Food Processing & Food Safety

Maximizing cleaning efficiency & reducing food safety risks with Nanobubbles

MOLEAER®

Our Mission

We unlock the power of **nanobubble technology** to increase

Efficiency

Productivity

Sustainability

MOLEAER

Less Water, Less Energy, Less Chemicals

About Moleaer

- Moleaer is a platform technology company, offering a new class of science to improve a wide range of processes.
- Moleaer delivers value **where >90% of water is used.**
- Nanobubbles drive sustainability: enabling industries to produce more while using significantly **less water, energy, and chemicals.**

Founded: 2016, Los Angeles

1M Gallons Treated Per Minute

3,500+ Global Installations

Deployed in 55+ Countries

16 Unique Patent Families

Over 1,000 Customers

~100 Employees

4 Global Assembly Facilities and Warehouses

Scaling by partnering with industry leaders, including:

Jacuzzi
EVONIK Leading Beyond Chemistry
royal brinkman global specialist in horticulture
Husqvarna
TESS TEKNISK FAGHANDEL
xylem
ABInBev

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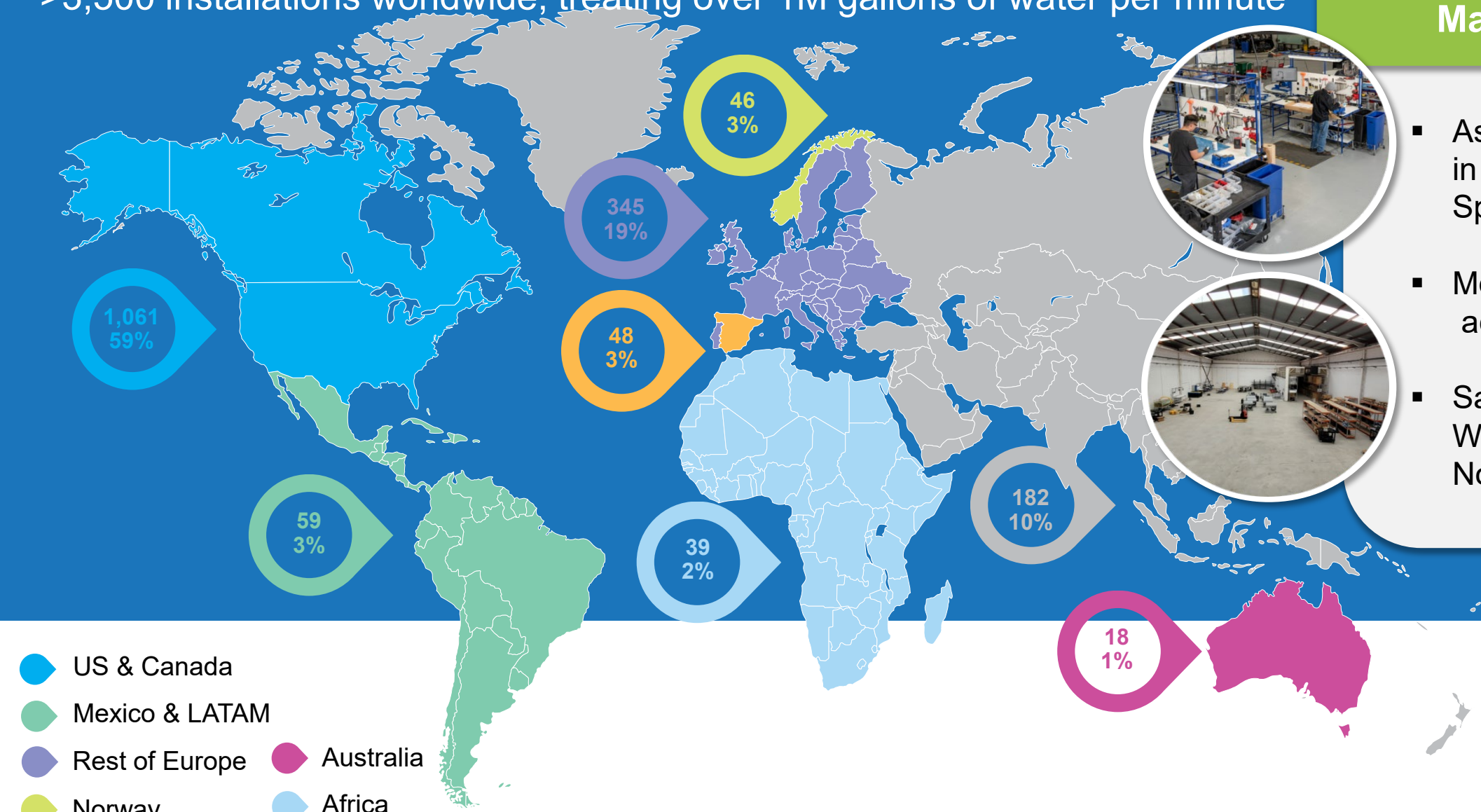
Global Leader in Nanobubble Technology

>3,500 installations worldwide, treating over 1M gallons of water per minute



High Production Manufacturing

- Assembly Facilities in Los Angeles and Spain
- Mobile Assets across the U.S.
- Sales Offices & Warehouses in Norway & Chile

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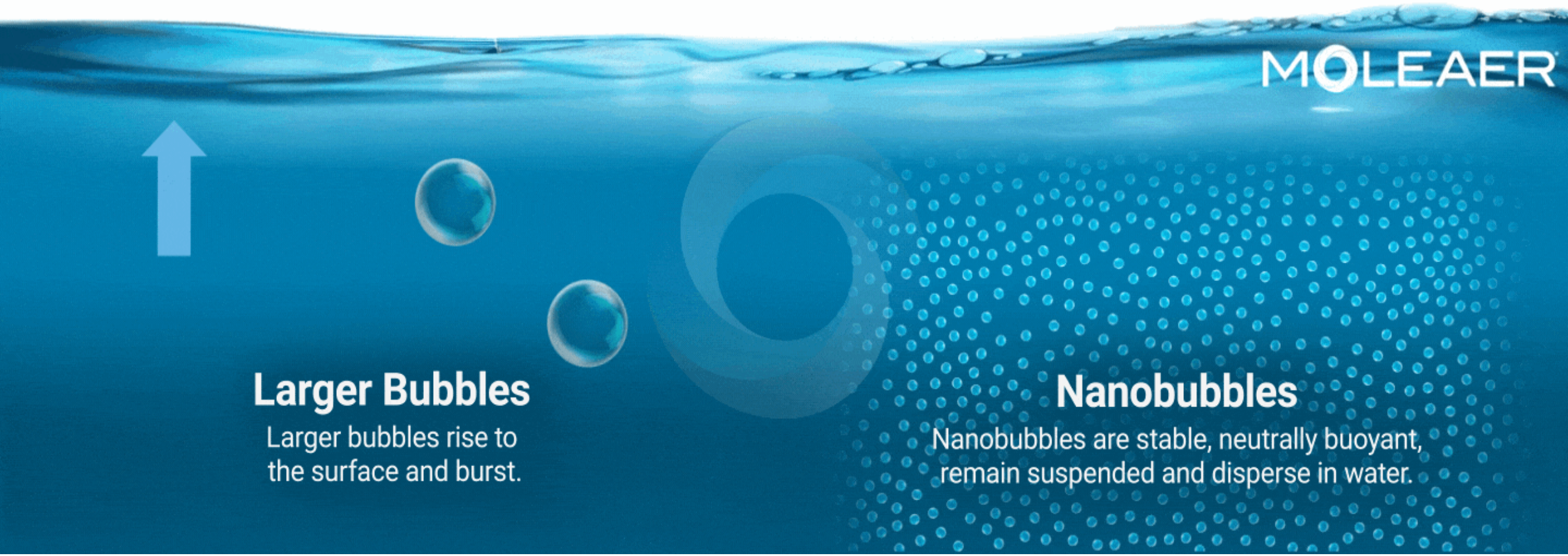
What Are Nanobubbles?

Moleaer is the pioneer and global leader in nanobubble technology



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The Science Behind Nanobubbles: Unique Properties & Behaviors

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Nanobubbles in Action: Surface Charge & Scouring

Anti-Biofouling and Bacteria Control

Nanobubbles have a strong negative surface charge and are attracted to hydrophobic surfaces.

Anti-Biofouling & Scale Inhibitor

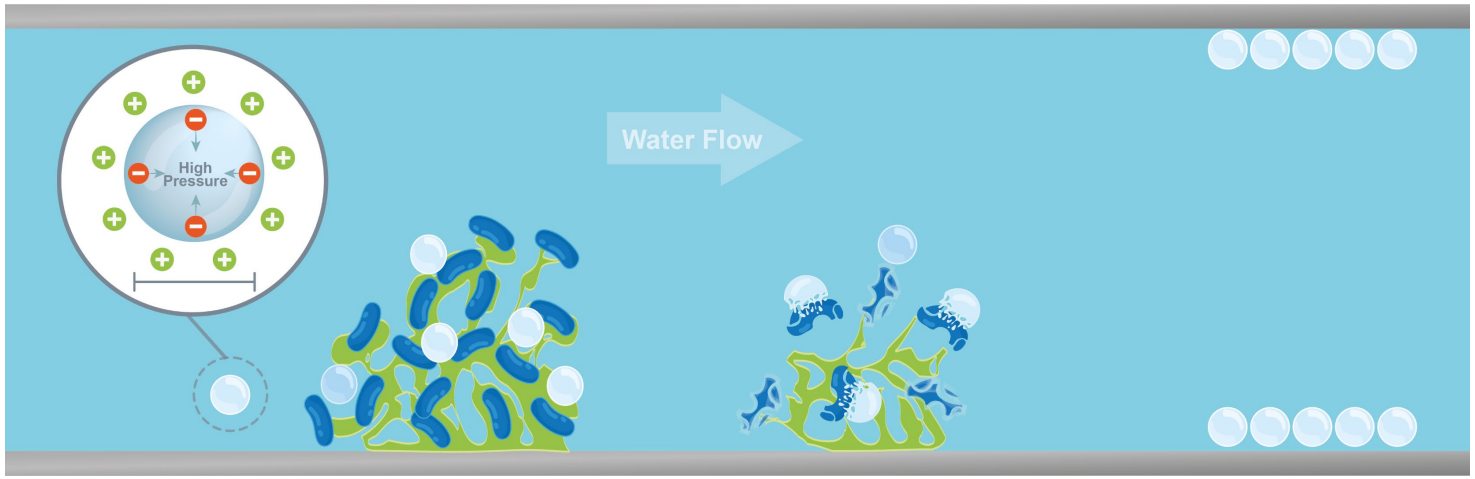
- Bubble surface charge attracts and binds contaminants
- Biofilm is scoured from surfaces

Food Safety

- Prohibits bacteria from forming on surfaces
- Promotes aerobic/beneficial microbial activity

