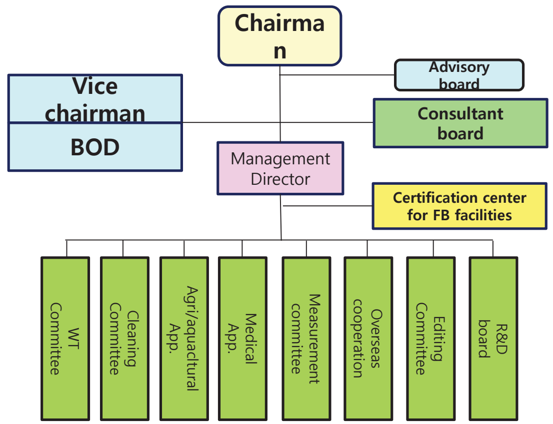
Ⅱ Status in agricultural application

Korea FBIA



1. Summary in application for agriculture

- To increase DO
- To increase mass transfer
- To function in inactivation and sterilization against pathogens

- Increase in growth of plant
- Remove residual pesticides around plants
- Improve growth rate, numbers, quality, freshness, impurity
- Facilitate in eco-friendly cultivating agricultural products, organo-products, rapid cultivation, purification of agricultural water
- Use in smart farm

National Mirror Committee on Fine bubble Technology (ISO/TC281) (2019.4.25 ~)

No	Organization	Position	Name
1	Inha Univ (KFBIA, Consultant Board)	Prof.	Chang Gyn KIM
2	Ilsung Cop. (KFBIA, Director)	CEO	Youngbae JI
3	Daehyun EnTEC Co. Ltd. (KFBIA member)	CEO	Jungyu KIM
4	SBENE Co. Ltd (KFBIA, Director)	CEO	Minhee Lee
5	Kyunghee Univ. (KFBIA, Director)	Prof.	Haedong
6	New Water Tec Co. Ltd. (KFBIA, President)	Senior Researcher	Young Cheol PARK
7	Haesung Enginering Co. Ltd. (KFBIA member)	Director	Taejin YOON
8	Sewon EnE Co. Ltd. (KFBIA, Director)	CEO	Sungyong CHOI
9	Shinansan Univ.	Prof.	NamChul CHO
10	Seoul Univ. (KFBIA, Consultant Board)	Prof.	Hyunju PARK

Increase of Dissolved Oxygen and Temp. Control in the Aquacultural Farm (NWT, 2019)

* DO increase effect : > 30%; Temp. control Effect (≒ 0.5°C: July water temp. of Chunsu Bay: >28° C: to reduce fish mortality)

Ⅲ Case studies

04 Application of fine bubble technology in agriculture

Water culture

2. Cases in application for agriculture

Washing application of Fine bubble Technology in Agricultural field (Korea food re. Inst., 2019)

	Raw Vegetable	Tap water Washing	Microbubble water Washing	Storage Period(10°C)
Romaine Lettuce				7days
Lettuce				10days
Tango				8days

Decrease rate of surface micro-organism: 90~99%

=> Anti-browning effect after washing, increase of commercial value

4. Microbubbles Increase Glucosinolate Contents of Watercress (Nasturtium officinale R. Br.) Grown in Hydroponic Cultivation, Department of Horticulture, Chungnam National University, Agricutural Drought Mitigation Center, Korea Rural Corporation (KRC), Korea (2019)
5. A Good Nursery System of Strawberry in the Ebb and Flow Cultivation with Micro-bubble, Agricultural company R2Farms Inc., Department of Precision Mechanical Engineering, College of Science and Technology, Kyungpook National University, Korea(2017)
6. The Effect of Environmental Fine Bubble on the Production of Ginsenoside during the Growth Period of Ginseng Cultivation, Korea National College of Agriculture and Fisheries(2017)
7. A Convergent Study on Applying a fine bubble to ginseng seedling cultivation, Korea National College of Agriculture and Fisheries(2017)

04 Application of fine bubble technology in agriculture

Promote growth

Differences in Growth of young ginseng seedling (B : Fine bubble water treatment during growth, C : General water treatment during growth)

A Convergent Study on Applying a fine bubble to ginseng seedling cultivation

Chul-Hyun Ahn[1]

[1]Korea National College of Agriculture and Fisheries

Journal of the Korea Convergence Society Vol. 8. No. 8, pp. 191-196, 2017

Microbubbles Increase Glucosinolate Contents of Watercress (Nasturtium *officinale* R. Br.) Grown in Hydroponic Cultivation

Gwonjeong Bok[1], Jaeyun Choi[1], Hyunjoo Lee[1], Kwangya Lee[2], and Jongseok Park[1]*

[1]Department of Horticulture, Chungnam National University, Daejeon 34134, Korea
[2]Agricutural Drought Mitigation Center, Korea Rural Corporation (KRC), Daejeon 35260, Korea

Protected Horticulture and Plant Factory, Vol. 28, No. 2:158-165, April (2019) pISSN 2288-0992
DOI https://doi.org/10.12791/KSBEC.2019.28.2.158 eISSN 2288-100X

8. Sterilization Efficacy of Washing Method Using Based on Microbubbles and Electrolyzed Water on Various Vegetables, Korea Testing & Research Institute, Dept. of Food Science and Technology, Chungbuk National University, Korea(2011)
9. Study on reduction of microbial hazard of fresh-cut vegetables using microbubbles, Korea Food Research Institute(2010)
10. Washing Effect of Micro-Bubbles and Changes in Quality of Lettuce (Lactuca sativa L.) during Storage, Korea Food Research Institute, Korea (2009)

IV Summary

1. A study on application of micro-bubble system for drainage reuse in solid medium cultivation, Department of Agricultural Engineering, National Institute of Agricultural Sciences, Korea(2020)
2. Effect of combined washing with heat and microbubbles water on the quality of fresh-cut lettuce, Technical Service Center, Korea Food Research Institute, Department of Food Biotechnology, Korea University of Science & Technology, Research Group of Consumer Safety, Korea Food Research Institute, Food Analysis Center, Korea Food Research Institute, Korea(2020)
3. Effect of Fine Bubble Treatment on the Growth of Two-year-old Ginseng Department of General Education, Korea National College of Agriculture and Fisheries, Korea(2017)

