Need for Advanced Engineered Systems for Restoring the Lower Reaches of River Periyar

Vishnu Sasidharan[1]

[1]*Consultant Engineer, Cochin, Kerala, India*

Abstract - *India's booming population and rapidly expanding urban areas have exacted a huge toll on its rivers, which are badly polluted and choked by development. Periyar, the longest river in the state of Kerala is no exception, the reason for its polluted condition being the combined effect of domestic sewage, agricultural runoffs and industrial effluents. Whatever be the source of pollutants, properly designed engineered treatment system has to be employed. Even though conventional and traditional treatment methods are at times simple and easy to adopt, they seldom treats the effluents to the desired level of standards, which are these days very strict. This paper discusses a few advanced treatment systems that can be employed to treat the wastewater before releasing it to the environment.*

Keywords: *Periyar, river pollution, waste water treatment, bioreactors, hybrid treatment systems, aerobic treatment, anaerobic treatment, advanced oxidation processes*

1. INTRODUCTION

Periyar is the longest river and the river with the largest discharge potential in the Indian state of Kerala. It is one of the few perennial rivers in the region and provides drinking water for several major towns. The Periyar is of utmost significance to the economy of Kerala. It generates a significant proportion of Kerala's electrical power via the Idukki dam and flows along a region of industrial and commercial activity. The river also provides water for irrigation and domestic use throughout its course besides supporting a rich fishery. Due to these reasons, the river has been named the "Lifeline of Kerala". The city of Cochin, in the vicinity of the river mouth draws its water supply from Aluva, an upstream site sufficiently free of seawater intrusion. Twenty five percent of Kerala's industries are located along the banks of river Periyar. These are mostly crowded within a stretch of 5 kilometres in the Eloor-Edayar region, about 10 kilometres north of Cochin harbour [1].

The lower reaches of the Periyar are heavily polluted. Industries in the Eloor industrial zone discharge waste into the river. The tail of Periyar can be called as "a cesspool of toxins, which have alarming levels of deadly poisons like DDT, hexa and trivalent chromium, lead and cyanide [2]. Several studies have pointed out that the riverbed has deposits of heavy metals like lead, cadmium, mercury, chromium, nickel, cobalt and zinc and the ecosystem of the river has many dead zones [3]. Some of the major recommendations are ensuring zero effluent discharge from the industrial units in the Eloor-Edayar stretch and zero emission from companies. Pollution of the river and surrounding wetlands has almost wiped out traditional occupations, including fishing and farming [4].

2. SOURCES OF POLLUTION

The sources of pollution in the river Periyar can be categorized into three groups, namely sewage & garbage, agricultural runoffs and industrial effluents [5].

2.1 Sewage & Garbage

The river directly receives civic effluents from townships like Malayattoor, Kalady, Perumbavoor, Neriamangalam, Aluva and Parur. None of these local bodies possess proper sewage treatment facility. In the case of Cochin corporation sewage treatment system is inadequate and the untreated organic and inorganic refuse is being discharged into the backwaters.

2.2 Agricultural Runoffs

Periyar river basin has an approximate area of 528400 hectares. Out of this, around 39000 hectares is available as wet land and 166000 hectares as garden land. Major crops being cultivated in the river basin includes rice, coconut, areca nut, banana, rubber, vegetables etc. The upper reaches of the basin is utilized for plantation crops like tea, coffee, cardamom and rubber. This intensive agricultural practice all along the banks and watershed area has been enriching the river water with huge amounts of pesticides and fertilizers especially during surface run off in the rainy season. Besides, loosening of surface soil and removal of vegetation from catchment area generates problems related to soil erosion and siltation.

2.3 Industrial Pollution

The industries located in the lower reaches of Periyar daily consumes about 189343 cubic meters of water from the river and discharge about 75% as used water along with large quantity of effluents and pollutants. The major types of these industries are fertilizers, pesticides, chemicals and allied industries, petroleum refining and heavy metal processing, radioactive mineral processing, rubber processing units, animal bone processing units, battery manufacturers, mercury products, acid manufacturers, pigment and latex producers etc. The wide spectra of pollutants that adversely affect the natural environmental quality of the water of the river include toxic and hazardous materials such as heavy metals, phenolic, hydrocarbons, pesticides, radionuclides, ammonia and phosphates.

