IN-SITU BIOLOGICAL WATER TREATMENT TECHNOLOGIES FOR ENVIRONMENTAL REMEDIATION: A REVIEW

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ABSTRACT

The acceleration of urbanization and rapid development of economy led to making surface water pollution problem becoming more critical. Water treatment technologies can be generally classified as in-situ or ex-situ. In this paper, a comprehensive review describing the latest surface water remediation developments and technologies that can be suitable for in-situ applications. The review covers the related researches on river pollution control and remediation systems , however, more weight was given to bioremediation technologies (i.e. remediation using aquatic plants, remediation using aquatic animals, and Microbial Remediation) as one of the effective ways to deal with the pollution of natural water. At the moment, it was concluded that approaches to alleviate the river pollution problem should utilize the bioremediation as the primary technique, followed by the physical and chemical remediation as the supplementary means. Applying those methods for other polluted surface waters such as agricultural drainage water is recommended as well.

Keywords: In-situ remediation, surface water, removal mechanism, Biological treatment

1 INTRODUCTION

Water treatment technologies can be generally classified as in-situ or ex-situ. The former remediation involves treating the contaminated material at the site, while the latter involves the removal of the contaminated material to be treated elsewhere. Further categories results in the consideration of physical, chemical, and biological treatment techniques (Hamby 1996; Wang et al, 2012).

Surface water acts as a receptor of pollutants, which are washed out and carried by surface runoff from urbanized catchments or watersheds. Rapid urbanization leads to degradations upon water quality via eutrophication and pollution. Polluted surface water includes river and lakes as well as agricultural drains.Nearly all water bodies, including ground water, are affected by pollution.Polluted water loses its economic and aesthetic value.Resultantly, in many developed countries, water pollution is a major problem and many river basins have been found to show high organic matter concentration. Therefore, different pollution control methods and remediation were applied(Li and Chu 2003; Borin and Tocchetto 2007; Yudianto and Xie 2010; Yu et al., 2012; Cheepi 2012; Wang et al, 2012; and Saavedra et. al., 2015).

Presently, the utility of river aeration technology has relatively been mature in many countries.Research and practical applications showed that the artificial aeration can improve water quality effectively. Practically, Aeration systems can be utilized as standalone systems or as a support for other treatment facilities. Researches on using aeration as a primary system showed increase in dissolved oxygen concentration as well as decrease in BOD_5 and COD_{cr} values (Dunqiu et al., 2007; Yudianto and Xie 2011; Wang et al, 2012; Mostefa et al., 2012). Plus, experiments were carried out to improve the efficiency of constructed wetlands using aeration tubes. Successfully, the units with aeration had higher removal rates of BOD, NH_4^+–N, TP and TN (Green et al., 1996 and Zhang et al., 2010;Abu Hasan et al., 2012;Dong et al., 2012;Fan et al., 2013).

Besides aeration, water diversion and sediment dredging were used as physical water treatment methods for surface water. But water diversion found to be large and the cost was relatively high and sediment dredging would cause re-suspension of sediment (Mackie et al., 2007; Zhu et al., 2008; Wang et al, 2012).

Additionally, various chemical water treatment methods were utilized for both surface water and groundwater. For instance, flocculation, sedimentation and chemical agents were used to treat water with a large number of suspended solids and algae (Centi et al., 2003;Della Rocca et al., 2007; Wang et al, 2012). Despite the fact that in-situ chemical technologies offer significant benefits over the conventional ways, their use is still very limited because of technical uncertainties and regulatory or procedural barriers. In addition, caution needs to be taken in handling chemicals because these chemical treatment techniques inherently involve use of potentially hazardous chemicals, sometimes in large quantities. Effort is also needed to prevent mobilized contaminants from migrating into the surrounding environment (Yin and Allen 1999).

On the other hand, the bioremediation was advanced rapidly from 1990.Bioremediation is considered as one of many advantages, such as reduced cost, low environmental influence, no secondary pollution or pollutant movement, reducing pollutant concentration by the maximum extent, available for the sites where regular pollution treatment technology is difficult to be applied (Mingjun et al., 2009). Wilson and Clarke define biodegradation as the disappearance of environmentally undesirable properties of a substance. Another way of defining biodegradation is the breakdown of organic compounds by living organisms resulting in the formation of carbon dioxide and water or methane. These microorganisms are bacteria, fungi, and microfauna (e.g. protozoans, some worms, and some insects) (Hamby 1996).

In the bioremediation process, indigenous or cultivated microbes and other organisms are used to transform the poisonous and harmful pollutants to non-toxic substances under the controllable environment. According to the degree of human intervention, the bioremediation could be divided into natural and artificial bioremediation, and the latter could be divided into in-situ bioremediation and ex-situ bioremediation.

