OPINION

The Critical Issues of Pollutant Biodegradation for Bioremediation Not Being Addressed

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Abstract: Biodegradation is still an active research topic for bioremediation development and clean up the contaminated sites, but current research reports have not dealt with this subject effectively to advance the basic science and provide a fundamental basis for applications. Degradation study is based on the availability of metabolically capable microorganisms, and then the biotransformation and degradation by them shall be on the further in-depth results of the biochemical pathway through isolation and identification of the degradation intermediates. In addition, the relevant genes and proteins can be also investigated based on the biodegradation reactions. There are a number of pitfalls on the degradation research and results reported currently, but the microbes and the metabolism shall be identified as the central focal points to advance the science of this topic prior to the application can be tested under different scenarios.
Keywords: Biodegradation, bioremediation, pollutants, degradation pathway, sequencing

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Introduction

Environmental pollution by anthropogenic chemicals has been known to threaten ecosystem function and bioremediation has been proposed for development to clean up such pollutants in the contaminated sites (Alexander, 1999; Atlas, 1995; Liu and Suflita, 1993). Pollutants can be either organic or inorganic in their chemical composition, and they have a wide range of different physical and chemical properties to dictate their fate and toxicity in the different compartments of the ecosystems (Alexander, 1999). As a result, pollutant toxicity is not as easily assessed and understood as in the laboratory comparing with ecosystems and over time of ageing (Alexander, 1995). Recently, endocrine-disrupting chemicals and pharmaceuticals are new emerging contaminants (Schwarzenbach et al., 2006; Gu, 2020) together with other persistent ones are becoming the focal issues in different parts of ecosystems. Many publications are being made on biodegradation and bioremediation of different environmental pollutants by microorganisms or in different settings, but many of them do not show new results to the current available knowledge on this topic in my view (Gu, 2016).

Bioremediation is generally stated or argued as the optimal option for removal of pollutant contamination in different ecosystems or contaminated sites, and the common reasons are biological, effective, economical and efficient, and no secondary pollution to name some of them routinely (Atlas, 1995; Gu, 2020; Liu and Suflita, 1993). These reasons actually are not concrete facts, at least for some of them, and they are actually illusion in science, even today. Unfortunately, very few people probe these for the validity and actual truth before accepting the statements without demanding the substantial information. Because of this situation, I would like to discuss here that the scientific advancement of this topic has suffered a significant drawback because of the current ambiguous situation preventing it for further development.

The Research Framework

There are plenty of reports on biodegradation of persistent organic pollutants (POPs) and new chemicals from industrially production to newly made ones, but there has been very little significant progress made on the fundamental science on this topic (Gu, 2016, 2022a). First, tradition has a strong influence on the ways in which the research is still being carried out in the same or similar ways. Some of the common protocols are to isolate and characterize the microorganisms, bacteria or fungi, and then to test a selective pollutant and its concentration change through exposure to the microbe for a period of time. During the incubation, the concentrations

of the chemical are monitored and presented as a proof of degradation when concentration of the selective chemical shows a decrease over time (Gao and Gu, 2021; Gu, 2016). Though the data seem to be fine for a beginner, no in-depth and substantial results on the transformation or degradation are the critical issues here, e.g., mass balance and stoichiometry. If good guidance is available coupling with adequate efforts made, it is possible to construct the biodegradation pathway based on the identification of the degradation intermediates as a significant step forward. With such results, the enzyme and gene responsible for the biochemical reaction can then be proposed and also further investigated to make concrete progress on the fundamental understanding of the degradation of the selective pollutant. In a similar way, mixed culture of different microorganisms or a stable consortium can also be used to achieve similar results, and the significance and impact. With this proposed framework or paradigm for pollutant degradation research, the most important focal elements are the microorganisms, being pure culture or mixed population or stable consortium as the biocatalyst. At the same time, the metabolism of transformation and degradation shall be sharply focused through a thorough analysis of the degradation intermediates during the active metabolic growth of the microbial population (Gu, 2016; Gao and Gu, 2021) as illustrated in Figure 1. Both the microbes and the metabolism are becoming the two strong pillars to support a research investigation of this research topic.

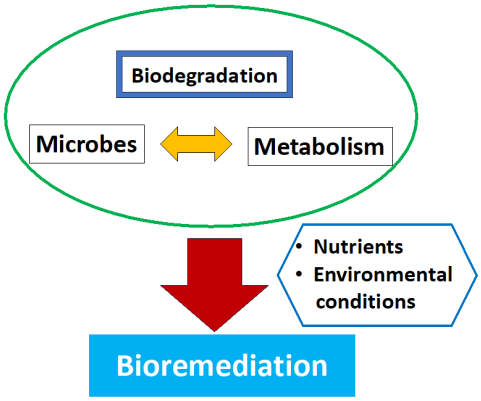

Figure 1. A proposed research framework of the two key elements in biodegradation and the relationship between biodegradation and bioremediation

The Biocatalysts

The central issue of biodegradation is based on two key elements, the effective microbe as the catalyst as one arm and the biochemical reaction of metabolism as the other (Figure 1). From this scheme, it is clear that the most important requirement is to obtain a pure culture of microorganisms in single species, mixed population or consortium before additional effort to identify the potentials on biodegradation. To obtain unique and useful microbes, it is not an easy task as too many reports simply adopt the same or similar one without any innovation on this part, especially on the media. Enrichment and culturing technique can be established (Chen and Gu, 2022; Gu, 2021) and some of the first important microbe for unique biochemical reaction was achieved using new approach of enrichment culturing method for an original discovery on biological de-chlorination (Sheton and Tiedje, 1984a, 1984b).

