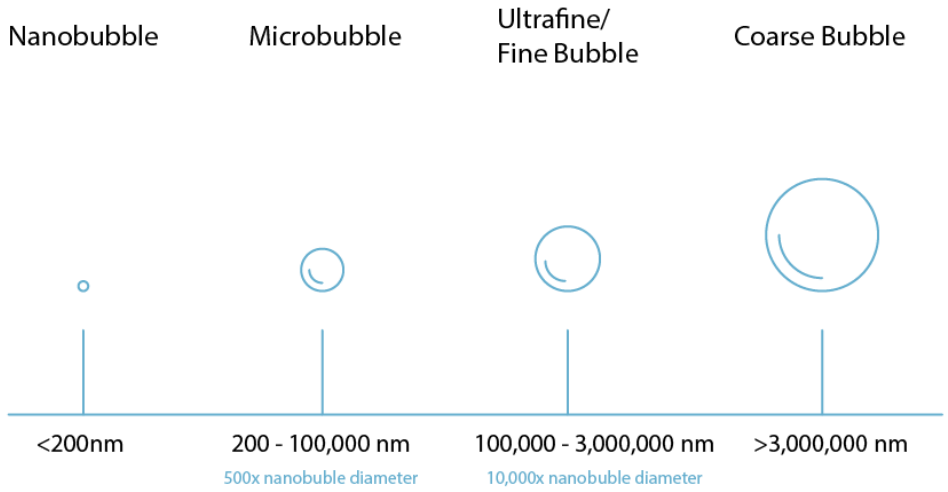

SIO
A Billion Bubbles of Life

What are Nanobubbles ?

Nanobubbles are long-lasting gas-containing cavities in aqueous solutions.

Due to their size, nanobubbles exhibit unique properties that improve numerous physio-chemical, physio-mechanical and biological processes



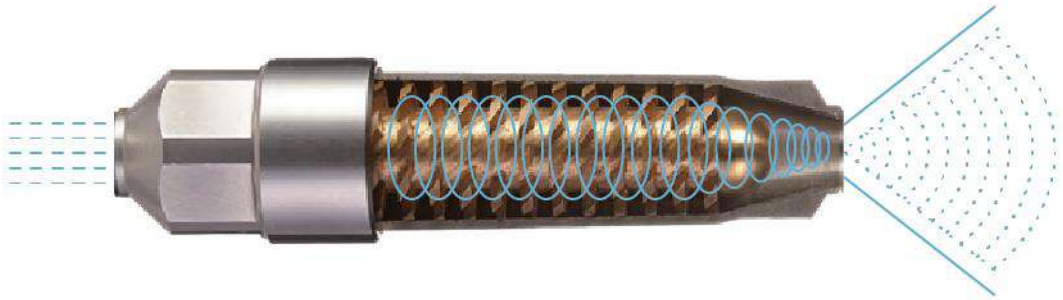
The SIO patented bulk Nanobubble generation method consistently produces high density solutions of optimally sized nanobubbles, averaging 100 nm in diameter and ranging between 50 and 100 nm.

Nanobubbles of this size are stable in liquid because they have reached equilibrium with bubble surface tension, internal pressure, external pressure, surface charge, and their environment.

Their stability and size give them neutral buoyancy and remain suspended until they interact with surfaces or contaminants.

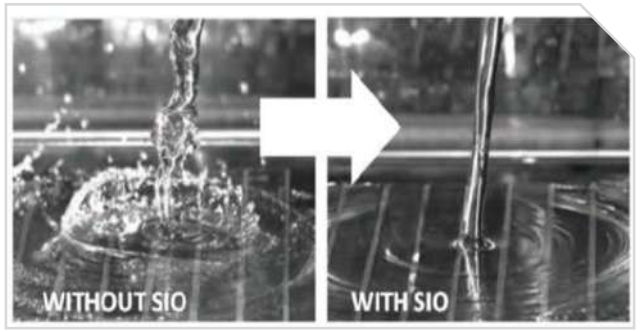
The SIO Advantage

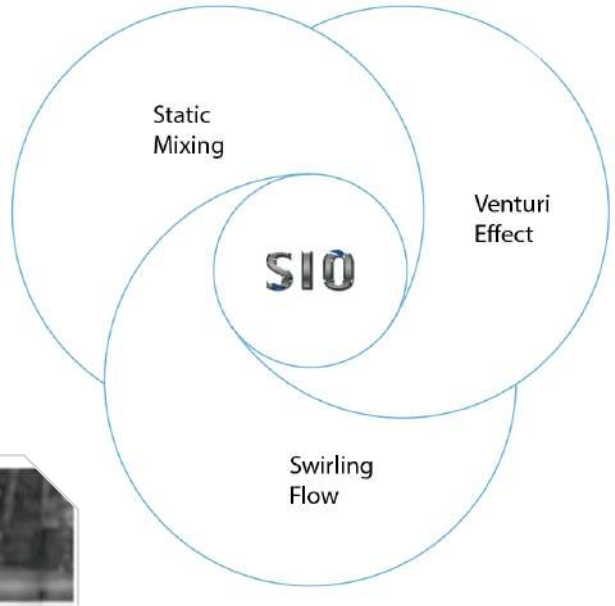
The SIOs unique, patented process of combining the following three fluid mechanic principals contribute to the hydrodynamic cavitation and shearing forces used to produce a high concentration of stable ultra-fine bubbles.



Static Mixing

A method for combining fluid materials which are forced fed over a pattern of mixing elements to generate a homogenous fluid stream.