Indeed, many in-situ remediation processes such as ecological floating bed techniques and constructed wetlands have been developed for bioremediation of polluted surface water and have obtained satisfactory results (Cao et al., 2012).

Thus, providing an updated comprehensive review of the used systems and its applications and efficiencies is warranted. This paper reviews in a holistic manner the latest surface water remediation developments and technologies that can be applied as in-situ. Further, detailed information about such techniques with its benefits and research needs are introduced.

2 REMEDIATION TECHNIQUES

2.1 Aquatic Plants

The plants with strong absorption for pollutants and good tolerance could be planted in the polluted water. Accordingly these plants can mitigate or fix water pollutants through adsorption, absorption, accumulation and degradation for water purification(Gagnon et al., 2012; Wang et al, 2012).However, plants vary considerably in their tolerance of pollutants and in the amount of that they can take up from soils and water. Some of these accumulating plant species reveal the mineral composition of those substrates, for example, in the soil, sediment and water. This ability can be used in contamination bio-indication or, if the biomass and bio-productivityare high, in phytoremediation (Favas et al., 2012).

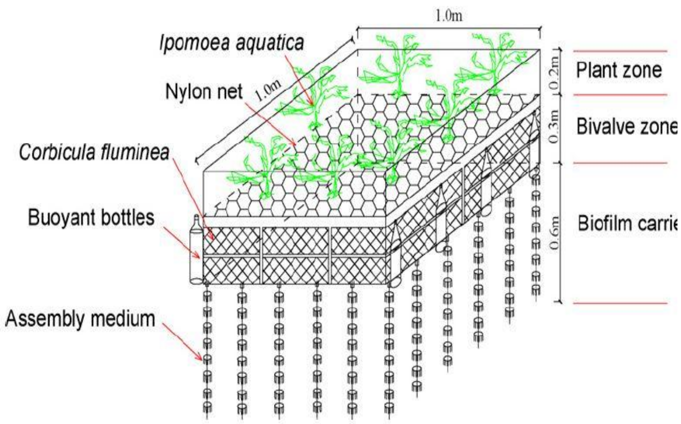

Figure 1.a. Schematic diagram of the integrated ecological floating-bed (Li et al., 2010)

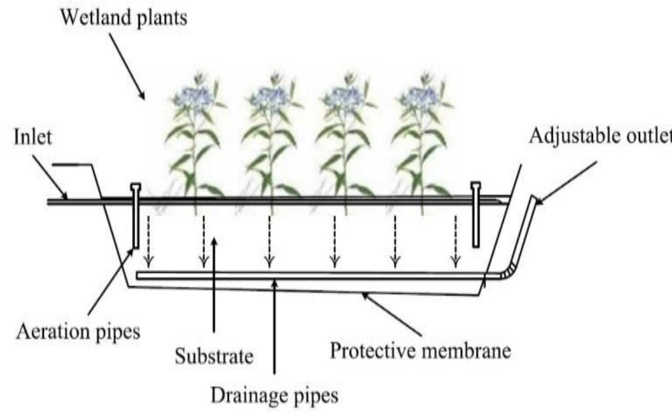

Figure 1.b. The structure of Integrated Vertical-flow Constructed Wetland (Chen et al., 2008)

Figure 1. Major plant based systems used for surface water remediation

In the past 3 decades, plants suchas *Eichhornia crassipes* and*Pistia stratiotes* have been used for upgrading effluent quality (Zimmels et al., 2008). Additionally, foxtail alga, bond weed, common reed (*Phragmites communis*), cattail (*Typha latifolia*),macrophytes, duckweedand Canna indica were used for wastewater treatment purposes (Nahlik et al, 2006; Ruan et al., 2006; Dunqiu et al., 2007;Wang et al, 2012; Sims et al., 2013). Therefore, based on the purpose and the available facilities, aquatic plants can be introduced for surface water remediation in different treatment systems such as constructed wetlands and floating bed systems (e.g. Ruan et al., 2006; Dunqiu et al., 2007; Sun et al., 2008; Zhao et al., 2012) or it can be submerged like algae (e.g. Kalin et al., 2005). Illustration for the mentioned systems used for surface water remediation is shown in figure 1.

Remediation mechanismis not only by assimilating pollutants directly intoplant's tissues, but these plantsalso act as catalysts for purificationreactions. Plus, aquatic plantsincrease the environmental diversity in therhizosphere and promote variety of chemical and biochemical reactions that enhance purification (Hadad et al., 2006).The major characteristics of aquatic plants involve their extensive root system and rapid growth rate whichmade them an attractive biological support media for bacteria (Zimmels et al., 2008). Besides, Motility and chemotaxis enable the bacteria to move towards plant roots where they can benefit from root exudates as carbon and energy source, and may therefore contribute to survival and rhizosphere colonization (Steenhoudt and Vanderleyden 2000).