Nanobubbles Modes of Action

- Reduce water surface tension
- Physically scour biofilm from surfaces
- Increase ORP (Oxidation-Reduction Potential)
- Nanobubbles promote oxidizers efficacy in microbial control
- Coat surfaces with nanobubbles to help prevent new biofilm formation



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Food Safety Benefits of Nanobubble Technology

- Chemical-free microbial reduction on food surfaces
- Reduction in water and chemical usage
- Reduce fungal and bacterial load on product surface and in process water
- Remove biofilm buildup & reduce clogging risks
- Remove organic matter debris
- Reduce fungicide load in discharge to public waterways through fungicide oxidation

A Solution for Consistently Safer, Cleaner Produce

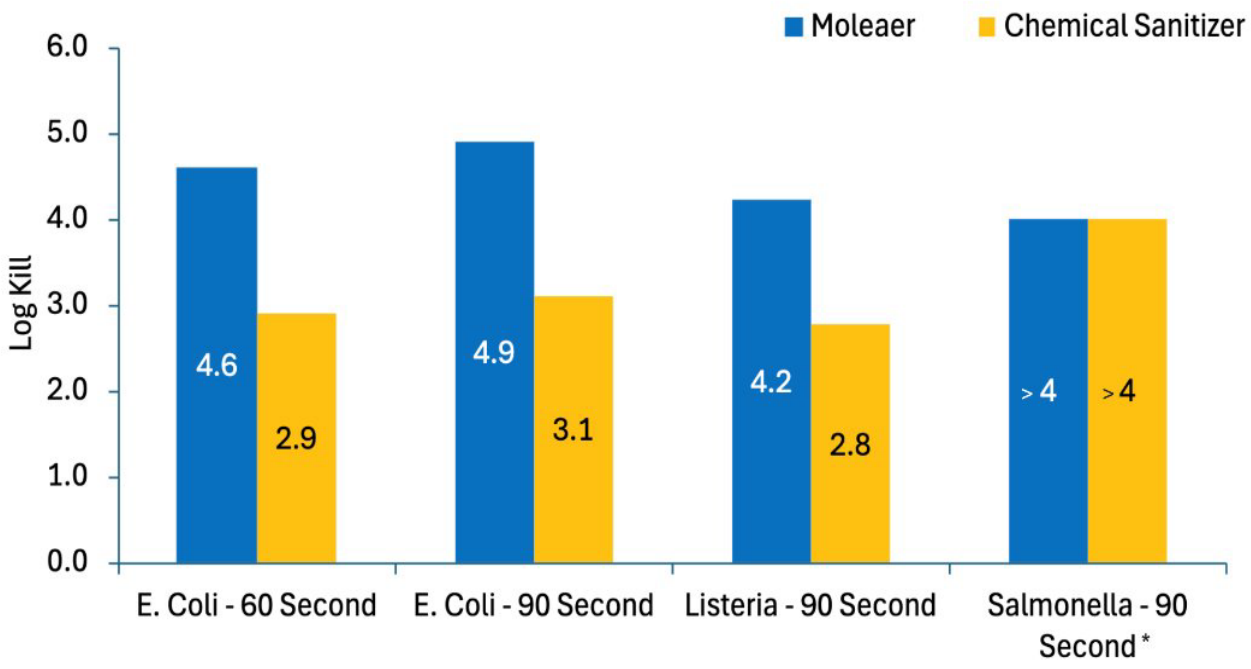
$NOVO_3^{TM}$ provides superior pathogen reduction while keeping food free from chemical residues.

- Consistently achieve 4-5 log kill for the most common bacteria causing foodborne disease in humans.
- Outperforms traditional solutions, including chemicals, which typically achieve a 3-log kill.

Certifications & Standards

CETEC Laboratory · CDC's ELITE Program · GRAS Approved Ingredients · ISO 17025 · FDA · USDA

Disinfectant Efficacy



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The Scientific Breakthrough: Nanobubbles Plus Ozone for Pathogen-Free Surfaces

Why Ozone?

Highly Reactive & Powerful: ozone is a strong oxidant with excellent disinfection properties.

Fast-Acting Disinfectant: quickly neutralizes bacteria, disinfects water and kills harmful bacteria.

Residue-free: leaves no harmful byproducts or chemical residues.

The Historical Ozone Challenge
Traditionally, it has been difficult to get ozone into water safely and effectively without off-gassing.

Moleaer's Breakthrough Technology

- **NOVO3 technology** safely and efficiently dissolves ozone in water.
- **Enhanced Disinfection:** Nanobubbles extend ozone contact time, improving its oxidative power.
- **Scrubbing Action:** Nanobubbles help remove dirt and contaminants from surfaces.
- **The Result is Dual-Action Cleaning:** Oxidative strength combined with nanobubble scrubbing power.

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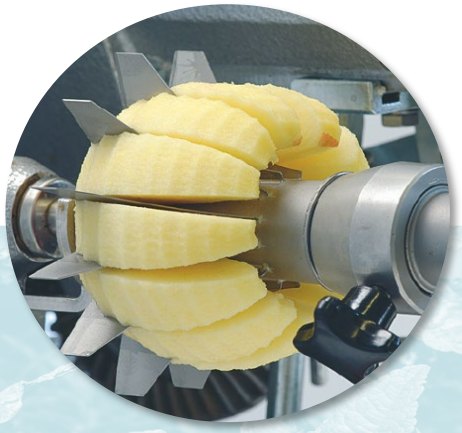
Benefits: Elevating Food Processing & Washing Safety Post-Harvest



Unique Benefits of Nanobubbles

Enhance the removal of bacteria from food handling surfaces, ensuring a safer environment for processing

Reduce the risk of cross-contamination

Promote surface hygiene and operational efficiency

Improve sustainable practices by reducing water & chemical consumption

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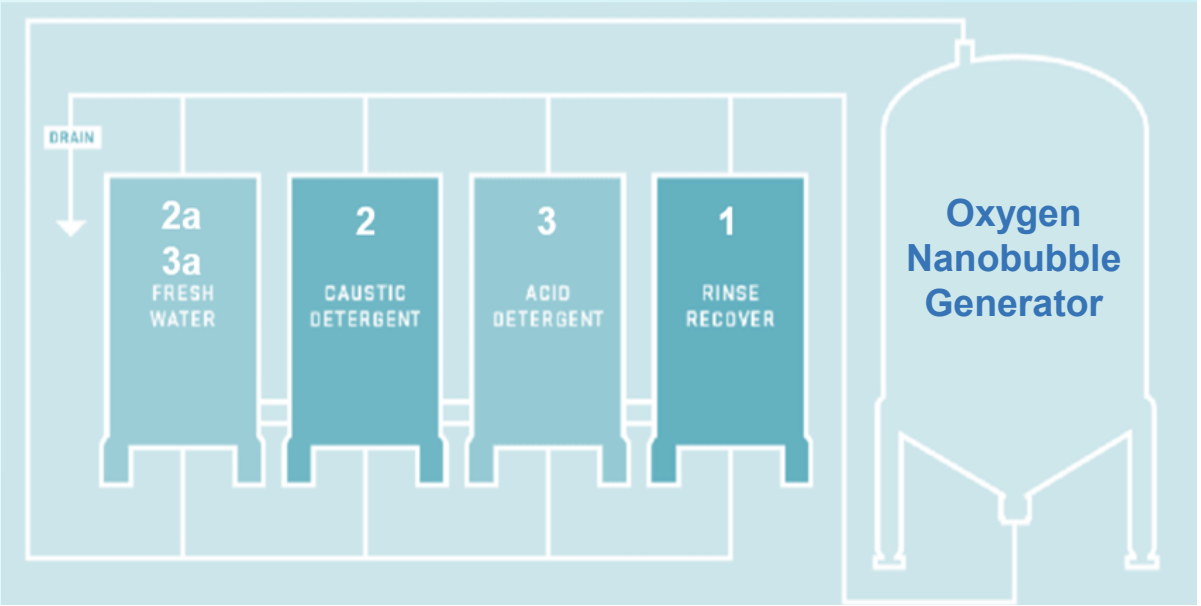
Benefits: Improve Clean-in-Place (CIP) Efficiency & Biofilm Removal

- **Enhanced Biofilm Removal:** Nanobubbles disrupt and prevent biofilm reattachment on stainless steel and plastic surfaces
- **Sustainable Solution:** Reduces water and chemical usage
- **Improved Cleaning Efficiency:** Ensures coverage of hard-to-reach surfaces within CIP systems



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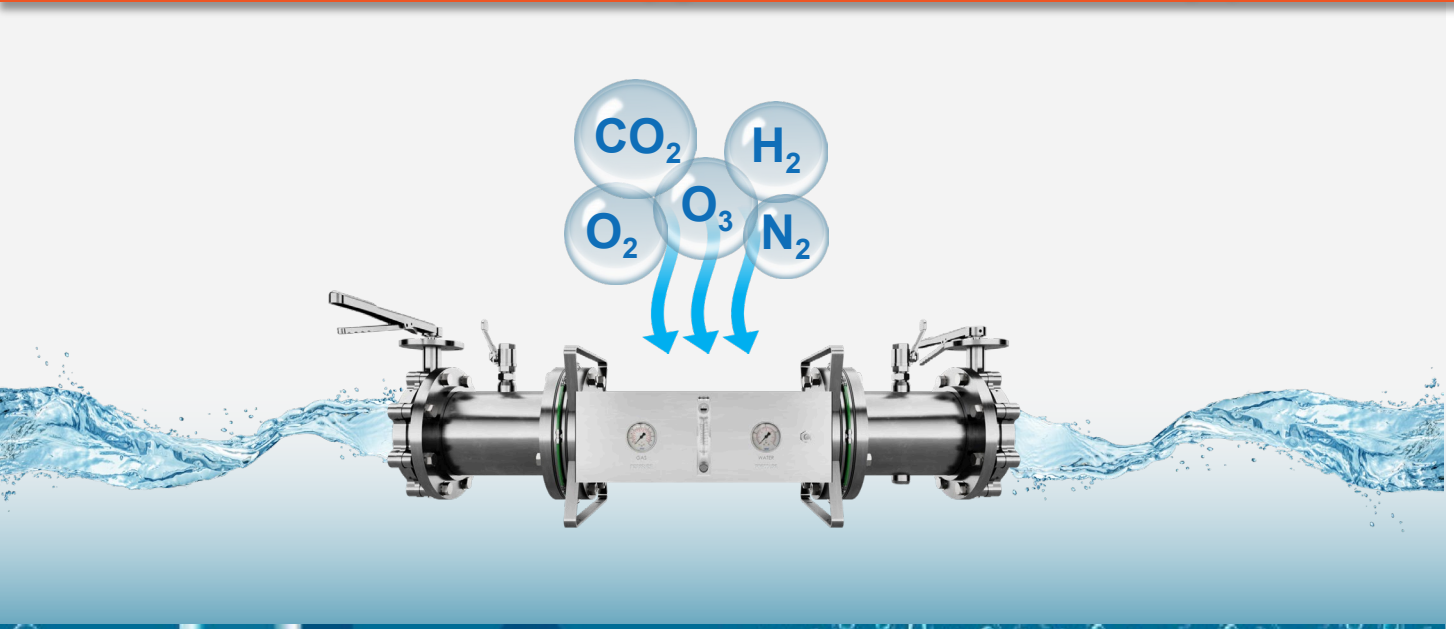
Moleaer Nanobubble Generators: Patented Technology for Superior Efficiency

Best-in-class Oxygen Transfer Efficiency | Robust, Scalable, Easy-to-Install Technology



LARGER BUBBLES
Rise to Surface & Burst

NANOBUBBLES
Producing trillions of 100nm sized bubbles, Stable, Neutrally Buoyant Invisible to the Naked Eye

Moleaer's patented technology introduces two forms of gas into water: **Dissolved and Nanobubbles**

Dissolved Oxygen

Dissolved Oxygen = amount of oxygen in water.

