

Another important aspect is environmental sustainability. Biotechnological methods contribute to the conservation of natural resources by promoting more efficient use of water and soil. For example, drought-resistant crops require less irrigation, which is crucial in areas facing water scarcity. In addition, reduced pesticide use helps preserve biodiversity and prevent soil and water contamination.

However, despite its numerous advantages, biotechnology also raises several concerns. One of the main issues is the potential impact of genetically modified organisms on ecosystems and human health. Although many studies confirm the safety of GM crops, public skepticism and ethical debates still exist. Another challenge is the economic aspect, as biotechnology technologies can be expensive and not equally accessible to all farmers, especially in developing countries.

Furthermore, there are concerns related to the loss of biodiversity and the dominance of large agricultural corporations. The widespread use of genetically modified crops may lead to the reduction of traditional plant varieties, which are important for maintaining genetic diversity.

To address these challenges, it is essential to implement proper regulations and ensure responsible use of biotechnology. Governments and international organizations should develop policies that promote safe and equitable access to biotechnological innovations. Education and awareness are also important, as they help society better understand the benefits and risks associated with biotechnology.

In conclusion, biotechnology plays a crucial role in the development of modern agriculture and sustainable food systems. It offers effective solutions to global challenges such as food security, climate change, and environmental protection. However, its application must be carefully managed to minimize risks and ensure long-term benefits for society and the environment. The future of agriculture largely depends on the successful integration of biotechnology with sustainable practices.

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BIOREMEDIATION: USING MICROORGANISMS TO CLEAN THE ENVIRONMENT

У публікації проведено огляд методу біоремедіації, який використовує мікроорганізми для видалення або нейтралізації забруднювачів навколишнього середовища. Було проаналізовано використання бактерій, грибів та водоростей для відновлення середовища та економічна ефективність даного методу.

Ключові слова: біоремедіація, мікроорганізми, забруднення навколишнього середовища, біодеградація, рекультивація ґрунту, очищення води, екологічні технології.

The publication reviews the bioremediation method, which uses microorganisms to remove or neutralize environmental pollutants. The use of bacteria, fungi and algae for environmental restoration and the economic efficiency of this method were analyzed.

Keywords: bioremediation, microorganisms, environmental pollution, biodegradation, soil remediation, water treatment, eco-friendly technology.

Bioremediation is a method of waste treatment that involves the use of organisms such as bacteria, fungi and others to remove or neutralise contaminants from a polluted site. Aerobic and anaerobic microorganisms are used to treat domestic and industrial wastewater, groundwater and contaminated soil; biogas is produced during the processing of agricultural waste [2].

Microorganisms break down pollutants by using them as a source of energy or by cometabolising them with a source of energy. More specifically, bioremediation involves the formation of an energy product in a redox reaction in microbial cells. These reactions include respiration and other natural functions necessary for cell maintenance and reproduction [3].

The adaptability and biological systems of microbes make them an ideal choice for remediation. Carbon is the most important nutrient for microorganisms. Microbes from various environments have been used for bioremediation. Examples of microbes include *Achromobacter*, *Alcaligenes*, *Xanthobacter*, *Arthrobacter*, *Pseudomonas*, *Bacillus*, *Mycobacterium*, *Corynebacterium*, *Flavobacterium*, *Nitrosomonas*, and others [7].

The global problem of unsuitable drinking water can be specifically addressed through bioaugmentation, a type of bioremediation that involves adding non-native, non-pathogenic microbes to contaminated areas. The treatment of contaminated water sources using natural processes, including bioaugmentation and biofiltration, is an environmentally sustainable and economically sound practice not only in developing countries, where unsafe drinking water is linked to 80% of all diseases, but also in developed countries. There is a long history of using microbes to produce clean drinking water, dating back to the 19th century when beach and microbial filtration were used. Unfortunately, for some, the fear of microbes and their association with disease has led to less desirable methods, such as disinfection, which not only has long-term negative health effects, but is also virtually impossible to completely rid water of microbes. This leads to the development of microbes that are resistant to detergents and the possibility of more dangerous microbes entering the water system. On the other hand, another microbial community can be created through natural filtration through granular media, similar to sand, on which microorganisms grow. Microorganisms remove inorganic compounds such as ammonium and methane, as well as organic compounds [4].

Microorganisms have evolved to be able to use oil as an energy source, so they are extremely adept at breaking down petroleum substances. As a rule, different groups focus their activity on a specific petroleum compound, breaking it down into smaller, more easily digestible elements, such as carbon dioxide or water. Although this entire mechanism occurs gradually, it is a perfect 100% method of microbial remediation [1].

Cleaning using biological methods (bioremediation) usually takes place in multi-component and uneven conditions, for example, in soils where harmful substances are bound to soil particles, are in a dissolved state or in the form of gases. This biological method of remediation can be implemented in two main ways: at the site of contamination (in situ) or outside it (ex situ), depending on the specifics of the situation and the needs at hand. The first option includes methods such as microorganism-stimulated aeration (bioventilation), irrigation of the contaminated area (biospray) and the use of plants (phytoremediation), as well as the use of physical, chemical or thermal processes. This method eliminates the need to move polluting materials and reduces the negative impact on nature. It is considered a feasible and environmentally sound method for the selective removal of organic pollutants without harming flora and fauna, and is suitable for working with pollutants whose concentration is low but environmentally significant [6].

The effectiveness and speed of the microbial biodegradation process are influenced by factors such as the availability of nutrients, the level of hydration, the pH and the temperature regime in the soil mass. All soil microorganisms need moisture for their life and cell function. The presence of water regulates the process of water and dissolved nutrients entering and leaving microbial cells. However, excessive moisture, characteristic of waterlogged soil, is undesirable because it critically reduces the amount of oxygen available for aerobic respiration. The optimal moisture content in the soil for the destruction of petroleum hydrocarbons is considered to be

between 45% and 85% of its water-holding capacity (field moisture capacity), or approximately 12% to 30% by weight [5].

Bioremediation is a promising and effective approach to environmental remediation that promotes the regeneration of natural habitats without excessive human intervention. Using natural mechanisms, this method is one of the safest for the environment and most cost-effective options for combating pollution. In the future, bioremediation may become the leading methodology in combating environmental pollution. Scientists are actively engaged in the creation of microorganisms with a modified genome that would have an enhanced ability to destroy toxic compounds. At the same time, experiments are continuing on the integration of nanotechnological developments in tandem with biological purification techniques [7].

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FORMATION OF STUDENT AUTONOMY IN AI-ENHANCED LEARNING ENVIRONMENTS IN HIGHER EDUCATION

У роботі досліджено проблему формування автономії студентів у середовищі навчання, збагаченому технологіями штучного інтелекту, у закладах вищої освіти з акцентом на викладання англійської мови. Проаналізовано дидактичні можливості AI-інструментів щодо забезпечення індивідуалізації навчання, формування навичок самостійної навчальної діяльності та розвитку метакогнітивних стратегій. Розкрито трансформацію ролі викладача та зміну характеру навчальної взаємодії в умовах використання ШІ. Окреслено ризики, пов'язані з академічною недоброчесністю та надмірною залежністю від цифрових інструментів. Обґрунтовано, що ефективне формування автономії можливе за умови методично виваженого впровадження ШІ, спрямованого на розвиток критичного мислення та відповідального використання технологій.

Ключові слова: автономія студентів, штучний інтелект, викладання англійської мови, заклади вищої освіти, персоналізоване навчання, самостійна навчальна діяльність, цифрова педагогіка.

The paper examines the formation of student autonomy in the context of artificial intelligence-enhanced learning environments in higher education, with particular reference to