The mechanisms responsible for $BOD_5$and COD reduction were probably bacterial degradation in which oxygen photosynthetically produced by the plant's leaves were transferred to the root zones for the bacteria growing in the system bed to biodegrade the organic compounds (Sawaittayothin et al., 2007).

In addition to the organic pollutants, aquatic plants, especially the algae, can be also used for the removal of nonconventional pollutants like uranium from wastewater (Kalin et al., 2005). Table 1 summarizes the hydraulic retention time (HRT), target water quality, and pollutants removal rates for the major aquatic plants based systems. For the constructed wetlands, the wide ranges in removal rates are due to the effect of wastewater type and media used. Meanwhile, the change in flow direction changes the removal rates for the Floating Bed Systems.

Table 1. Major aquatic plants based systems used for surface water remediation.

System	Target polluted water	HRT	Removal rate (%)			
			BOD	COD	TN	TP
Constructed Wetlands	Polluted rivers (Ruan et al., 2006) Domestic wastewater Farm wastewater (Saeed et al., 2012)	2-10 days (Saeed et al., 2012)	71-84 (Saeed et al., 2012)	78-84 (Saeed et al., 2012)	50-100 (Saeed et al., 2012)	90 (Wang et al, 2012)
Floating Bed Systems	Polluted rivers (Sun et al., 2009)	2-5 days (Dunqiu et al., 2007; Sun et al., 2009)	83-96 (Xie et al., 2004)	94.6 (Sun et al., 2009)	72-86 (Sun et al., 2009; Xie et al., 2004)	63.6 (Dunqiu et al., 2007)
Artificial seaweed (AquaMats)	Polluted rivers or streams (Jiao et al., 2011)	7.8 Hours (Jiao et al., 2011)	72.7±6.4 (Jiao et al., 2011)	58.1±5.2 (Jiao et al., 2011)	25.9±4.3 (Jiao et al., 2011)	—

Of course, there are certaindisadvantages of using the planted floating-bed in lake restoration.First, it is difficult to control the hydraulic retention time and thepollutants loading rate when this treatment system is applied atreal field sites and secondly, these systems in tropical and sub-tropical areas are especially vulnerable to natural disasters such as hurricanes or typhoons (Li et al., 2010). Moreover, problem facing plant based systems is being sensitive to nutrient availability, pollutants load and seasonally changes, as a result of the change of natural metabolic activities (El-Shafai et al., 2007;Yudianto and Xie 2011). Therefore, some treatment systems were invented to simulate the natural aquatic plants and to overcome the disadvantages of the living plants. AquaMats, for instance, are a type of artificial seaweed with a high surface area that is designed to encourage colonization and growth of anaerobic bacteria, aerobic bacteria, algae, zooplankton and other aquatic organisms (Jiao et al., 2010). Further, removal of pollutants by bacteria in the system can be enhanced by methods such as immobilized bacteria (Sun et al., 2009) and/or by utilizing biofilm carrier (Li et al., 2010). Increasing the plant coverage plays an important in enhancing the removal efficiency as well (Zhao et al., 2012). Plus, the choice of appropriate plant species has been shown to generally improve pollutant removal and this seems an important avenue to explore for optimizing treatment system efficiency (Gagnon et al., 2012).

Nevertheless, the planted based systems regarded as a low-cost, solar-energy-based and eco-friendly technology for in situ purification of surface waterasan important ecological remediation to control water eutrophication (Li et al., 2010; Saeed et al., 2012).

2.2 Aquatic Animals

Cultural eutrophication is a major problem in many surface waters. It has a number of undesirable effects such as increase of phytoplankton biomass. High phytoplankton biomass reduces water transparency and increases pH in euphotic waters and thickness of the anoxic layer above the bottom. It may produce taste, odor and other drinking water treatment problems (Morita et al., 2008; Xiao et al., 2010; Ma et al., 2010, 2012b). When Microcystis blooms break out in the water source, there is a dramatic increase in the phytoplankton population in the raw water causing disruption of coagulation and sedimentation processes, and filters clogging thus affecting water quality (Henderson et al., 2008). In addition, the bio-toxins released by some species of cyanobacteria and some disinfection byproducts formed through the oxidation of phytoplankton cells also threaten public health (Ma et al., 2010, 2012b).