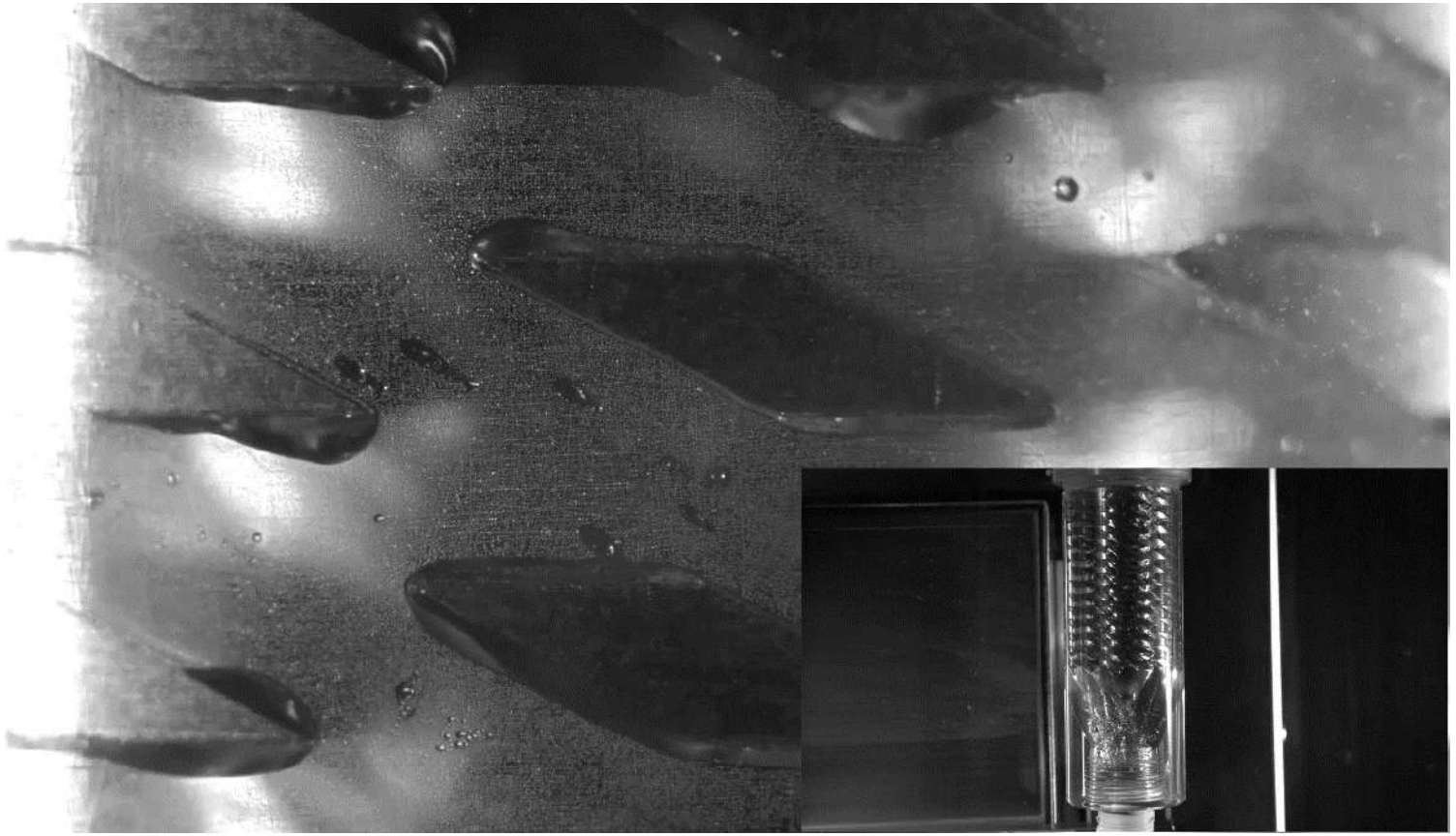
Venturi Effect

The Venturi Effect is the reduction in fluid pressure caused by fluids passing through multiple channels of different widths. At the same time, it induces cavitation which leads to the formation of bubbles.

Swirling Flow

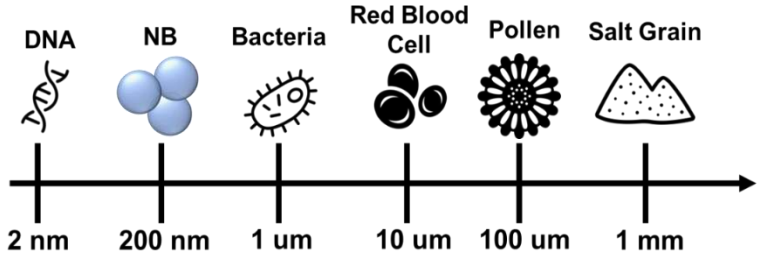
A method in which a swirling flow is generated in the device. The strong centrifugal force of the flow generates fine bubbles due to high smash and shear action of the fluids.

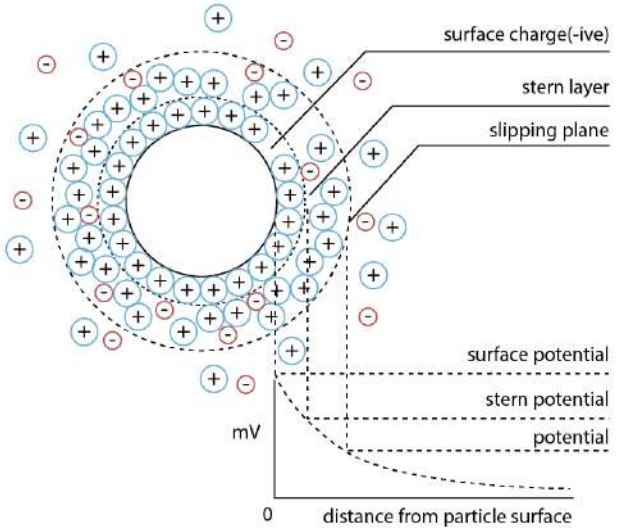
Generation of nanobubbles with a mean particle size between 50-100 nm



The Unique Characteristics of Nanobubbles

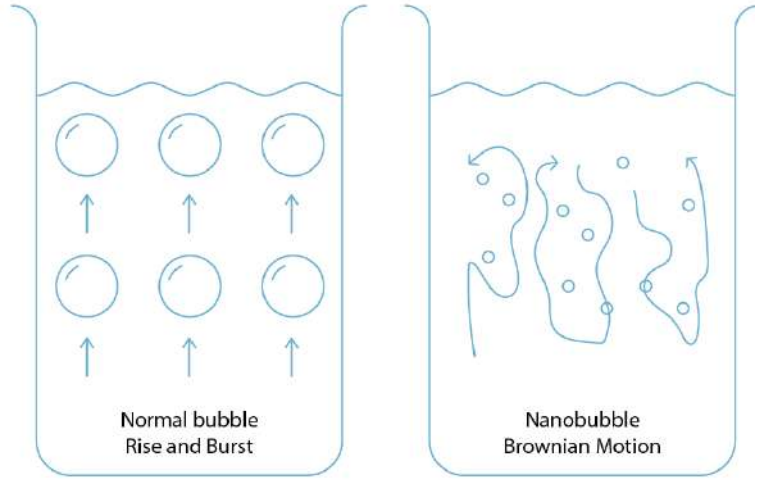
Nanobubbles are one of the smallest known bubble sizes, roughly 2500 times smaller than a single grain of salt, or less than 200 nanometers (nm) in diameter.