3. CONVENTIONAL METHODS

The various conventional methods of treating wastewater consist of a combination of physical, chemical and biological processes and operations to remove solids and organic matter. These have several shortcomings such as high operational costs, low removal efficiency and a high concern for secondary pollution [6]. The general scheme of conventional wastewater treatment is shown in Fig 1.

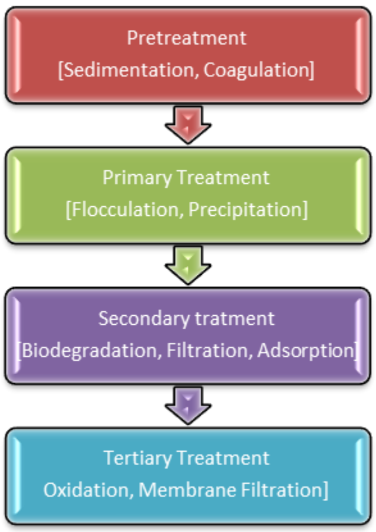

Fig 1: Conventional wastewater treatment scheme

4. ADVANCED ENGINEERED SYSTEMS

There are a number of advanced engineered systems that are employed in different parts of the world for the treatment of wastewater [7]. The key is to design such systems considering the nature and composition of the effluent to be treated and the level of standard prescribed by the concerned governing authorities. A few such systems are described in the subsequent sections.

4.1 Membrane Bioreactors

Membrane bioreactors (MBRs) use a combination of the activated sludge process with an additional membrane separation process. The advantages offered by MBRs over traditional activated sludge systems include reduced footprints, a decrease in sludge production, improved effluent quality and efficient treatment of wastewaters with varying contamination peaks. These reactors have been used in several countries for the treatment of a vast range of different wastewaters from municipal or industrial such as pharmaceutical industry [8],[9].

Details of process design considerations vary greatly depending on the wastewater being treated as well as the type of membrane reactor used. Operational design of the reactor is crucial as the membrane reactors are prone to membrane fouling. This disadvantage has been given as the major reason for MBRs not being as widely utilized in large scale wastewater treatments in comparison to traditional activated sludge plants. Numerous papers have been published investigating innovative ways in which membrane fouling can be controlled [10]. The critical flux is a widely accepted parameter used to characterize membrane fouling and can be defined as the flux below which no fouling of the membrane occurs.

Heavy metals found in wastewater streams with low pH values pose significant environmental problems and so many precipitation methods have been introduced but some of these, such as lime precipitation, create carbonates and hydroxides with the latter product being unstable. Membrane Bioreactors containing sulphate reducing bacteria have been seen as an alternative to the precipitation process with lime.

4.2 Two Phase Partitioning Bioreactors

Two-phase partitioning bioreactors use a non-biodegradable, biocompatible and non-volatile organic solvent placed on top of an aqueous phase, which is aerated. These were developed for the high yield production of inhibitory products. Potential was later shown for the bioremediation of toxic compounds due to the ability of the system to supply sub-inhibitory amount of the toxic compound to the aqueous phase due to equilibrium considerations [11].

The system is considered to be self-regulatory as the xenobiotic is delivered to the aqueous phase at a rate determined by the consumption rate of the microorganisms. There are distinct advantages to this system compared to traditional activated sludge systems and other aerobic systems, including the limited exposure of the microorganisms to organic components in the wastewater, thus reducing any toxic effects as well as offering distinct and clear increased initial loading rates of xenobiotics. Potential disadvantages include the contact of the biodegrading micro flora with the metal ions, resulting in an additional step of biomass removal before effluent discharge.

Several studies have focused on degradation of xenobiotics using this type of aerobic degradation reactor configuration. The scope of research on xenobiotic degradation covers the degradation of single xenobiotics and complex mixtures of xenobiotics in two-phase reactor systems. In one such study looking at the degradation of benzene in a two-phase reactor using Alcaligenes xylosoxidans Y234 it was shown that 63.8% of the benzene added into the system was degraded during a 24 hour period while 36.2% was stripped by aeration. Benzene was identified as an important xenobiotic, as it is known to be toxic to numerous microorganisms and is hard to degrade when found at high concentrations. The stripping effect was then adjusted in order to encourage more biological degradation of the benzene and results from the adjusted parameters showed a 99.7% degradation of the initial loaded 7000 milligrams. These results demonstrate the effectiveness of the two-phase reactor in dealing with potentially toxic xenobiotics. Therefore, all wastewater from chemical industry that may contain toxic xenobiotics compounds can be treated with two-phase partitioning bioreactor.