In comparison to physical and chemical remediation methods, biological treatment for phytoplankton control in large water body, such as lakes and reservoirs are effective (Ma et al., 2010, 2012b). Plus, it is well documented that aquatic animals such as clam, snail or other filter-feeding shellfish had prominent effect on nutrients removal in eutrophic water body (Li et al., 2010; Wang et al, 2012). The biological treatment of stocking filter-feeding silver carp in eutrophic water body has been widely applied to control excessive phytoplankton and improve water quality in the world (Xiao et al., 2010; Ma et al., 2010, 2012a)

Generally, silver crap (Hypophthalmichthys molitrix) have a long lifespan (~6-10 years, or even 20 years) in natural water bodies (Ma et al., 2012a). Silver carp is commonly stocked in reservoirs in developing countries and was intensively stocked in newly constructed reservoirs in China in the 1970s. It is an omnivorous filter-feeder that can filter particles > 10 µm, including zooplankton and phytoplankton (Xiao et al., 2010).

Filter-feeding fish such as silver carp have been shown to select zooplankton on the basis of prey escape ability; for instance, cladocerans are more vulnerable than copepods to fish predation due to lower escape ability (Zhao et al., 2013). Another representative example is the improvement in water quality of the Potomac River (America) following the establishment of large numbers of the Asia clam C. fluminea in the early 1980s, where Chl-a concentration appeared to be strongly depleted less than 1g/L (the minimum permissible limits by WHO) (Li et al., 2010).

On the other hand, through excretion and behavior, it can promote nutrient regeneration. Therefore the species imposes both top-down and bottom-up effects on the ecosystem at the same time (Xiao et al., 2010).

In addition to the worldwide application of silver carp to improve water quality in large bodies such as lakes or reservoirs, silver carp has also been used in relatively smaller water bodies such as water works, as a pretreatment method to decrease the phytoplankton concentration in algae-laden raw water and total phosphorus removal efficiencies could exceed 50% with 5 days flow detention time (Ma et al., 2010, 2012a, 2012b)

These experiments have shown that filter-feeding fish are able to reduce phytoplankton biomass to a certain degree, although the final efficiency depends on the characteristics of the given ecosystem. However, the application of such biomanipulation may lead to different effects depending on (1) the composition of the initial plankton community (zooplankton and phytoplankton), (2) the species and stocking density of fish, and (3) temperature (Xiao et al., 2010).

Although silver carp cannot completely control phytoplankton smaller than 10 µm, single-cell algae due to the size character of gill rake morphology of silver carp, it shows effectiveness in dealing with phytoplankton larger than 10 µm, especially colony-forming cyanobacteria (Ma et al., 2010, 2012a, 2012b).

However, controversies remain about using this fish to control algal biomass for instance, several studies have shown that stocking silver carp fails to reduce phytoplankton biomass in the presence of large herbivorous cladocerans. One major reason for this failure found to be the grazing pressure on phytoplankton by zooplankton is reduced as a result of fish predation (Zhao et al., 2013).

Meanwhile, high biomasses of silver carp have been generally used in biomanipulation research and few studies have involved low fish biomass. But researches showed that the impact of fish on the plankton community was much greater than that of nutrients. High total phosphorus concentrations in the control treatment and relatively low temperatures may reduce the importance of nutrient enrichment. These results suggest it is not appropriate to use a low biomass of silver carp to control phytoplankton biomass in warmer, eutrophic fresh waters containing large herbivorous cladocerans (Zhao et al., 2013).

Further, these filter-feeding characteristics directly caused the phytoplankton size distribution biased toward miniaturization. Therefore, this biological treatment using silver carp could be applied only to deal with groups of Microcystis-dominated eutrophic water, and was not appropriate in water bodies where single-cell micro phytoplankton were dominant. Especially when silver carp are used in water treatment, a cautious attitude should be taken based on the evaluation of phytoplankton biomass and species structure features in raw water (Ma et al., 2010, 2012a).

Moreover, the introduction of filter-feeding bivalve to floating-bed system promoted the purification efficacy due to the filter-feeding on algae and other kinds of organic nitrogen. It is suggested that filtration by bivalves might improve water quality by removing seston and chlorophyll-a from water bodies, thus reducing the concentrations of suspended sediments, detritus, and particulate bound nutrients in aquatic systems. Furthermore, the introduction of C. fluminea extending the food chain of floating-bed systems promoted the in organization of particulate organic nitrogen and phosphorus, and improved the biodegradability of particulate organic matters through the physiological activity of C. fluminea including filter-feeding, digestion and excretion (Li et al., 2010).

As for its high removal efficiency for colony-forming Microcystis, low cost, and environmental friendly manner, silver carp shows a great prospect in pre-treating Microcystis-dominated eutrophic water (Ma et al., 2010, 2012).

However, the efficiencies of aquatic animal based systems for different phytoplankton species, and the dynamic change process of phytoplankton cell size distribution are rarely reported. Moreover, the inorganic or organic pollutants in raw water and some bio-toxin released from Microcystic are harm to silver carp and then affect the effectiveness of this biological treatment. Therefore, the further study in the toxicology and the security of water quality is needed (Ma et al., 2012b).