Moleaer's technology **dissolves oxygen** with best-in-class efficiency in any depth.

Nanobubbles

Charged gas particles, 1/1000th thickness of hair.

They do not rise, **do not easily dissolve**, catalyzing physical, biological, and chemical reactions.

NEO N by Moleaer: Nanobubble Production at Scale

NEO N Features

- Available from 50 to 250 gpm
- 90% Oxygen transfer efficiency
- ~1 billion nanobubbles per ml
- Onboard PSA Oxygen Generation at 92%
- Plug and play installation
- Quiet operation
- Optional Ozone

NEO N Applications

Food Safety & Sanitation

- Produce and Seafood Washing
- Food Handling Surfaces Sanitation
- CIP Systems
- Pipeline Cleaning
- Cool & Heating Systems
- Ice Making Machinery

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$NOVO_3$ by Moleaer: High-Efficiency Produce Cleaning, Without Harsh Chemicals

- $NOVO_3$ is a **commercial-grade solution** delivering effective sanitation without harsh chemicals.
- Designed to **reduce health risks** and prevent cross-contamination in the kitchen.
- Seamlessly integrates into existing prep sink systems and **activates automatically** with water flow.
- Provides superior pathogen reduction and **outperforms traditional solutions**.

Nanobubbles + Food Safety Research Validation

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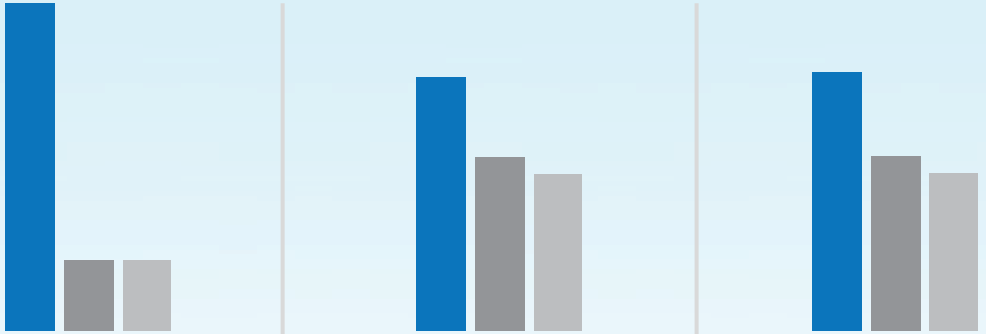
Efficacy of Nanobubble Technology: DO & Nanobubbles

MOLEAER versus Competitor 1 / Competitor 2 Performance



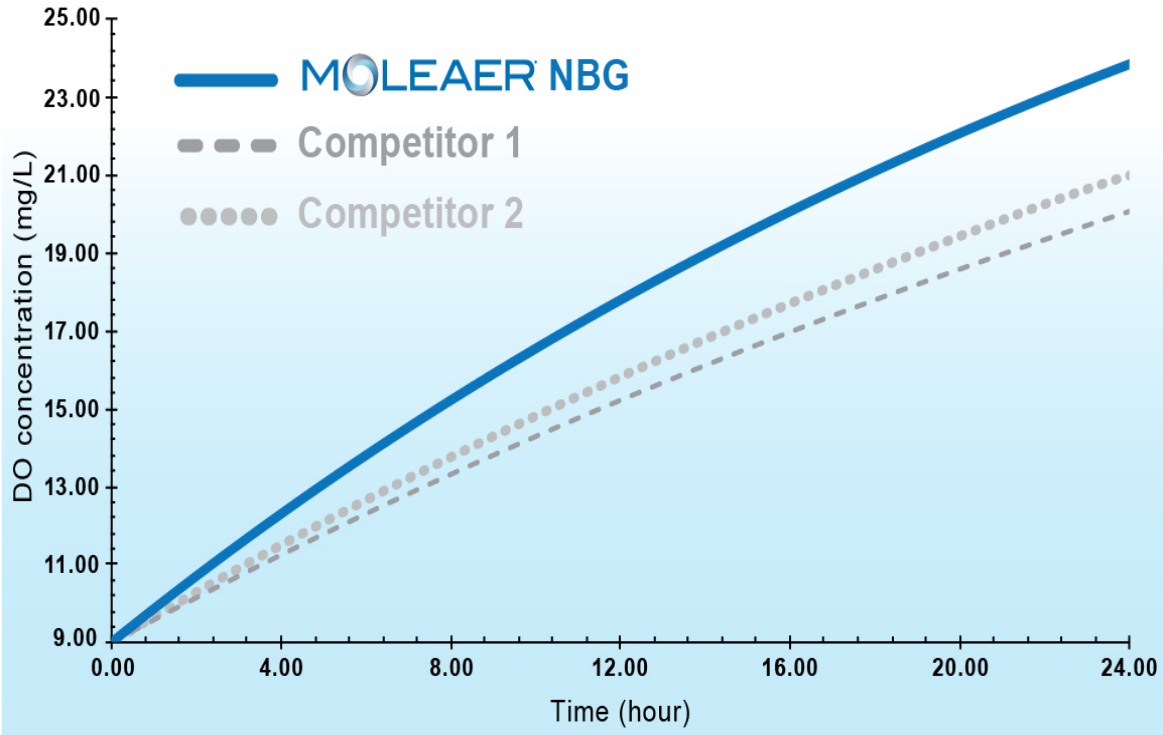
Nanobubble Production in One Water Cycle	Standard Oxygen Transfer Efficiency	Dissolved Oxygen Uptake
Competitor 1: **Moleaer 5X+ Higher**	Competitor 1: **Moleaer 1.5X+ Higher**	Competitor 1: **Moleaer 1.5X+ Higher**
Competitor 2: **Moleaer 5X+ Higher**	Competitor 2: **Moleaer 1.4X+ Higher**	Competitor 2: **Moleaer 1.4X+ Higher**

Moleaer Competitor 1 Competitor 2

Moleaer's Technology:

- Produces 5x more nanobubbles
- 1.5x higher transfer efficiency
- 1.5x higher dissolved oxygen uptake

DO uptake at gas = 8 lpm, 2 bars, 20C, tank volume 250 m3



Moleaer's Technology:

- Reaches elevated DO concentrations quicker
- Achieves higher DO concentrations

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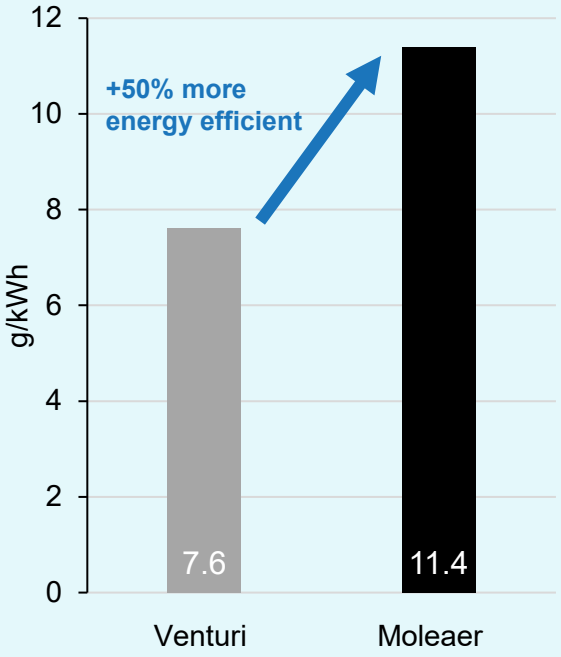
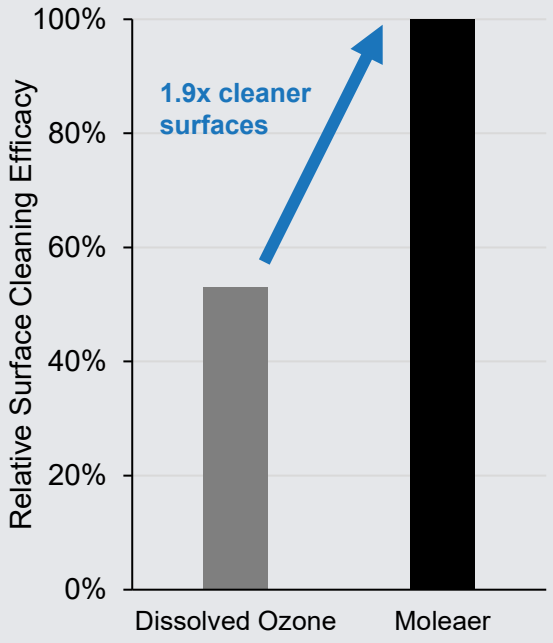
Ozone Nanobubbles Enable Numerous Benefits

