Chapter 2
Water Pollution, Human Health and Remediation

Komal Jayaswal, Veerendra Sahu and B. R. Gurjar

Abstract Water is considered as the most essential source of life and important part of our natural resources. Due to rapid industrialization, urbanization and lack of awareness among people to consider water as a crucial commodity, around 80% of the world population is now facing water supply and security threat. In fact, about 2% of planet water is fresh and only 0.036% of water is accessible for use, rest 1.96% is present in polar ice caps, underground wells and aquifers. Furthermore, freshwater resources are progressively becoming unavailable due to huge amount of pollution in drinking water sources and also due to ignorance by human or industries and government authorities. The increasing water contamination by discharging untreated effluent is major problem faced by humanity worldwide. For this, government authorities and other organizations concerned about water conservation, awareness among people, strict laws about water security, sustainable and cost-effective wastewater treatment technology to overcome water pollution and water shortage problem for humans and biodiversity.

Keywords Water pollution · Wastewater treatment · Bioremediation Ecology

2.1 Introduction

Water is the most vital among all natural resources and considered as the most important for life. Due to rapid industrialization, urbanization and lack of awareness among people to consider water as a crucial commodity, around 80% of the world population is now facing problem related to water supply and security (Vorosmarty et al. 2010). While planet earth is mostly covered with water, however, only about 2% of water can be considered for use and rest 98% is seawater that is unsuitable

K. Jayaswal (✉) · V. Sahu · B. R. Gurjar
Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee-Haridwar Highway, Roorkee 247667, Uttarakhand, India
e-mail: jayaswal.komal@gmail.com

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for drinking due to presence of salts. In fact from 2% of fresh water only 0.036% is accessible for use, rest 1.96% is present in polar ice caps, underground wells and aquifers. Furthermore, freshwater resources are progressively becoming unavailable due to huge amount of pollution in drinking water resources due to ignorance by human or industrial and government authorities (Kumar Reddy and Lee 2012).

Due to ignorance a large number of water resources get contaminated and become unsuitable for drinking and other purpose. Moreover, remaining freshwater resources gets progressively polluted due to discharge of untreated pollutants, chemicals and hazardous waste from thousands of industry directly into water body. Evolving industrialization and rapid population growth lead to more water demand that definitely marks water as a precious and fundamental commodity (Vorosmarty et al. 2010).

Emergent pollutants that are entering in water supply systems are pesticides, synthetic fertilizers, chemical compounds like dyes, heavy metals, hormones, personal care products, detergents, pharmaceuticals product that directly or indirectly may enter into the aquatic system and finally affect human health. Apart from this, waterborne pathogenic microbes enter the water system from research laboratory, hospitals, untreated sewage, septic tanks and various tanneries, food processing and meat packaging industries (Schwarzenbach et al. 2010). Pollutants have direct effect on human health and ecosystem. Apart from anthropogenic sources, other natural factors that strongly affect water quality are floods, storm, volcanic eruptions, earthquakes, etc. Major water pollutants have been shown in Fig. 2.1. New techniques have to be developed in coming years, for clean water supply otherwise water scarcity may lead to water wars and insecurity at social and political levels.

Fig. 2.1 Sources of water contamination (Kumar Reddy and Lee 2012)

Without any proper strict regulation by government authorities and concerned organizations, this severity of problem cannot be controlled. Lawmakers must impose strict policy for industries, organization and people for proper waste management, treatment of discharge effluent, proper working of treatment plant and strictly follow the effluent discharge standard. The increasing water contamination by discharging untreated effluent is major problem faced by humanity worldwide. In fact, in developing country like India even though facilities are available but due to mishandling practices and lack of sanitation awareness, water resources are not properly utilized. In India, this problem is related to both rural and urban areas, for example in most of the Indian city collection of household drinking water is dependent on season and infrequent supply results in storage of water. During storage of water, there is a chance of contamination and level of contamination increases by number of factors like quality of container used, place of storage, water collection site and handling practices (Brick et al. 2004). To overcome this problem, government authorities and other organization have to issue strict laws about water regulation and security and also develop cost effective and sustainable wastewater treatment technology to overcome water pollution and water shortage problem for humans and biodiversity. Apart from this awareness campaigns must launch to make people aware about importance of water (Kumar Reddy and Lee 2012; Vorosmarty et al. 2010).