2.3 Microorganisms

In this technology microorganisms are used to decompose, transform, absorb the pollutant in the water. Results to date generally confirm the existence of the appropriate microbial functional groups, e.g. nitrifiers, denitrifiers, SRB, SOB etc., responsible for removal of specific pollutants the wastewater (Faulwetter et al., 2009; Wang et al, 2012).

The complex microbial community present in the biological treatment facilities has a requirement for carbon, nitrogen and phosphorus for the maintenance of basal metabolism and cell growth (Yeoman et al., 1988).Respiration and fermentation are the major mechanisms by which microorganisms break down organically-derived pollutants into assumed harmless substances such as carbon dioxide (CO_2), nitrogen gas (N_2) and water (H_2O). Furthermore, end products, such as sulfide, generated by some types of respiration can enable other known removal mechanisms. In respiration, the microbe induces a transfer of electrons from a donor compound of higher energy state (typically organic carbon, OC) to an electron acceptor of lower state using the energy differential for growth and reproduction (Faulwetter et al., 2009).

Nutrients reach surface waters from many sources.For shallow lakes, release of phosphorus had larger potential ecologic crisis (Liyuan and Enfeng 2011; Varol 2013). Removal mechanism of phosphorus by microorganisms is important. Acinetobacter jobnsonii strain 210A is the strain for which most information is presently available on polyphosphate metabolism. There are indications that other bacteria might also be involved in the enhanced phosphate removal from wastewater. For example, a Xanthobacter sp., two Moraxella strains and a Mtcrococcus sp. have been identified in polyphosphate-accumulating bacteria. One Moraxella strain was able to store polyphosphate cytoplasmati-cally as well as periplasmatically. In addition, it could fix high concentrations of phosphate on the cell surface. For the Micrococcus sp., microaerophilic growth conditions were required for the induction of phosphorus-accumulating activities (Egli and Zehnder 1994).

The mechanism involved in COD removal was studied in Biological Vessel (BV) as well. It was found that limited oxygen conditions resulted in the development of microaerophilic filamentous Beggiatoa on the surface of dense anaerobic sludge and resulted in the formation of granules with high settelability (Arora et al., 1995).

Nitrogen is one of the major nutrients that wastewater treatments attempt to eliminate in order to avoid water pollution. Biological nitrogen removal is traditionally achieved by auto-trophic nitrification and heterotrophic denitrification processes (Araujo et al., 2011).Presently, nitrogen (ammonia) removal is mostly carried out through two conversion steps, namely, aerobic nitrification and anaerobic denitrification.(Morita et al., 2008).

Anaerobic ammonium oxidation (anammox) is the microbial conversion of ammonium and nitrite to dinitrogen gas. The functional microbes of anammox reaction are anammox bacteria, which were discovered in a wastewater treatment system for nitrogen removal. Anammox bacteria are prevalent in anoxic ecosystems and play an important role in both biological nitrogen cycle and nitrogen pollution control (Faulwetter et al., 2009; Ding et al., 2013).Anammox bacteria are autotrophic and have a notoriously low growth rate with minimum doubling times of several days. The anammox group has been split into five Candidatus genera: ‘Brocadia’, ‘Kuenenia’, ‘Scalindua’, ‘Anammoxoglobus’ and ‘Jettenia’. Phylotypes of these genera have been identified around the world, in diverse environments, such as wastewater treatment plant sludges, marine sediments, a few freshwater environments, and a brackish environment (Araujo et al., 2011).

On the other hand, Autotrophic nitrification consists of two successive aerobic reactions, the conversion of ammonium to nitrite by ammonium oxidizing bacteria (AOB, Nitroso-) and the conversion of nitrite to nitrate by nitrite oxidizing bacteria (NOB, Nitro-). AOB and NOB use CO2 and bicarbonate for cell synthesis and ammonium or nitrite as the energy source.The genera Bacillus, Micrococcus and Pseudomonas are most common in soils while Pseudomonas, Aeromonas and Vibrio are more common in aquatic environments (Faulwetter et al., 2009).

Nitrification rates are insensitive to the BOD loadings; as the BOD loading increases, suspended solids increase, preventing changes in the bulk BOD concentration (Downing and Nerenberg 2008). However, variety of environmental factors including temperature, pH, and salinity, as well as inhibiting substances such as ammonia and organic carbon loading may influence the diversity of nitrifiers (Faulwetter et al., 2009).Riley et al. (2005) observed better ammonium removal at higher organic load rates in winter but poorer removal with higher organic loadings in summer, suggesting organic loading influences on nitrification interact with temperature and other factors.