4.3 Sequencing Batch Reactors

A sequencing batch reactor (SBR) is a reactor in which an activated sludge process is carried out in a time oriented, sequential manner using a single vessel for all the phases of the process. The same steps involved in a conventional, continuous activated sludge process such as aeration, oxidation, sludge settling, and recycling are now conducted in batch one after the other.

In an SBR process, each cycle starts with the reactor nearly empty except for a layer of acclimated sludge on the bottom. The reactor is then filled up with the wastewater and the aeration and agitation are started. The biological degradation process begins during the filling step and proceeds, once the reactor has been filled up, until a satisfactory level of degradation of the pollutant is achieved. Then the aeration and agitation are stopped, and the sludge begins to settle. Depending on the time allowed for the sedimentation, anaerobic reaction can occur, which may reduce the organic content of the sludge. Once the sludge has settled, the clear top layer of treated wastewater is discharged and a new cycle can begin. Anaerobic sludge digestion may also be included as one of the steps in the cycle.

The main advantage of SBRs is that they can accommodate large fluctuations in the incoming wastewater flow and composition without failing. The same may not be true in conventional activated sludge processes, in which an increase in the incoming flow rate results in a lower residence time of the wastewater in the aeration tank and of the sludge in the clarifier, with potential failure of one of them or both. In addition, toxic shocks or significant changes in organic loading may produce alteration in the makeup of microbial populations of conventional activated-sludge processes, with consequent bulking or process failure. Instead, the wastewater residence time in SBRs can be extended until the microbial population has recovered and completed the degradation process. Similarly, the settling time can be varied to allow complete settling before discharging. In other terms, SBR processes, like all batch processes, are more flexible. On the other hand, the use of SBRs to treat a continuous wastewater flow requires the simultaneous use of multiple reactors and/or the presence of holding facilities to store the wastewater until an SBR becomes available. SBRs have been used also in denitrifying application [12], [13].

4.4 Upflow Anaerobic Sludge Blanket Reactors

Anaerobic treatment is now becoming a popular treatment method for industrial wastewater because of its effectiveness in treating high strength wastewater and economic advantages. Developed in the Netherlands in the late seventies, the upflow anaerobic sludge blanket (UASB) reactor was originally used for treating wastewater from sugar refining, breweries and beverage industry, distilleries and fermentation industry, food industry, pulp and paper industry. In recent times the applications for this technology are expanding to include treatment of chemical and petrochemical industry effluents, textile industry wastewater, landfill leachates, as well as applications directed at conversions in the sulphur cycle and removal of metals.

Essentially, the UASB reactor has four major components; sludge bed, sludge blanket, gas-sludge-liquid separator and a settlement compartment. The specific of an UASB are existence of granules sludge and internal three-phase GSL device (gas/sludge/liquid separator system). In a UASB reactor, anaerobic sludge has or acquires good sedimentation properties, and is mechanically mixed by the up-flow forces of the incoming wastewater and the gas bubbles being generated in the reactor. For that reason mechanical mixing can be omitted from an UASB reactor thus reducing capital and maintenance costs. This mixing process also encourages the formation of sludge granules.

4.5 Anaerobic Sequencing Batch Reactors

Anaerobic sequencing batch reactor (ASBR) is a high rate anaerobic process. The promising feature of the ASBR process is that granular biomass can be achieved, and in this way higher biomass can be maintained in the reactor with efficient biomass setting and a long solids retention time.

Anaerobic sequencing batch reactors allow typical biological anaerobic metabolism from substrate consumption to methane and carbon dioxide production and operate according to a set of cyclic steps; namely feed, reaction, settling and discharge. The main advantages of this type of operation are its operational simplicity, efficient quality control of the effluent, possibility of eliminating the settling step for both the affluent and effluent wastewater and flexibility of use in the wide variety of wastewaters to be treated. These characteristics indicate its potential application in situations requiring compliance with strict environmental control standards as well as when sewage is produced intermittently and has variable characteristics as a result of the type of downstream process. This technique can be used for the treatment of sulphate bearing chemical wastewater, automobile industry wastewater and hyper saline composite chemical wastewater [14],[15].

