

Water Pollution: Impact of Pollutants and New Promising Techniques in Purification Process

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ABSTRACT Water is a critical resource in the lives of people who both benefit from its use and who are harmed by its misuse and unpredictability (flooding, droughts, salinity, acidity, and degraded quality). Water is a finite and vulnerable resource. Consequently, consumption of polluted water puts lives and livelihoods at risk because water has no substitute. There are many ways in which water intended for human consumption can get polluted. These include wastes from industries like mining and construction, food processing, radioactive wastes from power generating industries, domestic and agricultural wastes and by various microbiological agents. Nowadays, water is being purified by various methods but research is being conducted to look for more reliable and cheaper methods that can purify water at an affordable cost. Various techniques have been developed like utilizing rechargeable polymer beads, seeds of *Moringa Oleifera* tree, aerobic granular sludge technology, resin based treatment and two-pronged water treatment technology.

INTRODUCTION

Water is that chemical substance which is essential for every living organism to survive on this planet. Water is needed by every cell of the organism's body to perform normal function. Water covers 71% of the Earth's surface, mostly in oceans and other large water bodies, with 1.6% of water below ground in aquifers and 0.001% in the air as vapor, clouds and precipitation (U.S. Geological Survey 2000). Water moves continually through a cycle of evaporation or transpiration (evapotranspiration), precipitation, and runoff, usually reaching the sea. Winds carry water vapor over land at the same rate as runoff into the sea. Over land, evaporation and transpiration contribute to the precipitation over land. Clean, fresh drinking water is essential to

human and other life. Some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability, a situation which has been called a 'water crisis' by the United Nations (Kulshre-shtha 1998). A recent report (November 2009) suggests that by 2030, in some developing regions of the world, water demand will exceed supply by 50% (Charting Our Water Future 2009).

Pure uncontaminated water does not occur in nature. Water pollution is any undesirable change in the state of water, contaminated with harmful substances. It is the second most important environmental issue next to air pollution. Any change in the physical, chemical and biological properties of water that has a harmful effect on living things is termed as 'water pollution' (WHO 1997). As a result of the unwanted human activities, water pollution is a growing hazard in many developing countries. A more serious aspect of water-pollution is that which is caused by human activity, and industrialization (Park 2009). There are also various micro-biological agents that include bacteria, viruses and protozoa which can also cause water pollution and may cause various water-borne diseases.

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The earliest recorded attempts to find or generate pure water date back to 2000 B.C. Early Sanskrit writings outlined methods for purifying water (Early Water Treatment 2009). These methods ranged from boiling or placing hot metal instruments in water before drinking it to filtering that water through crude sand or charcoal filters. These writings suggest that the major motive in purifying water was to provide better tasting drinking water. It was assumed that good tasting water was also clean. People did not yet connect impure water with disease nor did they have the technology necessary to recognize tasteless yet harmful organisms and sediments in water. Although various techniques have been developed in order to purify water so that it can be made safe and wholesome but large scale purification involves lot of finances. Research is being conducted worldwide in order to develop newer methods which can be used to purify water and that too at an affordable cost.

The main objectives of this study is to highlight the impact of various water pollutants which have rendered the water unsuitable for drinking and other domestic purposes and to enumerate new and affordable techniques which can be used to purify water for various purposes.

Facts and Figures Related to Water Pollution

Disease spreads by consumption of polluted water. It has been estimated that 50,000 people die daily world-wide as a result of water-related diseases (Nevondo and Cloete 1999). A large number of people in developing countries lack access to adequate water supply. In South Africa, it has been estimated that more than 12 million people do not have access to an adequate supply of potable water (Nevondo and Cloete 1999). Polluted water also contains viruses, bacteria, intestinal parasites and other harmful microorganisms, which can cause waterborne diseases such as diarrhea, dysentery, and typhoid. Due to water pollution, the entire ecosystem gets disturbed. Unsafe drinking water, along with poor sanitation and hygiene, are the main contributors to an estimated 4 billion cases of diarrhoeal disease annually, causing more than 1.5 million deaths, mostly among children under 5 years of age (WHO 2005). Contaminated drinking water is also a major source of hepatitis, typhoid and opportunistic infections that attack the immuno-compromised, especially persons

living with HIV/AIDS (UNICEF 2011). Almost 1 billion people lack access to safe and improved water supply. More than 50 countries still report cholera to WHO (World Health Organization). Millions are exposed to unsafe levels of naturally-occurring arsenic and fluoride in drinking water which leads to cancer and tooth/skeletal damage. An estimated 260 million people are infected with schistosomiasis (WHO 2004). 1.3 million people die of malaria each year, 90% of whom are children under 5. Impoverished slum dwellers in Angola draw drinking water from the local river where their sewage is dumped. Farmers on the lower reaches of the Colorado River struggle because water has been diverted to cities like Las Vegas and Los Angeles. In large parts of Africa, more than 60 percent of city dwellers are in fact slum dwellers. For many of them, water comes not from faucets inside their shacks but from water tankers or standpipes, neither of which is reliable as a water source. Open sewers increase the risk of water-borne diseases (UN works 2010).