2.2 Background

In twenty-first century, major problems faced by human society are interrelated to water quality and quantity issues. Furthermore, in coming decades these problems are going to be intensified in wider sense due to climate change that will result in melting of glaciers, rise in water level and temperature and change in water cycle pattern that is going to increase more frequent floods and droughts. A warmer climate can hold more moisture, causing 7% increase in water vapour with rise in every degree centigrade of temperature. Water vapour acts as greenhouse gas that drives earth's hydrological cycle and change in climate (http://earthobservatory.nasa.gov/Features/Water/). Lack of proper sanitation has directly related to lack of safe drinking water which affects human health, for example, untreated excreta enters into the food chain causing severe health issues. Other major problems related to water security are contamination of water source by pathogenic microorganisms and toxic chemicals which further lead to bioaccumulation in aquatic water plants and other living organisms including seafood and fish. Pollutants from domestic, agricultural and industrial sources merge to freshwater sources like rivers, lakes and groundwater aquifers without proper treatment. These pollutants cause physical, chemical and biological pollution of natural water resource, and it has become public concern in all parts of the world (Schwarzenbach et al. 2010).

Nutrients and natural organic constituents like nitrogen and phosphorus are present in relatively small amounts such as in milligram per litre, generally considered as macropollutants. The primary source of these pollutants is from agriculture by excessive use of fertilizers and animal manure, from fossils fuel used in industry, power and transportation sector which increases amount of nitrogen in air. Other sources of nutrients are from sewer system. The effects of these pollutants are generally well known, but the major challenges are in developing a sustainable treatment system, as high amount of nutrients can lead to generation of biomass concentration, eutrophication in lake and oxygen depletion. (Lohse et al. 2009; Heisler et al. 2008). Due to high concentration of salt in water, it becomes unfit for drinking and also inhibits the growth of agricultural crops. This condition is present near coastal areas in India and China. Intrusion of excessive marine salt into groundwater near coastal area due to overexploitation of aquifers which lead to inhibition of agricultural crops and direct mixing in fresh water makes it unfit for use (Kaushal et al. 2005; Kumar et al. 2015; Schwarzenbach et al. 2006).

Sometimes, even small concentration of synthetic and natural pollutants may exert adverse effect when present in mixtures, and accumulation of these pollutants causes acute and chronic effects on human health. For example, total inorganic nitrogen total phosphorus discharged into river worldwide is 21 and 5.6 (10^6 tons per year), respectively. Similarly, around 0.3–1 (10^6 tons per year) heavy metals like zinc, chromium, nickel, mercury, cadmium, lead get discharged into the river (Schwarzenbach et al. 2006). Apart from macropollutants, acute health effect may also be generated due to pathogenic microbes present in polluted water, so to control the effect of micropollutants on human health and aquatic life, appropriate and sustainable water treatment technology must be applied for preventing pollutants to enter water supply system (Schwarzenbach et al. 2010). Different treatment system has been evolved, but to select an appropriate treatment system based on type of pollutant entering in water system, proper maintenance and efficient removal have to be considered. However, selection method often signifies a challenge not only in the sense of technology but also for economic, social and political viewpoints (Filippelli 2008). Local needs, preferences and practice of local people govern the social issues for planning and development of overall technology framework. Apart from this, well-framed law and clear jurisdiction owned by government body control the implementation of technology (Massoud et al. 2009).

Globally, about 30% of available freshwater is consumed by industries and municipal corporation (Cosgrove and Rijsberman 2000) that generate a large amount of wastewater containing pollutants with different concentration. In majority, wastewater is discharged in natural water system without treatment or undergoes treatment that does not effectively eradicate most of the pollutants. Other sources are also responsible for micropollutants, these are runoff of million tons of pesticide from agricultural land, other from oil and gas spills worldwide (Eliopoulou and Papanikolaou 2007) and also from human-driven toxic chemicals such as heavy metals, metalloids and alloy.

