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BIODEGRADATION OF XENOBIOTICS USING CYANOBACTERIA

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Abstract

From the last two decades, expansion or setting of new industries, mining areas, and uses of huge amounts of pesticides in agriculture creates a pressure on environment by changing climatic conditions as well as pollution of water and soil. In this context, bioremediation or reduction of these xenobiotic compounds are urgent needs to mitigate the problems of environmental pollution or climate change. Currently various techniques have been used to remediate the heavy metals, oil spill, polyaromatic compounds, petroleum products but in long term these practices adversely affect the environment by their residues, discharge, disposed materials and their high persistence capacities. Therefore bioremediation using microorganisms have been preferred over conventional remediation technology. Present paper summarizes the role of various cyanobacterial strains and their methodology used during xenobiotic degradation.

Keywords: Cyanobacteria, Biodegradation, Physiology, Xenobiotics,

Introduction

Currently climate change is a most severe global problem, adversely affects the ecosystem and ecology of plants as well humans. Increasing concentration of pollutant in the environment is one of the prime reason for climate change and ultimately on the health and wealth status of human beings. The continuous use of chemical fertilizers and pesticides, new mining areas, industries and their non-degradable effluents are the main reason of environmental pollution (Kabata-Pendias and Pendias 1989; He and Yang 2007). Presence of xenobiotics, oil spills, heavy metals, pesticides, petro-chemicals, in the environment adversely affects short term or long term climate, health, productivity and ecology of plant as well as soil and their mitigation in natural ecosystems is still a complex process and appear as a global challenge for the researchers and government (Cerniglia et al. 1979, 1980).

Biodegradation of environmental pollutants using bacteria, fungi are the most commonly studied however, role of cyanobacteria in mitigation of xenobiotics have limited access, Therefore in the present paper, we have summarized the impact of xenobiotics on cyanobacteria as well as also studied the mitigation procedure of xenobiotics using cyanobacteria.

Cyanobacteria are oxygen evolving, gram-negative, ubiquitous prokaryotes flourished on the earth over two billion years ago (Sergeev et al. 2002; Ramanan et al. 2016). They found in diverse habitats in the form of free-living, symbiotic association with plants, fungi and animals adapted to various environmental conditions and characterized by great morphological diversity (Whitton 2000; Singh et al. 2014). Cyanobacteria play an important role in maintaining nutrient availability, porosity, soil pH, water holding capacity, reduction in soil salinity. In paddy fields cyanobacteria play important role in making N_2 availability to plant and soil by N_2-fixation (Wilson et al. 2001; Singh et al. 2014; Thajamanbi et al. 2016). Among different biological agents in mitigation of xenobiotics, organic pollutants, cyanobacteria used as a promising microorganism having capability for degradation, bioaccumulation, biotransformation of heavy metals, aromatic pollutants that are commonly present as pollutants (Chaillan et al. 2004; El-Sheekh and Hamouda 2014).

Effect of pollutants on environment and ecology of cyanobacteria

In the starting of this era, race of development, varieties of industries have been established, which subsequently releases waste effluents in the environment, which leads to pollution. Industrial effluent releases may be well regulated (e.g., industrial emissions) or it may be accidental (e.g., chemical or oil spills), which may be hazardous and biomagnificent to the terrestrial and aquatic environments. These constitutes wide range of compounds (i.e. persistent organic pollutants, POPs), heavy metals, sewage, plastic, petroleum products, which leads to environmental pollution and directly or indirectly involved in climatic changes, global warming, reduction of ground water levels, rise in ocean water level, ozone layer depletion (Brookes 1995; Varsha et al. 2011). These pollutants may be natural or anthropogenic and play major role in environmental pollution and can divided as oil spills, plastic, heavy metals, pesticides, xenobiotics, pharmaceuticals. These serious issues drag the focus of scientists more on the impacts of pollution and its mitigation procedure.

Cyanobacteria have capabilities for nitrogen-fixation and it is estimated that approximately 27% of total soil microbial biomass in the soil and aquatic ecosystems are of microalgae and cyanobacteria (Burns and Hardy 1975; McCann and Cullimore 1979). However, pollutant concentration exceeds the level of tolerance resulting bleaching of the cells and causes death. Under stress conditions, cyanobacterial response includes short-term adaptation in the photosynthetic apparatus to light quality. Moreover, prolonged stresses produce changes in functional organization of phycobilisomes as well as variation in PS II fluorescence yield (Fujita 1994).

The excess applications of pesticides that are frequently used in the rice fields have different effects on various nitrogen fixing cyanobacteria. Pesticides applications largely affect the environments, as well as microorganisms and also affect the physiology of microorganisms and also accumulate, detoxify, or metabolize some extent (Megharaj et al. 1994).