HUMAN ACTIVITIES RESPONSIBLE FOR WATER POLLUTION

Virtually all human activities produce some kind of environmental disturbance that contaminate surrounding waters. Eating (body wastes), gardening (pesticide and sediment runoff) and many other activities create byproducts that can find their way into the water cycle. For convenience, we can assign the large majority of sources of water pollution to three broad categories of waste (Mc Kinney and Schoch 2003).

- a. Industrial
- b. Agricultural and
- c. Domestic wastes

a. Industrial Wastes

Wastes from industry serve as major sources for all water pollutants. Many major industries contribute significantly to water pollution, but some of the important are the (i) manufacturing (ii) power-generating (iii) mining and construction, and (iv) food processing industries (Mc Kinney and Schoch 2003).

Manufacturing industries like chemical, oil refining, steel etc. contribute many of the most highly toxic pollutants, including a variety of organic chemicals and heavy metals (Mc Kinney

and Schoch 2003). Other industries have less potential impact but are still considered highly problematic when it comes to pollution. These industries include the textile, leather tanning, paint, plastics, pharmaceutical, and paper and pulp industries (Raja and Venkatesan 2010). In many cases, both the products, such as the paint or the pesticide, and the byproducts from the manufacturing process are highly toxic to many organisms, including humans.

Power generating industries are the major contributors of heat and radioactivity. Nearly all power plants, whatever the fuel, are major sources of thermal (heat) pollution. Radioactivity from nuclear power plants can pollute waters in a variety of ways, including discharge of mildly radioactive waste water and ground water pollution by buried radioactive waste (Mc Kinney and Schoch 2003). Radioactivity may be found in ground waters as well as surface waters. In ground waters it may be due to radioactive material present in underground rocks, while in surface waters it may have been passed on with effluents from uranium mining and enrichment plants (Rao 2001).

The mining and construction industries are major contributors of sediment and acid drainage. There are basically four main types of mining impacts on water quality (Mining and Water Pollution 2011).

- 1) Acid mine drainage
- 2) Heavy metal contamination and leaching
- 3) Processing chemicals pollution
- 4) Erosion and sedimentation

Water plays many critical roles within the field of food science. It is important for a food scientist to understand the roles that water plays within food processing to ensure the success of their products. Water hardness is also a critical factor in food processing. It can dramatically affect the quality of a product as well as playing a role in sanitation. The food processing industry is very diverse. Major sectors include fruit and vegetables, dairy, meats and fish, alcoholic and non-alcoholic beverages, oils, and packaged foods. The most common environmental concerns in the industry are water consumption and wastewater discharge, chemicals used in processing and cleaning, packaging reduction and disposal, and food scraps and refuse (Mc Kinney and Schoch 2003).

b. Agricultural Wastes

These are generated by the cultivation of crops and animals. Globally, agriculture is the leading source of sediment pollution which includes plowing and other activities that remove plant cover and disturb the soil. Agriculture is also a major contributor of organic chemicals, especially pesticides (Mc Kinney and Schoch 2003). Pesticides are widely used in modern agriculture in most countries throughout the world and in a large range of environments. But environmental monitoring increasingly indicates that trace amounts of pesticides are present in surface and underground water bodies, far from the sites of pesticide application (Voltz et al. 2007). The use of nitrogen fertilizers can be a problem in areas where agriculture is becoming increasingly intensified. These fertilizers increase the concentration of nitrates in groundwater, leading to high nitrate levels in underground drinking water sources, which can cause methemoglobinemia, the life threatening “blue baby” syndrome, in very young children, which is a significant problem in parts of rural Eastern Europe (Yasso et al. 2001). Some pesticides are applied directly on soil to kill pests in the soil or on the ground. This practice can create seepage of pesticides to groundwater or runoff to surface waters.

c. Domestic Wastes

These are those that are produced by households. Most domestic waste is from sewage or septic tank leakage that ends up in natural waters. In the past, some cities dumped untreated or barely treated sewage directly into rivers, lakes, or coastal waters. Plant nutrients occur in the form of nitrogen and phosphorus. These come not only from human waste, but also from fertilizers used extensively in household lawns and gardens (Mc Kinney and Schoch 2003). Today, many people dump their garbage into streams, lakes, rivers, and seas, thus making water bodies the final resting place of cans, bottles, plastics, and other household products (Groundwater Quality 2003). Most of today's cleaning products are synthetic detergents and come from the petrochemical industry. Most detergents and washing powders contain phosphates, which are used to soften the water among other things. These and other chemicals

contained in washing powders affect the health of all forms of life in the water.