Additional natural micropollutants are incorporated from biological sources, which produce taste and odour in water, and these are not a major toxicological problem, but it leads to great aesthetical concern. There are also a large number of hazardous waste sites, for example abandoned industrial and previous military sites, from where toxic pollutants may find their way directly into natural water system, such as groundwater. In India, hazardous waste sites is present in states like West Bengal, Uttar Pradesh, Gujarat, Kerala, Madhya Pradesh, Orissa, Maharashtra and Karnataka, having heavy metal and aromatic hydrocarbon in high concentration (http://www.cpcb.nic.in/LIST_OF_HW_CONTAMINATED_SITES.pdf).

Report shows that around 100,000 toxic chemicals have been registered, most of them are in daily use (Schwarzman and Wilson 2009), so there are numerous passages by which these chemicals may enter freshwater system like industrial discharge directly into water body, toxic chemicals from agricultural fields and also from biological production of toxins and malodorous compounds (Schwarzenbach et al. 2006). In this chapter, we attempt to focus on worldwide water pollution problem, different types of natural and synthetic water pollutants present in natural water body and their sources, effects on human health, biodiversity and their remediation.

2.3 Agricultural Water Demand, Its Uses and Effects

A large number of chemicals are used to maintain crop production and to increase agricultural growth rate every year. Other than this, several tons of pesticides are consumed to control pests, weeds, insects and other microorganisms. These pesticides and other chemicals generally contain hundred different types of active ingredients that directly impart toxicity to humans and other biota. These chemicals not only pollute soil, water resource, biota and ecosystem but also it stretches its effect to farmers and consumers (Galt 2008; European Commission 1991), and these contamination due to their continuous exposure to living organisms are of great concern.

Very high concentrations of pesticides and their intermediate products such as triazines and chloroacetanilides are detected in US rivers, and due to their high permissible range, it can effect nontarget organisms in soils and whole aquatic systems and also affect the quality of surface and groundwater (Gilliom 2007). Pesticides like dichlorodiphenyltrichloroethane (DDT), hexachlorocyclohexane (HCH), aldrin and dieldrin which are organochlorine in nature are commonly used in developing countries like India due to low cost and effectiveness among several pests. Use of pesticides like HCH, DDT, endosulfan, phorate are common in some parts of India like Punjab, Maharashtra, Karnataka, Gujarat and Andhra Pradesh (Abhilash and Singh 2009). These pesticides are used for crops like cotton, vegetables, sugarcane rice.

Effective mitigation measures have to be designed to prevent pesticides and others chemicals to reach surface and groundwater. Pesticides runoff is dependent on hydrological properties of soil like water flow patterns, permeability, topography, meteorological conditions and absorption behaviour of chemical composition of pesticides (Leu et al. 2004). Pesticides applied to crop at first were degraded by soil microbes and chemical reactions, further it also absorbs in organic matter present in soil. It transforms into other metabolites but does not completely degrade. The final pathway of pesticides in environment takes place through volatilization in atmosphere, runoff in dissolved and particulate form to surface water bodies like river and mixing in groundwater through leaching process (National Research Council 1993).

Water contamination takes place through runoff of pesticides containing rainwater from roofs and roads in urban areas, which lead to pollution in drainage and sewer system. Pesticides application in agricultural practice causes direct exposure and health risk for workers, and extensive use of pesticides leads to water and soil pollution. In the area prone to high pesticides concentration, effective mitigation measures have to be applied by replacing or restricting extensive use of pesticides (Leu et al. 2004a; b). To maintain ecological balance and biodiversity, extensive use of pesticides in agricultural land has to be controlled and further direct exposure of pesticide chemicals to workers and farmers has to be regulated. Report shows that due to accidental exposure of pesticides, poisoning of 3 million people and 20,000 accidental deaths takes place per year in developing countries (United Nations Environment Programme 2007). The main role of the agricultural practices in most developing countries is to attain and sustain food security issues for the emerging populations, also keeping in mind about type of agricultural practices, pesticides and agrochemicals usage and their effect on human and other living being. With increasing trends in urbanization and industrialization, development in agricultural practices also increases which lead to water usage and quality issues. Due to extensive pesticides usage per hectare of agricultural land in developing countries, their concentration monitoring and effect assessment for human and plants health are often limited and implementation of regulations for maintaining pesticide concentrations are limited (Menezes and Heller 2008; Agrawal 1999).

