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Применение технологии озонирования в гидропонных системах для улучшения качества воды и стимулирования роста растений

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Аннотация. Технологии гидропонного выращивания приобретают всё большее значение в современном сельском хозяйстве благодаря эффективному использованию воды и питательных веществ. Однако поддержание качества питательного раствора и предотвращение микробного загрязнения остаются важными задачами в гидропонных системах NFT (техника питательной плёнки). В данном исследовании рассматривается применение технологии озонирования для улучшения качества воды и стимулирования роста растений в NFT-гидропонных установках. Обработка озоном способствует обеззараживанию питательного раствора, снижению количества вредных микроорганизмов и повышению концентрации растворённого кислорода. Для оценки процессов переноса кислорода и распределения питательных веществ в условиях озонирования были выполнены математическое моделирование и компьютерное имитационное исследование. Полученные результаты подтверждают высокий потенциал технологии озонирования для улучшения качества воды и повышения эксплуатационной устойчивости NFT-гидропонных систем.

Ключевые слова: гидропоника, NFT-система, озонирование, водоподготовка, растворённый кислород, перенос кислорода, питательный раствор, рост растений, математическое моделирование.

Application of ozonation technology in hydroponic systems for improving water quality and plant growth

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Abstract. Hydroponic cultivation technologies are becoming increasingly important in modern agriculture due to their efficient utilization of water and nutrients. However, maintaining nutrient solution quality and preventing microbial contamination remain significant challenges in NFT (Nutrient Film Technique) hydroponic systems. This study investigates the application of ozonation technology for improving water quality and enhancing plant growth in NFT hydroponic installations. Ozone treatment contributes to nutrient solution disinfection, reduction of harmful microorganisms, and enhancement of dissolved oxygen concentration. Mathematical modeling and computer simulations were performed to evaluate oxygen transport and nutrient distribution processes under ozonation conditions. The obtained results confirm the potential of ozonation technology for improving water quality and operational stability in NFT hydroponic systems.

Keywords: hydroponics, NFT system, ozonation, water treatment, dissolved oxygen, oxygen transport, nutrient solution, plant growth, mathematical modeling.

1. Introduction

Hydroponic systems are widely applied in modern agriculture because they enable efficient plant cultivation without soil while minimizing water consumption and nutrient losses. Among various hydroponic methods, the NFT (Nutrient Film Technique) system is considered one of the most efficient technologies due to the continuous circulation of nutrient solution around plant roots [1-2].

Despite these advantages, NFT systems are highly sensitive to microbial contamination, oxygen deficiency, and instability of nutrient composition. The accumulation of bacteria, fungi, and organic residues in the circulating nutrient solution may negatively affect plant growth and reduce crop productivity.

In recent years, ozonation has been increasingly applied for water treatment in agricultural and hydroponic systems. Ozone possesses strong oxidizing and disinfecting properties capable of eliminating harmful microorganisms while simultaneously increasing dissolved oxygen concentration in water [3-5].

Therefore, the application of ozonation technology in NFT hydroponic systems represents a promising approach for improving water quality, enhancing oxygen transport processes, and creating optimal conditions for plant development.

2. Aim of the research

The aim of this research is to investigate and mathematically model the influence of ozonation technology on dissolved oxygen transport, nutrient stability, and plant growth in NFT hydroponic systems.

3. Methodology

In this research, mathematical modeling was used to analyze oxygen diffusion and mass transfer processes in an NFT hydroponic system with ozone treatment. The movement of the nutrient solution is described by the flow rate equation:

$$Q = vA,$$

where:

- Q – flow rate;
- v – flow velocity;
- A – channel cross-sectional area.

The oxygen transport process in the nutrient solution is described using the diffusion equation:

$$\frac{\partial O}{\partial t} = D_o \nabla^2 O - k_o O + S_{oz}$$

where:

- O – dissolved oxygen concentration;
- D_o– oxygen diffusion coefficient;
- k_o– oxygen consumption coefficient by plant roots;
- S_{oz} – ozone-induced oxygen source term.

Computer simulations were performed in MATLAB to analyze oxygen distribution and nutrient solution stability under different ozonation conditions.

5. Results

The simulation results demonstrated that ozonation increases dissolved oxygen concentration in the nutrient solution. Improved oxygen availability positively affects root respiration and supports stable plant growth.

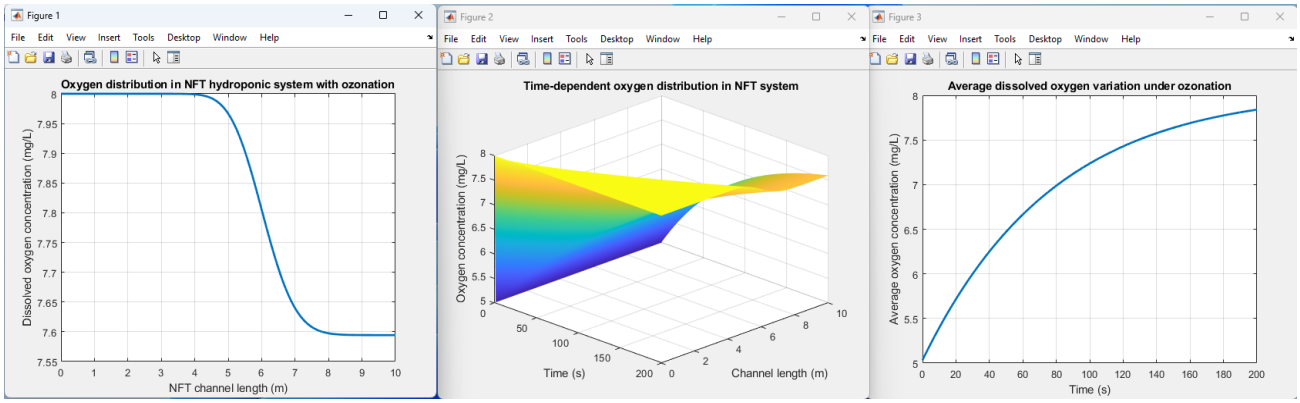

Figure 1. Simulation results of dissolved oxygen distribution and transport processes in an NFT hydroponic system under ozonation conditions.

Simulation data show that dissolved oxygen concentration changes along the hydroponic channel and over time due to nutrient circulation and root oxygen consumption. The gradual stabilization of oxygen concentration confirms the positive influence of ozonation on nutrient solution aeration. The developed model also showed that ozone treatment contributes to reducing microbial contamination and improving nutrient solution stability during circulation. Enhanced oxygen transport characteristics were observed under moderate ozonation intensity. Overall, the simulation results suggest that ozonation technology may improve operational stability and resource efficiency in NFT hydroponic systems.

6. Conclusion

This study demonstrates that ozonation technology can be effectively applied for improving water quality and oxygen transport processes in NFT hydroponic systems. Ozone treatment increases dissolved oxygen concentration and supports nutrient solution stability. The developed mathematical model may be used for optimization and automated control of hydroponic installations. The proposed model may be useful for improving the efficiency and stability of modern hydroponic cultivation systems.

7. Scientific novelty

The scientific novelty of this research lies in the development of a mathematical model of an NFT hydroponic system that simultaneously considers ozone-assisted oxygenation and oxygen diffusion processes in the nutrient solution.

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