Advanced Nanobubble Technology: A Sustainable Solution for Modern Farming Challenges

Mohammad Abdul Waseem
Postdoctoral Researcher, Institute of Agri-Food, Animal and Environmental Sciences (ICA3), Universidad de O'Higgins, Chile.
Corresponding Author: mohammad.abdul@servicios.uoh.cl

What is nanobubble technology

Agriculture faces mounting challenges due to climate change, soil degradation, and water scarcity. To address these issues, innovative technologies such as nanobubbles are revolutionizing irrigation and for plant health management. Nanobubbles—tiny gas bubbles measuring between 70 and 120 nanometers—offer a highly efficient method for enhancing dissolved oxygen (DO) levels, improving soil structure, and promoting beneficial microbial activity.

Unlike conventional aeration methods, nanobubbles remain suspended in water due to their neutral buoyancy and unique brownian motion, ensuring even distribution of oxygen throughout the soil profile. As they collapse, nanobubbles release hydroxyl radicals, which help in pathogen control, biofilm reduction, and improved nutrient absorption. These properties make nanobubble technology an effective and sustainable solution for modern agriculture, allowing farmers to reduce chemical inputs, optimize water usage, and increase crop yield.

Key Mechanisms of Nanobubble Technology

Increased Dissolved Oxygen: Nanobubbles introduce high levels of dissolved oxygen into the water. This oxygen boosts the aerobic microbial activity in the soil, promotes better nutrient uptake by plants, and enhances root health and size. Oxygenation of water has long been established as beneficial for plant growth and health,

Physical Properties of Nanobubbles

Additional plant growth and health benefits are also delivered as a result of the unique physical attributes of nanobubbles themselves. Due to their extremely small size, nanobubbles reduce the surface tension of water, leading to improved soil penetration and more efficient water distribution. Additionally, when nanobubbles collapse, they release hydroxyl radicals that create a mild oxidative effect, which directly impacts certain algal, fungal, and bacterial communities. This further supports plant health by improving irrigation water quality, reducing algae formation, and suppressing a portion of the microbial population that includes several problematic soil-borne pathogens such as *Pythium*, *Phytophthora*, and *Fusarium*. At the same time, nanobubbles encourage the proliferation of beneficial microorganisms like *mycorrhizae*, *Bacillus*, *Trichoderma*, and *Streptomyces*, contributing to a more balanced and resilient soil microbiome. Furthermore, the technology helps reduce biofilm formation in irrigation lines and emitters, enhancing system efficiency and reducing maintenance requirements.

Mechanisms of Nanobubble Technology

Physical and Chemical Properties

- Nanobubbles measure between 70 and 120 nanometers, about 2500 times smaller than a grain of salt.
- Their neutral buoyancy allows them to move randomly through the water via Brownian motion.
- The negative charge and hard surface of nanobubbles help remove biofilm from irrigation lines.
- Nanobubbles reduce surface tension, improving soil infiltration and capillary action of nutrients.

Oxygenation and Microbial Enhancement

- Nanobubble technology achieves over 85% oxygen transfer efficiency, significantly enhancing dissolved oxygen (DO) levels
- Higher DO levels promote beneficial aerobic microbial activity in the soil, enhancing nutrient uptake and root health.
- High concentrations of nanobubbles can hold up to four times the conventional dissolved oxygen limit, replacing traditional aeration methods.

Benefits of Nanobubble Technology in Agriculture

1. Improved Soil and Plant Health

- Enhances soil flocculation, reducing soil compaction and improving water infiltration.

- Supports a healthier root system by delivering more oxygen to the root zone.
- Facilitates efficient water and nutrient absorption, leading to better plant growth.

2. Disease Prevention and Microbial Control

- Releases hydroxyl radicals upon collapse, which help control harmful soil-borne pathogens such as *Pythium, Phytophthora,* and *Fusarium*.
- Promotes beneficial microbes like *mycorrhizae, Bacillus, Trichoderma,* and *Streptomyces*, leading to a more balanced soil microbiome.
- Reduces algae formation in irrigation water, improving water quality.

3. Increased Crop Yield and Quality

- Consistently increases crop yields across various farming systems.
- Enhances fruit quality traits such as higher Brix levels and firmness, leading to better market value.
- Improves resilience to environmental stresses like drought and heat.