Mitigation of xenobiotics using cyanobacteria

Xenobiotics is a broad term used for chemical compounds like pesticides, polynuclear aromatic hydrocarbons of soil is a significant environmental problem and has its negative impact on human health and agriculture. The potential health hazard of a xenobiotic compound is a function of its persistence in the environment as well as the toxicity of the chemical class. Polycyclic aromatic hydrocarbons (PAHs) are a group of organic compounds which contain carbon and hydrogen with the carbon arranged in a series of adjoining six member benzene rings and is present in water, crude oil and tars (El-Bestawy et al. 2008). There precursors for PAHs present in crude oil reportedly include natural products, such as steroids, which have been transformed through chemical conversion to aromatic hydrocarbons over time. They are known to be recalcitrant and are not easily degradable. These xenobiotics are considered as hazardous because of their potential trophic biomagnifications and acute toxicity (Ughy et al. 2015).

Like other microorganism cyanobacteria also have natural ability to degrade moderate amounts of organic pollutants (Safari et al. 2016; Pimda and Bunnag 2012). These organisms not only help in detecting pollution but also play important role in transformation of many pollutants from non-degradable to biodegradable (Megharaj et al. 1989). The transformation or degradation capacity of pollutants varies according to cyanobacterial species.

The cell walls of cyanobacteria are composed of lipids, polysaccharides and carbohydrates that bears negatively-charged functional groups. Most metals are bound to the negatively-charged groups, these ionic interaction, forms the basis for metal removal from wastewaters. Beside this adsorption of metal onto cell surface, production of extracellular polysaccharides, uptake into cells, incorporation into vacuoles or aragonite ($CaCO_3$) structures, and precipitation on the cell surface or internally can occur (Varsha et al. 2011).

Various authors reported the potential role of cyanobacterial strain in xenobiotic degradation. Cáceres et al. (2008) reported transformation capacity of five different species of cyanobacteria in, fenamiphos pesticide to its primary oxidation product fenamiphos sulfoxide. Sorkhoh et al. (1992) reported the presence of cyanobacterial mats in the Arabian Gulf Coasts after oil pollution their presence showed their bioremediation potential to degrade hydrocarbons. In another study, Safari et al. (2016) reported the role of cyanobacterium *Fischerella ambigua* ISC67 in biodegradation of crude oil and also studying their impact on physiological responses. The results showed the growth of cyanobacterium in the presence of crude oil is almost same as of control. So these growth rates are nearly equal and sometimes lower than the control sample. Muñoz et al. (2003) in his study reported phenol, salicylate, and phenanthrenedegrading capacity of green alga *Chlorella sorokiniana.* In another study Muñoz et al. (2006) reported algal–bacterial consortium of *C. sorokiniana* and *R. basilensis* in removal of salicylate and heavy metals from the solutions. In another study Ichor et al. (2016) reported time dependent influence of aerobic heterotrophic bacteria–cyanobacteria interaction during biodegradation of poly aromatic hydrocarbons. In another previous studies various cyanobacterial genera like *Aphanocapsa, Anabaena, Microcoleus, Nostoc, Oscillatoria and Phormidium* had been reported, that have significant potential in hydrocarbons degradation under aerobic conditions (Prince 1993). In another study Radwan and Al-Hasan (2001) reported the n-alkanes degradation potential of *Microcoleus chthonoplastes* and *Phormidium corium* cultures.

Some authors reported the, long-term strategy of cyanobacteria along with bacterial consortia for the removal of metal pollutants; Kalin et al. (2004) described three-step process for the detoxification of uranium from the wastewaters. This method follow a sequential trend for the removal, in the first step ligands present in algal cell walls efficiently remove U(VI) from wastewaters, then in the second step it remove U-algal particulates from the water column to the sediments. Then after, the dead algal cells provide carbon, nitrogen and phosphorus to the heterotrophic bacteria for the final reduction of U (VI) to U (IV).

Future prospective

Environmental pollution or climate change is one of the severe environmental problems, appears due to the industrial effluents, accumulation of heavy metals, petrochemicals degradation, oil spills, accumulation of pollutants and other fragmented compounds of polyaromatic hydrocarbons, petrochemicals, either anthropogenically or naturally. There is an urgent need to degrade these xenobiotic compounds in sustainable and eco-friendly way. It is found that cyanoabacteria is abundantly present, so there should need advancement in technologies for microbial remediation or phytoremediation by the uses of various cyanobacterial strains. Microbial strains use different methods like bioaccumulation, production of chelating agent, extracellular polymeric substances in phytoremediation. So, exploitation of such micro-organisms or cyanobacteria is needed for their sustainable use in phytoremediation.

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