Proposed Solution:

- Treatment of PCW by microbubble-catalytic ozonation processes

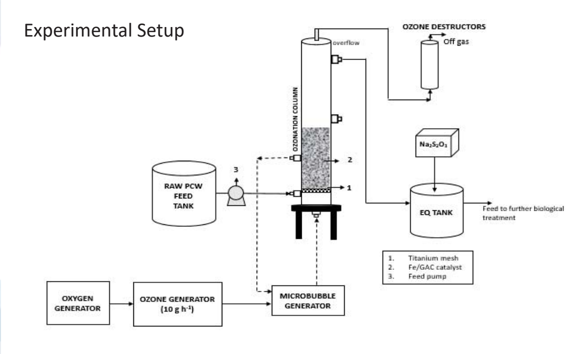
Raw PCW

↓

AOP Pre-treatments
- Conventional Ozonation
- Microbubble Ozonation
- Microbubble + Catalytic Ozonation

↓

Biological Process



APEC Workshop I

j) 19:00-19:15

Novel Development & Application of FBT in Singapore

Dr Chee-Wee Lee

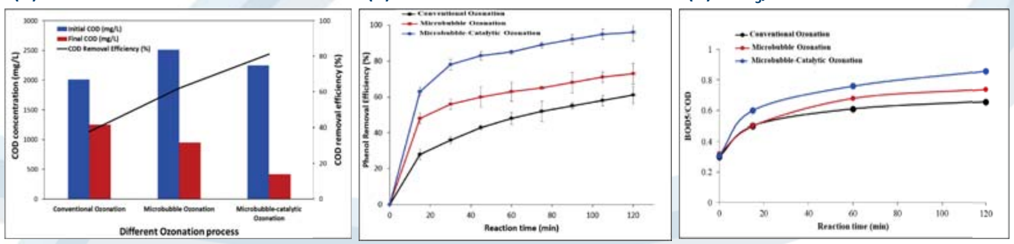
Aquaculture Innovation Centre, Temasek Polytechnic

January 21, 2021 **Singapore**

Results:

- Microbubble-catalytic ozonation can achieved
  - 81% COD & 97% phenols removal efficiency
  - highest BOD_5/COD ratio (enhancement from 0.31 to 0.87)

(A) COD **(B) Phenol** **(A) BOD_5/COD**



L. Jothinathan, Q.Q. Cai, S.L. Ong, and J.Y. Hu (2021). *Organics removal in high strength petrochemical wastewater with combined microbubble-catalytic ozonation process*. Chemo Sphere 263: 127980.

Project: Combined Microbubble-Catalytic Ozonation Process For High Strength Petrochemical Wastewater Treatment

Drs L. Jothinathan, QQ. Cai, S.L. Ong & J.Y. Hu

Centre for Water Research, Department of Civil & Environmental Engineering, National University of Singapore, Singapore

Current Scenario:

- Phenol is used as raw material in many industries such as plastic and petrochemical industries etc
- Petrochemical wastewater contains high levels of recalcitrant organic compounds that impose huge challenges on conventional wastewater treatment processes due to their inhibition effects and high treatment cost
- Advanced oxidation processes (AOPs) was proven to be efficient for degrading recalcitrant organics

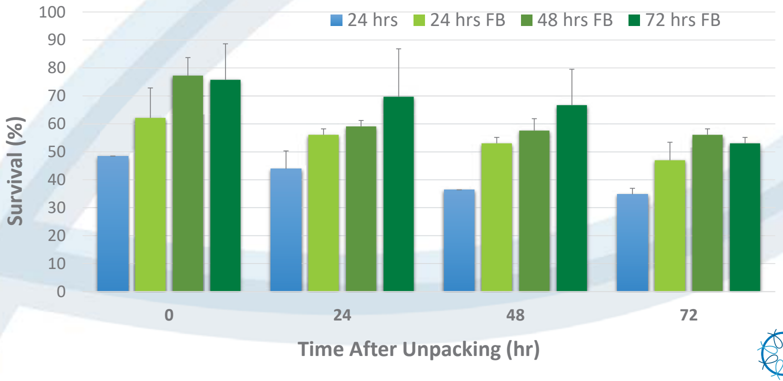
Characteristics of Petrochemical Wastewater (PCW)

Parameters	Value
COD (mg/L)	1,900-2,800
BOD_5/COD	0.25-0.35
TOC (mg/L)	600-900
pH	7.0-7.5
Phenols (mg/L)	150-250
TDS (mg/L)	1,500-1,800

aquaculture innovation centre

Results:

- Shrimps can survive without water for >12 hrs with proper conditioning
- Animals pre-conditioned in FB water prior packaging recovered better from the logistic stress



Project: Waterless Shipping of Live Shrimps with Fine Bubble Technology

Aquaculture Innovation Centre,
Temasek Polytechnic, Singapore

Current Scenario:

- Shipping live shrimps in a waterless condition is a practical, profitable but challenging endeavour
- Extremely dependent on transit environment to maintain
  - Optimum selling conditions
  - Minimum mortality
- The whole process is extremely stressful to animals
- Needing special pre-conditioning protocol to mitigate logistic and environmental stress and abuse

Project: A New Fine Bubble Cleaning Method on Aerospace Parts

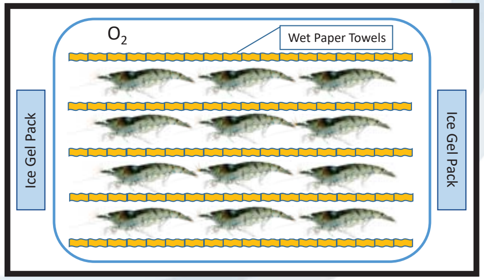
Dr He Wei
MPD/SIMTech, A*Star, Singapore

Current Scenario:

- Cleaning processes for parts of aero-engine use large quantities of chemicals which are not environmental friendly
- The contamination of aero-engines can be tough to be removed
- The cleaning mechanism of fine bubble is mainly through the interaction between the bubbles and the contaminations on the surface

Experimental Design:

- Species: *L. vannamei*
- Healthy animals were used
- Pre-conditioned at 5 ppt salinity in **normal** or **FB water**
- Cooled down from 30°C to 15°C over 2 hrs using cooler
- Packed shrimps (30 g size) in waterless styrofoam box
- Maintaining oxygenated, cool and humid condition
  - From 16.5°C to 19.5°C over **12 hrs**



Technology Gap:

- The slow interaction between the fine bubbles and the contamination on the surface

Proposed Solution:

- To use acoustic meta-surface to focus the ultrasonic energy to enhance the interaction between the fine bubbles and contamination on the surface to improve the cleaning effect on the aero-engine parts
  - i.e. integration of the acoustic meta-surface and ultrasonic source to drive the fine bubbles
- To achieve energy efficiency; less water usage; no chemical usage; less waste water discharge etc.

aquaculture innovation centre

Thank You

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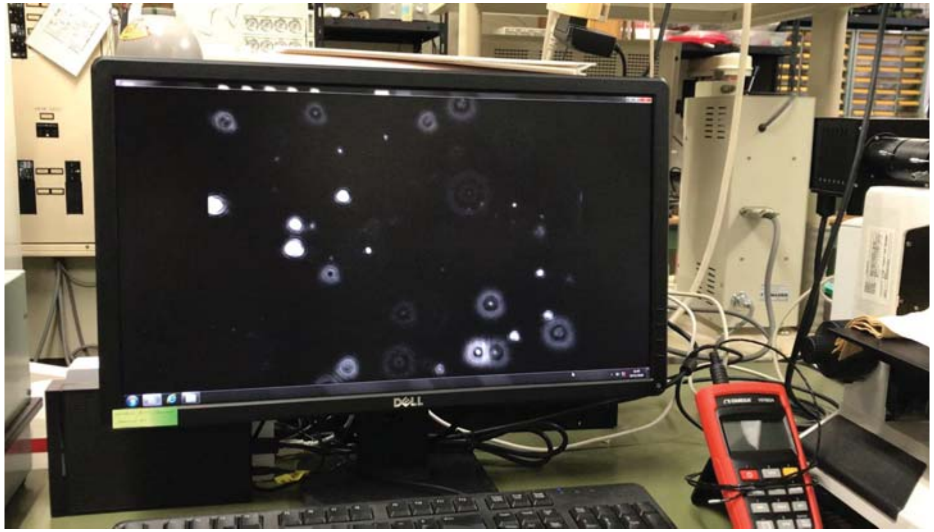
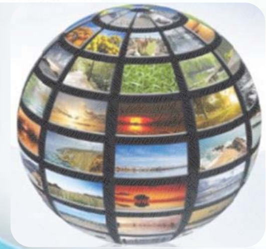
Air Ultrafine bubbles observed



APEC Workshop I

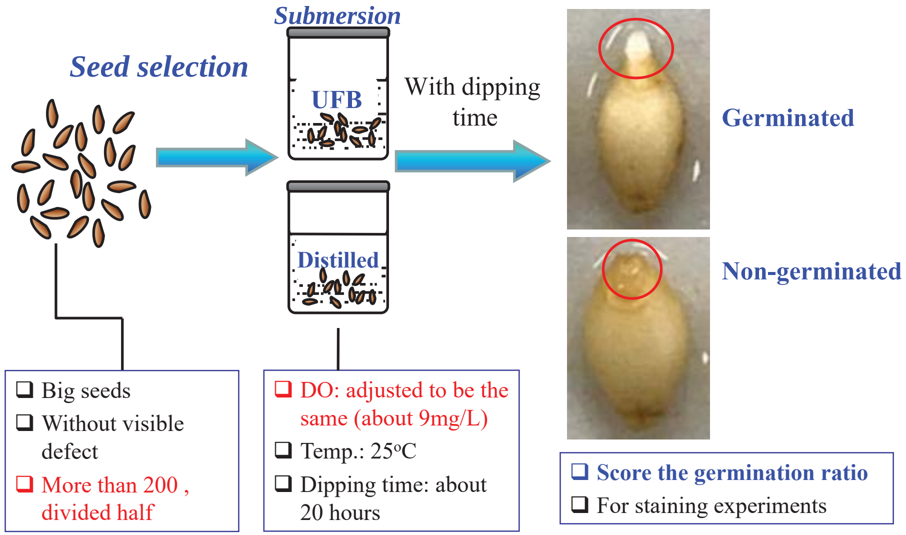


I) 19:30-19:45 Promotion effect of air ultrafine bubbles on barley seed germination

Dr. Seiichi Oshita,
The University of Tokyo
Japan

January 21, 2021

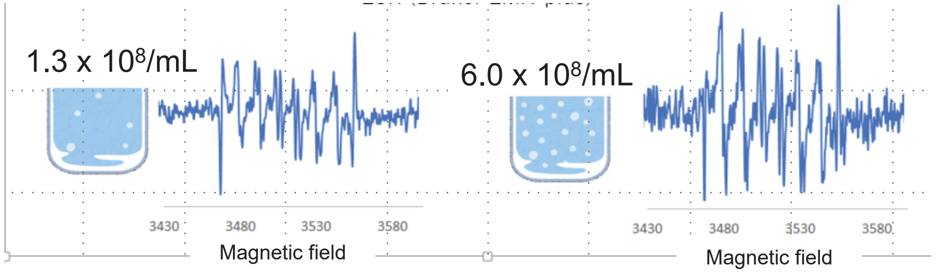
Procedure of the observation of barley seed germination



Objectives

- Apply UFB water to seed in order to confirm the promotion of germination.
- Mechanism of promotion effect
- Minimum viable number concentration of UFBs for promoting the germination of barley seeds

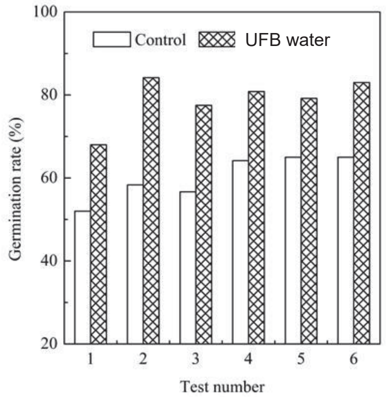
ESR signal intensities of ・OH of different UFB number concentrations



ESR: EMX-plus (Bruker)
CYPMPO was used as a spin trapping reagent.