4. Water and Cost Efficiency

- Reduces water usage by up to 25% while maintaining or improving crop production.
- Minimizes the need for chemical inputs by reducing disease pressure and enhancing soil health.
- Prevents biofilm and deposits in irrigation lines, reducing maintenance and labour costs.

Integration into Existing Irrigation Systems.

- Farmers can adopt nanobubble technology with minimal modifications to their current irrigation setup.
- The technology ensures uniform distribution of oxygen-rich water, optimizing plant health and productivity.

Applications of Nano Bubble (NB) Technology in other fields

Nano Bubble technology is being actively researched and implemented in multiple fields due to its unique chemical and physical properties. Beyond irrigation, its applications include:

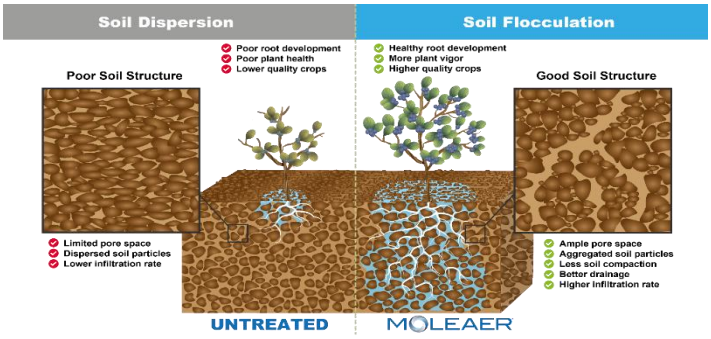
Pesticide Removal and Food Safety: NB-enhanced ozonation technology has been identified as a promising approach for pesticide degradation. This technique is effective in breaking down residual pesticides on fruits, vegetables, and food grains. Studies show that the integration of NB technology with ozone gas improves dissolution efficiency and enhances pesticide removal. It reduces the health risks associated with pesticide residues, contributing to safer food production.

Wastewater Treatment: NB technology is an effective solution for wastewater treatment by improving aeration, flotation, and disinfection processes. The high stability of nanobubbles allows for prolonged oxygenation, reducing the energy demand compared to traditional aeration systems. Nanobubbles facilitate the breakdown of pollutants and contaminants, contributing to a more sustainable water treatment approach.

Aquaculture: Provides high levels of dissolved oxygen, supporting healthier fish populations and reducing mortality rates. Prevents excessive algae growth and improves water clarity by controlling microbial activity in aquatic environments. Reduces reliance on chemicals and enhances sustainable fish farming practices.

Hydroponics and Controlled Environment

Agriculture Improves nutrient absorption efficiency, ensuring optimal plant growth in soilless cultivation systems. Helps maintain stable water quality, reducing the risk of pathogen growth in hydroponic setups. Enhances crop resilience under controlled growing conditions.

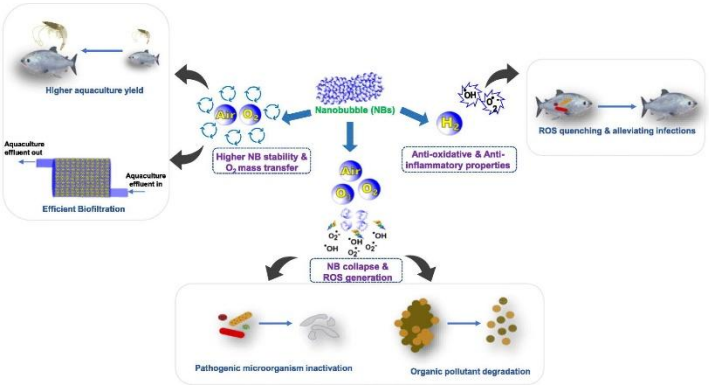


Source: Molecular advance nanobubble technology

Conclusion

Nanobubble technology presents a revolutionary advancement in agricultural irrigation, offering a sustainable solution to enhance crop yields, reduce water consumption, and improve plant health. By increasing dissolved oxygen levels, reducing

biofilm formation, and promoting beneficial microbial activity, nanobubbles provide a cost-effective and environmentally friendly approach to modern farming. As the agricultural sector faces challenges such as climate change and water scarcity, nanobubble technology emerges as a critical tool for ensuring efficient resource utilization and long-term productivity.



Source: (Yaparatne et al., 2024)

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