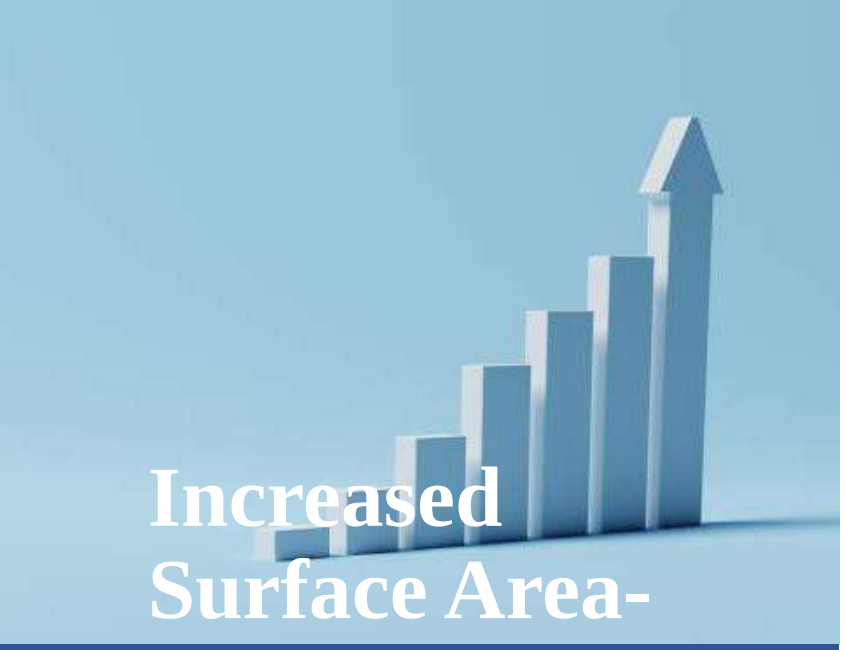




Nanobubbles have a strong negative surface charge that keeps them stable in liquid and enables them to continuously participate in and stimulate physical, biological, and chemical interactions.

Nanobubbles are neutrally buoyant and can remain suspended in liquid for weeks without rising to the surface and off-gassing.



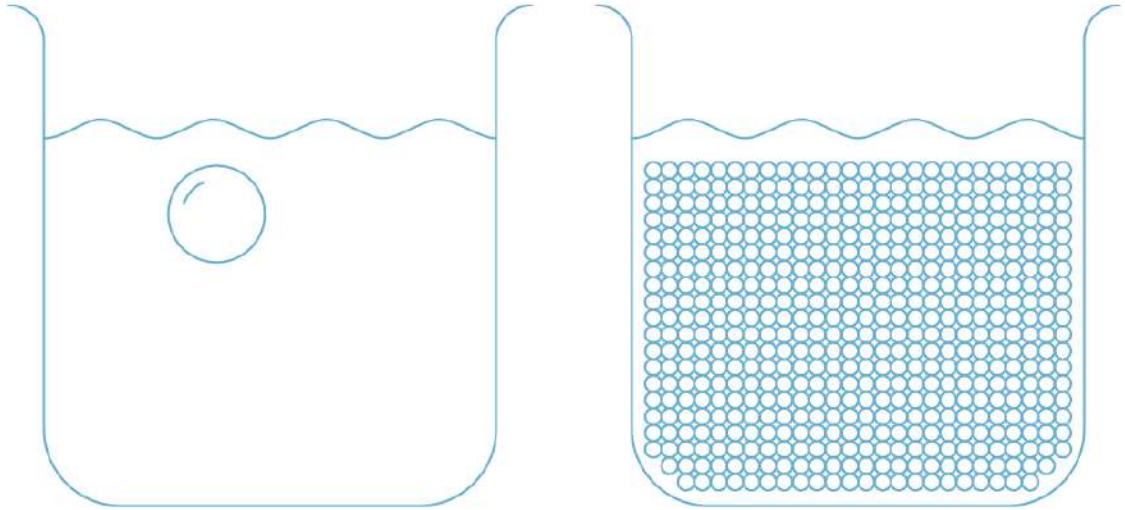


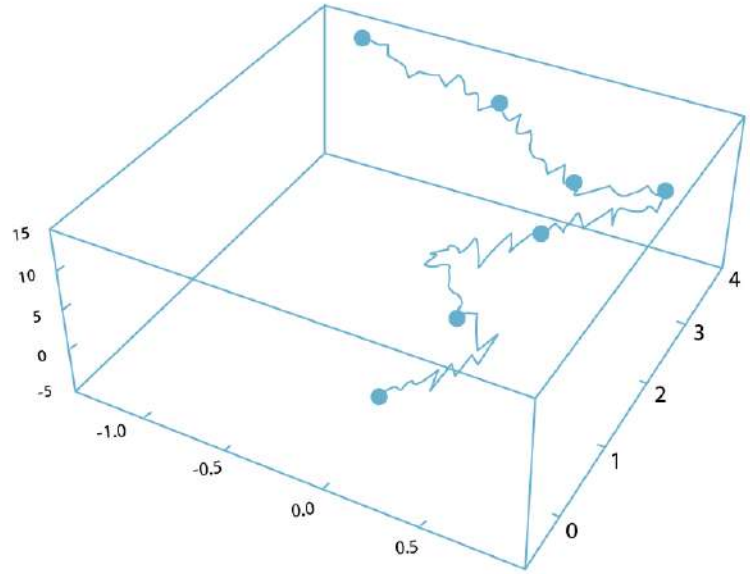
Increased Surface Area-to-Volume Mass

- Creates a stabilized fluid platform for process optimization
- Shortens reaction times
- Improves Heat Exchange efficiency
- Improves chemical conversion efficiency
- Penetrates into organic materials including biofilms
- Drastically reduces pipeline & equipment corrosion

When one square mm of water is filled with nanobubbles, the surface-to-volume mass increases Exponentially as compared to water filled with normal bubbles.