Promotion of seed germination at the same DO (25°C, 20h submersion)

DO: 9 mg L^{-1}



DO of ultrafine bubble water was adjusted to the same as control water by introducing N_2.

Germination ratio
Distilled water: **59%**
UFB water: **78%**

S. Liu et al. (2013), *Chemical Engineering Science*

Possible mechanism of seed germination promotion

- Ultrafine bubbles generate ROS (・OH).

↓

- ROS outside seeds (・OH) play as a signal molecule and provoke the generation of ROS ($O_2^{\cdot -}$) inside seeds.

↓

- α-amylase (starch degrading enzyme) activity increases.

↓

- Seed germination is promoted.

Pergamon
Free Radical Biology & Medicine, Vol. 18, No. 4, pp. 775–794, 1995

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Review Article

SUPEROXIDE AND HYDROGEN PEROXIDE IN RELATION TO MAMMALIAN CELL PROLIFERATION

Roy H. Burdon
Department of Bioscience and Biotechnology, University of Strathclyde, Glasgow, Scotland, UK

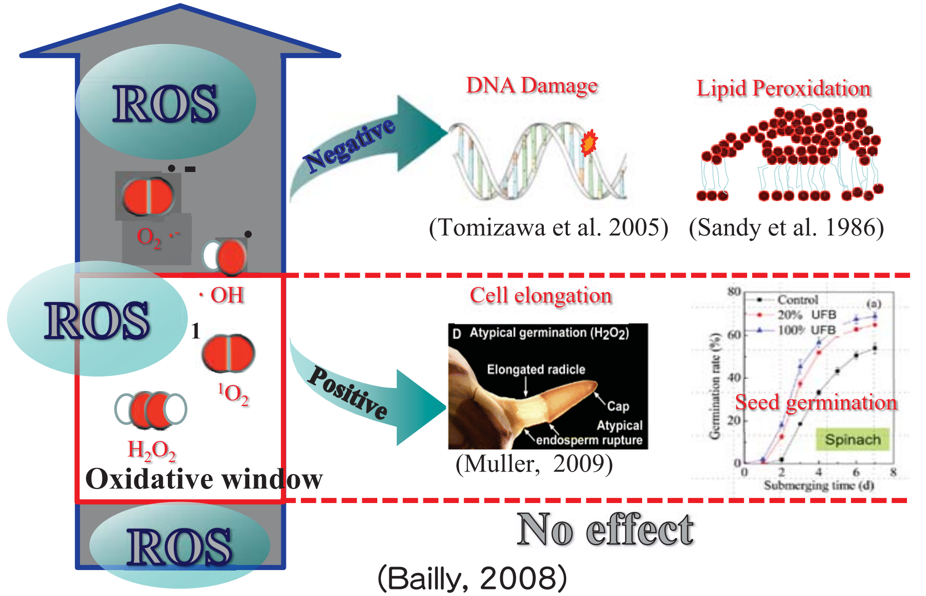
Table 1. Cell Types in Which Superoxide or Hydrogen Peroxide Elicit Growth Responses

Addition	Cell Type	Reference
Superoxide anions	human fibroblasts	29
	hamster fibroblasts (BHK-21)	26,27
	human histiocytic leukeamia cells	33
	human amnion cells	31
	Balb/3T3 cells	30, 37
	mouse epidermal cells (JB6)	32
	rat colonic epithelial cells	34
Hydrogen peroxide	mouse osteoblastic cells (MC3T3)	35, 101

ROS (Reactive Oxygen Species)

superoxide and hydrogen peroxide can each stimulate growth and growth responses in a considerable variety of cultured mammalian cell types when added exogenously (Table 1).

Role of ROS



(Bailly, 2008)

Concentration of ROS ($O_2^{\cdot -}$) in seed

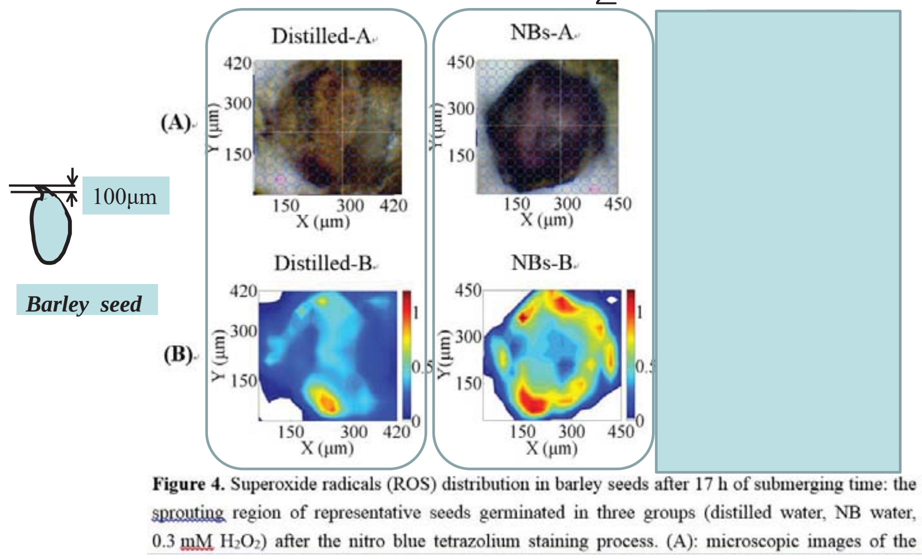


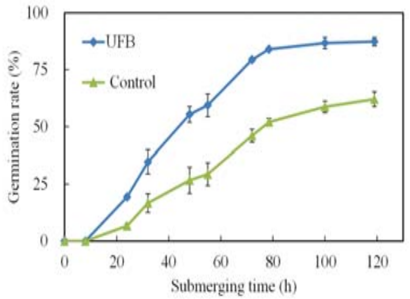
Figure 4. Superoxide radicals (ROS) distribution in barley seeds after 17 h of submerging time: the sprouting region of representative seeds germinated in three groups (distilled water, NB water, 0.3 mM H_2O_2) after the nitro blue tetrazolium staining process. (A): microscopic images of the