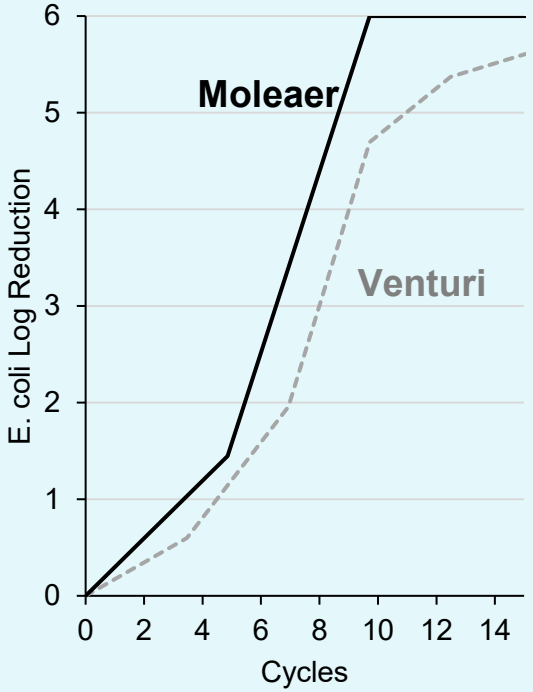
Higher Ozonation Efficiency



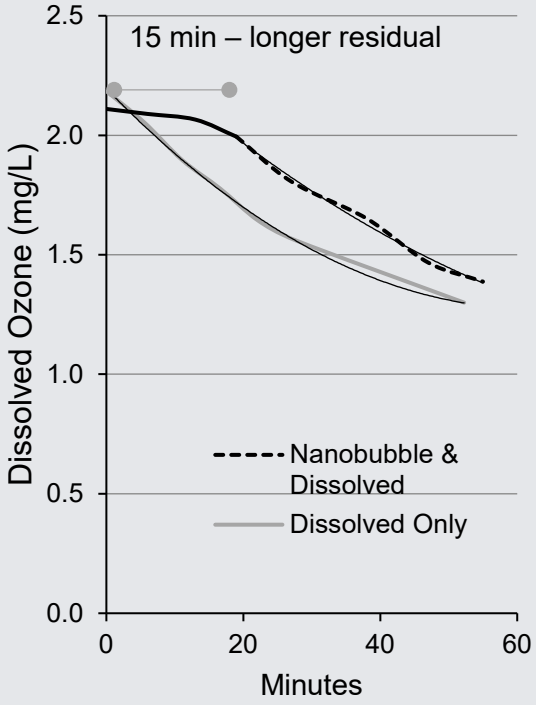
Improved Surface Cleaning



Faster Disinfection Rates



Extended Dissolved Ozone Residual



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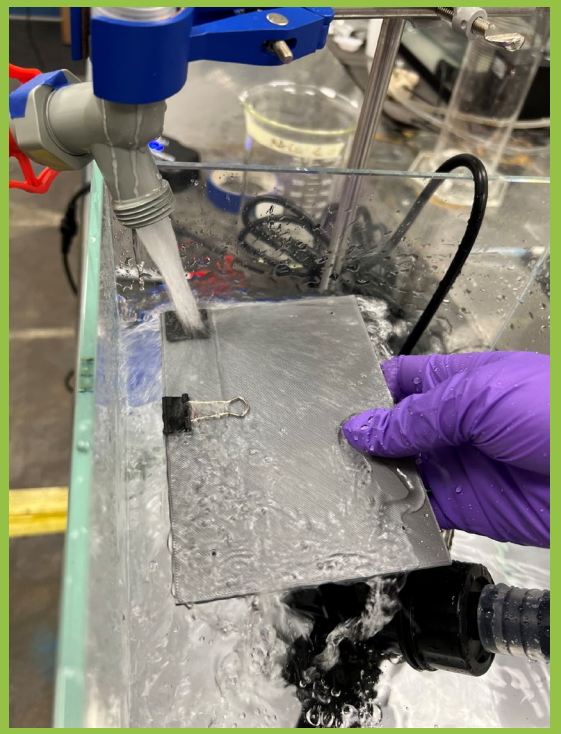
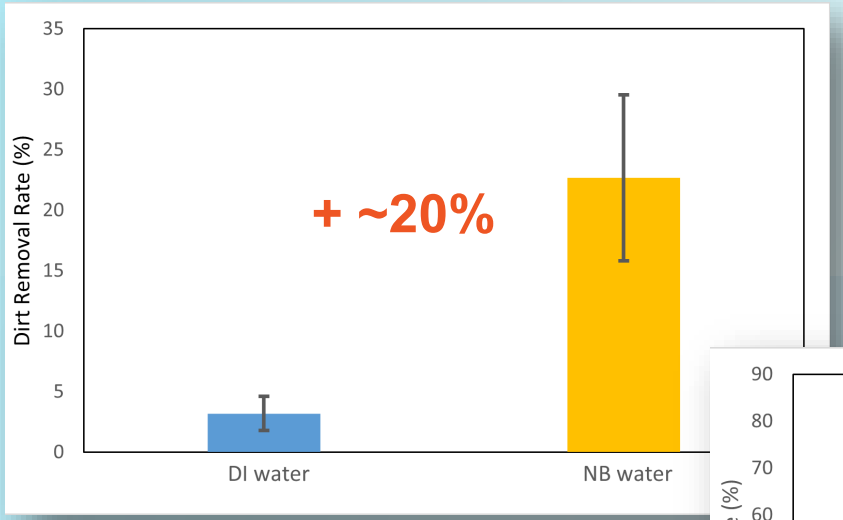
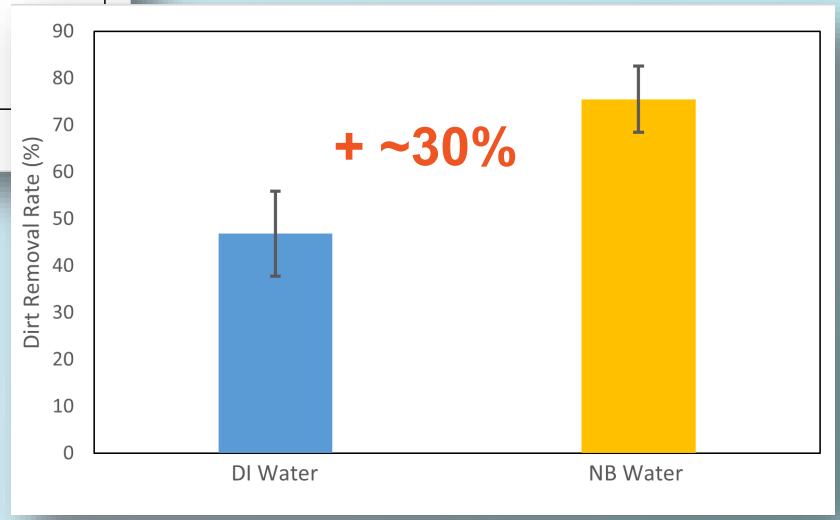
Air Nanobubble Cleaning Proof of Concept

Moving Water Test



Results: Dirt Removal Rate with Air Nanobubbles





Data Source: Moleaer R&D

**Absolute results are highly dependent on dirt composition and substrate*

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Surface Cleaning Research by University of Maine

Summary of Research

On acrylic, ozone nanobubbles are:

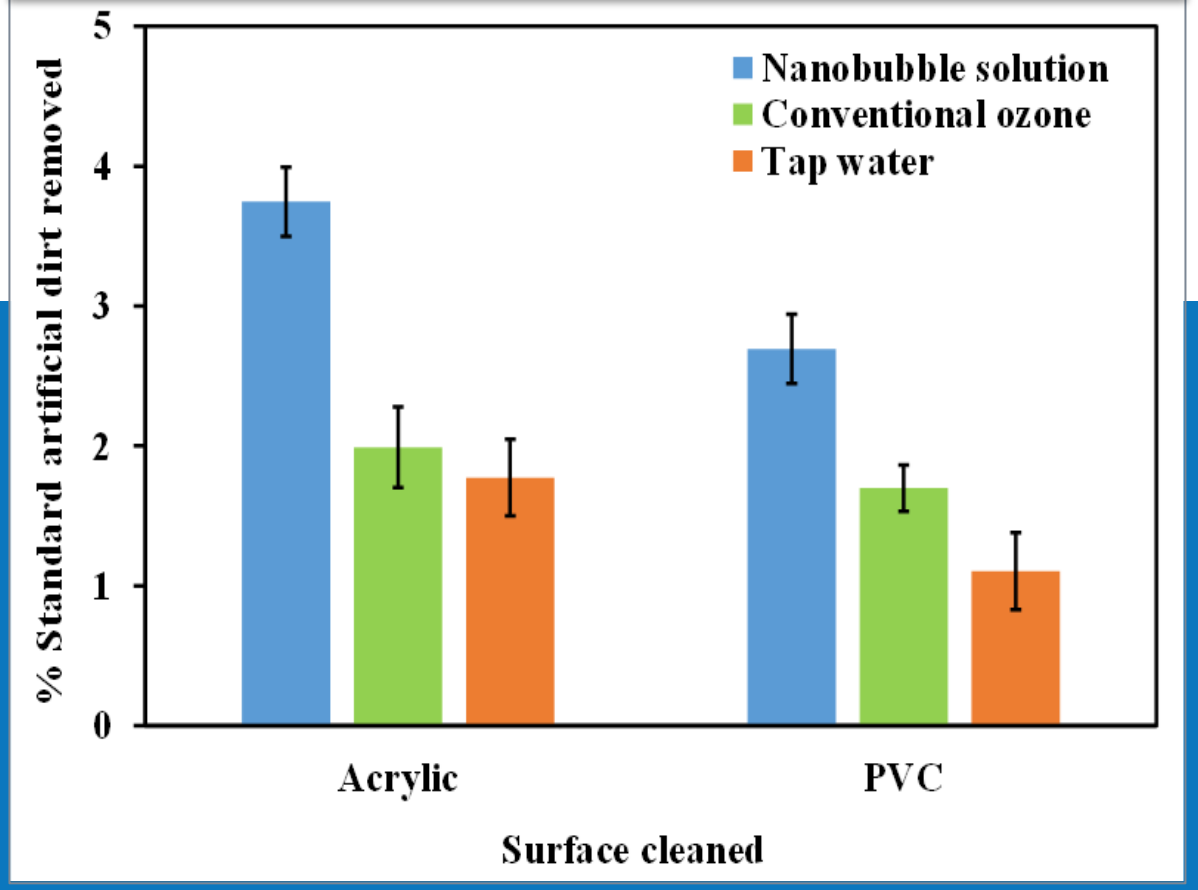
- 1.9x better than diffuser ozone
- 2.1x better than tap water

On PVC, ozone nanobubbles are:

- 1.6x better than diffuser ozone
- 2.1x better than tap water

Data Source: Dr. Apul, University of Maine

Dirt Removal Rate

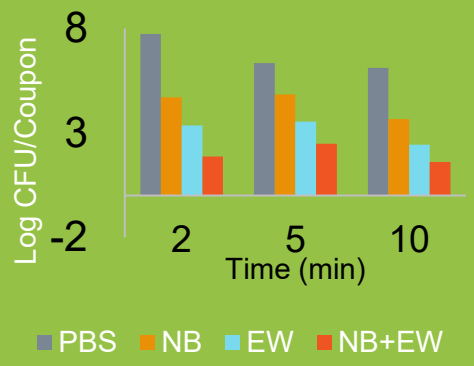


Biofilm Treatment Research by Virginia Tech

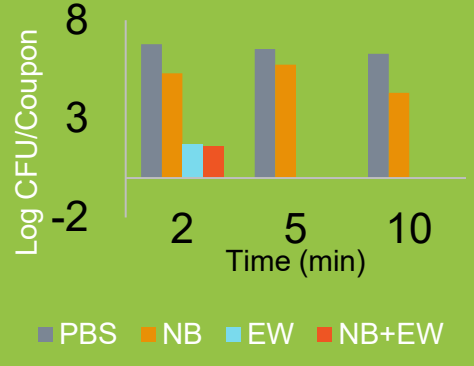
Summary of Research from Virginia Tech

- Using oxygen nanobubbles enhances the removal rates of Listeria from food handling surfaces
- They reduce food spoilage and risk of food-borne illness
- They reduce chemical cost or improve the performance of chemicals

