. However, total annual utilizable water resources of the country are 1086 km3 which is only 4% of world's water resources (Kumar *et al*., 2005) [29]. Total annual utilizable resources of surface water and ground water are 690 and 396 km3, respectively (Ministry of Water Resources, 1999) [34]. Consequent to rapid growth in population and increasing water demand, stress on water resources in India is increasing and per capita water availability is reducing day by day. In India per capita surface water availability in the years 1991 and 2001 were 2300 m3 (6.3 m3/day) and 1980 m3 (5.7 m3/day) respectively and these are projected to reduce to 1401 and 1191 m3 by the years 2025 and 2050, respectively (Kumar *et al*., 2005) [29]. Total water requirement of the country in 2050 is estimated to be 1450 km3 which is higher than the current availability of 1086 km3.

Much of the wastes of civilization enter water bodies through the discharge of waterborne waste from domestic, industrial and non-point sources carrying unwanted and unrecovered substances (Welch, 1992) [53]. Although the collection of wastewater dates back to ancient times, its treatment is a relatively recent development dating from the late 1800s and early 1900s (Chow *et al*., 1972) [12]. Modern knowledge of the need for sanitation and treatment of polluted waters however, started with the frequently cited case of John Snow in 1855, in which he proved that a cholera outbreak in London was due to sewage contaminated water obtained from the Thames River (Cooper, 2001) [13]. In developed nations, treatment and discharge systems can sharply differ between countries and between rural and urban users, with respect to urban high income and urban low-income users (Doorn *et al*., 2006) [17]. The most common wastewater treatment methods in developed countries are centralized aerobic wastewater treatment plants and lagoons for both domestic and industrial wastewater.

The degrees of wastewater treatment vary in most developing countries. Domestic wastewater may be treated in centralized plants, pit latrines, septic systems or disposed of in unmanaged lagoons or waterways, via open or closed sewers (UNEP, 2002). In some cases industrial wastewater is discharged directly into water bodies, while major industrial facilities may have comprehensive inplant treatment (Carter *et al*., 1999; Doorn *et al*., 2006) [9, 17]. In many developing countries the bulk of domestic and industrial wastewater is discharged without any treatment or after primary treatment only. In Latin America about 15% of collected wastewater passes through treatment plants (with varying levels of actual treatment). In Venezuela, 97% of the country's sewage is discharged raw into the environment (Caribbean Environment Programme, Technical Report, 1998) [8]. Even a highly industrialized country such as China discharges about 55 percent of all sewage without treatment (The People's Daily, Friday, November 30, 2001) [48]. In a relatively developed Middle Eastern country such as Iran, the majority of Tehran's population has totally untreated sewage injected into the city's groundwater (Tajrishy and Abrishamchi, 2005) [47]. In South Africa where some level of wastewater treatment is observed, Momba *et al*., (2006) [35] reported the poor operational state and inadequate maintenance of most of the municipalities' sewage treatment works as leading to the pollution of various water bodies thereby posing very serious health and socio-economic threats to the dependants of such water bodies. Most of sub-Saharan Africa is without wastewater treatment (Sci-Tech. Encyclopaedia, 2007).

Modern civilization, armed with rapidly advancing technology and fast growing economic system is under increasing threat from its own activities causing water pollution, (Singh *et al*. (1989). India is the seventh largest country in the world with a total landmass of 3.29 million sq. km, population over 1 billion, 29% of which live in urban areas spread over 5162 towns. With enormous natural resources and growing economy India is the second largest pool of technical and scientific personnel in the world. Pollution from small size industries (SSIs) puts the Indian regulators in front of a difficult arbitrage between economic development and environmental sustainability. The uncontrolled growth in urban areas has made planning and expansion of water and sewage systems very difficult and expensive (Looker, 1998) [30].

Aerobic activated sludge reactors have been used on a limited scale as bio-scrubbers for the treatment of odorous air (Bowker, 2000) [6]. Despite numerous positive reports from full scale applications in North America, little data are available on the actual performance of these systems with wide ranging concerns on reduction of settling efficiency due to changes in filamentous organisms and bacterial flocks (Burgess *et al*. 2001) [7]. These concerns are alleviated in MBRs where gravitational settling of the microbial solution is replaced by physical filtration. Also, the diffusion and bioconversion of odorous gases are a function of contact time, bubble size, and reactor configuration (Burgess *et al*. 2001) [7]. Submerged MBRs incorporate the membrane unit within the bioreactor and rely on gas and liquid scouring to clean the membrane surface. Since modern livestock operations are equipped with blowers and ventilation systems, booster fans could be added to increase outflow pressure. This concept was explored in past research efforts when biofilter beds (compost and wood chips) were tested for odour removal (Mann *et al*. 2002) [32].

