Environmental biotechnology and bio-energy studies in Kuban state university

Nikita Volchenko, Alexander Khudokormov, Andrey Samkov, Sergey Karasev, Maria Veselovskaya, Alexander Kalashnikov, Emma Karaseva
Department of Biology, Kuban State University, Russia

corresponding e-mail: volchenko.n@mail.ru
postal address: (KSU), str. Stavropol'skaya 149, 350040 Krasnodar, Russia

Kuban State University has a scientific school of microbiology and environmental biotechnology. Different strains of oil-degrading microorganisms were effectively used for oil-polluted wastes cleaning. Some new scientific directions develop intensively. Microbial fuel cells were developed for wastewater treatment and electric current generation. Microalgae were used as a source of lipids for biofuel.

Keywords: Bioremediation, oil-degrading microorganisms, microbial fuel cell, microalgae lipids

Introduction

Studies in area of environmental biotechnology is traditionally made in Kuban State University (KubSU). Research on oil-degrading bacteria has more than 20 years experience. Particularly, the university focuses on interdisciplinary research projects in fields of biology, physics, and chemistry. One of this projects is a creation of microbial fuel cells (MFC). The MFC can be able to receive the electric energy from wastewater and other wastes. The other branch of bioenergetic studies is screening of microalgae as a new source of biofuel. The research results is commercialized through the University’s business incubator and some innovative companys.

Oil biodegradation and bioremediation

It is estimated that the annual input of petroleum contamination in the environment makes 25 million metric tons, the majority of which is sourced from anthropogenic sources in Russia. In southern Russia, the problem of oil-contaminated soil and water is also topical issue (Philp, Ivshina, Kuyukina, Losinsky, Kovalenko, and Karaseva, 2003; Karaseva, Girich, Khudokormov, Aleshina, and Karasev, 2005; Karaseva, Khudokormov, Volchenko, and Melnikov, 2003). Microbiological methods are the most progressive technologies and they are based on usage of oil oxidizing bacteria (Karaseva et al., 2003). Bioremediation is a process in which microorganisms metabolize contaminants either through oxidative or reductive processes. The advantage of biological methods is not only their relatively low costs, but also they provide almost 100% utilization of pollutants (Karaseva et al., 2003). Bioremediation often addresses multiphase and heterogeneous environments, such as soils in which the contaminant is present in association with the soil particles, dissolved in soil liquids, and in the soil atmosphere. Because of these
complexities, successful bioremediation depends on an interdisciplinary approach involving such disciplines as microbiology, engineering, ecology, geology, and chemistry. The biodegradation of petroleum and other hydrocarbons in the environment is a complex process; its quantitative and qualitative aspects depend on the nature and amount of the oil or hydrocarbons, the ambient and seasonal environmental conditions, and the composition of the autochthonous microbial community.

**F I G U R E 1. BIOTECHNOLOGICAL COMPLEX BIOREACTOR “OKA-01-100T” (BUSINESS INCUBATOR OF THE KUBSU)**

Department of Genetic, Microbiology and Biotechnology in KubSU has the collection of oil-destructive microorganisms of more than 900 strains of bacteria. It includes microorganisms producing biosurfactants and plant hormones, such as auxin (Baker and Herson, 1994). They are widely used to phytoremediation of contaminated soils. Depending on the characteristics of oil-sludge it is possible to reduce concentration of hydrocarbons from 350-500 g/kg to 7-15 g/kg within 3-8 months. The using of phytoremediation technology allows reducing the oil concentration to 1-2 g/kg.

The department also works on development and production of biological product serving as oil destructor and phyto-stimulator. Automatic and aseptic 100 liter bioreactor, based in business incubator of KubSU, is used in this project (Figure 1).

**Microbial fuel cell**

Alternative energy represents another important direction of the university. Researchers work on interdisciplinary research projects assuming interaction of several areas of science - physics, biology, chemistry, etc. One such project is the development of alternative energy sources - microbial fuel cells. A microbial fuel cell or biological fuel cell is a bio-electrochemical system generating a current by mimicking bacterial interactions found in nature. A microbial fuel cell (MFC) is a device that converts chemical energy to electrical energy by the catalytic reaction of microorganisms (Logan, 2008). The MFC can be used in cleaning of brewery and domestic wastewater, water desalination, hydrogen production, powering remote sensors, pollution remediation, and as a remote power source.
(Jiansheng, Ping, Yong, and Kaishan, 2011; Guzman, Cooke, Gaya, Radachowskya, Girguis, and Chiua, 2010). Many applications are in testing phase and can be prepared for widespread application in near future. MFC studies suggest several domains of application: wastewater treatment, decomposition of organic solid wastes to generate energy from the sediment of ponds. Figure 2 shows the appearance of MFC designed to generate energy from waste liquid.

**Figure 2. MFC with liquid wastes in volume 6,5 l**

Our research group investigates the electric generation from wastewater of sugar factory. Another trend is the microbial decomposition of paper waste to carbon dioxide and bioelectricity. Carbon dioxide is the source of the carbon and energy to algae. Figure 3 shows the electrical power of a single cell MFC, loaded with a scrap of paper hydrolysis products.

**Figure 3. Electric power of MFC loaded with liquid wastes**

The territory of Kuban State University is located near the shores of Karasun Lake. Bottom sediments were used to produce electric energy by benthic MFC. By placing one electrode into lake sediments rich in organic matter and the other one in the overlying oxygen rich water, electricity can be generated at sufficient levels to power supply of some water devices. This conditions the process of bioremediation of bottom sediments in a lake (Hong, Choi, Chung, Song, and Kim, 2009).
Microalgae as a new source of biofuel

During the last decade, fossil fuel depletion and global warming issues have strongly motivated research on fuel production from biomass. In comparison to oil fuel, biofuel can represent an improvement in terms of CO₂ fossil emissions. However, such technology can also induce negative environmental impacts, caused for instance by pesticides and fertilizers, and can also create a competition for land use with food crops. Therefore the use of first generation biofuel as a sustainable alternative to fossil fuels is questionable and has been the subject of debates (Crutzen, Mosier, Smith, and Winiwarter, 2008). On the other hand, microalgae seems to be an attractive way to produce biofuel due to their ability to accumulate lipids and their very high actual photosynthetic yields; about 3-8% of solar energy can be converted to biomass whereas observed yields for terrestrial plants are about 0.5% (Huntley and Redalje, 2007, Li, Horsman, Wu, Lan, Dubois-Calero, 2008). These interesting properties lead to potential productivities (in terms of oil production per ha and per year) which are higher than those of rapeseed or sunflower (Chisti, 2008). The high productivity, moderate competition with feed crop and the possibility to uptake industrial sources of CO₂ have motivated studies depicting microalgae as an alternative source for biodiesel production (Li, Horsman, Wu, Lan, and Dubois-Calero, 2008; Chisti, 2008).

Despite strong interest from economics and science, there is still no industrial facility producing biodiesel from microalgae. Studies in this area remain restricted to lab and pilot scales. Hence, currently there is no thorough life cycle assessment of the production chain from microalgae culture to biodiesel.

The university team studies perspectives of cultivating algae in open ponds in the Krasnodar region - a region with the most favorable climate in Russian Federation. Cultivation is assumed to organize in open raceways with algae concentration of 0.5 g/L. Growth-rates observed in open raceways are usually lower than those in laboratory photobioreactors; it is more difficult to maintain optimal and stable growth conditions. Alternatively photobioreactors require much more expenses.
for building and maintenance (Figure 4). Biodiesel production from microalgae is an emerging technology considered by many as a very promising source of energy, mainly because of its reduced competition for land.

References