Stainless Steel



Plastic Slide

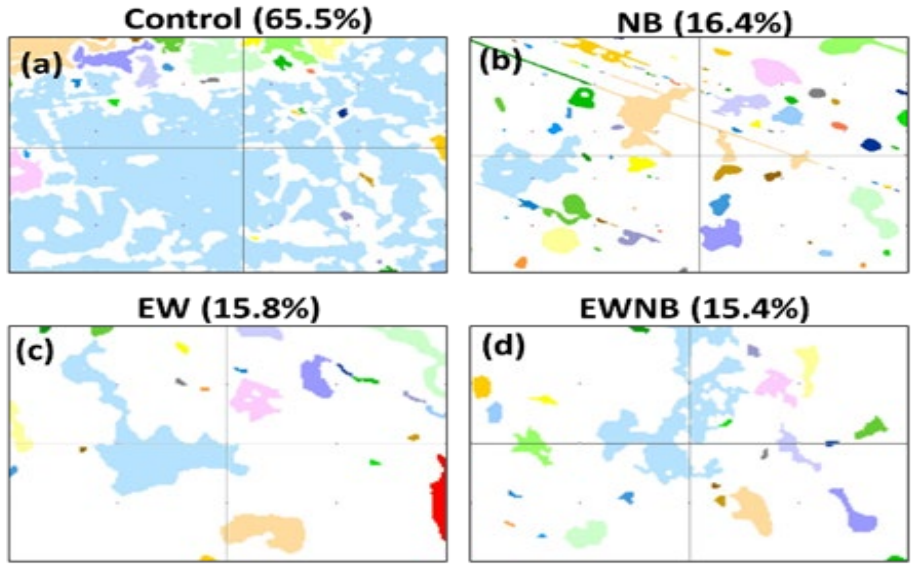


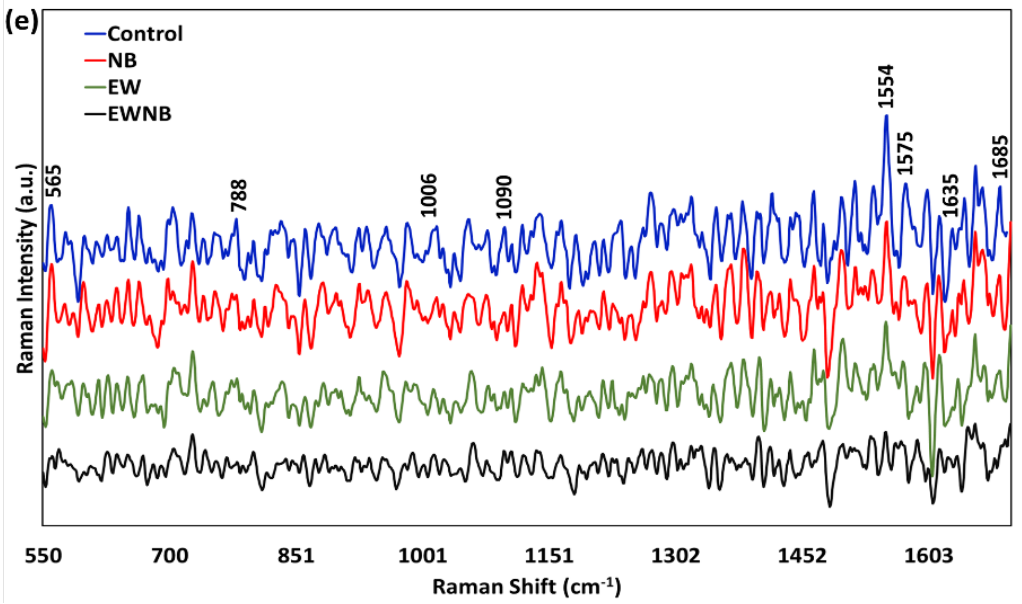
Legend

PBS: *Phosphate Buffer Saline (Control)*
NB: *Oxygen Nanobubbles*
EW: *Electrolyzed Water*
EWNB: *Electrolyzed Water + Oxygen Nanobubbles*

E. Coli: Survival of Biofilm When treated with Different Solutions

Virginia Tech research highlights how nanobubbles effectively penetrate & break down biofilm matrices





Chemical composition image of L. innocua biofilm EPS processed based on optical image and Raman maps in different treatments. L. innocua biofilm EPS SERS spectra fingerprints after treating with different solutions.

NB: Oxygen Nanobubbles

EW: Electrolyzed Water

EWNB: Electrolyzed Water + Oxygen Nanobubbles

Nanobubbles Inhibit Biofilm Reattachment on Surfaces

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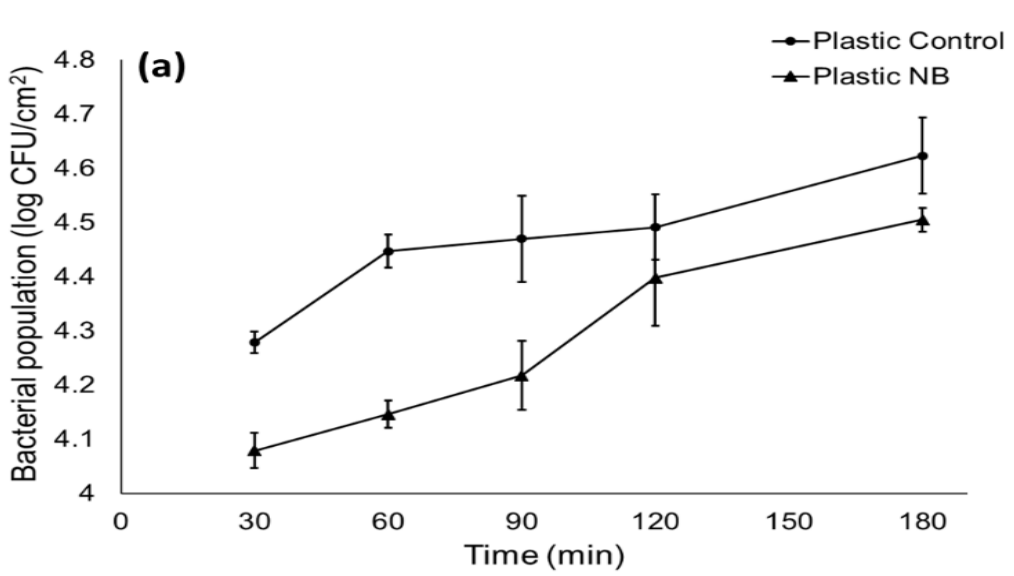
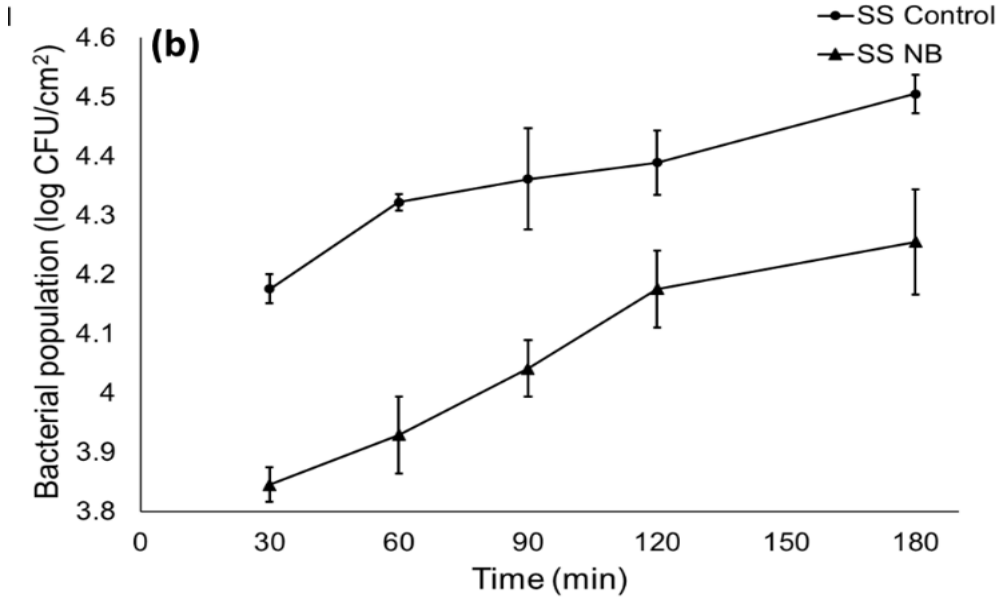
Plastic Surface



Stainless Steel (SS) Surface



Results showed that nanobubbles prevent reattachment and development of biofilm on both plastic and stainless-steel surfaces

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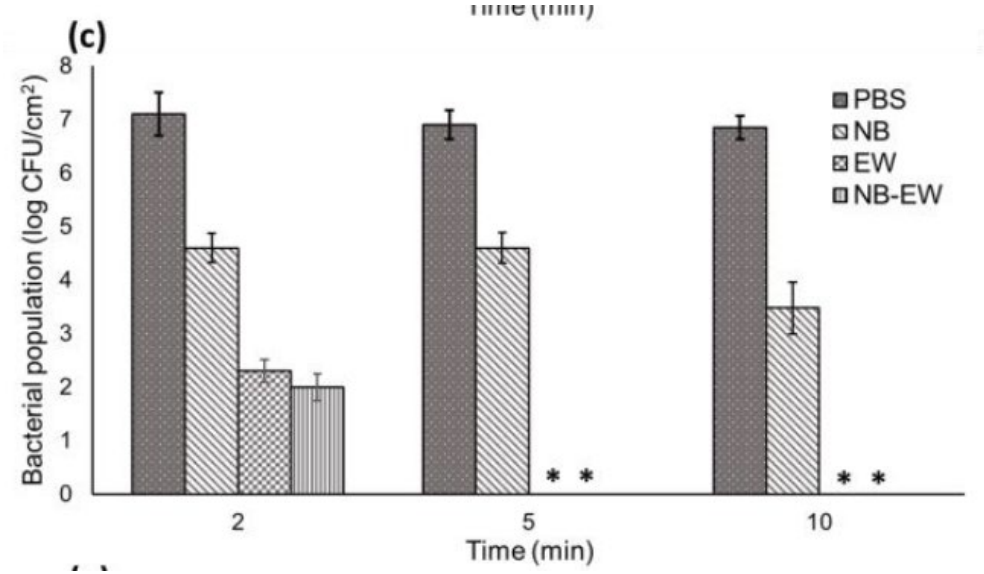
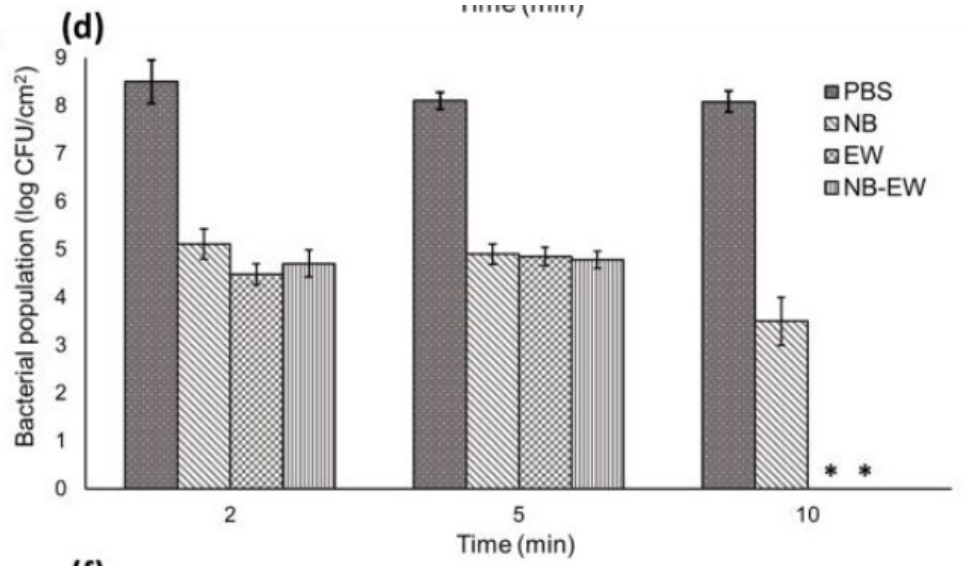
E. coli: Survival of Biofilm When treated with Different Solutions