Status of wastewater in India

The total wastewater generated by 299 class-1 cities is 16,652.5 MLD. Out of this, about 59% is generated by 23 metro cities. The state of Maharashtra alone contributes about 23%, while the Ganga river basin contributes about 31% of the total wastewater generated in class-1 cities. Only 72% of the total treated wastewater generated is collected. Out of 299 class-1 cities, 160 cities have sewerage system for more than 75 percent of population and 92 cities have more than 50 percent of population coverage. On the whole 70% of total population of class-1 cities is provided with sewerage facility, compared to 48% in 1988. The type of sewerage system is either open or closed or piped. The main objective of this study was to perform a review of the treatment of domestic sewage using the aerobic sludge to ensure effective discharge and/or re-use/recycling.

Wastewater treatment in India

Out of 16,662.5 MLD of wastewater generated, only 4037.2 mld (24 %) is treated before release, the rest (i.e. 12,626.30 MLD) is disposed of untreated. Twenty-seven cities have only primary treatment facilities and only forty-nine have primary and secondary treatment facilities.

Need of sewage treatment:

Wastewater treatment involves breakdown of complex organic compounds in the wastewater into simpler compounds that are stable and nuisance-free, either physico-chemically and/or by using micro-organisms (biological treatment). The adverse environmental impact of allowing untreated wastewater to be discharged in groundwater or surface water bodies and or lands are as follows:

1. The decomposition of the organic materials contained in wastewater can lead to the production of large quantities of malodorous gases.
2. Untreated wastewater (sewage) containing a large amount of organic matter, if discharged into a river / stream, will consume the dissolved oxygen for satisfying the Biochemical Oxygen Demand (BOD) of wastewater and thus deplete the dissolved oxygen of the stream, thereby causing fish kills and other undesirable effects.
3. Wastewater may also contain nutrients, which can stimulate the growth of aquatic plants and algal blooms, thus leading to eutrophication of the lakes and streams.

4. Untreated wastewater usually contains numerous pathogenic, or disease-causing microorganisms and toxic compounds that dwell in the human intestinal tract or may be present in certain industrial waste. These may contaminate the land or the water body, where such sewage is disposed.
For the above-mentioned reasons the treatment and disposal of wastewater, is not only desirable but also necessary.

Industrial, Municipal and Domestic Reuse of Wastewater
Municipal uses of treated wastewater include the irrigation of road plantings, parks, playgrounds, golf courses and toilet flushing etc. (Bouwer, 1993). Industrial reuses of wastewater include cooling systems, agricultural uses (irrigation and aquaculture), the food processing industry and other highrate water uses (Bouwer, 1993b; Khouri *et al*. 1994; Asano and Levine, 1996) [5, 28, 1]. In Middle Eastern countries, where water is scarce, dual istribution systems will, in the near future, provide high quality, treated effluents for toilet flushing to hotels, office buildings, etc. (Shelef and Azov, 1996) [44].
In India, wastewater is currently being used for irrigation, gardening, flushing, cooling of air conditioning systems, as a feed for boilers, and as process water for industries (Chawathe and Kantawala, 1987) [11]. In China, national policy has been developed that promotes the development of water-efficient technologies, and encourages the reuse of reclaimed municipal wastewater in agriculture first, and then for industrial and municipal uses (Zhongxiang and Yi, 1991) [55]. In Japan, reclaimed wastewater is used for toilet flushing, industry, stream restoration and flow augmentation to create "urban amenities" such as green space (Asano, Maeda, Takaki, 1996) [1].

