BIOREMEDIATION OF WATER: A SUSTAINABLE METHOD OF DECONTAMINATING WATER BODIES IN INDIA

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ABSTRACT

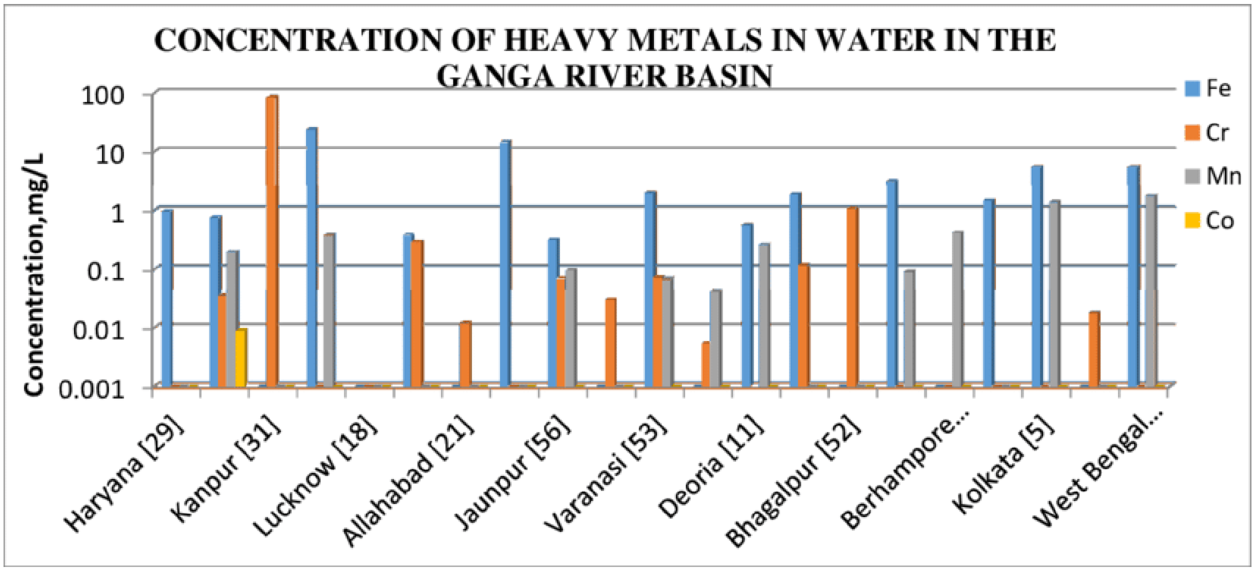
Of late, the Indian government has been betting high on the bioremediation technology to clean water bodies including our national river Ganga. Last year, the Central Pollution Control Board demonstrated a successful trial of the technology at a river basin in New Delhi. In such, scholars need to study the effectiveness and possible drawbacks of the technology that might be mitigated through a scientific and collective approach. Bioremediation technology uses aquatic plants and microorganisms to degrade and convert toxic pollutants such as oil, heavy metals, fertilizers, and pesticides into harmless compounds. The technology is cost-effective as it does not require transportation of water and can be carried out at the site. The technology is a bit sensitive to environmental factors but can be carried out anywhere with some manipulation of the environment. Overall, the technology is cost-effective and seldom produces secondary wastage that may harm the aquatic or non-aquatic life in some other way.

Keywords*: bioremediation, water pollution, aquatic life*

1. INTRODUCTION

Pollution of water bodies such as lakes, ponds, rivers as well as seas and oceans have been a major negative outcome of the modern world following the industrial revolution. Oil spillage in the oceans and a high concentration of pesticides and toxic metal pollutants in smaller water bodies such as rivers and lakes have been a major environmental concern for some time. These toxic pollutants eventually come to affect human lives through the food chain due to the non-biodegradable and biomagnifications characteristics of these pollutants. Leather factories in Kanpur, copper, and other metal plants in other cities and other industrial wastes are directly discharged into rivers without being treated first. Municipal wastes, including sewage, and agricultural waste such as fertilizers and pesticides also find their way to these water bodies without pre-disposal treatment. Soon enough, these limited sources of freshwater also become unfit for human consumption. Cases have been found of some industries, in cities of Gujarat and the other Indian States, that discharge their toxic industrial waste directly into the groundwater. Such illegal and inhuman disposal of waste has come to adversely affect the lives of people living in the surrounding villages, where a significant fraction of villagers who are dependent on groundwater for their lives come to develop cancer and other murderous diseases. Besides, contaminated river bodies do not only affect human lives when directly consumed. These toxic metals and other pollutants are non-biodegradable and due to biomagnifications, they eventually find their way to human food through the interconnected food chain.