2.4 Groundwater Contamination, Sources and Effects

2.4.1 Groundwater Contamination by Geogenic Sources

Aquifers geological composition generally causes leaching of toxic elements in water supply. Arsenic, fluoride, iron, chromium and selenium are main elements concerned with groundwater contamination. Arsenic among all these contaminants has caused extreme health effects and risk to the life of people in different countries. In Bangladesh, about 95% of the total population uses groundwater from 10 million tube wells. From this, around 60% underground water wells near Ganga and Brahmaputra river system contain arsenic beyond permissible limit as reported by World Health Organization (WHO) (Ahmed et al. 2004). High concentration of arsenic is due to weathering of arsenic-containing rocks in mountain ranges, deposition of organics in floodplains of rivers and due to high residence times of water in groundwater aquifers which cause anoxic condition for release of arsenic in water. Other factors that affect groundwater with arsenic contamination are mobilization of arsenic at high pH with oxygen-rich groundwater; this phenomenon occurs in arid areas such as US Midwest, eastern Australia and central Asia (Amini et al. 2008). Health effects caused due to high arsenic concentration are high blood pressure, neurological dysfunctions and pigmentation in limbs that lead to keratosis by accumulation in the skin, hair and nails (Chen et al. 2009). Chronic effect of arsenic leads to skin, lungs and internal organ cancer. It has been reported that carcinogenic effect of arsenic is caused due to contamination level greater than 50 μg As/L (Smith et al. 2002). Different technologies have been developed like membrane filtration, adsorption for treatment of arsenic contaminated water, but due to high cost of treatment, these methods cannot be used at places with alarming situations, so there is a need to develop cost effective, feasible and alternative techniques like rainwater harvesting, water sources from deep aquifers for rural areas in developing countries. For developing countries simple, effective and economical treatment technology is required. Furthermore, alternative methods like rainwater harvesting and adsorption techniques have to be implemented to improve water quality.

2.4.2 Groundwater Contamination by Anthropogenic Sources

Groundwater contamination is related to geological formation of aquifers, where pollutants enter into underground water table and pollutants transported to other stretch of drinking water source. Groundwater contamination results from municipal solid waste landfills sites, nuclear waste site, hazardous waste sites, accidental spills, runoff from agricultural land and waste discharge from industry. Many abandoned sites where illegal dumping and discharge of waste materials take place can result in groundwater pollution. Around 100 million tons of waste gets discarded that contains radioactive and hazardous water which enters groundwater table through leaching by contaminated landfills (United States Environmental Protection Agency 2008). Some of the contaminated sites are under maintenance and control conditions but most of them are expected to release toxic waste to environment. In addition, thousand tons of oil, petroleum and other chemical spills take place every year which resulted in pollution of water during storage and transportation process. Types of toxic chemicals that fluxes from contaminated site are fuel hydrocarbon, chlorinated ethane, pesticides, radio nuclear waste from nuclear weapon testing sites, explosive chemicals from ammunition plants, heterogeneous and non-categorized disposed waste and wastewater (Schwarzenbach et al. 2010). In fact, leachate composition at landfill sites is heterogeneous and complex as only few contaminant species are identified, so if there is need to monitor type of waste dispose at these sites, continuous monitoring of leachate material and groundwater is needed. Groundwater is directly used for drinking, and these persistence contaminants took several decades to decompose, so monitoring and assessment are necessary to check health risk and exposure of chemicals on human body. For this implementation of cost effective, reliable and sustainable approach is needed.