Recently, several new nitrogen-removal processes have been developed, one of which is completely autotrophic nitrogen- removal over nitrite (CANON). In the CANON process, two major groups of bacteria are responsible for autotrophic nitrogen removal: aerobic ammonium-oxidizing bacteria (AerAOB) converts ammonium to nitrite with oxygen as the electron acceptor and anaerobic ammonium-oxidizing bacteria (AnAOB) subsequently oxidizes ammonium with nitrite as the electron.

Practically, two different microorganisms-based methods were used for surface water remediation. First method is Microbial Dosing Method and the second one is Biofilm method. Researches related to each

2.3.1 Microbial Dosing

This technology uses specific and efficient microorganism to decompose, transform, absorb the pollutant in the water, to purify quality of the river by sifting of the efficient microorganism, optimized construction of the microorganism.FLO-1200 achieved remarkable results in the river pollution control under the conditions of river aeration. Zhang Li added bio-energizer, combined water mixing and strengthened the ability of microbial degradation artificially for water purification (Wang et al, 2012).

Taylor et al., 2012 utilized two kinds of microbial reagents to remediate a heavily polluted river in Fangcun District, China, which became a black and odorous river. The retention time was around 20 hours. The reagents were directly diluted with river water before inoculation. The results of the small-scale experiment indicated that the removal rate increased with the increase of photosynthetic bacteria (PSB) concentration. The COD_{Cr} and NH_3-N removal (corresponding removal rate are all over 60%). Furthermore, Field-scale test was undertaken, Except for SS, the total removal rates for each pollutant all exceeded 70 percent. Eventually, they recommended applying this method to remediate other heavily polluted rivers.

Mingjun et al., 2009 carried out a field trial of bioremediation in 60 m^3 of eutrophic water body in a local park for four months. A little amount of natural humic acid was added to speed up flocculation and deposition of the superfluous algae. Thus, the multiple microbial preparation used was composed of nitrobacteria, mixed bacteria and humic acid. The following conclusions were drawn: Pollution indexes of TN, TP, NH4+-N, COD and turbidity were declined differently, and the rates were 77.8%, 72.2%, 94.2%, 60.0% and 85.6%, respectively. After bioremediation, the color of lake turned light green from dark green and clearer. The turbidity declined and DO increased. The water environment improved. Thus the problem of Lake Eutrophication can be solved radically by bioremediation.

2.3.2 Bio-film

The bio-film technology utilizes bio-membrane attached to the natural river bed and micro-carrier to move the pollutants in the river through adsorption, degradation and filtration under the conditions of artificial aeration or dissolved oxygen. Gravel contact oxidation method, artificial packing contact oxidation method, thin layer flow method, underground stream purification method, etc. The strengthening purification technology of The bio-film technology for river purification in Japan and South Korea and other countries were river researched by Japanese were mainly indirect purification, which was to build the purification facilities on the side of the river (Wang et al, 2012).

Takada et al, 1994evaluated the role of biofilm attached on streambed in LAS degradation in the stream using Environmental observations and laboratory biodegradation experiments using biofilm collected from Nogawa river bed located in southern part of Tokyo, Japan. Three batch culture experiments and one continuous culture experiment were conducted. For most observations, greater than 80% of the LAS were removed within 2-3 h of the travelling time. The batch culture experiments clearly indicate that the existence of the biofilm accelerates the biodegradation of LAS (Chen et al., 1995).

For the same river, gravel contact oxidation was utilized, the packing was gravel, and the removal rates of BOD and SS were 72.3% and 84.9% respectively. With new non-woven fabric as packing, the drainage ditch facilities in Chiba County was set on the side of the ditch, and the removal efficiency of SS reached 97%, the removal rates of BOD and COD were 88% and 70% respectively (Wang et al, 2012). Moreover, Wu et al., 2006 used Plant-biofilm oxidation ditch for in-situ treatment of polluted water. The system was designed for in-situ treatment of municipal sewage or polluted lake water in combination with plant biofilms for performing N and P removal. And running experiments at pilot scale for about 1.5 years resulted in the following observations: 1) The system was quite satisfactory and stable for treatment of municipal sewage and polluted lake water in removing COD, NH4+-N and P. 2) The direct uptake of N and P by plants was negligible in comparison with the total removal by the system, but indirect mechanisms via plant root exudates and biofilms merit further studies. The proposed process could dramatically reduce the costs of sewage collection, the land-space requirement and the construction costs compared with conventional sewage treatment plants; might be suitable for treatment of both municipal sewage and polluted lake water; and could lead to the promotion of wastewater treatment in many developing countries.

