HSR (LONDON),
HOUGHTON STREET REVIEW JOURNAL
ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

DRINKING WATER SCARCITY AND THE ROLE OF BIOLOGICAL TREATMENT TECHNOLOGIES IN THE MODERN IT ECOSYSTEM

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Doi: https://doi.org/10.5281/zenodo.23538624

Abstract. This scientific article addresses the critical global issue of drinking water scarcity and analyzes the strategic importance of integrating advanced biological wastewater treatment technologies with modern Information Technology (IT). In the era of digital transformation and the Fourth Industrial Revolution (Industry 4.0), traditional environmental management practices are undergoing a profound evolution. The authors comprehensively explore the synergy between biological processes (such as activated sludge, biofilters, and anaerobic membrane bioreactors) and digital systems, including the Internet of Things (IoT), Artificial Intelligence (AI), Big Data, and Supervisory Control and Data Acquisition (SCADA) systems. Special attention is dedicated to the business administration perspective, illustrating how the fusion of IT and biotechnology optimizes operational expenditures, ensures environmental compliance, and aligns with ESG (Environmental, Social, and Governance) principles. The paper delivers an extensive theoretical and practical framework supported by digital monitoring architectures and financial rationales.

Keywords: water scarcity, biological treatment, information technology, Internet of Things, Artificial Intelligence, Business Administration, ESG, automation, environmental management, bioreactors.

1. INTRODUCTION AND BACKGROUND

In the 21st century, the scarcity of clean drinking water has emerged as one of the most pressing macroeconomic and ecological challenges confronting humanity. According to the United Nations, billions of people worldwide suffer from severe water stress aggravated by climate change, exponential population growth, rapid urbanization, and intensive industrial pollution. Fresh water is no longer viewed as an inexhaustible natural asset; rather, it has transformed into a critical strategic resource that dictates regional survival and shapes the stability of global markets.

For business administration and corporate governance, this crisis translates directly into severe operational, legal, and reputational risks. Corporations face increasingly strict environmental regulations, escalating water tariffs, and punitive fines for discharging inadequately treated effluents. Under these conditions, legacy mechanical and chemical purification methods exhibit severe financial and environmental deficiencies: they are highly energy-intensive, depend on the continuous consumption of costly chemical reagents, and frequently result in secondary ecosystem contamination.

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Biological treatment technologies, leveraging the natural metabolic processes of specialized microorganisms (bacteria and protozoa), present a superior and sustainable alternative. However, managing living biological entities effectively within large-scale industrial and municipal treatment plants requires high-precision regulation. Consequently, information technology serves as the decisive catalyst, binding environmental engineering and corporate efficiency into a highly structured, manageable system.

2. BIOLOGICAL WATER TREATMENT TECHNOLOGIES AND MECHANISMS

The core of biological wastewater treatment lies in the biochemical degradation of organic and select inorganic pollutants by microbial communities. The primary configurations of these systems include:

• Aerobic Systems (Activated Sludge, Biofilters, Aeration Tanks): Microorganisms utilize dissolved oxygen to oxidize organic impurities, converting them into carbon dioxide, water, and new cellular biomass. This method is exceptionally efficient at removing nitrogen, phosphorus, and carbonaceous fractions.

• Anaerobic Systems (Anaerobic Digesters): These biochemical processes operate entirely in the absence of free oxygen. Anaerobic bacteria break down complex organic compounds while synthesizing biogas (methane and carbon dioxide). This byproduct can be captured and utilized to generate thermal or electrical energy, serving as a critical asset for minimizing a corporation's carbon footprint.

• Membrane Bioreactors (MBR): An advanced technological architecture that integrates biological degradation via activated sludge with high-efficiency physical separation of purified water and biomass using ultrafiltration membranes. MBR installations guarantee elite effluent quality, empowering enterprises to pioneer circular water-reuse loops within production facilities.

3. INTEGRATION OF INFORMATION TECHNOLOGY IN THE ENVIRONMENTAL SECTOR

The bridge linking microbiology and operations management consists of an advanced IT stack that enables real-time data acquisition, high-fidelity analysis, and autonomous decision-making.

3.1. Internet of Things (IoT) and Sensor Networks

Microorganisms in bioreactors are intensely sensitive to ambient environmental fluctuations. Drop-offs in dissolved oxygen, sudden temperature spikes, or volatile pH shifts can trigger massive bacterial mortality events (such as sludge bulking), halting the purification pipeline for weeks. Industrial IoT sensor arrays continuously track key metrics of wastewater at the inflow, within the reactor core, and at the final discharge point. This telemetry is transmitted via wireless protocols (LoRaWAN, Wi-Fi, 5G) directly to cloud analytics architectures, successfully eliminating human error from environmental containment tracking.