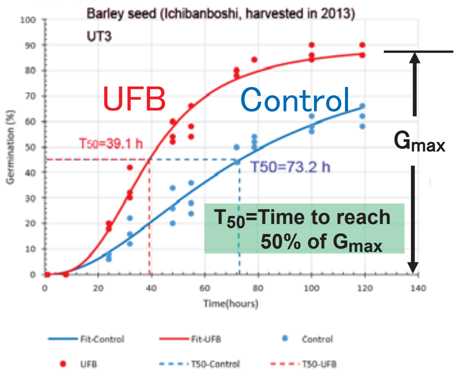
(Liu et al.,, ACS Sustainable Chem. Eng., 2016, 4 (3), pp 1347–1353)

Analysis of germination promotion by using s-shaped model (Ritz et al., PLOS ONE, 2015)

s-shaped model (dose-response model)

$$G(t_i) = \frac{G_{max}}{1+\exp[B\{\log(t_i)-\log(T_{50})\}]} \quad \text{------- (1)}$$





(T_{50} = time required to reach 50% of maximum germination rate)

α-amylase activity (Barley seeds)

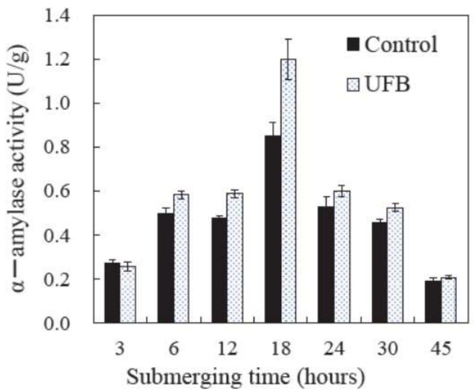


Fig. 13 α -amylase activity of seeds submerged in UFB and Control water.

Oshita et al., Japanese J. Multiphase Flow, 34 (1), 194-204, 2020

Thank you for your attention!

Acknowledgement to financial support by
METI International Standardization Program, FBIA and
Grant in Aid for Scientific Research (B: 18H02302) by JSPS, Japan.

Table 1 Promotion effect of UFB on germination of barley seeds

Exponent	Number concentration (/ml)	Storage duration (month)	T_{50}, control (h)	T_{50}, UFB (h)	G_{max}, Control (%)	G_{max}, UFB (%)	Significant difference	P±Δ P
6	The UFB water with the bubble number concentration of the order of 10^6/ml did not show any promotion effect on seed germination.						NO	
7	$1,1 \times 10^7$	25	20,4	19,6	92,0	97,0	NO	3,9±4,2
	$3,1 \times 10^7$	26	20,7	18,9	95,0	92,0	YES	8,7±1,7
	$3,5 \times 10^7$	25	20,4	18,7	92,0	95,0	NO	8,3±3,9
	$7,2 \times 10^7$	11	14,6	13,0	92,0	94,0	YES	11,0±1,6
8	$1,5 \times 10^8$	45	73,2	39,1	62,0	87,3	YES	46,6±2,2
	$2,0 \times 10^8$	44	102,8	49,7	49,3	82,7	YES	51,7±1,9
	$2,3 \times 10^8$	38	46,4	39,6	37,3	44,0	YES	14,7±5,0
	$2,4 \times 10^8$	34	22,0	20,9	91,3	91,3	YES	5,0±1,1
	$5,6 \times 10^8$	34	22,0	20,7	91,3	93,3	YES	5,9±1,5
	$6,6 \times 10^8$	38	77,6	37,9	37,3	76,7	YES	51,2±6,9
9	$1,4 \times 10^9$	27	15.2	13.2	99.3	97.3	YES	13.2±1.8

AIST

APEC Workshop I

FBIA

m)19:45-20:15

Development of Application Standards and Cooperation by data sharing

Akira YABE, Dr. Eng.
National Institute of Advanced Industrial Science and Technology (AIST)
& Dr. Mitsuru TANAKA, FBIA Japan

January 21, 2021 **Japan**

Conclusions

1) UFB water can promote seed germination without using any chemicals.

2) ROS (・OH) generated by UFB provokes the seed germination.

3) Minimum viable number concentration of UFBs for promoting the germination of barley seeds is in the range of the order of 10 to the 8^{th} power.

"Development of application standards and cooperation by data sharing"

0.5 h (Dr.YABE & Dr.TANAKA)

Introduction of ISO Technical Specification on "Test method for evaluating the growth promotion of hydroponically grown lettuce" . Discussions on cooperation for Agro- and aqua- farming and water treatment applications of FBT by data sharing

ABSTRACT

The standardization of test method for application of fine bubble technology, in particular in agro-, aqua- farming and water treatment area is time and cost consuming and has great variety of objects, such as species or environments. In practice, standardization requires generalization over a certain and agreed scope, while individual R&D for application of fine bubbles is focused on a specific object. In order to accelerate the standardization, strategic cooperation among individual R&Ds will be effective, by mutually sharing information of R&Ds. For example, among the deliverables of ISO activity, "Technical Report" (assigned to "for data") can be used for announcing the test procedures and result of he test to public in order to benefit the formation of generalization idea and facilitate development of modified test procedure.

Basic information describing individual R&D, namely data, will be proposed to facilitate such cooperation among R&Ds in APEC region.