4.6 Advanced Oxidation Processes

Advanced Oxidation Processes (AOPs) are treatment processes which involve the generation of highly reactive radicals especially hydroxyl radicals in sufficient quantity to effect water purification. These treatment processes are considered as very promising methods for the remediation of wastewaters containing non-biodegradable organic pollutants. Hydroxyl radicals are extraordinarily reactive species that attack most of the organic molecules. The AOPs are mainly used as a pre-treatment stage for industrial wastewater remediation. These techniques improve the destruction of persistent contaminants.

Among various AOPs, the Fenton reagent is one of the most effective methods of organic pollutant oxidation. The Fenton reagent has been found to be effective in treating various industrial wastewater components including aromatic amines, a wide variety of dyes as well as many other substances like pesticides and surfactants [16]. Therefore, the Fenton reagent has been applied to treat a variety of wastes such as those associated with the textile and chemical industries. The advantage of the Fenton reagent is that no energy input is necessary to activate hydrogen peroxide. Therefore, this method offers a cost-effective source of hydroxyl radicals, using easy to handle reagents.

4.7 Hybrid Systems

A hybrid system is designed to take advantage of unique features of two or more processes. In other words, integrated systems are defined here as those waste treatment processes that utilize both aerobic and anaerobic organisms to achieve the desired objective of producing an environmentally accepted and stable final waste product. As more knowledge becomes available on the microbiology of each the two classes of microorganisms, they are likely to be selectively used to solve more difficult wastewater treatment problems by exploiting the specific degradation potentials of each group. In turn, this will require the design of appropriate reactor configuration capable of maintaining the desired conditions for the microbial activity to take place.

For instance, it is cost effective to treat high strength wastewater effluents with a combination of anaerobic-aerobic processes. This was recently shown by Eckenfelder et al., whose economic analysis pointed out that if the wastewater has a BOD in excess of 1000 mg/L a combined anaerobic-aerobic process can be advantageous [17]. This approach has been used in different applications, including a recent one involving the combined use of powered activated carbon and both anaerobic (first) and aerobic (second) stages [18],[19]. These applications were developed primarily to treat high-strength wastewater. In all these case the reactors used for each stage were of the type described above for each class of organisms.

Moreover, anaerobes can have an additional feature that makes them attractive in wastewater. Anaerobic organisms have recently been shown to be responsible for a number of reductive reaction processes that could have a significant impact on the treatment of certain classes of hazardous compounds. In particular, anaerobic organism have been shown to be capable of reductively dehalogenating a number of toxic compounds, such as chlorinated aromatics, that are very recalcitrant to aerobic degradation. Therefore, a possible alternative for the treatment of such compounds is their sequential exposure to specialized anaerobic and aerobic cultures. If the process is operated continuously, it requires the sequential use of two reactors maintained under anaerobic and aerobic conditions, respectively.

5. CONCLUSIONS

The industries situated along the lower reaches of Periyar face formidable environmental regulatory challenges in treating their wastewater effluents. Therefore, this paper cites a few advanced technologies that are followed in different parts of the world to treat industrial wastewater. These options are being shown to be technologically and economically feasible.

Membrane bioreactors use a combination of the activated sludge process with an additional membrane separation process. They possess several advantages over the traditional activated sludge processes. Two-phase partitioning bioreactors can be used for the bioremediation of toxic compounds due to the ability of the system to supply sub-inhibitory amount of the toxic compound to the aqueous phase due to equilibrium considerations. Treatment of wastewater in an SBR can be carried out in a time oriented, sequential manner using a single vessel for all the phases of the process, with the added advantage that they can accommodate large fluctuations in the incoming wastewater flow and composition without failing.

Both ASBR and UASB reactors are highly efficient systems, the former having high potential in situations requiring compliance with strict environmental control standards and the latter being very effective for chemical and petrochemical industry effluents. AOPs are found to be promising for the remediation of wastewaters containing non-biodegradable organic pollutants.

In addition to these, hybrid systems can be designed to take advantage of unique features of two or more processes, thereby producing an environmentally accepted and stable final waste product.

ACKNOWLEDGMENT

The author would like to thank all those whose direct or indirect assistance proved to be a milestone in writing this paper.