3.2. Artificial Intelligence and Predictive Analytics

Neural networks trained on extensive historical datasets (Big Data) are capable of forecasting the dynamics of complex biological systems. For example, machine learning algorithms can predict peak volumetric or organic loading shocks (such as sudden industrial dumpings or storm-water surges) hours before they physically strike the facilities. Capitalizing on these predictions, the AI autonomously modulates aeration intensities, cutting up to 30-40% of the electrical energy consumed by industrial compressor machinery.

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4. IT PLATFORM ARCHITECTURE FOR BIOREACTOR MANAGEMENT

A state-of-the-art digital infrastructure for bioreactor monitoring comprises a well-defined three-tier architecture:

1. Physical Layer (Bottom): Industrial sensors (pH, ORP, dissolved oxygen, turbidity, COD, BOD) and mechanical actuators (pumps, valves, variable frequency drives on compressors).
2. Control and Communication Layer (Middle): Programmable Logic Controllers (PLCs) that harvest signals from the physical instrumentation and relay them through digital gateways to the primary network.
3. Information and Analytics Layer (Top): Enterprise SCADA systems and executive ERP/BI dashboards. At this tier, corporate leaders do not merely track technical variables; they monitor macroeconomic parameters, including the specific cost to treat a cubic meter of water, energy consumption curves, regulatory environmental compliance indexes, and multi-variable operational risk metrics.

5. ECONOMIC IMPACT AND BUSINESS ADMINISTRATION (ESG)

The deployment of combined IT and biotechnology frameworks yields tangible competitive advantages for modern enterprises. First, advanced automation defuses operational hazards and drastically reduces the overhead associated with manual laboratory testing. Second, precise forecasting and algorithmic process optimization drop operational expenditures (OPEX) by streamlining energy use and minimizing excess secondary sludge mass volumes.

From a strategic management perspective, digital environmental stewardship is paramount for maintaining compliance with rigorous ESG criteria. Companies that showcase transparent, data-driven water conservation strategies and automated zero-pollution workflows secure higher corporate credit scores, unlock access to 'green' capital markets, and capture the loyalty of modern eco-conscious demographics.

Conclusion. The escalating global deficit of drinking water demands a fundamental restructuring of corporate and civil water resource frameworks. Biological purification practices represent the eco-friendliest and most viable option for reviving aquatic ecosystems. Nevertheless, their scaling and operational durability remain strictly contingent upon the depth of their integration with information technology. The 'Smart Water Treatment' paradigm, situated at the nexus of microbiology, mechanical engineering, and IT, unveils breakthrough horizons for modern business administration, transforming corporate ecological obligations from an expenditure liability into a core source of long-term commercial sustainability and technical innovation.

REFERENCES

1. Atahanov, S., & Rasulova, F. (2025). NEVROLOGIK VA RUHIY KASALLIKLARNI DAVOLASHDA ZAMONAVIY KOMPYUTER TEXNOLOGIYALARNING O'RNI VA ISTIQBOLLI USULLARI. Наука и технология в современном мире, 4(7), 87-91.
2. Atakhanov, S., Khasanov, I., & Ergashboev, O. (2025). THE ROLE OF MODERN COMPUTERS İN THE DİAGNOSİS AND TREATMENT OF HYPOTHYROİDİSM. Инновационные исследования в современном мире: теория и практика, 4(10), 154-156.
3. Атаханов, С., & Эргашев, Ф. (2025). РОЛЬ ИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ В ДИАГНОСТИКЕ И ЛЕЧЕНИИ СЕРДЕЧНЫХ ЗАБОЛЕВАНИЙ. Modern Science and Research, 4(4), 642-651.

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ISSN: 2058-5519|Impact factor-15.9
http://houghtonstreetreview.com/index.php/hsr

4. Atakhanov, S. A., & qizi Yoqubjonova, U. N. (2025). THE ROLE AND SIGNIFICANCE OF MODERN COMPUTER TECHNOLOGIES IN THE DIAGNOSIS AND TREATMENT OF HEART DISEASES IN ADOLESCENTS AND YOUNG CHILDREN. EduVision: Journal of Innovations in Pedagogy and Educational Advancements, 1(4), 483-488.
5. Атаханов, С., & Касымова, М. (2025). ДИАГНОСТИКА, ПРОГНОЗИРОВАНИЕ И ЛЕЧЕНИЕ АНЕМИИ С ИСПОЛЬЗОВАНИЕМ НОВЕЙШИХ КОМПЮТЕРНЫХ ТЕХНОЛОГИЙ. Педагогика и психология в современном мире: теоретические и практические исследования, 4(8), 18-22.