Plant Surface



E. Coli O157:H7 Biofilm Removal

Stainless Steel (SS) Surface



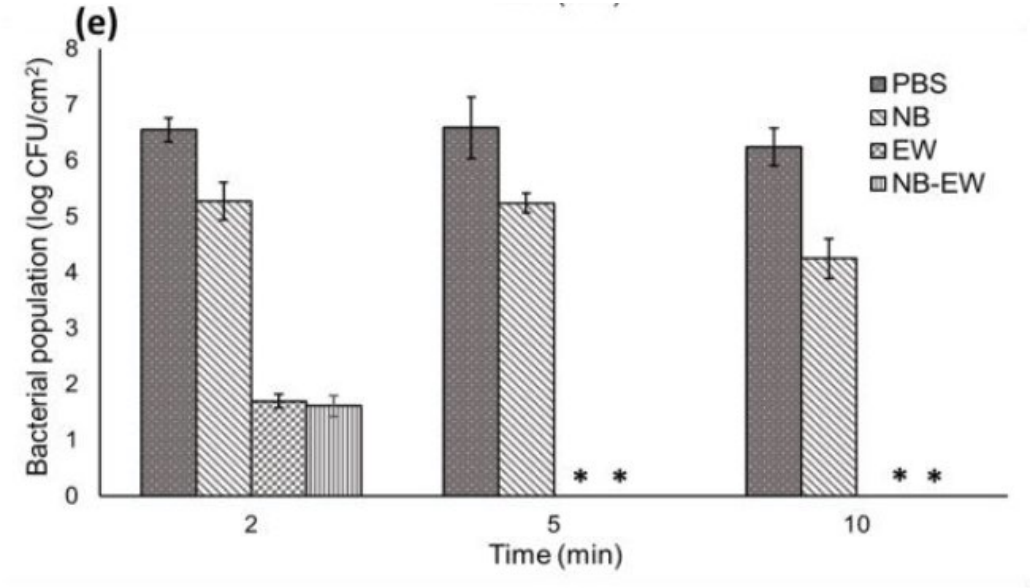
E. Coli O157:H7 Biofilm Removal

Key Findings:
O_2 Nanobubbles alone achieved a 4.6 log reduction of *E. coli* on Stainless Steel within 10 minutes

PBS: Phosphate Buffer Saline
NB: Oxygen (O_2) Nanobubble
EW: Electrolyzed Water [Hypochlorous acid (275 PPM)
NB + EW: Oxygen Nanobubbles + Electrolyzed Water

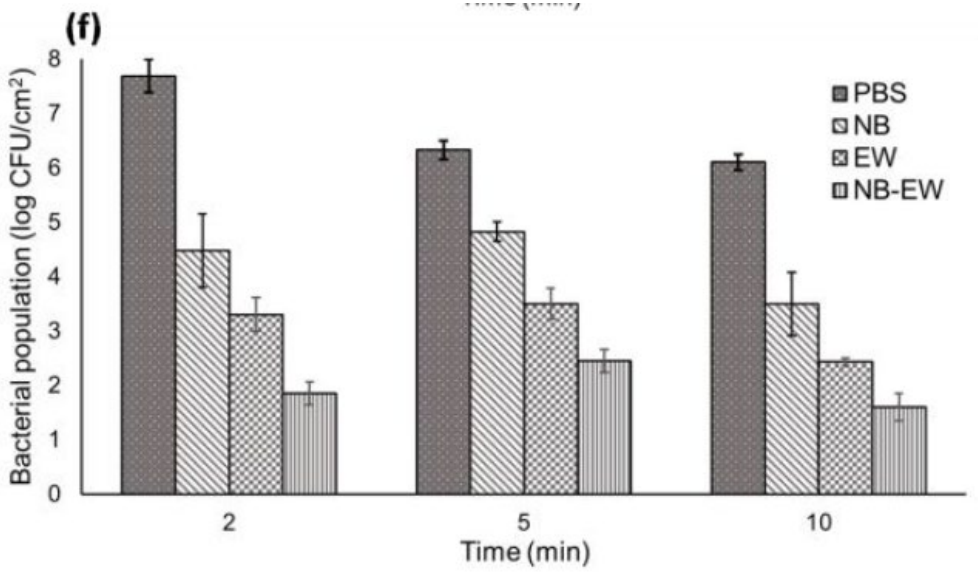
Listeria: Survival of Biofilm When treated with Different Solutions

Plant Surface



Listeria Innocua Biofilm Removal

Stainless Steel (SS) Surface



Listeria Innocua Biofilm Removal

Key Findings:
O_2 Nanobubbles alone achieved 3.8 log reduction of Listeria on Stainless Steel within 10 minutes

PBS: Phosphate Buffer Saline
NB: Oxygen (O_2) Nanobubble
EW: Electrolyzed Water [Hypochlorous acid (275 PPM)
NB + EW: Oxygen Nanobubbles + Electrolyzed Water

Nanobubbles vs. Bleach: A Sustainable Solution for Bacteria Control

Vibro Control, Down East Institute, US

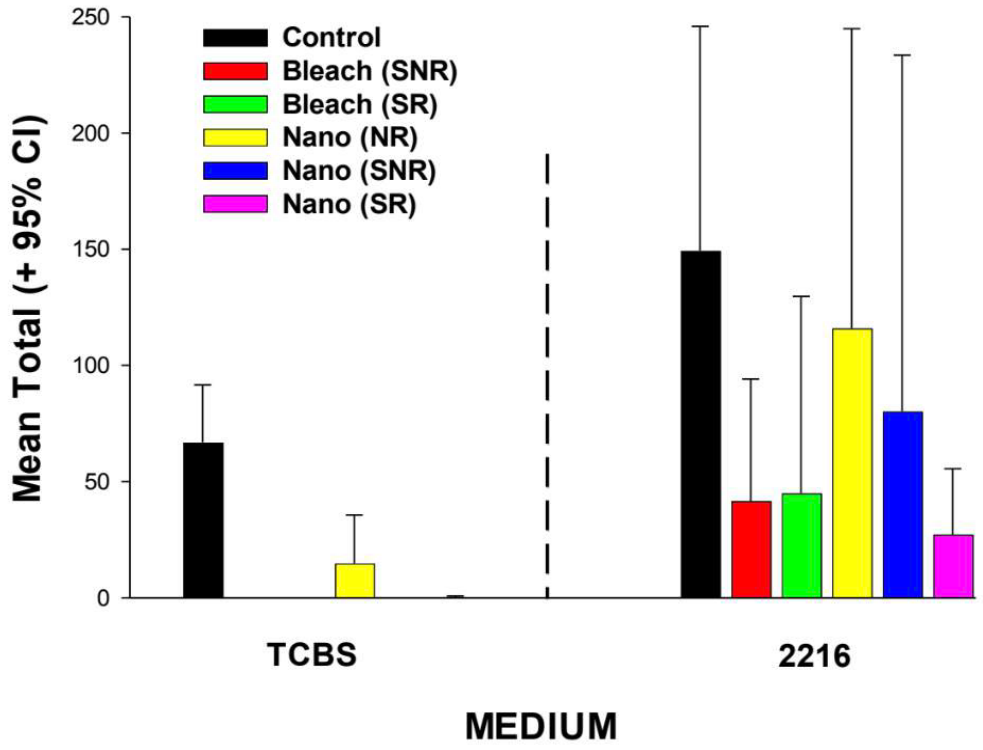
In this test, the performance of oxygen nanobubbles was compared to bleach as a method to kill common marine bacteria, such as Vibrio.

Key Findings:

- Results suggest that nanobubbles perform as well as a bleach solution in terminating harmful *Vibrio* species

Legend

SNR: Bleach, Scrub, No Rinse
BSR: Bleach, Scrub, Rinse
NR: Nanobubble, not scrubbed, not rinsed
NB, SNR: Nanobubble, Scrub, No Rinse
NB, SR: Nanobubble, Scrub, Rinse