Micro-organisms Causing Water Pollution

There are various micro-biological agents which can also cause water pollution if drinking water gets contaminated with these agents. The pathogenic agents involved include bacteria, viruses and protozoa which may cause diseases that vary in severity from mild gastroenteritis to severe and sometime fatal diarrhoea, dysentery, hepatitis or typhoid fever (WHO 1996). Most of them are widely distributed throughout the world. Faecal contamination of drinking water is only one of several faeco-oral mechanisms by which they can be transmitted from one person to another or, in some cases, from animals to people.

Most of the mortality and morbidity associated with water related disease especially in developing countries is due directly or indirectly to infectious agents which infect man through:-

- 1) Ingesting pathogenic bacteria, viruses or parasites (protozoans and helminthes) in water polluted by human or animal faeces or urine. Diseases in this category include cholera (*Cholera vibrio*), shigellosis (dysentery caused by *Shigella* spp.), typhoid (*Samonella typhi*), paratyphoid (*Samonella paratyphi*), diarrhea (*Escherichia coli*), hepatitis (Hepatitis virus) and poliomyelitis (Polio virus) (Obasohan et al. 2010).
- 2) Diseases associated with scarcity of water for personal hygiene (bathing, hand washing), laundering clothes and cleaning of cooking utensils. In this category of diseases are scabies, yaws, skin ulcers, conjunctivitis and trachoma (Obasohan et al. 2010).
- 3) Diseases associated with ingestion or penetration of human skin by infective forms that require a snail, fish or other aquatic hosts. Examples include schistosomiasis, clonorchiasis and paragonimiasis (Obasohan et al. 2010).
- 4) Diseases from being bitten by insect vector which breeds in or around water. They include malaria, dengue, yellow fever, filariasis (mosquito-borne);

trypanosomiasis (tse-tse fly-borne) and onchocerciasis (black fly-borne) (Obasohan et al. 2010).

NEW TECHNIQUES IN WATER PURIFICATION PROCESS

1. Point-of-use Water Purification Using Rechargeable Polymer Beads

'Halo-pure' is one such enabling technical advance in the development of an entirely new biocidal medium in the form of chlorine-rechargeable polystyrene beads that is based on patented chemistry inventions from the Department of Chemistry at Auburn University (Dunk et al. 2005). The discoveries were natural but creative outcome of a series of studies, covering more than a decade of research, focused on stabilizing chlorine on water insoluble, synthetic polymer surfaces.

The fundamental principles of the technology are deceptively simple to understand, although their incorporation into a reliably reproducible and practical medium for water sanitation has taken years of intense effort and research. Porous polystyrene beads are similar to those used for water softener resin beds, are modified chemically so as to be able to bind chlorine or bromine reversibly in its oxidative form. All that is required is enough free chlorine to surround the binding site. Almost no free chlorine is released when the beads are placed into the water flow. Typical levels range from 0.05 ppm to 0.20 ppm free available chlorine. This is not enough to kill anything without lengthy incubation. Hence, the swift efficacy of Halo-pure depends on intimate contact between the microbes and the bound halogen on the polymer. What you have, then, is a solid surface, effectively biocidal on contact to contaminants in the water and repeatedly rechargeable when periodically exposed to free halogen. In this way, a powerful antimicrobial component can be introduced into a water purifier that will not run out of steam, and have to be discarded. Instead, it can have its power regularly and conveniently "topped up" by the user. Organisms make contact with the display of chlorine, for example, on the surface of the beads, and pick up enough halogen to inactivate them in short order. Those not killed within seconds suffer a near-death experience, and succumb quickly in the product

water as the adherent chlorine slowly damages the organism to the point of fatal consequences (Dunk et al. 2005).

The technology holds the promise of reducing the impact of water borne diseases throughout the developing world. Its widespread use could contribute to the realization of UN goals for access to safe water for all by 2015. And it could do so without resort to the massive infrastructure investments that are needed to reach this goal using more conventional centralized sanitation and distribution approaches (Dunk et al. 2005).

2. Water Treatment Using the Seeds of the *Moringa oleifera* Tree

Using natural materials to clarify water is a technique that has been practiced for centuries and of all the materials that have been used, seeds of the *Moringa* have been found to be one of the most effective. Studies have been conducted since the early 1970's to test the effectiveness of *Moringa* seeds for treating water (Paterniani et al. 2010). These studies have confirmed that the seeds are highly effective in removing suspended particles from water with medium to high levels of turbidity (*Moringa* seeds are less effective at treating water with low levels of turbidity).