Groundwater contamination quantification and treatment approaches are phytoremediation, site excavation, pump-and-treat procedures and permeable reactive barriers (Salt et al. 1998). However, most of the remediation methods are very expensive and also more time is required for decay process. Treatment methods include removal of contamination source, catalytic reaction to immobilization of metals and conversion to biodegradable (organic) materials. Nowadays, remediation strategies include microbial or abiotic degradation processes. Presence of high amount of carbon source along with microbes at contaminated site leads to anoxic conditions, which further proliferates the growth of different microbial community at site which helps in degradation of certain types of waste materials. Anoxic condition helps in growth of metal reducing microbes which transforms organic and inorganic pollutants. Thus, for elimination of waste, proper assessment and understanding of type of contaminant along with its reactivity and mobility with other contaminants, geographical conditions of landfill site are required. Analytical tools such as stable isotopes analysis method provide information about specific compound, its transportation and transformation behaviour in groundwater during pollution and accidental spills conditions (Hofstetter et al. 2008).

2.5 Surface Water Contamination, Sources and Effects

Mining operations trigger in large amount of waste deposits which cause significant environmental problems. Generally, these generated wastes get oxidized by air and weathering by precipitation which further contaminates water resources. Mining activities result in large amount of waste to finally yield significant end products. Around 1,000 tons of waste materials are produced per kilogram of pure metal, during extraction of rare metals like gold, copper and nickel. Ores of iron, coal and copper contain large amount of sulphide, which further oxidizes in presence of air and water and forms sulphuric acid by acid mine drainage (Blodau 2006). It has been estimated that worldwide about 20,000 km of river stretch and 70,000 ha of lake and reservoir area are effected by acid mine effluent (Johnson and Hallberg 2005). Further, mining of precious metals uses large amount of synthetic chemicals, power supply and water that lead to environmental pollution and risks.

For example, during mining operation of gold, chemical extraction method is used that requires toxic elements like mercury and cyanide that directly affect human and environment. This chemical extraction process consists of mercury amalgamation and cyanide extraction process (Schwarzenbach et al. 2010). In above methods, gold traces are mixed with liquid mercury, which is further extracted by heating and evaporation in atmosphere. While heating process, this mercury gets released to atmosphere and local people and workers are directly exposed to neurotoxic metals. Biomagnification of mercury takes place during its discharge in surface water which causes health risk problem to aquatic system, organisms and human populations. On the other hand, at lower gold concentration and larger volume, cyanide method is used. In this method, oxidative leaching of gold takes place, which forms complex in aqueous solution, after that adsorption takes place and recycling of cyanide solution takes place. In general, for extraction of 1 kg of gold, around 700 tons of water and 140 kg of cyanide are required (kg) (Mudd 2007). Health issues related to cyanide are that it blocks enzyme function in respiratory chain process in higher organisms that cause sudden death. For adult human, 100 mg of cyanide is highly toxic while for fishes a much lower concentration that is 0.05 mg/L in water also causes death (Schwarzenbach et al. 2010).

Improved extraction processes should be implemented for gold extraction, for this toxic element like mercury and cyanide need to be replaced by less toxic extraction chemicals like halogens and thiourea (Dudka and Adriano 1997; Akcil 2003). Apart from this, upgraded sustainable processes and safety methods are needed to be adapted for extraction process. Enforcement of strict law should be there for health and environmental risks related to mining operations.

2.6 Pharmaceuticals and Personal Care Products in Wastewater and Drinking Water

Municipal wastewater significantly contributes to micropollutants in the form of organic pollutant into the environment; mostly consist of pharmaceutical and personal care product. Pharmaceuticals products include hormone regulator, sedative, contraceptives, lipid regulators, antibiotics, painkiller, anti-inflammatory, anti-depressants and others medicines. Every year, new pharmaceuticals products are launched in market. In fact, every year pharmaceuticals products contribute 8% of total research and development expenses. It can be extrapolated with this data that 300 new pharmaceuticals compounds hit market every year. The world-level market of pharmaceuticals compounds was 100,000 tons per year that were worth of US$773 billion, with the highest per capita sales in the USA with US$676 (Schwarzenbach et al. 2010; Kummerer 2013).

These products are highly bioactive and their concentrations are generally in nanograms to micrograms per litre of water and wastewater system. In municipal raw sewage, the range of pharmaceutical products is in micrograms per litre which confirms that sewer lines are main path for pharmaceutical discharge in water bodies. At present, pharmaceutical compounds are separated from wastewater system by biodegradation and absorption from sludge generated in system (Schwarzenbach et al. 2010). Due to formation of metabolites, complete mineralization of compounds does not take place during biodegradation process. Therefore, from ecotoxicological point of view, toxic effect of the compound is not only due to parent compound but also transformed metabolites need to be considered. As such in case of iopromide, during an iodinated X-ray contrast medium process, 12 metabolites were identified, that are equally toxic in nature as parent compound (Schulz et al. 2008). In pharmaceutical compounds, toxicological effects are not only due to parent compound but also due to their transformed metabolite in wastewater system.