TCBS is Vibrio-selecting media; 2216 is general growth media

Evaluating Biofilm Removal: Vibrio Parahaemolyticus Solutions at Virginia Tech

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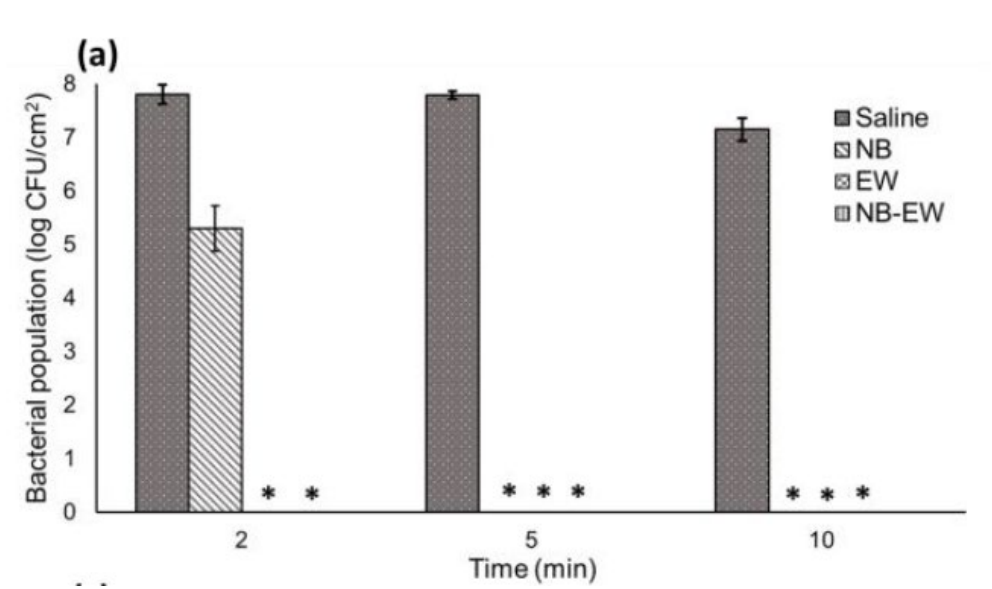
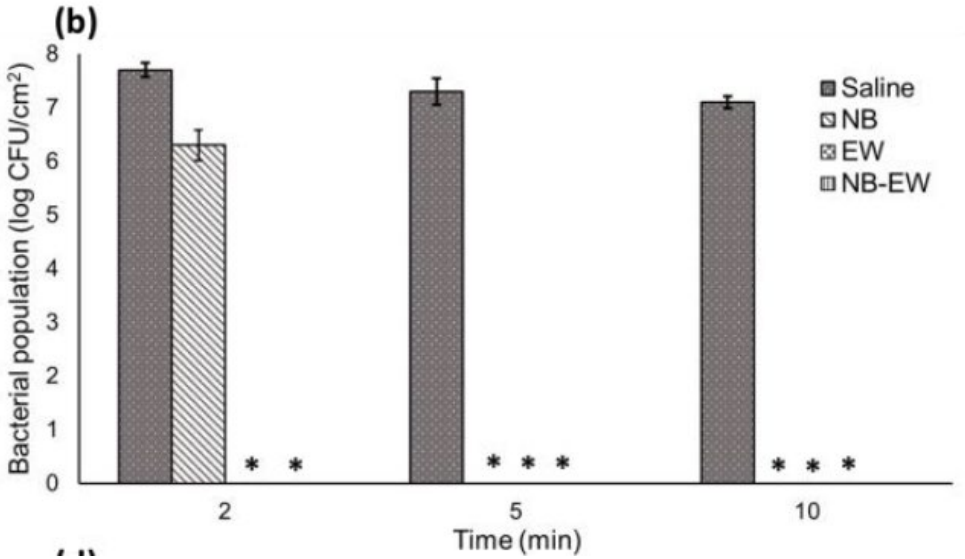
Plastic Surface



Survival Of Biofilm When Treated With Different Solutions

Stainless Steel (SS) Surface



Survival Of Biofilm When Treated With Different Solutions

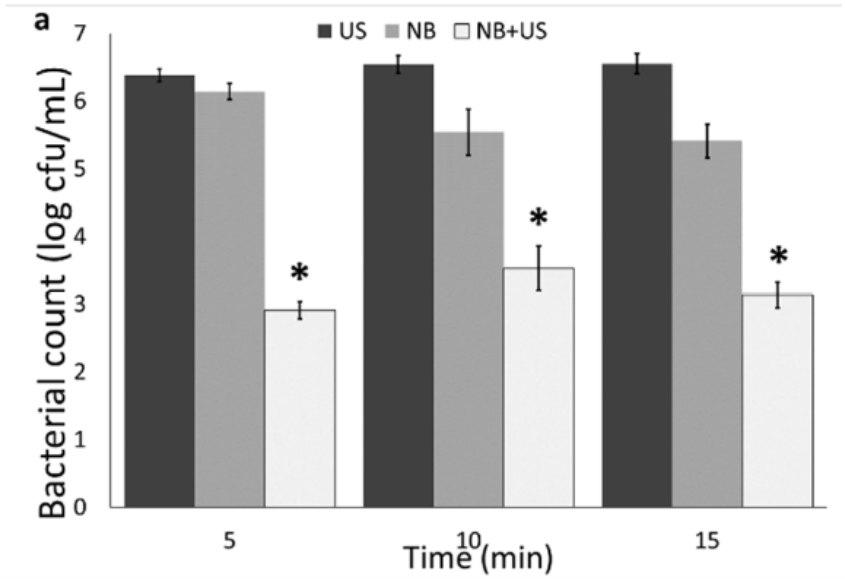
Key Findings:
O_2 Nanobubbles achieved complete Vibrio removal within 5 minutes.

NB: Oxygen Nanobubble
EW: Electrolyzed Water [Hypochlorous acid (275 PPM)]
NB + EW: Oxygen Nanobubbles + Electrolyzed Water

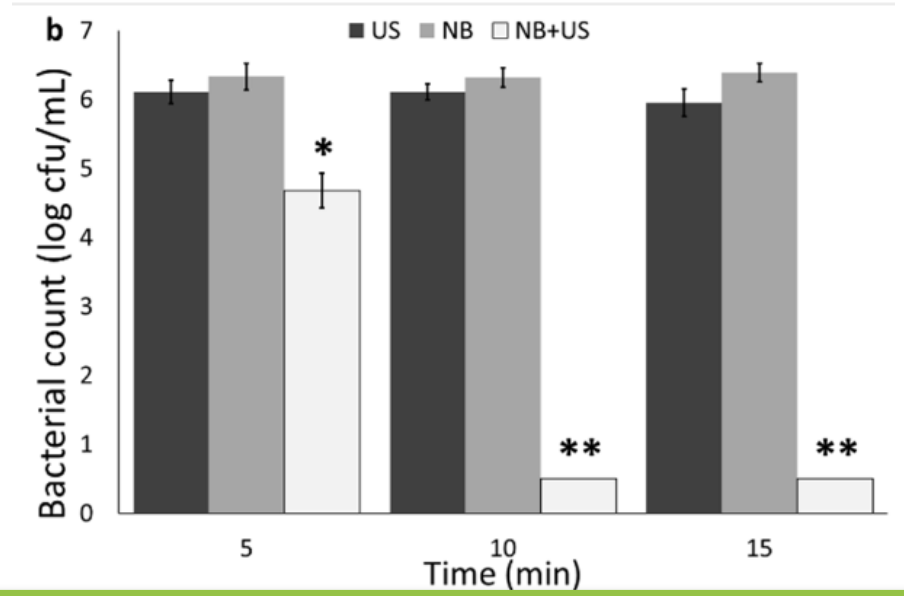
Evaluating Biofilm Removal: Vibrio Parahaemolyticus Solutions at Virginia Tech

VIRGINIA TECH

Vibrio



Aeromonas



Key Findings:
Results showed that the combination of nanobubbles and ultrasound induced a more than 3 and 6 log cfu/mL reduction in V. parahaemolyticus and A. hydrophila, respectively. This demonstrates that nanobubbles and ultrasound are a powerful chemical treatment to inactivate pathogens

Figure 4. (a) *V. parahaemolyticus* and **(b)** *A. hydrophila* count in nanobubbles (NB), ultrasound (US), and NB + US at different exposure times. Statistical difference was determined based on $p < 0.05$ (*). Samples with two asterisks (**) were below the limit of detection (0.5 log cfu/mL).

Nanobubbles + Food Safety Case Studies

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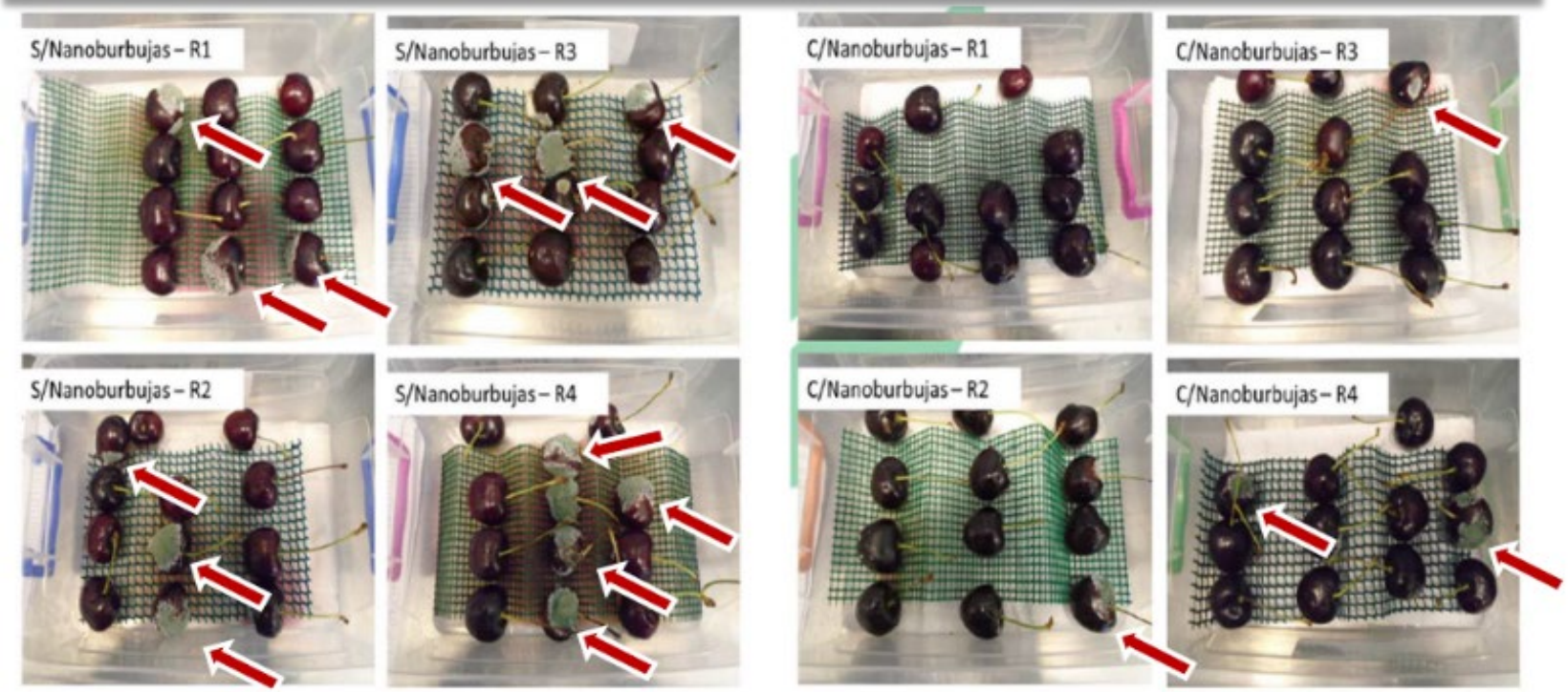
Case Study: Nanobubbles Wet Packing Trials, Sweet Cherries

Study Results

Fungicide combined with oxygen nanobubbles demonstrated significant efficacy in removing bacterial and fungi from the surface of cherries during wet packing trials.