REFERENCES

[1] https//Wikipedia.org/wiki/Periyar_river.
[2] Wanchoo A (2003) "Toxic Pollution". Greenpeace India.
[3] Maya K (2005) "Studies on the nature and chemistry of sediments and water of Periyar and Chalakudy rivers, Kerala, India". PhD thesis, Cochin University of Science and Technology.
[4] John H and Varier M (2017) "The Periyar is dying: How South Kerala's lifeline has become an industrial sewage drain". News report, thenewsminute.com.
[5] Documentary write-up (2007) "A poisoned river means a dying population", www.ireness.net.
[6] Crini G, Lichfouse E (2018) "Green adsorbents for pollutant removal", Environmental chemistry for a sustainable world, Springer International Publishing.
[7] Awaleh MO, Soubanesh YD (2014) "Wastewater treatment in chemical industries: the concept and current technologies", Hydrology Current Research 2014 Vol 5:164.
[8] Ozgun H, Dereli RK, Ersahin ME, Kinaci C, Spanjers H, et al. (2013) "A review of anaerobic membrane bioreactors for municipal wastewater treatment: Integration options, limitations and expectations", Separation and Purification Technology 118: 89-104.
[9] Alberti F, Bienati B, Bottino A, Capannelli G, Comite A, et al. (2007) "Hydrocarbon removal from industrial wastewater by hollow-fibre membrane bioreactors", Desalination 204: 24-23.
[10] Yang Q, Chen J, Zhang F (2006) "Membrane fouling control in a submerged membrane bioreactor with porous, flexible suspended carriers", Desalination189: 292-302.
[11] Munoz R, Guieysse B, Mattiasson B (2003) "Phenanthrene biodegradation by an algal-bacterial consortium in two – phase partitioning bioreactors", Applied Microbiology and Biotechnology 61: 261-267.
[12] Oliveira RP, Ghilardi JA, Ratusznei SM, Rodrigues JAD, Zaiat M, et al. (2008) "Anaerobic sequencing batch biofilm reactor applied to automobile industry wastewater treatment: Volumetric loading rate and feed strategy effects", Chemical Engineering and Processing: Process Intensification 47: 1374-1383.
[13] Fakhru'l-Razi A, Pendashteh A, Abidin ZZ, Abdullah LCC, Biak DRA, et al. (2010) "Application of membrane-coupled sequencing batch reactor for oilfield produced water recycle and beneficial re-use", Bioresource Technology 101: 6942-6949.
[14] Luo G, Li P, Tan H, Du J, Liang W (2013) "The start-up and saline adaptation of mesophilic anaerobic sequencing batch reactor treating sludge from recirculating aquaculture systems", Aquacultural Engineering 54: 9-15.
[15] Zaiat M, Rodrigues JAD, Ratusznei SM, Camargo EFM, Borzani W (2001) "Anaerobic Sequencing Batch Reactors for Wastewater Treatment: a Developing Technology", Applied Microbiology and Biotechnology 55: 29-35.
[16] Rodríguez M (2003) "Fenton and UV-vis based advanced oxidation processes in wastewater treatment", Degradation, mineralization and biodegradability enhancement. Universitat de Barcelona, Spain.
[17] Eckenfelder WWJ (1989) "Industrial Water Pollution Control", McGraw-Hill, New York.
[18] Collivignarelli C, Urbini G, Farteni A, Bassetti A, Barbaresi U (1990) "Anaerobic-Aerobic Treatment of Municipal Wastewaters with Full-Scale Upflow Anaerobic Aludge Blanket and Attached Biofilm Reactors", Water Technology22: 475-482.
[19] Cardenas-Robles A, Martinez E, Rendon-Alcantar I, Frontana C, Gonzalez-Gutierrez L (2013) "Development of an activated carbon-packed microbial bioelectrochemical system for azo dye degradation", Bioresource Technology 127: 37-43.

BIOGRAPHIES

Vishnu Sasidharan is a consultant engineer based in the city of Cochin, Kerala, India. He was awarded Bachelor of Technology in Civil Engineering and Master of Technology in Geotechnical Engineering from Cochin University of Science and Technology, Cochin, Kerala, India. He is a lifetime member of Indian Geotechnical Society - Kochi Chapter.