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Applied Microbiology 2016- Microbial biosensors for environmental applications and the potential of microbial fuel cells -Reshetilov Anatoly- Russian Academy of Sciences

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Abstract
Our first works on biosensors dealt primarily with the event of electrochemical type microbial biosensors. The aim of the research was to think about the applied potential of microbial cells and to spotlight the results obtained in developing models of analytical devices for detection of readily utilizable useful organic compounds (carbohydrates, alcohols, organic acids) and toxic compounds (hydrocarbons, surfactants). The basis of these biosensors was Clark-type electrodes, electrodes obtained by screen printed techniques and supported field-effect transistors. Then we focused our interest of research, the purposeful application of microorganisms for assessment of biochemical oxygen demand (BOD) was considered. We used empirically chosen cultures of bacterial and yeast cells to form biosensor receptor elements. During the last several years the aim of the search was to study the characteristics of the microbial fuel cells, the development of microbial fuel cells not distinctly different from microbial biosensors. This approach yielded several positive results: Fragments of cell membranes (membrane fractions) were intensively used; nanomaterials were applied to develop electrodes; a novel approach based on the converter-based accumulation of electricity was applied for accumulation of electrical energy. These topics are considered in the presentation.

Fast industrial growth has accelerated environmental pollution globally. Moreover, environmental pollutants are widely distributed and diverse. Among environmental pollutants, heavy metals and organic compounds have attracted particular attention given their large presence in natural environments (soil, air, water, plants, etc.. More recently, consistent with the U.N. waste monitoring report, it's estimated that approximately 42 million plenty of electronic waste is generated globally once a year, mainly composed of heavy metals and organic pollutants. The Greenland MAP Core program has demonstrated organic pollutants within the Arctic show a decreasing trend, aside from the polychlorinated biphenyl (PCB) compound group. While the existence of pollutants represents an ecological risk, and also poses a threat to human health and the natural environment, bioremediation processes (e.g., microbial remediation) can remove or degrade heavy metals and organic pollutants. Pollution remediation is inevitably related to the monitoring of toxic substances in environmental governance. Hence, real-time monitoring of toxicity components in natural environments is of paramount importance.

Fast sensing and analysis of toxic compounds may be a great challenge thanks to their complexity. Traditional toxin detection methods specialise in ultraviolet spectrometry and high performance liquid chromatography (HPLC); however, these analytical methods are usually time-consuming and unsuitable for in place analysis. Biosensors are developed as promising tools for fast and selective detection of varied analytes. The recognition elements integrated within traditional biosensors, which can be fluorescent molecules, enzymes, or immobilized microorganisms, are costly and wish laborious implementation processes. In addition, their low sensitivity and specificity further restricts the potential for giant scale applications. Thus, developing a quick and cost-effective biosensor for toxicity detection is extremely urgent. Recently, microbial cell (MFC)-based biosensors have shown great application prospects for environmental pollutant monitoring, since they provide a moment and convenient alternative, ensuring the potential for permanent and long-term monitoring. They are usually composed of a cathode chamber and an anode chamber separated by a proton exchange membrane (PEM), allowing protons to migrate from the anode to the cathode and preventing oxygen diffusion into the anodic chamber. Anaerobic respiring bacteria are inoculated into the anodic compartment, where the microbes generate electrons and protons by consuming organic matter. Electrons are conveyed through the anode and pass through an external circuit to the cathode. Combined with the O2 from air, protons and electrons react within the cathodic chamber, and eventually form H2O.
Previously, MFC-based biosensors are widely used for water quality testing through monitoring dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). However, these indicators cannot distinguish the dominant organic pollutants. Using MFC-based biosensors for monitoring specific organic compounds may become a completely unique trend for his or her application. Although several reviews have focused on the subject of MFC-based biosensors, there's no report on MFC-based biosensors for specific substrates. Here, we summarize the latest research outcomes and describes their sensing mechanism. We then

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further evaluate several factors influencing their behavior and discuss means by which their performances could by improved, more particularly regarding the choices of membrane types and anode materials. In addition, we investigate modified non-linear modelling techniques for MFC-based biosensors, and briefly present possible future research directions, particularly in terms of popularization and potential applications.

2. The Mechanisms Governing MFCs Used as Biosensors

The electrochemically active microorganisms (EAMs) in an MFC catalyze the degradation of an organic material (fuel), and thus the electrons subsequently released during this degradation process are transferred to the anode surface. Therefore, the electricity generated by the MFC is that the key parameter that directly reflects the metabolic activity of the precise microbes present at the anode. Thus, understanding of the electron generation mechanism of the MFC is significant towards comprehending the analytical applications and operating procedures of MFC-based biosensors. Shewanella oneidensis MR-1 and Geobacter sulfurreducens have often been chosen as representative strains driving the mechanisms of extracellular electron transfer (EET). Based on the available studies, two mechanisms driving charge transfer from biofilms towards the anode surface have been proposed. One is that the direct electron transfer (DET) and therefore the other is mediated electron transfer (MET)

Physical contact between bacterial cell membranes and therefore the MFC anode may be a prerequisite of DET. Moreover, the membrane-bound electron transport proteins of EAMs, including c-type cytochromes, multi-heme proteins and OmcZ, can transfer electrons from the inside of the bacterial cell to an outer-membrane (OM) redox protein. Some dissimilatory bacteria lack c-cytochromes and instead, use conductive filamentous extracellular appendages termed bacterial nanowires. Regarding the MET pathway, flavins and riboflavins secreted by S. oneidensis MR-1 are demonstrated because the electron shutters and dominate the extracellular electron transfer. Furthermore, phenazines were also established as intrinsic electron shuttles in Pseudomonas species. Although numerous compounds have been introduced into MFCs as exogenous redox mediators to facilitate the electron transfer to electrodes, these exogenous redox mediators achieved relatively low currents and required continuous addition of the exogenous compound.