Further, biofilm processes, such as aerated bio-filter biological fluidized bed, suspended carrier biofilm reactors (SCBR), etc., are commonly used in surface water remediation. Immobilization of biomass in the form of biofilms is an efficient method to retain slow growing microorganisms in continuous flow reactors. These systems operated as aerobic or anaerobic phases with freely moving buoyant plastic biofilm carriers (Wang et al., 2005).More specifically, microorganisms grow attached on small carrier elements that are kept in constant motion throughout the entire volume of the reactor, resulting in uniform, highly effective treatment (Trapani et al., 2008).

The moving bed reactors provide distinct advantages, including being simple in operation, at low risk of losing the biomass and less temperature dependent (Wang et al., 2005). In addition, they have better control of biofilm thickness, higher mass transfer characteristics, they are not subject to clogging and they have a lower pressure drop (Trapani et al., 2008 and Moussavi et al., 2009).

Given its specific advantages, moving bed reactors are the most common activated sludge modifications used for industrial wastewater treatment (Moussavi et al., 2009), secondary effluent from sewage treatment plant (Chiemchaisri et al., 2003), and river water (Chiemchaisri et al., 2008). Ateia et. al., 2014 investigated the removal of organic matter from agriculture drainage water using MBBR. It was concluded that COD removal could reach up to 95% when the biofilm was acclimated to the same salinity level.

The biological contact oxidation process (BCOP), also called submerged biological filter or contact aeration system, is a hybrid wastewater treatment system, taking the advantages of both activated sludge process and biofilm process, e.g., no bed clogging and sludge bulking. Li et al., 2009 study two types of biological contact oxidation processes (BCOP). Step-feed (SBCOP) unit and Inter-recycle (IBCOP) unit were designed to investigate the treatment of heavily polluted river water. When spring dry season arrived, considering the lower substrate concentration of the raw water and positive effect of temperature rise on biological treatment, the total influent of each unit was 71.3 L/h with an HRT of 2h. During the summer rainy season, in order to enhance the nitrification in the two biological treatment units, the total influent of each unit was recovered to 26.4 L/h with an HRT of 5.4 h. Further, the recycling ratio was 200% for the IBCOP. The results showed that The SBCOP unit had higher adaptability and better performance in the reduction of pollutants, i.e., with the average removal efficiency for COD, TN, and TP of 58.0%, 9.7%, and 40.4% in the winter, 46.4%, 24.7%, and 45.1% in the spring, and 66.5%, 27.2%, and 47.3% in the summer, respectively. Therefore, SBCOP is more applicable for the treatment of river water.

Yu et al, 2006 studied the treatment efficiency of a gravel contact oxidation treatment system located in Guandu, Taiwan. This system was constructed at the riverside. The river water was inducted into an influent well by piping, and then pumped to a storage tower by submersible pumps. Finally, the river water flew into the system by gravity. They reported that the removal rates of BOD, TSS and $NH4^{+}$-N with an average of 46 %, 71% and 24 %, respectively. The hydraulic retention time (HRT) for better removal of SS was 15-20 hours, 13-17 hours for BOD, and 10-15 hours for $NH4^{+}$-N.

Juang et al., 2008 evaluated the treatment efficiency of a gravel contact oxidation treatment system which was newly constructed under the riverbed of Nan-men Stream located at the Shin Chu City of Taiwan. The design flow rate of this system was 10,000 CMD (m3/day) and the HRT ranged between 1.5~3 hours. River water flew through the whole system by gravity. During wet days, if the river flow rate is higher than the design flow rate, the superfluous flow will directly pass through the treatment system to the downstream of the river. The results showed that the average removal rates of five-day biological oxygen demand, total suspended solids and NH 4+-N were 33.6%, 56.3% and 10.7%, respectively. And they reported that since the river water flew through this system by gravity, no power was consumed in the whole treatment process and the operation and maintenance cost was apparently reduced. Plus, further studies might be required to confirm whether higher HRT will improve the treatment efficiency of this gravel contact oxidation system.

Bio-ceramics were used as the carrier to treat a polluted river in Shenzhen, and the average removal rates of NO_2- N, NO_3- N, COD, turbidity, color, Mn and alga were 90.8%, 84%, 21.4%, 62%, 47%, 89% and 68% respectively. Based on the use of sewage treatment technology by rubber packing inner loop fluidized bed bio-film, the average removal rates of COD and ammonia were 88.16% and 91.8%, and the highest removal rates were 94.64% and 94.08% respectively. Wang Shu mei installed aerators, bio-film and added special bacteria in the river, and the removal rates of COD_{Cr}, BOD_5, NH_4+-N, TN, TP and SS were 67.4%,87.7%, 34.3%, 30.3%, 53.3% and 39.7%, the dissolved oxygen and transparency in the river increased from 0.9 mg/L and 12.5cm to 7.6 mg/L and 137.5cm respectively. Yang Tao laid the biological filter media on the river surface, and the average removal rates of COD, ammonia nitrogen and total phosphorus were 40.00%, 36.43% and 43.02% respectively (Wang et al, 2012).