Moringa oleifera seeds treat water on two levels, acting both as a coagulant and an antimicrobial agent. It is generally accepted that *Moringa* works as a coagulant due to positively charged, water-soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxins, etc) allowing the resulting "flocs" to settle to the bottom or be removed by filtration. The antimicrobial aspects of *Moringa* continue to be researched. Findings support recombinant proteins both removing microorganisms by coagulation as well as acting directly as growth inhibitors of the microorganisms. While there is ongoing research being conducted on the nature and characteristics of these components, it is accepted that treatments with *Moringa* solutions will remove 90-99.9% of the impurities in water (Paterniani et al. 2010).

Solutions of *Moringa* seeds for water treatment may be prepared from seed kernels or from the solid residue left over after oil extraction (presscake). *Moringa* seeds, seed kernels or dried presscake can be stored for long periods but *Moringa* solutions for treating water should

be prepared fresh each time. In general, 1 seed kernel will treat 1 liter (1.056 qt) of water.

Dosage Rates: Low turbidity NTU (Nephelometric Turbidity Units) <50 1 seed per 4 liters (4.225 qt) water

Medium Turbidity: NTU 50-150 1 seed per 2 liters (2.112 qt) water

High Turbidity: NTU 150-250 1 seed per 1 liter (1.056 qt) water

Extreme Turbidity: NTU >250 2 seeds per 1 liter (1.056 qt) water

3. Water Purification Using Aerobic Granular Sludge Technology

With the new aerobic granular sludge technology, aerobic (thus oxygen using) bacterial granules are formed in the water that is to be purified. The great advantage of these granules is that they sink quickly and that all the required biological purifying processes occur within these granules (Delft University of Technology 2006).

The technology, therefore, offers important advantages when compared to conventional water purification processes. For example, all the processes can occur in one reactor. Moreover, there is no need to use large re-sinking tanks, such as those used for conventional purification. Such large tanks are needed for this because the bacteria clusters that are formed take much longer time to sink than the aerobic granule sludge.

The aerobic granular sludge technology is very promising, and has been nominated for the Dutch Process Innovation Award. The technology is now in the commercialisation phase. In the coming years, further research will be continued. Testing of this purification method is being done on a larger scale. The first installations are already in use in the industrial sector (Delft University of Technology 2006).

4. Resin Based Treatment for Colour and Organic Impurities Removal

The rapid industrialization during the last few decades has resulted in tremendous increase in demand of water for industries. A large quantity of water used is ultimately discharged into water bodies and land as waste water from various unit operations related to various industrial processes, and is responsible for their pollution (Kumar and Bhatia 2007). Attempts

have been made to prevent the adverse aesthetic effects associated with industrial waste water discharges by accelerating the removal of colour during treatment of the variety of industrial wastes. Colour removal is also important if the water has to be made suitable for drinking purpose because many times underground water comes with colour and this colour has to be removed prior to drinking.

Among the manufacturing operations, the textile dyeing and finishing industries are directly affecting colour; which is the most noticeable characteristic of both the raw waste and treated effluent from this industry. Although biological treatment of these waste waters is usually effective in removing a large portion of oxidizable matter, but it is frequently ineffective in removing colour. The present method for colour removal uses a green colour basic dye, an anion exchange resin called 'Duolite A171/SC' and a column made of borosil glass of height 40cm. From the results it was concluded that resin treatment is a better method than conventional biologic process even at much higher filtration rate (Kumar and Bhatia 2007).

CONCLUSION

Water is a renewable natural resource. Due to ever increasing industrialization, urbanization, this precious resource is continuously under stress. There are multiple dimensions to water quality and its deterioration. Water pollution is rendering much of the available water unsafe for consumption. The pressure of increasing population, loss of forest cover, untreated effluent discharge from industries and municipalities, use of non-biodegradable pesticides/ fungicides/ herbicides/insecticides, use of chemical fertilizers instead of organic manures, etc are causing water pollution. Moreover, there are numerous water borne diseases like cholera, diarrhoea, dysentery etc. which are transmitted by drinking contaminated water. There are various new water purification techniques which have come up to purify water for example by using rechargeable polymer beads, using the seeds of *Moringa oleifera* tree, purifying water by using aerobic granular sludge technology etc. Research is being conducted all over the world to develop more and more techniques which can generate pure water at low cost. All these techniques are being developed to ensure that in near future

everyone will have access to clean and pure water and that too at an affordable cost.

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