LESS TOIL AND TROUBLE WITH TINY BUBBLES

ULTRAFINE BUBBLES induce new properties that can change how we can use water.

Tiny bubbles of gas — less than a micrometre in size — could spawn a multi-billion-dollar industry, by transforming the normal characteristics of water and other liquids, making them potentially useful in diverse fields, including agriculture, cleaning, hydroponics and water treatment.

Fine bubbles are classified into microbubbles (1–100 micrometres in diameter) and ultrafine bubbles (smaller than 1 micrometre in diameter). Unlike the bubbles in soda drinks and champagne, ultrafine bubbles are invisible to the naked eye. And this size difference is reflected in how they behave.

▲ **The use of fine bubbles in wastewater treatment could speed up aeration of sludge and reduce energy use.**

"Ultrafine bubbles have very different properties from larger bubbles," says Takashi Hata, a professor at Kochi National College of Technology in Shikoku, Japan. In particular, they are neutrally buoyant, can hold a large electric charge, and can be held in place by surface tension.

Far from being scientific curiosities, ultrafine bubbles have potential for practical applications, such as industrial cleaning, offering many advantages. "Using water containing ultrafine bubbles for cleaning could reduce the amount of water needed and also decrease, or even eliminate, detergents and chemicals," explains Masateru Hirae, senior managing director at Science-Co Ltd, an Osaka-based manufacturer of water purifiers and ultrafine-bubble products.

FAR FROM BEING SCIENTIFIC CURIOSITIES, ULTRAFINE BUBBLES HAVE POTENTIAL FOR PRACTICAL APPLICATIONS

This has a flow-on effect, Hirae says, reducing both the energy used to treat water and the environmental impact of chemicals. He notes that ultrafine-bubble technology can contribute to at least four of the 17 United Nations' Sustainable Development Goals (SDGs), namely SDG 6 (clean water and sanitation), SDG 12 (responsible consumption and production) and SDGs 14 and 15 (life below water and life on land, respectively).

THE SCIENCE OF BUBBLES

Part of the power of ultrafine bubbles lies in their high surface area. "For the same total bubble volume, ultrafine bubbles will have a much greater total surface area than larger bubbles," explains Hata. "This greatly increases their chemical reactivity, physical adsorption and mass transport at gas–liquid interfaces."

Abstract Aerial Art/DigitalVision/Getty

The buoyancy of bubbles also depends on their size. Visible bubbles of gas with diameters greater than 100 micrometres rise rapidly to the surface of a liquid, while microbubbles rise more slowly. In contrast, ultrafine bubbles have a low buoyancy and can remain suspended in water for months.

These properties can be used in many applications — for example, in wastewater processing, the much slower rise of fine bubbles through 'activated sludge' means oxygen transfers to wastewater more slowly, speeding up sludge aeration while reducing energy use; likewise, the slow rise of fine bubbles in aquaculture settings gives more reaction time, and it has been shown to improve the levels of dissolved oxygen in a well-stocked indoor shrimp farm.

▲ **Shower heads that generate fine bubbles could reduce the amount of detergents needed, benefiting the environment and consumers.**

Scientists and engineers generate ultrafine bubbles using hydraulic and electrochemical systems to cause liquids to oscillate. Because they are invisible to the naked eye, it has been challenging to measure and study ultrafine bubbles, but new laser diffraction and scattering methods have recently allowed them to be studied with more precision.

AN EXPANDING INDUSTRY

The potential of ultrafine bubbles for industrial applications is just beginning to be tapped. A 2022 report by Research and Markets, a market research company, predicts that the manufacture and supply of ultrafine bubbles will expand to a multi-billion dollar industry over the coming decade, with applications across agriculture, aquaculture, hydroponics and water treatment.

One area that stands to benefit significantly from ultrafine bubbles is agriculture. A hydroponics nutrient solution containing them accelerated the growth of lettuce seedlings over two weeks by a factor of 1.4[1], while cabbage plants, fish and mice showed improved growth rates after consuming water infused with ultrafine bubbles[2]. The mechanism has yet to be clarified, but the researchers speculate that plants and animals may have more energy available for growth due to increased metabolism and less breathing under hyperoxia conditions. And including ultrafine bubbles in water applied to soybean seedlings suffering stress from nutrient deficiency improved their growth[3].

Water containing ultrafine bubbles of ozone is also being used to clean and sterilize equipment used for artificial kidney dialysis[4]. It has been shown to have the same bactericidal effects as the detergents sodium hypochlorite and peracetic acid, which are typically used to clean and disinfect organic matter. But the ozone-containing water does not suffer from corrosiveness, strong odour and potential for skin irritation associated with those detergents.

Further applications could emerge following the discovery that ultrafine bubbles can inhibit the cell growth of certain bacteria, adding to the utility of using ultrafine bubbles of oxygen in wastewater treatment, which can kill unwanted bacteria at the same time as improving aeration. Fine bubbles of ozone can also be used to kill a pathogenic fish bacteria in a freshwater aquaculture system[5].

And fine bubbles are promising for domestic uses as well. Science-Co Ltd has been developing and manufacturing fine-bubble products for consumers, including bathtubs, shower heads and taps since 2007. "Fine bubbles in water used for washing can adhere to dirt and grime attached to the skin, similar to soap, allowing users to reduce or eliminate detergents and disinfectants that can both irritate skin, and also add to water pollution," says Hirae. Microbubbles in water used for bathing have also been shown to remove dead skin.

Taps that generate ultrafine bubbles may also improve domestic fabric laundering, Hirae says, with research showing that fine bubbles in water can enhance the effect of surfactants, reducing the amount needed for washing clothes and potentially reducing waste water from household laundry.

Ultrafine bubbles not only have the potential to improve life on Earth. Scientists at the University of Maine are now exploring the use of fine bubbles to enhance life-support functions on spaceships, such as water treatment and algae growth. ■

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