The increase in surface area dramatically enhances aerobic bacteria activities in th liquid and the efficacy of chemical reaction between the supplied gas and liquid ingredients





Brownian_Motion. Diagram demonstrates a three-dimensional Brownian motion path of a single nanobubble

The Proven Benefits of Nanobubbles

- Higher dissolution efficiency and longer retention time.
- Reduction in surface tension and finer fluid particles.
- Rapid, ultrafine and thorough mixing.
- Higher zeta-potential and colloidal dispersion.
- Reduce chemical applications

Physical Separation of Suspended Particles

Nanobubbles have a strong negative surface charge that prevents them from coalescing and enables them to physically separate small particles and droplets such as emulsified fats, oils, and grease
from water

Remove & Prevent Buildup

Nanobubbles effectively prevent and remove unwanted buildup in wet environments. They scrub surfaces in food washing, drip lines, swimming pools, and irrigation pipes, reducing the need for harsh chemicals that can damage pipes and filtration system

Chemical-free Means for Improving Water Quality

When nanobubbles are stimulated, they destabilize and collapse, releasing the hydroxyl radical. The hydroxyl radical (HO) is one of the strongest known oxidizers commonly used to destroy hard to treat and hard to kill contaminants in water.

Aeration, Oxygenation & Gas Transfer

Nanobubbles remain suspended & disperse to deliver gas throughout the liquid volume.

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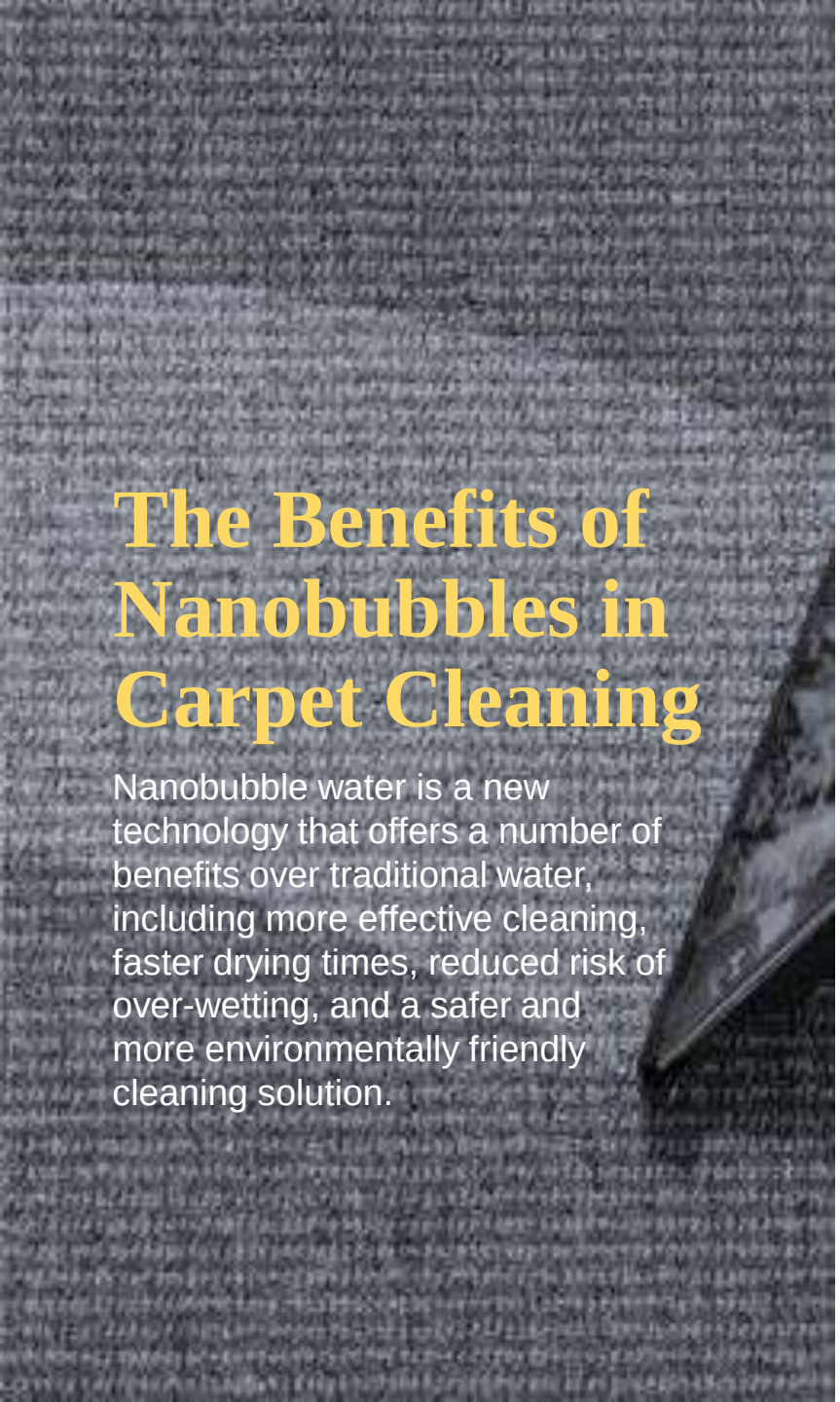
VIRGINIA TECH

FUTURE FOODS LAB
CELLULAR Agriculture Initiative



The Benefits of Nanobubbles in Carpet Cleaning

Nanobubble water is a new technology that offers a number of benefits over traditional water, including more effective cleaning, faster drying times, reduced risk of over-wetting, and a safer and more environmentally friendly cleaning solution.

