“X-Raying” The Processes of Bioremediation and Biodegradation

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Once released in the environment, organic pollutants are distributed in water, soil, air and biota. Their existence in the environment causes huge harm to human health. Currently, the most effective methods to remove these organic pollutants from the environment are bioremediation and biodegradation, which use different kinds of plants and microorganisms. However, both processes may trigger more serious secondary damage to humans and animals. The toxic genes of organic pollutants are not only resident in and exhibited by the parent compounds, but may also be inherited by their daughter and/or granddaughter products during the processes of bioremediation and biodegradation. Furthermore, in specific ratios, these mixtures of parent compounds and daughter products may present more toxic packages to human health. In addition, even though the end result of metabolism and degradation of the organic pollutant is the same i.e. disappearance of the pollutant, whether occurring by biodegradation or bioremediation, different processes may have different metabolic pathways and give birth to different metabolites, which lead to different toxicity. Therefore, we should not only focus on the removal of organic pollutants, but also comprehensively “x-ray” their metabolic processes and metabolites to better predict and comprehend the fate and toxicity of organic pollutants.

Take polychlorinated biphenyls (PCBs) as an example. It is common knowledge in scientific circles that PCBs are a group of persistent organic pollutants with multiple modes of toxicity, such as mutagenicity and carcinogenicity. More importantly, even though they are categorized as persistent pollutants, PCBs “give up” their persistence and form many different metabolites with different ratios in different processes of bioremediation and biodegradation. The major metabolites of PCBs include dechlorinated counterparts, hydroxylated metabolites, methoxylated metabolites and methylsulfonated metabolites, which have different properties and may produce more toxic effects on the biota. With regards to bacterial degradation, different environmental variables (e.g. aerobic and anaerobic conditions) will result in the production of different metabolites of PCBs. This scenario offers the choice to select the processes with low toxic metabolites in practical application. However, the premise of selecting optional processes based on the desired toxicity outcome implies that we should have a clear understanding of and insight into the metabolic network of PCBs.

The best way to elucidate all the metabolic processes of bioremediation and biodegradation is the detection of the metabolites. Indeed, progress has been made on the research of metabolites and metabolic pathways. However, we still face a lot of challenges to decipher and construct detailed metabolic processes. One major challenge is the limitation imposed by detection techniques. Although we have many instruments, such as GC-MS/MS and LC-MS/MS, to detect the trace organic pollutants and their metabolites, we still need to improve the sensitivity and speed of instruments, such as multidimensional GC and/or LC-MS/MS systems for the ultra trace metabolites and unstable metabolites. Another major challenge is the availability of standards for metabolites. Many conjectures about metabolites and possible metabolic pathways stop at the hypothesis level because we cannot identify them without standards. Even though radioactive compounds are effective tools to probe the metabolic processes, this method is also challenged due to the unavailability of standards for confirmation of unknown metabolites. The challenges faced in understanding the metabolic pathways in bioremediation and biodegradation, and the current gaps that exist, can provide a powerful engine for further research.

Considering the specific toxicity of metabolites and the mixture of parent compounds and their metabolites, we should have a precise understanding of the metabolic processes occurring under different conditions. It would be foolhardy to ignore the possibility that in the pursuit of our desire to reverse the ills caused by the irresponsible discharge of organic pollutants, we are making a bad situation worse, if the metabolites are more toxic than the parent compounds. Increased knowledge about the processes involved in bioremediation and biodegradation will enable us to make more informed decisions on whether or not to pursue the removal of parent compounds without due consideration to the potential lethal effects of their metabolites. Such an approach will provide us with alternative schemes to design the metabolic processes. Therefore, “X-raying” every tiny process of bioremediation and biodegradation of organic pollutants is a big issue for current and future research.

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