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Concepts and Difficulties of Electro-assisted Groundwater Bioremediation

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Abstract

Although bioremediation is envisioned as a significant method of reducing groundwater contamination, its application is hampered by the need for chemical addition and the low bioavailability of contaminants or electron donors/acceptors. Since it offers distinct advantages in terms of environmental friendliness, controllability, and treatment effectiveness, electrochemical systems have attracted significant attention as a promising way to improve such processes. For its practical application, there are also possible dangers and sizable engineering difficulties. This review provides the first thorough introduction to this developing technology, explores its possible applications and present difficulties, identifies knowledge gaps, and looks ahead to potential field application opportunities. It is important to have a better understanding of how microbiology behaves when subjected to electrochemical stimulation, as well as the requirements for process monitoring, modelling and assessment techniques, and field research in the future.

Keywords: Bioremediation; Groundwater; Electrochemical

Introduction

An international environmental concern and health hazard is groundwater contamination. Numerous organic substances, heavy metals, nitrate, and other compounds with concentrations ranging from ng/L to mg/L are among the typical pollutants in subterranean aquifers. While in-situ remediation is thought to be more advantageous in these regards, traditional "pump and treat"-based treatment approaches typically suffer from high energy or chemical consumption, poor removal of the low-mobility contaminants bound to soil particles, and disturbance of the aquifer ecosystem. Several prerequisites must be met for the microbe-based bioremediation. First, there must be microbes that can absorb and biochemically digest the pollutants. Second, it's important to ensure that the right growth conditions are in place, including the physicochemical parameters (such as pH, temperature, and toxicity) as well as the bioavailability of nutrients and electron donors/acceptors [**1-4**]. Finally, either directly or through mediators, the pollutants must be reachable by the bacteria. Therefore, even though natural bioattenuation can take place in contaminated aquifers, the remediation efficiency is typically low because of a lack of the aforementioned requirements. Biostimulation, or the additional injection of nutrients and other supplementary components to support microbial activity and growth , or bioaugmentation, or the addition of particular pre-grown microbial cultures, is typically used to get around these limitations [**5**]. These processes can, however, result in secondary contamination, adverse changes to aquifer conditions, and even ecological risks. They also require regular supplementation with chemicals that donate or accept electrons. In general, bioremediation can happen in groundwater, but typically not quickly enough to reduce risks or it may even create new ones. In the past few years, there has been an increase in research activities to better understand the underlying principles and assess the viability of this emerging remediation scheme, but its practical application is still in its infancy. Understanding what is currently preventing this technology from being implemented on a large scale and looking ahead to the possibilities are of utmost importance at this point [**6-8**]. The current analysis examines the current restrictions placed on groundwater bioremediation and considers how some of these restrictions might be lessened by using an electrochemical system as a stimulation technique. Here is a summary of electro-assisted bioremediation's possible applications and difficulties in decontaminating subsurface environments. There is discussion of the information gaps, engineering difficulties, and required future work to support its practical use [**9**].

The present issues of groundwater in-situ bioremediation

A wide range of groundwater contaminants, including pesticides, fuels, and different inorganic chemicals or metals, are potentially amenable to bioremediation due to the metabolic adaptability of environmental microorganisms. However, at certain contaminated sites, there are frequently insufficient environmental conditions for the bioconversion process to occur, which has a negative impact on the effectiveness of restoration.

Electrochemical [10]

Electrochemical methods may help to some extent with the aforementioned difficulties. Placing polarised electrodes in the contaminated aquifer is the fundamental idea behind electro-assisted bioremediation of groundwater. Through a number of ways, the pollutant removal could be electrochemically improved. First, electrodes can directly assist microbial metabolism as electron donors or acceptors, reducing the bioavailability of electron donors and acceptors. Many different hydrocarbons, aromatic organics, and inorganic contaminants like nitrate, sulfate, and heavy metals can all be converted to bioactive compounds through the use of electrochemical methods.

Discussion

There are several microorganisms that may detoxify or degrade different pollutants in natural underground aquifers, and many of them are also able to interact electrochemically with a solid electrode. In a variety of groundwater environments, this lays the groundwork

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for the use of electro-assisted bioremediation technologies. Although its viability has been proven in lab tests, many of the underlying mechanisms and deciding elements. In Europe, there isn't a single, all-inclusive source for information on remedial activities. The needed data must be compiled from several sources, keeping in mind that quantitative data are not always comparable to one another. This means that the country-based depiction of projects and technologies is frequently unrepresentative. A fraction of the current cleanup initiatives or technology applications are only seldom mentioned, therefore the information that is available is frequently incomplete. In nearly every site, the contamination causes a plume of contaminated groundwater to develop. A containment and/or cleanup mechanism for the plume is required to stop the contamination from reaching potential targets (such as drinking water wells). Activated carbon adsorption and air stripping are the two physical-chemical processes that are typically used to treat extracted groundwater in P&T approaches. This is done for a variety of reasons. For the long-term remediation of contaminated sites, in situ bioremediation is a very promising and economical technology. It may also offer hope for the long-term management of contaminated sediments. Microorganisms are applicable to an increasing variety of contaminants and contamination scenarios due to their wide metabolic diversity. However, applying in situ bioremediation at a particular site is "knowledge-intensive" and necessitates a thorough comprehension. As a function of runoff and deposition, contaminated sediments serve as the environment's last dumping ground for pollutants. Because sediment contamination in rivers, lakes, and harbours is so widespread, they represent long-term sources of environmental toxins and a threat to the security of the environment in Europe and its partner nations.

Conclusion

Despite the many different types of groundwater contamination, electrochemical methods can easily increase microbial power, as has been demonstrated in several laboratory studies. Fortunately, nature already has a microorganism-based solution in place. Consequently, electro-assisted bioremediation is a viable approach for treating contaminated groundwater. The lack of understanding of the microbiology in such systems limits its field application, though.

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