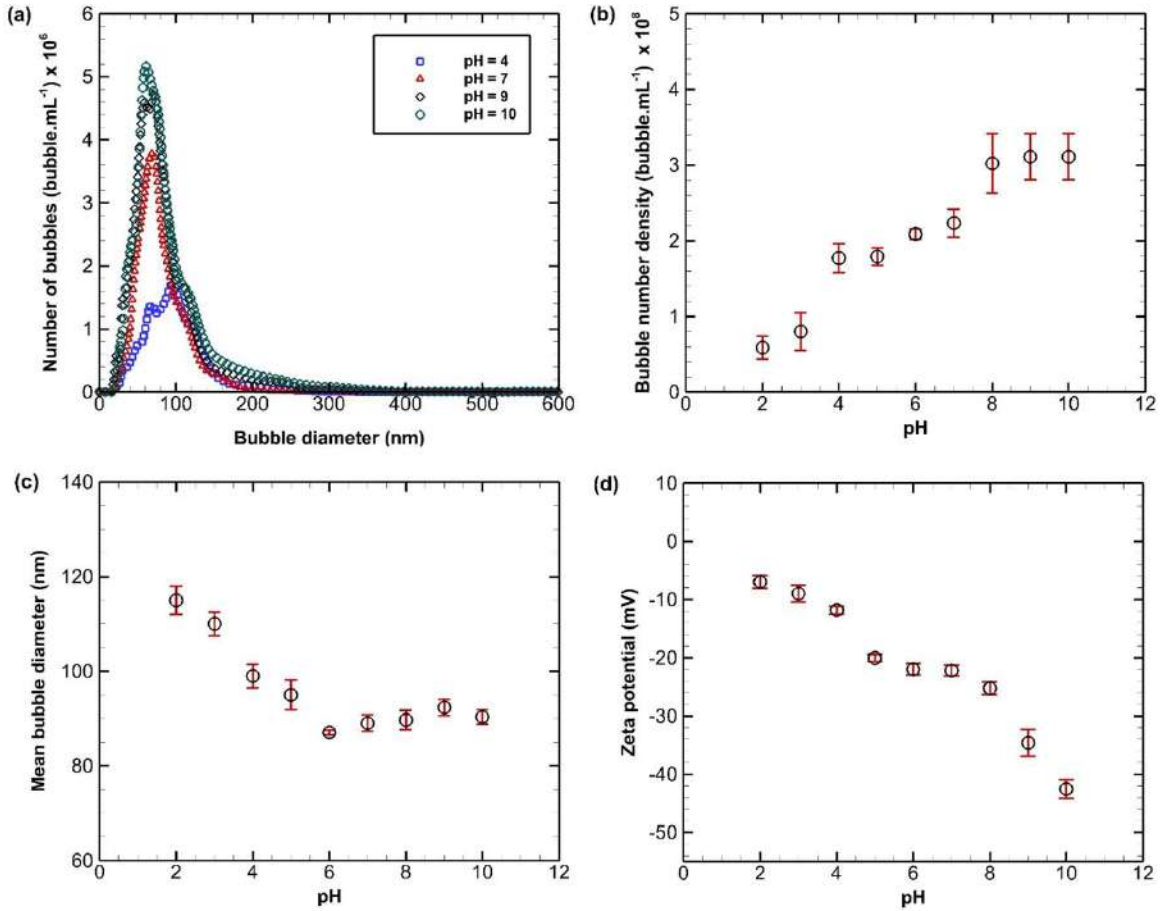
- High surface area: Nanobubbles have a very high surface area to volume ratio, which means that they have more surface area to interact with dirt and grime. This makes them more effective at cleaning than traditional water molecules.
- Long lifespan: Nanobubbles can live for several hours or even days, which gives them more time to clean.
- Increased oxygen concentration: Nanobubble water has a higher concentration of oxygen than traditional water. This oxygen can help to break down dirt and stains.
- More effective cleaning: Nanobubble water can clean carpets more effectively than traditional water by lifting and removing dirt, grime, and stains more deeply.
- Faster drying time: Nanobubble water dries faster than traditional water, which means that carpets can be back in use more quickly.
- Reduced risk of over-wetting: Nanobubble water is less likely to over-wet carpets than traditional water, which can reduce the risk of mold and mildew growth.
- Safer and more environmentally friendly: Nanobubble water is a safe and environmentally friendly cleaning solution. It does not require the use of harsh chemicals or detergents, and it produces less wastewater.

Stability of Nanobubbles in High pH Solutions

The mean bubble diameter decreases as the water pH increases to a value of about 6, remaining constant thereafter at higher pH values.

The zeta potential is negative and increases in absolute value with increasing pH, reaching substantial magnitudes at high pH values.

A high zeta potential is synonymous with high colloidal stability which indicates that nanobubbles are much more stable in alkaline solutions (1)



Effects of pre-adjustment of water pH on US-generated bulk nanobubble suspensions.