With or without the microbes, it is a widely used procedure to carry out the genome or metagenomic sequencing and annotation of the genome and its genes and possible enzymes, but such DNA-based results cannot be used as a proof of degradation or biochemical reaction because of the genes or enzymes re-constructed from the metagenomics are not verified (Chen and Gu, 2022; Gu, 2022b). If the active genome information can be obtained through RNA extraction and reverse transcription, transcriptomics and metatranscriptomics are far meaningful and better choices than genomic DNA to advance the science. On metabolic activity and transformation/biodegradation potential, it is still preferred to establish the biochemical transformation pathway of any pollutant by the responsible microorganisms as choices for the fundamental and basis information on the subject of biodegradation research as previously conducted (Evans, 1977). Without such data and information derived from basic chemistry or biochemistry, the results are simply generic products from mass production without new finding, therefore no contribution to the development of science on this topic as original output (Gu, 2016, 2022a). Based on the trendy approach, any discussion and proposal for bioremediation are simply groundless to say or claim honestly. Gene-based approach is relatively new and can be used, but the complementary part of the chemical biotransformation must be established simultaneously to be useful. Gene identification and manipulation is a separate topic and will not be discussed here.

To carry out degradation assay, several rules must be obeyed, including the target organic pollutant as the sole source of carbon and energy for the microorganism, culture medium does not contain other nutrients that can be used by the microorganisms for growth, and the pollutant shall be soluble directly or by facilitation of other inert chemical, e.g., surfactants (Gao and Gu, 2021; Gu, 2021). When experiments are conducted with consideration of these, the isolation and identification of the degradation intermediates can be on a firm ground, but there is still no guarantee for success yet.

Available Substrate Concentration

Concentration quantification of pollutants in the environmental samples and culturing flasks is not a simple business because majority of the environmental pollutants are not water soluble or dissolved only insignificantly in water. Such property makes them easily bioaccumulated to cause toxicity and related issues including tumor and cancer in animals. In this case, the concentration of chemical in a laboratory culture

medium must be assessed with proper abiotic control, and quality control and quality assurance must be implemented to account for the recovery before make any claim on degradation or degradation rate (Gu, 2016, 2017). It is a general way to show that a decrease of a chemical concentration over time as evident for degradation, but this claim can be made only when the abiotic control has been conducted and the stability of the chemical is confirmed so that no abiotic contribution to the transformation of the chemical can be involved. On the other hand, manipulation of the axis of figure showing the concentration change data or microbial biomass is an issue deserving more attention, especially for the beginners (Gu, 2017). It is useful to make a distinction between degradation and degradation rate because the latter is a time-based change of pollutant or substrate concentration while the former can be simply raw concentration data of the analytical ones for the pollutant involved. It is suggested that the word disappearance or concentration be used to replace the degradation on a matter-of-fact scenario for the data obtained and then reported when no further results are available.

The specific concentration of a pollutant for degradation evaluation in a study is chosen without any scientific basis or guideline to follow currently. In my opinion, the concentration of any organic pollutant shall be assessed for microbial maintenance, metabolism and toxicity as a suite of information required (Gao and Gu, 2021). When the concentration range for microbial metabolism is known for a selective chemical, the degradation capability by the microorganism involved can be truly assessed without biases from lack of adequate energy or toxicity issues to inhibit the growth resulting in no positive result. Within this proposed research structural scheme, transformation and degradation of pollutants can be investigated through the chemical identification of degradation intermediates and construction of the degradation reactions and pathway (Figure 2). In addition, the gene and enzyme can be further studies based on the biochemical pathway information. This could be the logic sequences for effective and efficient research on biodegradation of toxic pollutants.

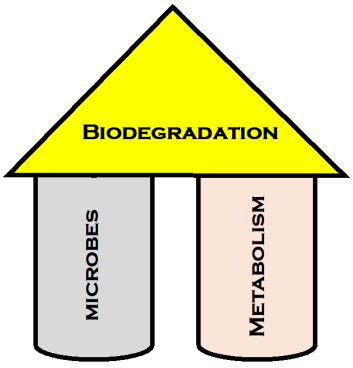

Figure 2. A conceptual model of research on biodegradation supported by two key pillars, the microbes involved and the biochemical capability of them in biochemical reactions for metabolism

Bioremediation can be proposed and tested on site, but the laboratory tested microbes is not likely to be the successful microbe to compete with the indigenous population in the polluted environment (Gu, 2020). Because of this, in situ remediation by using pure species of laboratory microorganisms is not likely a good and effective way to proceed. This may be discouraging to many of us, it is probably that is why very few research have shown their successful data by tracing the activity and physiology of the inoculated ones into soils or sludge for their performance. Issues relevant to the field will be communicated in my next article.

In conclusion, the concept and framework of biodegradation are mostly based on an effective microbe and also the transformation or degradation capability for metabolizing a target pollutant. With the two pillars for this tower in a hypothetical structure, degradation can be a visible beacon on the top of this stable structure. My recommendation here is simply a sharp focus on both the microbes and the metabolic processes with some meaningful strategic plans inside each of these key elements to yield original and new research results to enlighten this research topic and the specific directions.

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Conflict of Interest

Author declares that there is no conflict of interest in the information presented here.

Ethical Approval

This article does not contain any studies with human participants or animals performed by the author involved.

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