Various measures and scientific techniques have been tested and applied to decontaminate water bodies. A flagship program of PM Narendra Modi to rejuvenate the Ganga river and other programs to decontaminate rivers such as Yamuna, Brahmaputra and other water bodies have seen a growing body of research into various physical and chemical techniques in an attempt to find some sustainable and effective method of cleaning our water bodies. Bioremediation is one of the various methods and the Indian government is betting high on this program. It is because of this reason also that I chose to study whether the method was as effective and sustainable as has been bet upon. So, what is bioremediation, and how does this decontaminate polluted water bodies of its toxic pollutants.



[Graph Credit: Goel et. al, 2013]

2. WHAT IS BIOREMEDIATION AND HOW DOES THIS WORK?

Bioremediation is a branch of biotechnology that uses naturally occurring bacteria, fungi, and other microbes to remove toxic metals and other pollutants present in the soil, water, and other environments. And when the process uses aquatic plants to do the job, it is called Phytoremediation. Thereupon, these processes use manipulation to get our water bodies cleaned using the very naturally occurring microbes and plants. These can as well be used to remove oil spillage, fertilizers, and toxic metal pollutants from rivers, ponds, lakes, and groundwater. The method is simple and requires no special labs either. These microbes and plants can be fostered in labs not very far from the polluted water bodies and then these microbes and plants can be released into these water bodies themselves. Thereupon, the method does not require any transportation of lab chemicals or transportation of the contaminated water to any lab. All it requires are the microbes and plants themselves. Further, some of these microbes and plants multiply in the presence of toxic metals and pollutants after being released into the polluted water bodies. However, there is a catch. These microbes and aquatic plants require some certain environmental conditions to thrive and would not be effective otherwise. Yet, with some manipulation of the environment, that is anyway not very expensive to do, bioremediation can be used efficiently and effectively to decontaminate water bodies almost anywhere on earth. Bioremediation, therefore, is a cost-effective and reliable form of decontamination which has become increasingly common nowadays for the removal of the atmosphere. Now, we shall take a deeper look into the process and its advantages as well as its shortcomings.

So, how do these microbes decontaminate water bodies? They simply eat up those toxic metals and other pollutants and let off carbon dioxide and water. In the process, they use oxygen, and through a process called oxidization, they degrade these toxic substances. Bioremediation includes phytoremediation and rhizoremediation.

Phytoremediation: Phytoremediation uses plants to decontaminate water bodies and rhizoremediation uses microbes to do the job. In phytoremediation, plants may use their roots or their leaves to absorb and adsorb toxic metals. Aquatic and semi-aquatic vascular plants such as pennyworth (*Hydrocotyle umbellata*), duckweed (*Lemna minor*), water hyacinth (*Eichhornia crassipes*), water-velvet (*Azolla pinnata*) can absorb toxic metal pollutant substances such as lead (Pb), Copper (Cu), Cadmium (Cd), Iron (Fe) and Mercury (Hg). These abilities of these power have been known for quite some centuries and have been used extensively in some countries in the last decades. Aquatic macrophytes such as *Pistoia stratotes, Hydrilla verticillata, Certophyllum demersum*, etc. have been a discovery of late and these are reportedly hyperaccumulators of Chromium (Cr), Mercury (Hg) Lead (Pb), Copper (Cu), Cadmium (Cd) and Manganese (Mn). These aquatic and semi-aquatic plants are known for their high tolerance levels of heavy metal pollutants by isolating and concentrating them either through phytochelatins or phytometallothion. Even the blue-green algae (scientific name- *cyanobacteria*) can accumulate heavy metals from contaminated water bodies.

Several plants can accumulate heavy metals from the soil as well, however, the same is out of the scope of this paper. These heavy metals such as iron (Fe), Manganese (Mn), Zinc (Zn), Molybdenum (Mo), Magnesium (Mg), and Copper (Cu) are perhaps required for the growth of these plants themselves. Some plants can absorb metals such as Cd (Cadmium), Lead (Pb), Cobalt (Co), Silver (Ag), Selenium (Se), Chromium (Cr), and Mercury (Hg) that do not contribute to their biological growth. This use of plants for remediation of toxic substances and decontamination of water bodies is known as *'Phytoremediation'.*

Rhizoremediation: Rhizoremediation refers to a plant-microbe interaction that is ultimately beneficial and useful towards the decontamination of water bodies. So, how does this work? Plant roots provide rich nutrients and act as biocatalysts for microbes to grow and thrive, and in turn, these microbes help decontaminate the water of its toxic pollutant substances. Pollutants such as polycyclic aromatic hydrocarbons (pesticides, herbicides, etc.) are converted into degradable compounds. Heavy metals such as Zinc (Zn), Copper (Cu), Lead (Pb) and Cadmium (Cd) are eaten up by these microbes, who, in turn, let off carbon dioxide and water. The latter process uses oxygen and oxidizes these toxic metals to decompose them. Several diverse mechanisms are employed for this and they include producing bio-surfactants, metal chelating siderophores, biofilm production, etc. Biosurfactants are amphiphilic molecules that form spherical or lamellar micelles that are solubilized hydrophobic contaminants in their core and enhance their bacterial degradation to simple harmless compounds. Producing metal-chelating siderophores is useful for the acquisition of heavy metals and other processes include increased humification, biofilm production, and acid production, etc.