APEC Workshop II

19:10-19:30

“a) Decolorization of Water by Ozone Fine Bubbles -Water Treatment "

Dr. Akira YABE

Special Advisor & Researcher Emeritus of National Institute of Advanced Industrial Science and Technology (AIST), Japan

September 16(Thu), 2021

INTERNATIONAL STANDARD ISO 20304-1:2020

Fine bubble technology — Water treatment applications — Part 1: Test method for evaluating ozone fine bubble water generating systems by the decolorization of methylene blue

1. Useful Ozone Fine bubble decolorization

Wastewater treatment, history over 30 - 40 years
The microbubble (size 50-100 μm) has a record of about 10 years

Oxidative dissolution

- Activated sludge (biological) treatment organic decomposition (COD, oil etc.)
- Persistent substance

Deodorizing

- Odor component, measures against foul odors

Decolorization

- Dyeing waste water, coloring water

Pumping out

- Air、oxygen bubble ⇒ Activated sludge (biological) treatment
- Ozone bubble ⇒ Decolorization、Deodorizing

Diversion of water、Operation of water

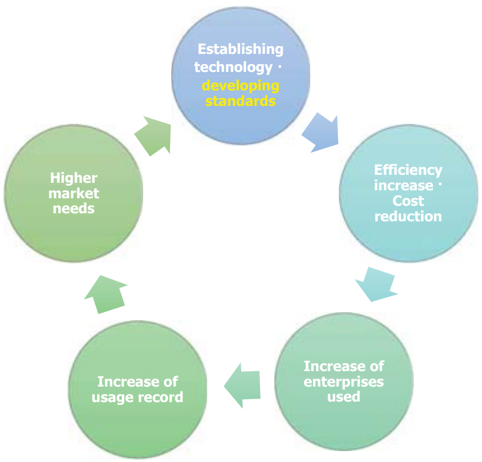
- Ozone bubble ⇒ Decolorization、Deodorizing、Advanced purification treatment

Puddle of water, Sea water

- Air、oxygen bubble ⇒ Supply of oxygen
- Ozone bubble ⇒ Decolorization、Oxidation treatment

Benefits of using Ozone Fine bubble

Decolorization using ozone is widely used



2. Purpose and flow of ISO Standard

【Necessity of standardization】

There are many cases of ozone fine bubble use cases, but there is no compliance standard

In Japan, the relation between the amount of ozone and the decolorization effect exists as a standard, but the evaluation method at the time of using fine bubbles has not been standardized yet

①Oxidative decomposition

Numericalization is possible by water quality analysis, but the mechanism is complicated

②Deodorizing

Numericalization is possible, but since evaluation is sensory evaluation, evaluation varies depending on the person

③Decolorization

It can be quantified by chromaticity and absorbance Evaluation in a short time

③Decolorization evaluation can be specified
Select this

Present state of Ozone decolorization technology

Present state of decolorization

① Bleaching method

Gas utilization, activated carbon adsorption, filtration, chemical treatment, etc

② Gas use

Ozone is mainstream

Micro bubble use (ejector method, air diffuser tube method as usual)

③ Ozone bleaching application field

- Industry (wastewater treatment)
  Dyeing factory, chemical factory, food factory, livestock-related etc.
- Public sector
  Water treatment plant (Advanced treatment), well water, reclaimed water, pool, aquarium etc.

1.Ozone Effect → Purify, Decompose, Decolor

2. +Diffuser Tube System →Enhance Ozone Effect

2. +Ozone fine bubble generating system
→Enhance Much more

3. Testing Decolorization performance of Ozone FB system
→standardized.

Cost Reduction
Swage water,
Industrial use water,
Water regeneration
Dye-house etc.,

Present state of Ozone decolorization technology

Present state of decolorization

① Bleaching method

Gas utilization, activated carbon adsorption, filtration, chemical treatment, etc

② Gas use

Ozone is mainstream

Micro bubble use (ejector method, air diffuser tube method as usual)

③ Ozone bleaching application field

- Industry (wastewater treatment)
  Dyeing factory, chemical factory, food factory, livestock-related etc.
- Public sector
  Water treatment plant (Advanced treatment), well water, reclaimed water, pool, aquarium etc.

absorbance

Logarithm ($\log_e$) of the ratio of the light intensity before to after the transmission of the test dye solution.

Indication residual concentration of dye in the solution.

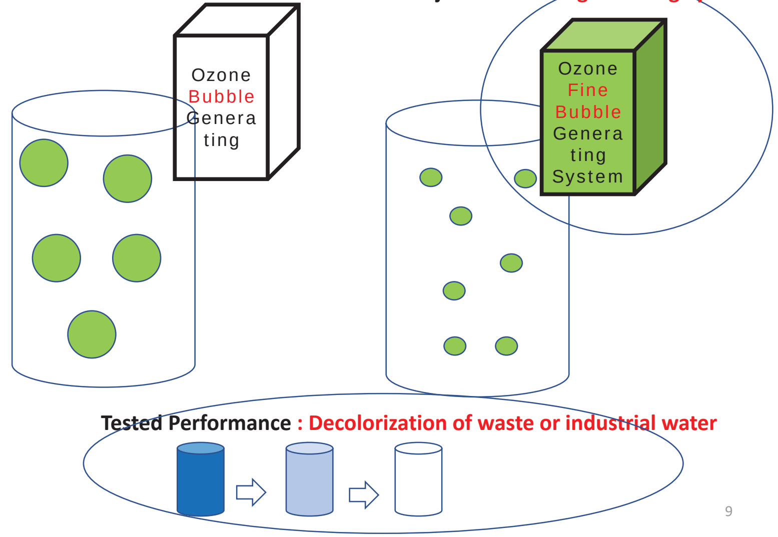
half-life of absorbance

duration for the change in absorbance to reach $\log_e(2/1)$ of the initial concentration, namely 50 % in intensity.