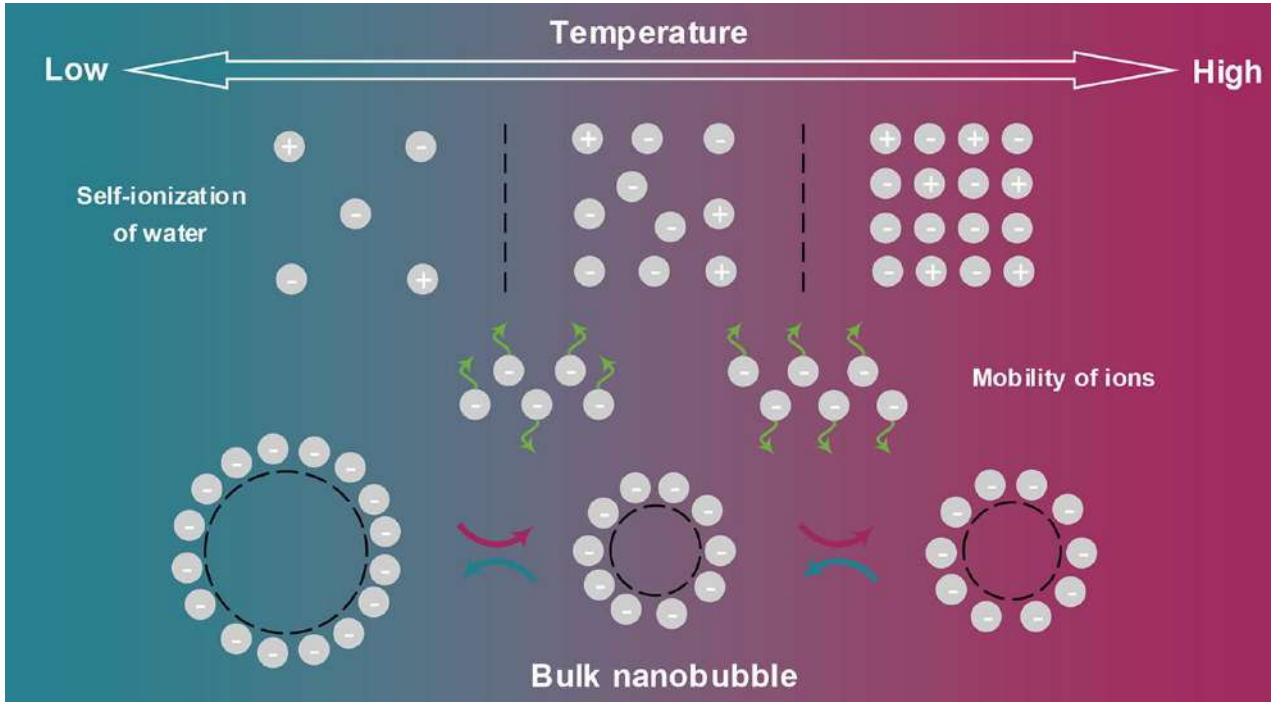
(1) N. Nirmalkar, A. W. Pacek, M. Barigou (2018)
School of Chemical Engineering, University of Birmingham, Edgbaston, Birmingham, U.K.

Nanobubbles Are Stable Over a Wide Range of Temperatures

Nanobubbles can sustain high temperature rises. It was found that nanobubbles can survive at temperatures even up to the boiling point of water[1]

Bulk nanobubbles not only survive but also tend to be more stable at higher temperatures. As the temperature increases, specifically, a pronounced narrowing of the bubble-size distribution is observed.

The overall mean bubble radius of this distribution first decreases and then increases slightly with increasing temperature[2]



1. Zhang X., Lhuissier H., Sun C., and Lohse D., " Surface nanobubbles nucleate microdroplets," Phys. Rev. Lett. 112, 144503 (2014)
2. Mingbo Li, Xiaotong Ma, Julian Eisener, Patricia Pfeiffer, Claus-Dieter Ohil, Chao Sun (2021)

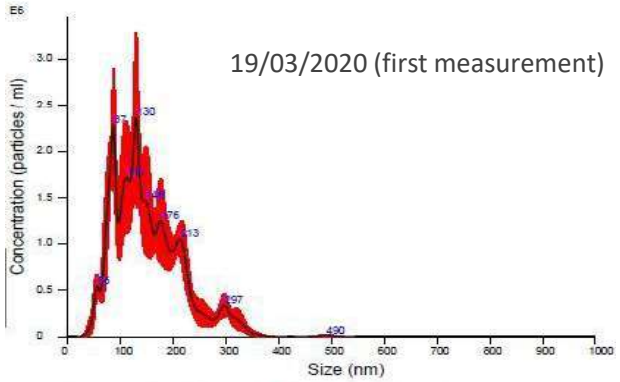
Nanobubble Retention Time Data

TOKYO METROPOLITAN UNIVERSITY

SIO processed pure water UFB longevity measurements

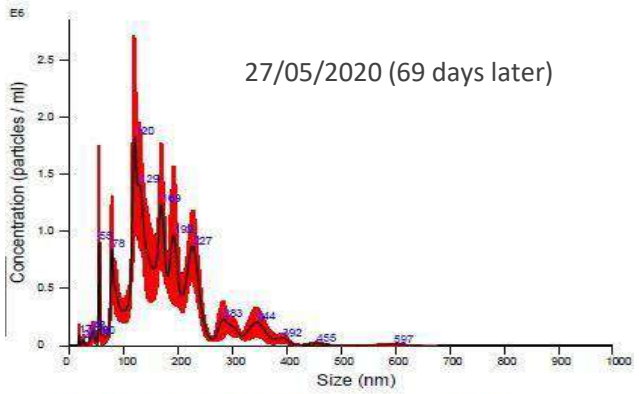
Made from single-pass generation, measured 69 days after first measurement by Tokyo Metropolitan University

				nm						particles/ml		
No.	SIO model	Measurement Date	Detect Threshold	mean	mode	SD	SD10	SD50	SD90	concentration	standard error	Error range(%)
1	SIO 1/4	20200319	5	150.9	129.0	65.1	79.0	137.3	234.3	2.61E+08	+/- 1.55e+07	5.9
2	SIO 1/4	20200527	5	178.7	119.4	80.6	92.3	165.7	288.8	1.57E+08	+/- 7.37e+06	4.6
		Rate of change		+18%	-8%		+16%	+20%	+23%	-38%		



19/03/2020 (first measurement)

Averaged FTLA Concentration / Size for Experiment:
Coffee Arrow 2020-03-19 16-45-48
Error bars indicate + / -1 standard error of the mean