3. LITERATURE REVIEW

3.1 Bioremediation to combat oil pollutants

The aquatic environment is polluted by oil in two ways:

(i) spillage and dumping of waste oil and leakage of oil tanks from vehicles onto road surfaces that eventually end up in the water bodies (Zakaria et. al, 2002), and

(ii) pollution of water with oil is also because of various human activities such as manufacturing, machinery, and engineering products, bilge cleaning, uncontrolled disposal of oil brine, domestic and industrial waste, recreational boating, spillage of industrial oil (Nadim et. al., 2000), runoff from land, automobile industrial activities, atmospheric depositions and mishandling and disposal of organic chemical products (Petrikevich et. al., 2003). Oil-based pollution of water bodies affect aquatic lives through physical and chemical alteration of natural habitat (Samiullah, 1985), lethal and sub-lethal toxic effects on the aquatic life (Moacir et al., 2008), exposure to crude oil may damage lungs, liver, kidneys, intestines and other internal organs of the aquatic birds and animals, impairment of reproductive organs in birds, fish and reptiles (Chen et al., 2008), plants covered with oil suffocate and do not photosynthesize, and in several other ways as has been pointed out by Szaro et al. (1978), Agnes et al. (2003), Nelson-Smith et al. (1971), Peterson (2001) and Michele and Peckoi (2000). Also, because of the non-biodegradable character of these toxic elements, these end up affecting human lives as well through a process called biomagnification.

Bioremediation method of treatment of oil pollution is effective since a majority of molecules in the crude oil and refined products are biodegradable and oil-degrading microbes are ubiquitous (Fayal et al., 195; Aislabie et al., 1998, Chaineau et al., 2000). Rahman et al. (2002), in their experiment, also found that individual bacterial consortium showed a significant rate of 78% of degradation rate compared to individual bacterial cultures that showed a degradation rate of only 41-66%. Further, the technology developed by Prof. Dr. Teruo Higa of the University of Ryukyus, Japan, Effective Microbes (EM) technology is useful in decontaminating water bodies of oil-based pollutants (Singh et al., 2010; Shrivastava et al., 2012).

3.2 Heavy Metal Pollutants

Contamination of water occurs also through leaching of heavy metals, metal corrosion, and atmospheric deposition (Weerasundara et al., 2017’ Francova et al., 2017). Sediments, however, remain the major reason for metal-based contamination of water bodies (Nagajyoti et al, 2010). Heavy metals such as Cadmium (Cd), Aluminium (Al), Manganese (Mn), Chromium (Cr), Nickel (Ni), Zinc (Zn), Lead (Pb) and Copper (Cu) are among the most toxic metal pollutants to the aquatic life and the human population.

Among the different processes under bioremediation, biosorption is a promising technique that has already played a central role in the removal of heavy metals in some countries. Heavy metals such as Copper (Cu), Zinc (Zn), Nickel (Ni), Chromium (Cr), Cobalt (Co), and Iron (Fe) provide the essential nutrients to some organisms (including plants, animals, and microorganisms). It is when the metal concentrations exceed a threshold when they become toxic. Microbes that are used to treat heavy metal pollutants do so in self-defense and use mechanisms such as enzyme secretion, cellular morphological changes, etc. that involve secretion of enzymes such as oxidoreductases and oxygenases. These enzymes increase the rates of bioremediation and various techniques of immobilization have improved, of late, the practice at industrial scales (Jacob et al., 2018). Some microbes even flourish in a highly concentrated environment of heavy metals.

4. CONCLUSION

Bioremediation is a useful and much-preferred technique of decontaminating water bodies such as rivers, lakes, ponds, and even groundwater. It is cost-effective and does not usually lead to secondary waste production in the process. It is, therefore, a safe and sustainable technology as compared to other chemical-based decontamination processes. On the other hand, a major drawback of the technology, as has been pointed out by scholars, is the limitations on the types of contaminants that it can remove effectively. Bioremediation tends to work best when breaking down organic substances and might not be very effective against non-organic pollutants. Another drawback is that the microbes require some certain environmental factors to flourish. This makes the technology a little more sensitive towards environmental factors as compared to other methods of decontaminating water bodies that are chemical-based. Ultimately, however, the technology remains preferred and countries including India are betting high on bioremediation to clean their rivers and other water bodies.

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