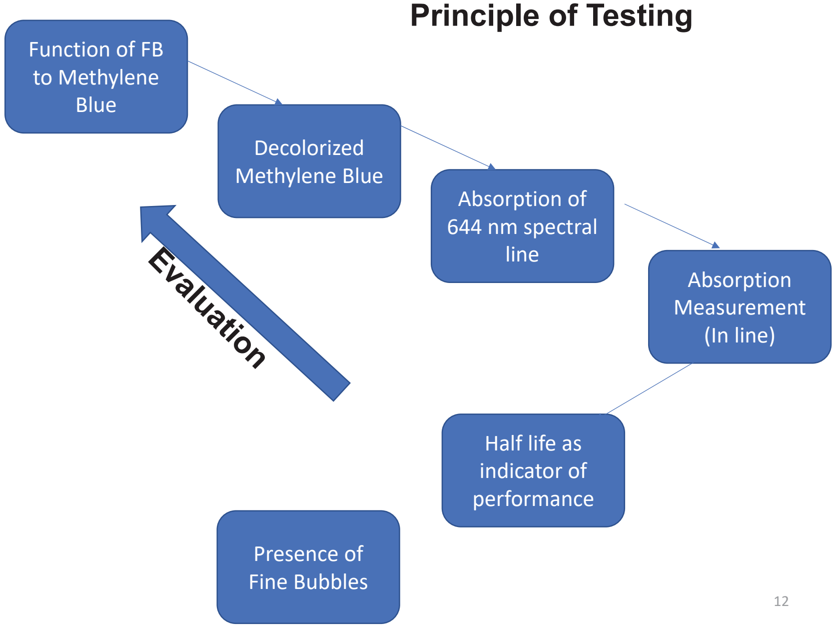
Measure of effectiveness of decolorization performance

Scope **This document specifies a test method to assess the performance of ozone fine bubble water generating systems used for decolorizing water-soluble dye in e.g. wastewater and industrial water**

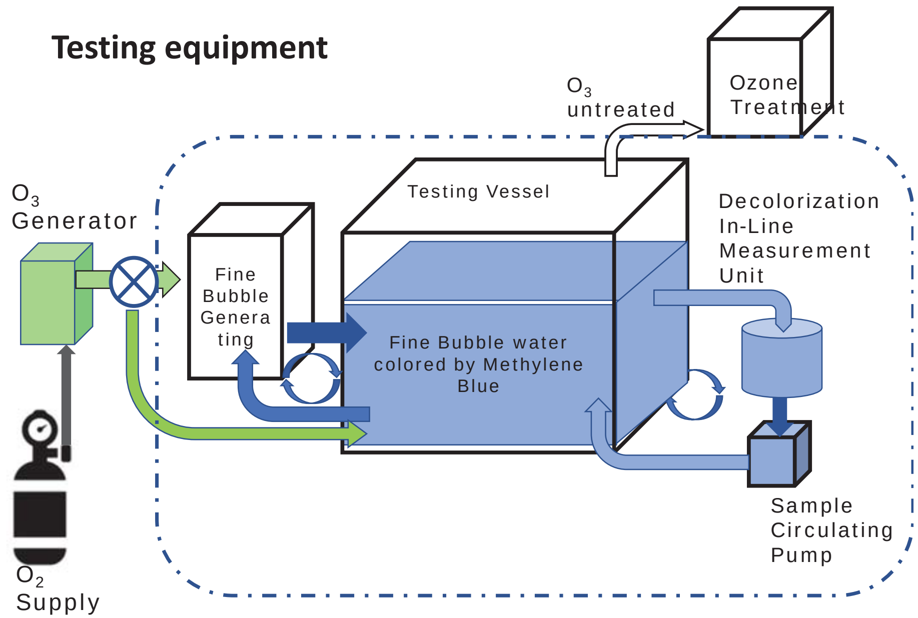
Tested Object :Ozone FB generating System



Principle of Testing



Testing equipment



Testing environment (Testing room)

Temperature: 23℃ ±3℃

Humidity(RH): 50% ±10%

Fine particulate free

Oxygen concentration: >90% (in case of O_2 supply)

Ozone Flow rate: 0.5 L/min (3 g/h)

Gas pressure to be reported.

FB generating system: Ozone oxidization resistive.

:Discharge FB water and Fed back in return

Test Tank: Sealed from Ozone leakage. Transparent walls. Capacity > 60 L.

Water depth 35 cm±1 cm at operation.

Bottom and Ceiling are identical structure.

Measuring instruments:

Ozone concentration measurement ISO 1431

Optical measuring instrument: in line structure with circulating pump for sampling of 7 L/min. flow rate.

pH meter: Calibrated

Water

Quality ISO 20480-2:2018,4.2.

Methylene Blue powder: ISO 10678

Standard solution: 0.15 g solution to 1 L water

Colored water

Dilute standard solution of 1 L to 60 L

pH: 8>pH>5

Initial temperature of water: 20℃±2℃

Absorbance measurements series

No. of Measurement cycle/ >5

No. of intensity measurement > 100/cycle

(Intensity vs time) recorded

Synchronize starting on measurement and generation

In case of off line instrument, measurement should be immediately after sampling.

Influence of fine bubbles directly to absorbance measurement shall be estimated or minimized by either

/Measurement on system operated without coloring

or /Measurement after decolorization is over by observing decolorization saturated.

Calibration of Absorption

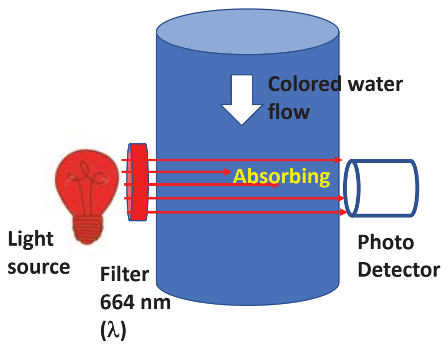
Prepare Calibrated standards with two less and three more than starting methylene blue concentration

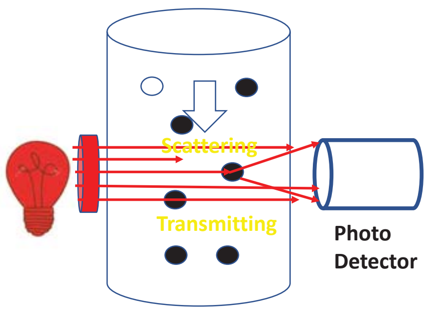
Measure three absorption for each standard

Calibration formula for absorption to concentration by regression

In-Line scheme puts the optical path into the transfer (sampling) piping

Absorbance is measured by using the ratio of detected intensity (C) to the intensity of light source (C_0).