Studies show that metabolites having more number of hydrophilic metabolites have less toxic effect as compared to more hydrophobic compounds present in their parent compounds. Moreover, the main issues related to pharmaceutical compounds are their ecotoxicological effect, as this water is used directly or indirectly for drinking and other purposes. Filtration of pharmaceutical compounds and their metabolites takes place through riverbank infiltration in the aquifers (Schwarzenbach et al. 2010). In previous study, it is shown that out of 19 antibiotic present in surface water, only one has been identified in the bank filtrate (Heberer et al. 2008). Some reports also suggested that complete removal of all potential pharmaceuticals compounds cannot be certain through riverbank filtration. Due to toxicological effect, pharmaceutical compounds and their transformed metabolites products are carefully tested. Moreover, from toxicological point of view, pharmaceutical compounds are carefully tested. Development of a new pharmaceutical compound requires proper details of drug kinetics, pharmacology and toxicology such as genotoxicity, carcinogenicity, reproductive and development toxicity. The final phase before launching of pharmaceutical products is clinical trial. Final phase is the clinical trial before launching (Schwarzenbach et al. 2010). On the basis of above context, risk of toxicity to the consumers seems quite low. However, studies are conducted for evaluation of long-term effect of these products on human and environmental health. As wastewater is the main source for pharmaceuticals, so different wastewater technology has been evolved, such as ozonation, polishing pond and activated carbon. Ozonation process has high treatment efficiency, and it has feasible operation and maintenance cost (Hollender et al. 2009). Other process such as polishing treatment of effluent helps in treatment of endocrine disrupting compounds. Alternatively, activated carbon in granular or powdered form along with oxidation and nanofiltration and reverse osmosis can be used as a promising technique for removal of these compounds (Schwarzenbach et al. 2010).

2.7 Contamination by Waterborne Viruses and Microbial Pathogens

Problems related to sanitation, hygiene and waterborne pathogen are of the major concern in developing countries. As in developed countries, maintenance of water supply infrastructure related to sanitation is already installed. Unfortunately, in developing countries where large amount of sewage is discharged into water body without treatment, so improvement in basic sanitation facility and treatment technology is necessary; moreover, access to safe drinking water is the primary requirement. It is the current estimation that 67% of the population in developing countries may not be able to have a proper sewerage system till 2030 (Schwarzenbach et al. 2010). Currently, in developing countries, there is an imbalance between urban and rural areas for proper sanitation and access to safe drinking water. Report shows that nearly 1.1 billion people across the world lacks potable water and 2.6 billion people have no proper sanitation facility.

Lack of proper sanitation and limited access to safe water causes 1.6 million deaths per year worldwide and from this most of cases are of developing countries, and the main cause of disease related to drinking water in developing countries is pathogenic viruses, bacteria, protozoa and insects developing on contaminated water. One of the reports predicted that contaminated water is responsible for 15–30% of gastrointestinal diseases. Other diseases caused by consumption of unsafe water are diarrhoea, cholera, stomach infection, skin problem, nausea, typhoid fever and legionellosis. Most increasing waterborne disease is typhoid fever that is caused by Salmonella typhi and Salmonella paratyphi, respectively. Even acute viral diseases like hepatitis A and E, rotaviruses and the other protozoa-related diseases caused by Giardia lamblia are often found related to inadequate supply of safe water and sanitation practices (Schwarzenbach et al. 2010). Pathogens like Cryptosporidium parvum, Campylobacter jejuni, enterotoxigenic and enteropathogenic *Escherichia coli*, *Shigella* spp., or *Vibrio cholera* cause most of the chronic health diseases (Albert et al. 1999). Pathogenic microorganisms such as *E. coli* and cryptosporidiosis generally cause outbreak of diseases in developed countries, due to microbial distribution in warm water supplies and air condition from houses, complexes and hospitals.