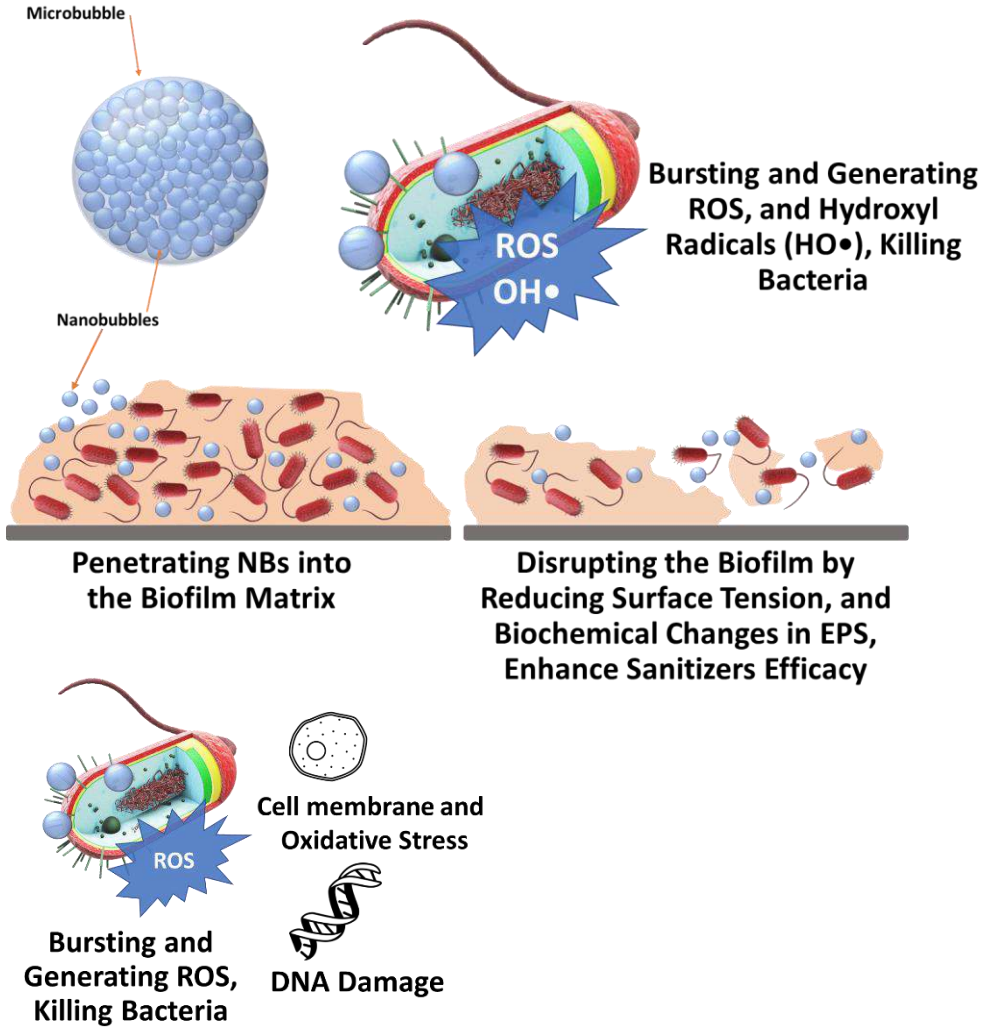
27/05/2020 (69 days later)

Averaged FTLA Concentration / Size for Experiment:
coffee arrow(2month later) 2020-05-27 17-12-44
Error bars indicate + / -1 standard error of the mean

Efficacy of Nanobubbles in Removing Biofilms

Virginia Tech, Department of Food Science and Technology

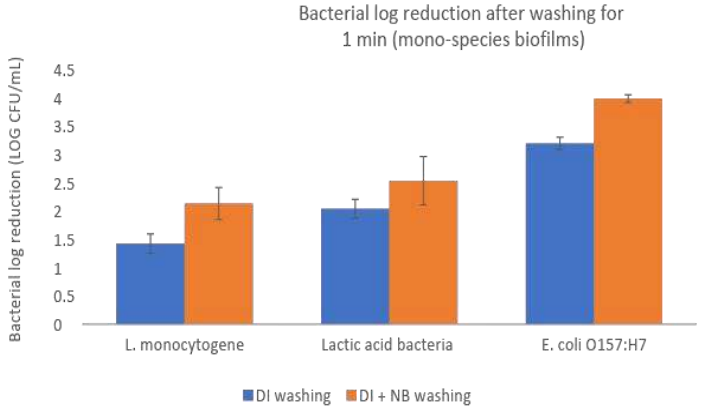
- Nanobubbles can significantly eliminate microbial biofilms on surfaces
- Nanobubbles will burst with Ultrasound and kill the bacteria
- Nanobubbles efficacy will be enhanced in combination with chlorine-based sanitizers
- Nanobubbles bacterial removal efficacy will be improved with shear force
- Nanobubbles can induce microbial injury
- Reduce chemical applications
- Increase sanitizers delivery to bacteria
- Penetrate into biofilms
- Proper for water treatment
- Proper for agricultural water treatment
- Could be used for removing biofilms from pipes
- Membrane sanitation in food industry



Biofilm Remediation

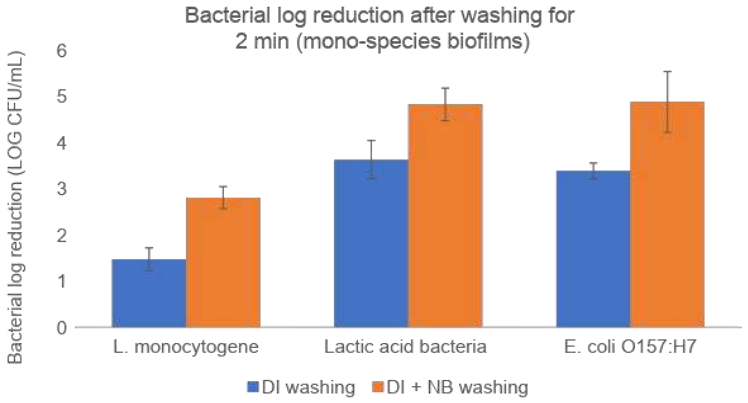
SIO nanobubbles penetrate and physically remove microbial biofilm on surfaces while preventing re-formation.