Biofilm carrier can be either artificial or biological media. Cao et al., 2012 used filamentous bamboo as a biofilm carrier (Biocarrier) for bioremediation of polluted river water. Beside evaluating the system under continuous flow conditions, they assessed the CODcr bioremediation efficiency when glucose was added to the river water in a hybrid batch reactor. Raw water was taken from a polluted river and poured into a wastewater tank. The flow rate was regulated using a peristaltic pump, and the column was operated in up-flow mode. In addition, air was supplied into the reactor from the bottom. The microorganisms used in the experiments were cultivated in the reactor, which was a hybrid system composed of filamentous bamboo and suspended activated sludge. The continuous flow reactor kept the same packing of filamentous bamboo used in the batch experiment, and had a hydraulic retention time (HRT) of 3.5 h. The bioremediation of polluted surface water by using biofilm on filamentous bamboo is feasible and effective. As a result, the mean CODcr removal rate reached 66.1% in a batch hybrid reactor, and glucose can be used to substantially increase the CODcr removal. Under continuous flow conditions, the removal rates of COD_{Mn}, $NH4^+$–N, turbidity, and bacteria were 11.2–74.3%, 2.2–56.1%, 20–100%, and more than 88.6%, respectively. Therefore, Polluted surface water with refractory organic pollution, low transparency, and high nitrogen pollution can be remediated by using biofilms on filamentous bamboo. The filamentous bamboo is beneficial to forming a rich microbial community. It is recommended that filamentous bamboo be widely used for the bioremediation of polluted river water instead of conventional bio- carriers and phytoremediation techniques.

Biocord is a man-made bio-reactor substrate, developed and manufactured for water management using microbe activity to passively treat water in controlled flow or storage applications. Biocord can also be used to treat wastewaterin oceans, rivers, lakes, marshes and manmade reed beds(Xingcheng et al, 2012).Research results illustrated that the bio-cord exhibited good filtration performance and effectively removed COD, NH3–N and TN with 26%, 65%, and 50% respectively. The flow rate of 4 L/min for 120 min, resulted in the water being completely replaced once every 10 min.The bio-cord fibers also provided suitable conditions and support media for microbial growth.

Recirculating ration is an important to improve the treatment efficiency. Liehr et al., 2003 compared peat filter and a recirculating sand filter (RSF) for onsite treatment. Both systems were able to meet secondary effluent standards for BOD5 and TSS. The RSF also was moderately effective at removing nitrogen (58%) while the non-recirculating peat filter was not (26%).

In addition, hydraulic loading rate (HLR), aspect ratio, granular medium size and water depth are determining factors in the performance of the biofilm-based systems (Garc et al., 2004). However, these techniques have drawbacks, such as complex water and air distribution systems, backwash requirements, occasional biofilm sloughing and a high nitrite residue in the effluent (Li and Chu 2003).

3 POTENTIAL RESEARCH NEEDS

Ammonia-oxidizing bacteria (AOB) populations may diversify with different types of biofilm attachment sites. AOB may also diversify within the TW biofilm itself and different organisms can be active in response to large micro-scale variations in the physiochemical environment (Faulwetter et al., 2009). So, if we need to understand what controllable factors turn critical functional groups on and off, we will be able to fully optimize performance.

On the other side, Water shortage problems made crucial need to explore all viable options toconserve current resources and explore new ones.The availability of ample quantities of Agricultural drainage water (ADW) creates considerable opportunities for recovering significant quantities of water from this source(Ahmed et al., 2003; Sorour et al., 2003;Talaat et al., 2003;Talaat et al., 2007). ADW as unconventional water sources is threatened by pollution from industrial and domestic wastewater in the developing countries, whereas there are no researches related the application of in-situ bioremediation for it. Therefore, researches and efforts should be madeon this aspect.

4 CONCLUSIONS AND RECOMMENDATIONS

After comparing and analyzing different techniques and clarifying the concepts of in-situ bioremediation technology, following points could be summarized:

- Bioremediation materials should be optimized and the bioremediation mechanism should be studied from different angles tofurther improve the bioremediation technology.
- The general experimental conditions of various technologies such as aeration, HRT, microbial preparation and dosing were determined.
- The appropriate microorganisms are acclimated to adapt to different polluted river.
- Researches and efforts should be made to reduce HRT for bioremediation technologies.
- The river pollution control technique for urban area should be investigatedand studiedin detail.
- These methods should be tested not on rivers and lakes only, but also on other polluted surface streams like agricultural drains.

Eventually, approaches to alleviate the surface water pollution problem should utilize the bioremediation as the primary technique, followed by the physical and chemical remediation as the supplementary means.

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