Due to discharge of untreated sewage in water supply system or other natural water body, nowadays, health-related problems are linked to both wastewater and drinking water supply. Moreover, issues related to sanitation, proper access to safe water, wastewater treatment and enforcement of strict regulation for water safety and conservation are given low priority and low number of funds is allocated for this purpose. Improved sanitation, proper and safe water supply, linked sewerage line to every house, proper treatment and management of waste can help to eradicate these health-related issues. World health organization (WHO) along with the United Nations Children's Fund has launched as a millennium development goal (MDG) to help people with access to safe drinking water and basic sanitation facility by 2015 (World Health Organization UNICEF 2006).

2.8 Wastewater Treatment Technology for Municipal Sewage: A Self-sustainable Option

To improve sanitation and to maintain human health and ecosystem, it is necessary to develop a sustainable and effective wastewater treatment system. The main aim of municipal wastewater treatment is to eliminate organic matter in the form of biological oxygen demand (BOD) and chemical oxygen demand (COD), and nutrients such as nitrogen and phosphorus and pathogenic microorganisms. Removal of nutrients from wastewater effluent causes decrease in eutrophication phenomenon that leads to proper growth of aquatic organization and high dissolved oxygen (DO) in water. It has been estimated that in developed countries, 50–95% of wastewater gets treated while in developing countries about 80% of effluents is discharged in river and lakes without prior treatment (Kumar Reddy and Lee 2012). Wastewater from industries not only leads to organic pollutant but also it is a source of heavy metals, synthetic dyes and organic compounds.

Treatment processes such as advanced oxidation, membrane bioreactor, neutralization of acid and base in effluent, resource recovery within system and activated carbon processes help to reduce these pollutants very efficiently, but unfortunately, these processes are not implemented in developing countries. Now it's high time to develop effective mitigation measure for wastewater treatment, as due to increase in water scarcity, treated wastewater is not only used in agriculture and recreational work but also for drinking purpose. For example, wastewater is recycled in Windhoek, Namibia since 1973 for obtaining drinking water (Schwarzenbach et al. 2010). In any country for selection of sewage treatment system, economy is first priority. Many sewage treatment systems such as activated sludge process (ASP), membrane bioreactor (MBR) are very efficient for organic and nutrient removal, but due to high cost of construction, operation and maintenance either it is not preferred or are not being maintained properly due to lack of understanding of system. For developing country like India, economical aspects are a major thing to be considered for development of sewage treatment plant.

Apart from this in developing countries, sewage treatment and other environmental issues are of low preference in comparison to other developmental issues such as food availability, health, education and industrial development as it does not have direct economical significance. So installation of highly advance and costly treatment technology is not preferable for developing countries. Now it is a time to develop sustainable, cost effective and appropriate sewage treatment system which is techno-economically feasible. Sometimes for developing countries, it is very tough to define about appropriate treatment technology as there is a serious concern about selection, because low cost is not only the criteria but removal efficiency, low operation and maintenance, low sludge withdrawal of the system are the criteria that are to be considered. So under these circumstances, a combination of anaerobic-aerobic system has to be considered as appropriate wastewater treatment system for developing countries.

In this context, a combination of up-flow anaerobic sludge blanket (UASB) reactor and down-flow hanging sponge (DHS) reactor is considered as an appropriate sewage treatment technology for developing countries (Tandukar et al. 2005, 2006). Combination of anaerobic–aerobic system for wastewater not only provides better removal efficiency but also can provide high removal efficiency at minimum operation control.

DHS reactor was developed as a novel, effective and low-cost post-treatment for UASB effluent to meet desired effluent standard. The principle of this system is based on conventional trickling filter process, in which media is replaced with polyurethane for high sludge retention in the reactor. This high sludge retention is due to the presence of more than 90% of the void space resulting in high biomass entrapment in packing media, which finally leads to long solid retention time (SRT). Moreover, DHS rector generates less sludge due to longer SRT which provides enough time for mineralization of sludge in system itself. Due to presence of natural ventilation, there is no requirement of external aeration or any other energy source. Oxygen present in the atmosphere gets incorporate to wastewater, while effluent moves downwards in the reactor and finally gives high DO in resultant effluent (Tandukar et al. 2005). UASB–DHS system not only provides better removal efficiency in terms of organic matter and nitrogen removal but removes pathogenic microorganisms.