Study: Reduce Surface Bacterial Contamination with Nanobubbles to Enhance Sanitation in Dairy Processing Facilities



DI water spray (1 min)
- 1.4 log of *L. monocytogenes*
- 2.0 log of Lactic acid bacteria
- 3.2 log of *E. coli* 0157:H7

DI + MNBs spray (1 min)
- 2.1 log of *L. monocytogenes*
- 2.5 log of Lactic acid bacteria
- 4.0 log of *E. coli* 0157:H7



DI water spray (2 min)
- 1.5 log of *L. monocytogenes*
- 3.6 log of Lactic acid bacteria
- 3.4 log of *E. coli* 0157:H7

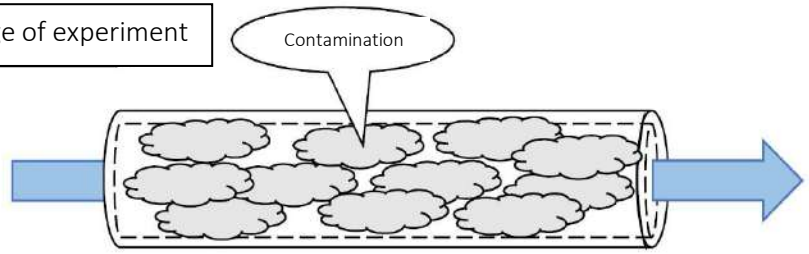
DI + MNBs spray (2 min)
- 2.8 log of *L. monocytogenes*
- 4.8 log of Lactic acid bacteria
- 4.9 log of *E. coli* 0157:H7

Cleaning Process Trial

Tokyo Metropolitan University

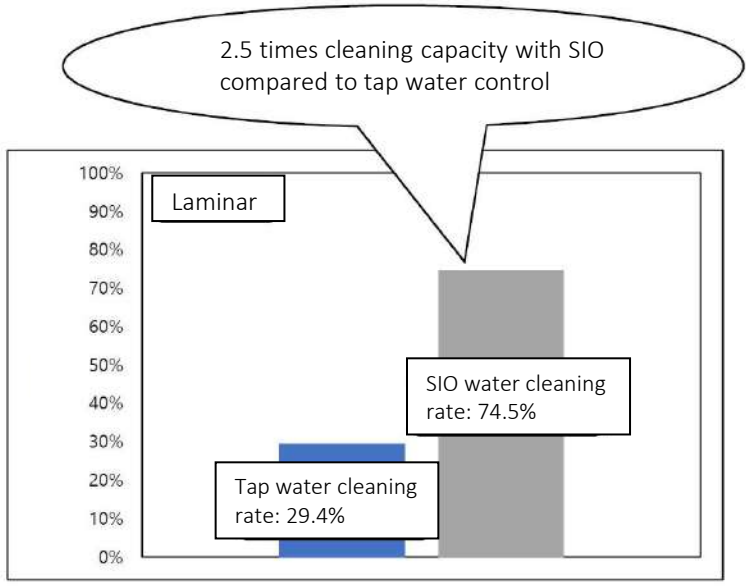
TOKYO METROPOLITAN UNIVERSITY

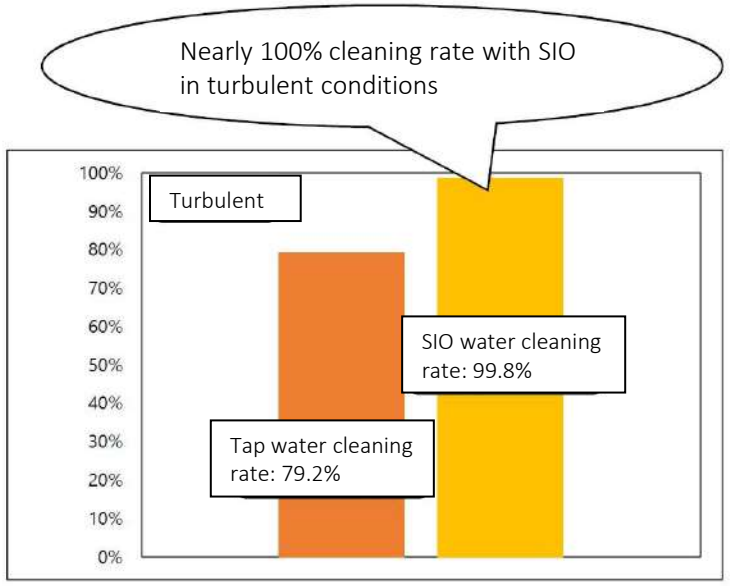
Image of experiment



Contamination was applied to the inside of the pipe and tap water and SIO Nanobubbles water were passed through it. The cleaning rate was calculated by measuring the mass before and after the water flow.

The SIO Nanobubbles water demonstrated higher cleaning ability in both laminar flow and turbulent flow conditions.





- SIO nanobubble water was created in a batch tank by running water through an SIO MS 25 unit at a flow rate of 23 LPM and pressure of 2 bar prior to applying to dirty piping.
- Reynold's number of laminar flow and turbulent flow were 1500 and 7000 respectfully during cleaning process.

Fine Bubble Industries Association

FBIA

West Nippon Express
Commercial bathroom cleaning
Tokyo Station

- Reduced cleaning time by 40%
- Reduced amount of water needed by 90%
- Reduced amount of cleaning detergent needed by 60%

--> Annual cleaning budget: $ 185 million.
Labor costs roughly 31.5%.
Material costs = 68.5%.

--> Cleaning manpower 919 hourly employees working 40 hours per week + 103 facility supervisors @ $ 41,600 annual salary.

Sustainable Applications

AGRICULTURE & HORTICULTURE
Heathier, higher yield crops using less chemicals.

AQUACULTURE
Reduced operational costs. Improved fish & ecosystem health.

BIOSCIENCE
Increased efficiency in drug delivery and treatment.

CEMENT
Increase compression and tensile strength. Shorter setting times.

CLEANING
Reduces amount of water and cleaning detergent needed. Reduces labor.

CLEAN IN PLACE
Reduction in chemical use. Energy savings. Reduction in time

COOLING TOWERS
Increase heat transfer & energy efficiency. Mitigate biofilm and eliminate odors

DENTAL
Prevent biofilm and other microbial contamination of dental unit water.

LAKES & PONDS
Algae mitigation, Healthier fish, less odor.

LIVESTOCK
Improved animal health, reduced stress levels, faster growth rates.

PRECISION MACHINING
Machines run faster ,increased tool life and heat transfer

WASTEWATER
Improved biological and chemical oxidation processes. Enhances physical separation

WCP Facility Solutions

Your Partner for Safe and Healthy Facilities

Thank You For Your Interest !

Ken Horton
President
WCP Facility Solutions
Tel: 480.861.1427
email: ken@wcpfacility.com
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