Genetically Engineered Microorganisms: A Problem Solving Approach for Bioremediation

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Journal of Bioremediation and Biodegradation is an open access journal which deals with the publication in the field of bioremediation and biodegradation. This journal removes the price barrier and permission barrier and provides wider and easier access to this literature. Open access policy allows free availability on the internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, use them for any other lawful purpose, without financial, legal, or technical barriers. This journal is most suitable to express my views on the use of Genetically Engineered Microorganisms (GEMs). This article will focus on the development of GEMs for bioremediation which will solve the problems associated with the use of wild strains, i.e. related to their monitoring, existence in the environment.

Nature has its own way of cleaning the environment by removing xenobiotics to maintain a perfect balance but in this era of industrialization the rate of xenobiotics discharges has crossed the tolerance limit of the nature. Therefore, there is a need to find out the method of remediating xenobiotics from the environment. Microbial remediation of xenobiotics has proved the effectiveness and low cost technology but there are severe limitations in using microbes. Thus, genetic engineering approaches are used by genetic engineers to construct new strains of microbes (Genetically engineered microorganisms, GEMs) that have the unique characteristics compared to the wild type broad spectrum of catabolic potential for bioremediation of xenobiotics. In 1970, the first GEMs called “superbug” was constructed to degrade oil by the transfer of plasmids which could utilize a number of toxic organic chemicals like octane, hexane, xylene, toluene, camphor and naphthalene.

GEMs have been developed by the identification and subsequent manipulation of certain genetic sequences. GEMs exhibit enhanced degradation ability for a wide range of xenobiotics and have potential for bioremediation from various environmental sources. Designing of GEMs is based on the information of interaction between microbes and xenobiotics, the genetic basis of their interaction, biochemical mechanisms, operon structure, molecular biology and ecological application.

There are several approaches for the construction of GEMs for bioremediation application. First approach is- the identification of organisms suitable for modification with the relevant genes. For instance, microorganisms are well adapted to survive in soil environment may not be able to survive in aquatic environment and hence cannot be used successfully. Therefore, aquatic microbes can be used to develop GEMs for bioremediation of aquatic sources. The use of such organisms would avoid the supplementation of nutrients to the inoculated environment, thereby reducing the costs incurred and maintenance required. Scientists have developed Anabaena sp. and Nostoc Ellipsoasporum by the insertion of linA (from P. paucimobilus) and fcbABC (from Arthrobacter globiformis) respectively. The gene linA controls the biodegradation of lindane (γ-hexachlorocyclohexane), and fcbABC confers the ability to biodegrade halobenzoates and can be used to remediate these pollutants from water sources.

The second approach is the pathway construction, extension and regulation. GEMs have developed by improving existing catabolic pathways or to extend these pathways to degrade some more compounds which are not possible to degrade by using wild strain. The complete catabolic pathway may be encoded by a single microorganism, or by a consortium of microorganisms, each performing one or more of the stages of bioremediation of xenobiotics. In this way, constructed GEMs possess the degradation capabilities of different microbial communities due to the alteration of gene sequences which further improve the efficiency and efficacy of the catabolic pathways.

Third approach is modification of enzyme specificity and affinity. It is the fact that each stage of the metabolic pathway is mediated by enzymes that are produced by the transcription and translation of specific genes. GEMs have been developed by hybrid gene clusters which alter their enzymatic activity and enzyme substrate specificities. These gene clusters encode the enzyme possessing improved transforming capability. E. coli strain is genetically modified to express a hybrid gene cluster for the degradation of trichloroethylene (TCE).

Fourth approach is—bioprocess development, monitoring, and control, and bioaffinity, bioreporter, sensor applications for chemical sensing, toxicity reduction, and end point analysis. There is scanty of reports on this approach. However, the use of lux gene-based system has been developed that offers several advantages for monitoring bioremediation processes. Bioluminescence can be easily detected and do not require expensive devices, exogenous addition of chemicals or co-factors. Further, GEMs possess chemical sensors that allow the monitoring of contaminant bioavailability rather than just contaminant presence. Bioluminescence producing GEMs also help us to understand the spread of microbes in the polluted area and end point of the bioremediation.

There are several developments in GEMs which overcome the limits of using wild type microbes. Microbes are confined to aerobic catabolic and co-metabolic pathways and therefore cannot be applied to anaerobic environment. GEMs are developed by inserting genes for oxygenases make it possible to use them in anaerobic environmental conditions. One must consider all the xenobiotics present in multi-contaminated sites before applying microbes for bioremediation. GEMs offer the properties of many microbes due to the insertion of genes in a single microorganism. Therefore, GEMs can be used successfully for bioremediation purpose. However, it is utmost important that to ensure

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about the risk to the environment and human health in using GEMs for remediation of pollutants. Microbes or GEMs which use xenobiotics as a source of carbon, energy and/or nitrogen, can get nutrients and grow there. Moreover, they may disperse in an uncontrolled manner and may cause adverse effects. Scientists have been developing a novel strategy to construct "Suicidal Genetically Engineered Microorganisms (SGEMs)" by exploring the antisense RNA-regulated plasmid addiction, proteic plasmid addiction and inducible degradative operons of bacteria. To design a novel S-GEM is based on the knowledge of killer-anti-killer genes that makes the microbes susceptible to programmed cell death after degradation of xenobiotics. This technology helps in the removal of microbes after bioremediation by their autolysis and therefore, reducing the risks to the human beings and environment.

Application of GEMs based remediation of xenobiotics is in the forefront due to eco-friendly and human friendly approaches. However, information on the genes is very limited which limits the development of GEMs. Second main obstacle in the application of GEM is the regulatory affairs and hazards associated with them. However, this problem may be tackled by the development and use of Suicidal Genetically Engineered Microorganisms. In future, this will be the most efficient technology if information on bioremediating tool (microbes), their genomes and biochemical mechanism work out. This will allow the application of GEMs in the field which is at present limited to laboratory experiments only.