2.9 UASB-DHS System as a Novel, Cost-Effective Treatment Technology for Municipal Wastewater

Various studies have been conducted by using different generation of DHS sponge media on bench and pilot scale reactor. These reactors have shown an excellent ability to polish the quality of UASB effluent in terms of organic matter, ammonium nitrogen, and suspended solids and pathogens removal to meet the desired effluent standards. Full-scale study on DHS system was conducted in India, and experimental results showed that DHS reactor is efficient and can be taken as viable option as post-treatment method for UASB effluent (Okubo et al. 2015).

Water quality parameter of 15 different UASB-FPU-based STPs in India were investigated and analyzed and found out that this system is not efficient to remove organic matter, ammonium nitrogen and pathogens to meet desired Indian effluent discharge standards. So to understand the practical approach of DHS as a post treatment of UASB water quality profiles and retained sludge need to be investigated (Sato et al. 2006). Organic matter removal takes place in DHS reactor due to anaerobic and aerobic biological degradation and also due to adsorption in sponge media. At first, organic removal takes place due to proliferation of heterotrophic bacteria as dominant-microorganisms. After removal of organic matter, ammonia nitrogen removal takes place by autotrophic bacteria. Maximum removal of NH_3–N takes place in the lower half of reactor due to presence of nitrifiers that convert NH_3–N to NO_3–N in the presence of oxygen. Higher biomass concentration in sponge media results in better organic and nitrogen removal. Apart from this, pathogenic microorganism gets removed due to adsorption in sponge media, predation by higher form of microorganisms, competition of space and food allows growth of certain microorganisms. High amount of active biomass retained in the sponge of DHS and corresponding longer SRT ensures a high degree of treatment at minimum operational control. These properties are important to hedge against any hydraulic or organic overload to the system during the real operation as well as to reduce sludge production (Mahmoud et al. 2009). The performance of reactor was attributed to its distinctive characteristics like high DO uptake, dense sludge retention and adequate sludge activity in sponge media. The results verified the practical-scale applicability of DHS reactor to developing countries for effective treatment.

2.10 Conclusions

To overcome global water pollution problems, it is required to develop an effective approach that fits at technological, sustainable, economical and within policies limit to meet desired treatment standard. Hazardous compounds, volatile chemicals, synthetic and toxic compounds should not be allowed to enter food chain or other sources of human and ecological biodiversity area or treated onsite in a closed system. Human food production areas like agricultural sector require protection from compounds that have bioaccumulation property. Globally, agricultural sector faces problem related to higher production yield and water shortage, and at the same time, environmental safeguards and contamination in food chain should be secured. Geogenic and anthropogenic sources must be identified, and different approaches should be developed to prevent water sources from these contaminants. To provide proper sanitation and to fulfil water demand, efforts have to be taken to develop sustainable and cost-effective wastewater treatment system. Household-centred sanitation system needs to be developed for proper sanitation facility. To meet water crises and cleaning, large-scale water pollution UASB-DHS system can be considered as a novel approach for wastewater treatment.

2.11 Way Forward

- In spite of advanced wastewater treatment process, efforts have to be designed to reduce mixing of toxic and hazardous chemicals into aquatic water body. This can be accomplished either by onsite treatment of these waste before discharge or to substitute these chemicals with less harmful chemicals.
- Industry should emphasize on designing new chemicals that have less environmental effect. In addition to this, improved and advance wastewater treatment systems should be introduced.

- Mining activities lead to surface and groundwater pollution, so proper mitigation approach should be developed to improve and develop effective removal techniques.
- Decentralized wastewater treatment system should be preferred over high-cost centralized system to allow reuse of water and other nutrients locally.
- Development of fast, cost effective and reliable detection technique for micropollutants and pathogens should be developed for wastewater and water quality assessment.
- Interlinking rivers is one of the approaches to overcome freshwater demand in future.

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