Planning and Implementing Wastewater Reuse
Appropriate Technology
A functional and sustainable wastewater management scheme begins at the household level and is largely dependent on the “software” or the human component (Khouri *et al*., 1994) [28]. Only when perception of need and perhaps, anticipation for a wastewater reuse system has been internalized at the neighborhood/user level, will planning and implementation be successfully executed (Khouri *et al*., 1994) [28]. Local level support of a treatment and recovery scheme can, in turn, catalyse pro-active institutions and vertical support from governments. Once the software component has been integrated into project development, the “hardware” or technological component can act to promote a comprehensive, integrated, and sustainable wastewater treatment and recovery strategy for the community - if it is well selected and "appropriate". Several features characterise an appropriate wastewater treatment technology that can be a sustainable amenity to a community. Denny, (1997) [16] has stated that wastewater treatment technologies in the developing world must have one overriding criterion: the technology must be cost-effective and appropriate. The following considerations should be made regarding the appropriateness of technologies:
1. The scheme or technology should be a felt priority in public or environmental health, and both centralised and de-centralised technologies should be considered (Veenestra and Alaerts, 1996) [51].
2. The technology should be low-cost and require low energy input and mechanisation, which reduces the risk of malfunction (Frijns and Jansen, 1996; Boller, 1997) [20, 3].
3. The technology should be simple to operate, be "local" labour intensive, maintained by the community not rely on expensive chemical inputs, such as chlorine, for tertiary pathogen reductions to meet quality guidelines, and should be able to recover resources (Mara and Cairncross, 1989; Frijns and Jansen; 1996; Boller, 1997) [33, 20, 3].
4. The technology should be capable of being incrementally upgraded as user demand or quality standards and treatment guidelines increase (Boller, 1997) [3].
Public acceptance of reuse projects is vital to the overall future of wastewater reuse and the consequences of poor public perception could jeopardise future wastewater reuse projects (Asano and Levine, 1996) [1]. The selection of any treatment technology must be accompanied in advance by a detailed examination of the self-sufficiency and technological capacity of the community. The treatment alternatives must be manageable by the local community. (Boller 1997) [3] suggests that skilled operation and maintenance are essential to attain satisfactory performance and that technologies must require the lowest level of maintenance and control. The overriding criterion is that the system must be capable of achieving acceptable levels of pathogen reductions to facilitate the recovery of effluent for irrigation and organic soil amendment (Yu *et al*., 1997) [54].
A number of conventional treatment technologies have been considered for treatment of wastewater contaminated with organic substances. Commercial activated carbon is regarded as the most effective material for controlling the organic load. However due to its high cost and about 10-15 % loss during regeneration, unconventional adsorbents like fly ash, peat, lignite, wood, saw dust etc. have been used for the removal of refractory materials, (Pandey *et al*., 1985) [39] for varying degree of success. Ionic liquids holds promise to provide better alternative to the toxic solvents, (Sheldon *et al*., 2001) [43].
The removal of organic material by adsorption has recently become the subject of interest of several workers, Nelson *et al*. (1969) [37]; Eye *et al*. (1970) [19]; Johnson *et al*. (1965) [27]; Deb *et al*. (1966) [15]; Gupta *et al*. (1978, 1990) [22]; Mott *et al*. (1992) [26]; Viraraghavan *et al*. (1994). They have explored the use of fly ash as an adsorbent for treatment of wastewater to remove toxic compounds and colour. Pandey *et al*. (1985) [39] has proposed a method for removal of copper from wastewater by taking fly ash as an adsorbent. The use of active filtration through alkaline media for the removal of phosphorus from domestic wastewater has been proposed by Johansson *et al*. (1998) [26]; and Drizo *et al*. (2006) [18]. Ozone is a very good oxidizing agent due to its high instability (reduction potential 2.07 V) when compared to chlorine (1.36 V) and (1.78V). It has potential to degrade large number of pollutants like phenols, pesticides and aromatic hydrocarbons and is used since the early 1970s in wastewater treatment (Robinson *et al*. 2001, Özbelge *et al*. 2002, Pera-Titus *et al*. 2004) [41, 38, 40]. The major drawback of the use of this method is, ozone has short half-life, it decomposes in 20 minutes so require continuous ozonation and making this method expensive to apply, (Slokar *et al*., 1998, Robinson *et al*., 2001) [46, 41].
Anaerobic wastewater treatment is a biological wastewater treatment without the use of air or elemental oxygen. Applications are directed towards the removal of organic pollutants in waste water, slurries and sludge. Complete replacement of aerobic with anaerobic technology is not yet possible as the effluent quality of anaerobic treatment systems

is not up to par. The anaerobic treatment is considered as a pre-treatment technique and has been applied in Colombia, Brazil, and India, replacing the more costly activated sludge processes. There are different types of digesters available, some have been proven effective over time, and others are still being tested. One of the most suitable digesters for tropical conditions is the UASB (Up flow Anaerobic Sludge Blanket).

Harada *et al*. (2007, 2006, 2005, and 2002) [23, 24, 25] has proposed a self-sustainable sewage treatment system with the combination of UASB as pretreatment unit and an aerobic reactor Down flow Hanging Sponge (DHS) reactor as a post treatment unit. The proposed anaerobic-aerobic bio conenoses of UASB and DHS fulfill the need for a simplified treatment system for developing countries because of its low cost, and operational simplicity, along with sustainability of the system as a whole.

Conclusion

This report is a review of variety of options that may be employed in the treatment, recovery and reuse of wastewater. It is apparent that a variety of options are feasible for use in the developing world and even more apparent that many low-technology options can be mixed and matched for very high efficiencies. Natural treatment technologies are attracting a significant level of interest by environmental managers. Natural treatment technologies are considered viable because of their low capital costs, their ease of maintenance, 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 energy in the form of biogas.

This report examined emergent issues and technological options related to the scale of collection and treatment systems. There is increasing momentum developing behind the notion that recycling loops, from point of generation (e.g., the household) to point of treatment and reuse must be shortened.

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