Sweet Cherry Wet Packing Trials



T0 – Fungicide Program

T1 – Fungicide Program + ONB

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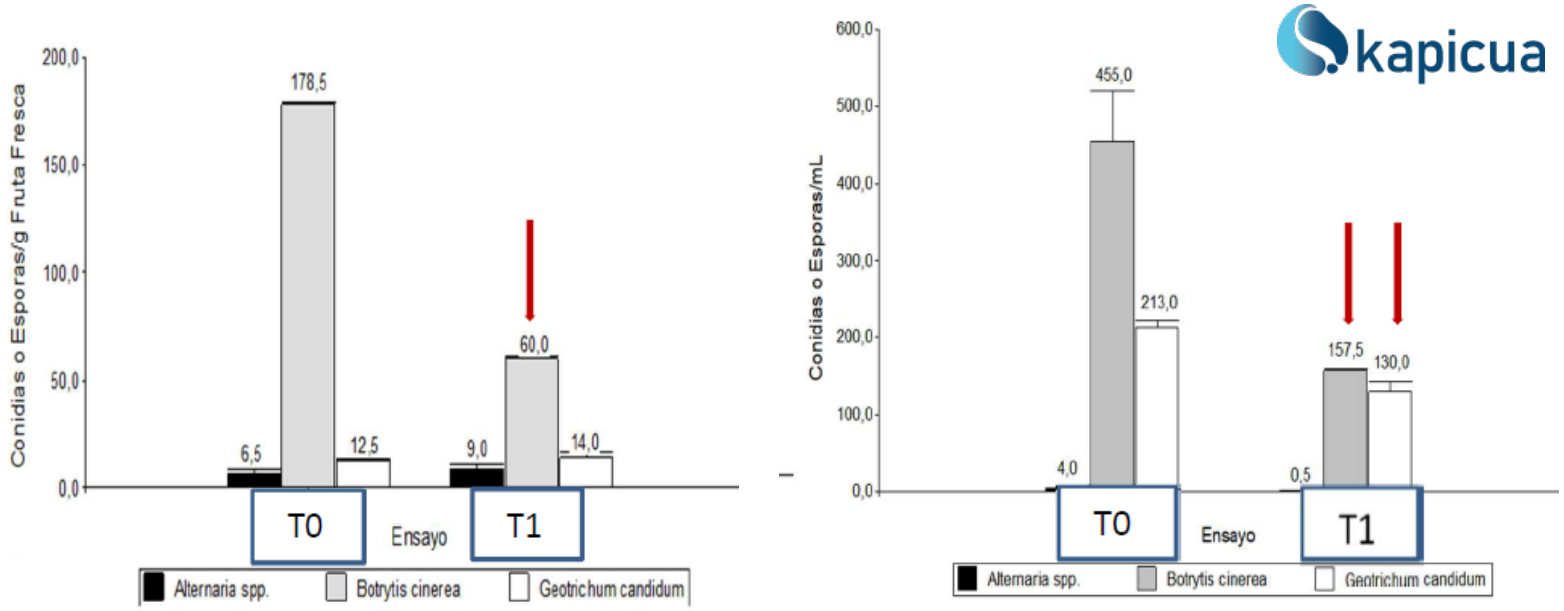
Case Study: Nanobubbles Wet Packing Trials, Sweet Cherries

Study Results

The study demonstrated a **significant reduction** in both the count and intensity of fungi on the surface of the fruit, highlighting the effectiveness of nanobubble technology in microbial control.

Sweet Cherry Wet Packing Trials



T0 – Sanitizing Program

T1 –Sanitizing Program + ONB

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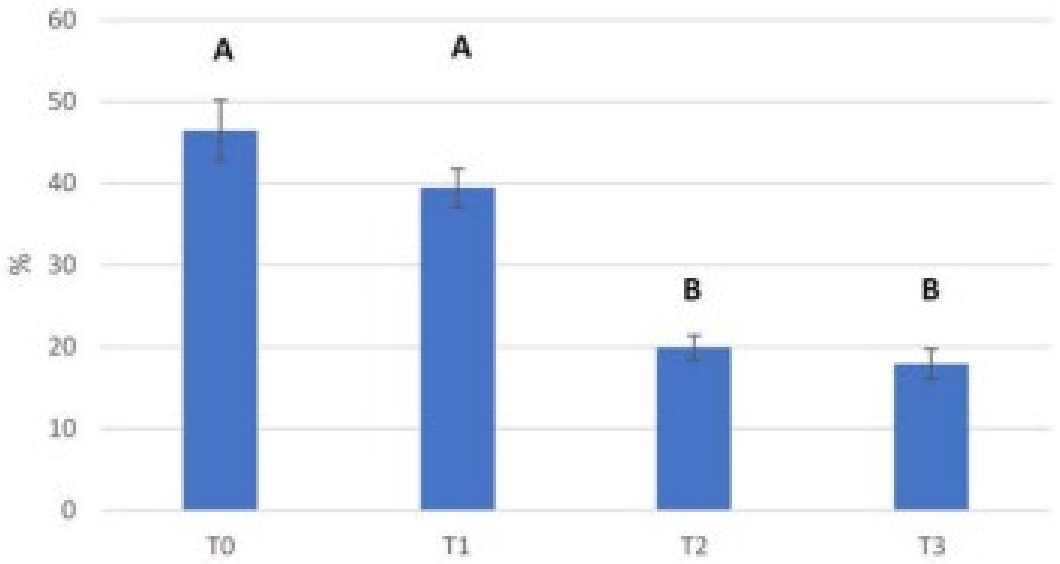
Case Study: Nanobubbles Citrus Wash, Drench

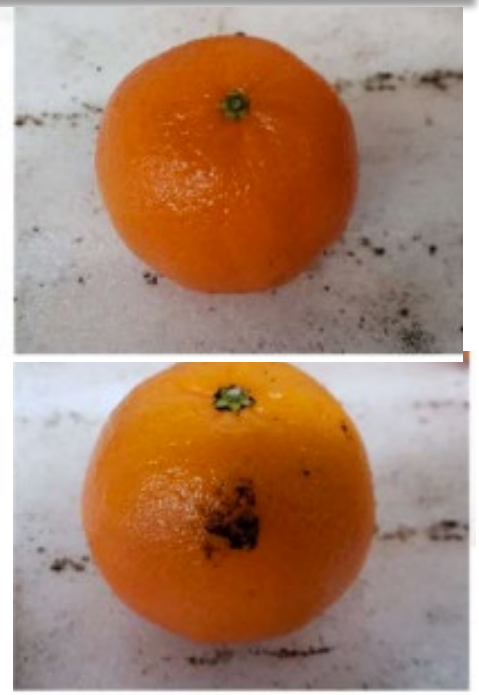
kapicua

Study Results

The study demonstrated that oxygen nanobubbles **significantly improved** the fumagin removal from fruit surface, enhancing existing processes.

Citrus Wash, Drench





T0 – Control (without drainage)
T1 – Drainage + Disinfectant
T2 – Drainage + Nanobubbles
T3 – Drainage + Disinfectant + Nanobubbles

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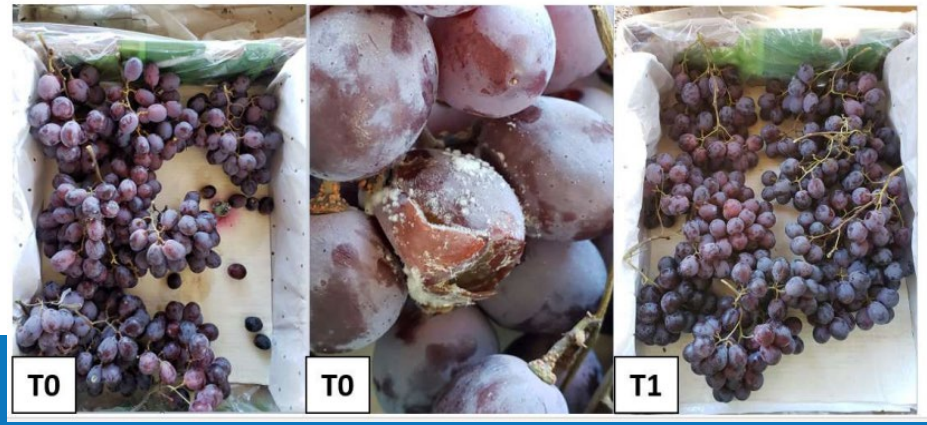
Case Study: Nanobubble Table Grapes, Foliar Spray

kapicua

Study Results

Foliar preharvest applications of oxygen nanobubbles **had a significant effect** decreasing fungal growth during postharvest.

Nanobubble Table Grapes



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Case Study: Nanobubble Apples

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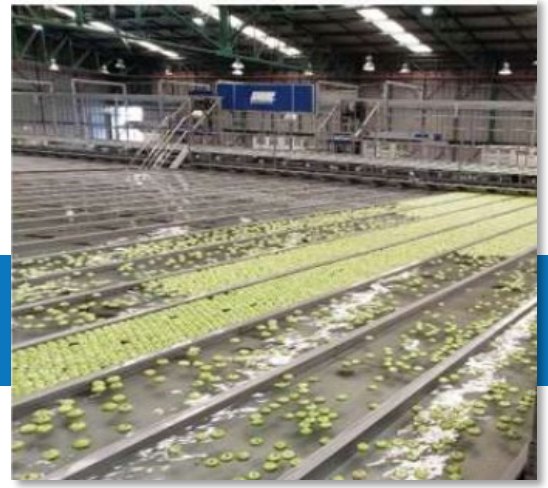
Study Results

Oxygen nanobubbles **significantly reduced** concentrations of *E. coli* and fecal coliforms.

Nanobubble Apples

0	Coliformes fecales	NMP / 100 mL	>2419,6
	E. coli		3,1
1	Coliformes fecales		<1
	E. coli		<1
2	Coliformes fecales		<1
	E. coli		<1



T0 – Control, without nanobubbles
T1 – With nanobubbles, 22 ppm
T2 – With nanobubbles, 15.2 ppm

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Case Study: Nanobubble Enhanced Dairy CIP Process

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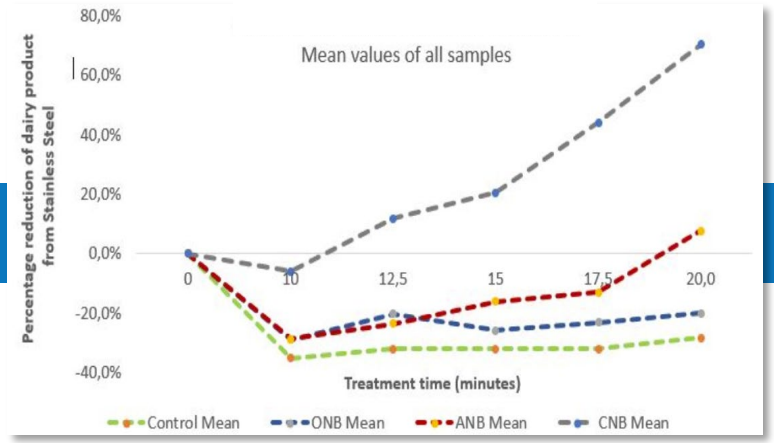
Study Results

Highest improvement observed was with **CO_2 Nanobubble Water** treatment was 349% more removal than control samples

Pictures of a Sample at Each Treatment Time Interval



Group A: Wash Without Chemical

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Thank You

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