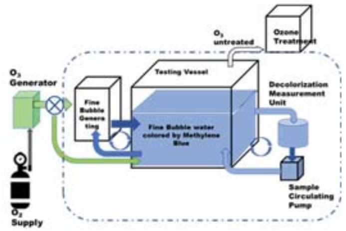
Absorbance Measurement

Decolorization Measurement

Scattering Measurement

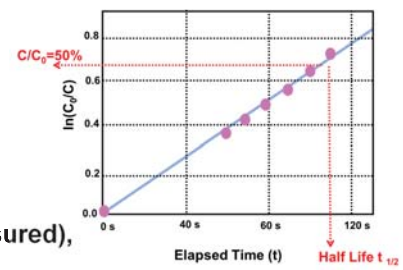
Turbidity Measurement

Operation Procedure



1. Installation of all equipment
2. Calibration of absorbance
3. Charge diluted water in the test vessel, 60 L and homogenize by stirring.
4. Measure initial absorbance (Initial absorbance measurement needs 1 minutes' warm up for steady operation of circulation system.)
5. Initialize ozone generator keeping the flow rate and gas pressure.
6. Connect ozone line to the FB generating system.
7. Start ozone generator and FB generating system.
8. Measure absorbance until intensity saturated.
9. Stop all equipment.
9. Keep safety of environmental ozone concentration during and after the operation.

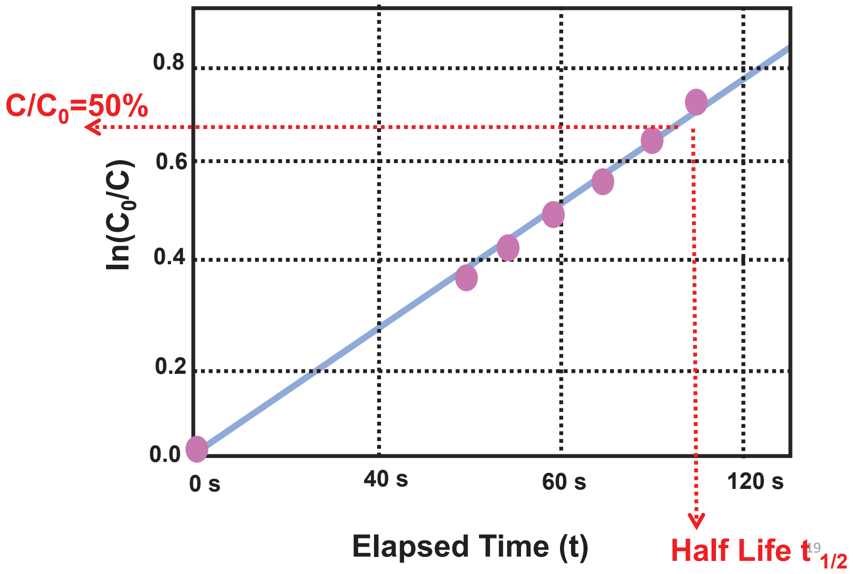
Analysis Procedure



Methylene blue concentration C(measured), C_0(initial).

1. Plot and preview measurement data points on absorption vs time sheet.
2. Find $t_{1/2}$ (half-life) with the C_0/C more than 2.
3. Fit the formula kt $=\log_e(C_0/C)$ to the dataset from t=0 to $t_{½}$
4. Evaluate the factor k.
5. Uncertainty evaluation: Dispersion of date and calibration uncertainties have to be summarized.
6. Size and number concentration of Fine Bubbles Refer to ISO 20480-2:2018

Progress of Decolorization and Linear Fitting for Half-Life

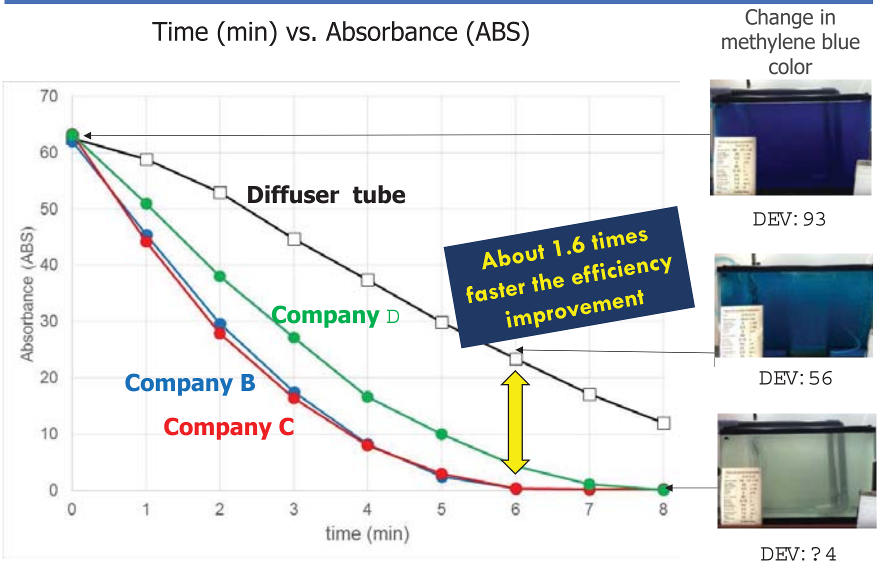


Test report

a) A reference ISO 20304-1;
b) Name of laboratory;
c)date of testing, place, test environment;
d) description of the fine bubble water generating system applied to the testing (identification, operation setting, major system parameters, water pressure, temperature, pH);
e) graph showing the decolorization effect test result
f) description of the decolorization effect test (fitting ratio $\log_e(C_0/C)/t$, uncertainty, ozone generation concentration);
g) description of test equipment used, description of the test procedure;
h) characteristics of fine bubble (size of fine bubble and number concentration)

Comparison between Diffuser tube and fine bubble water generator

Time (min) vs. Absorbance (ABS)

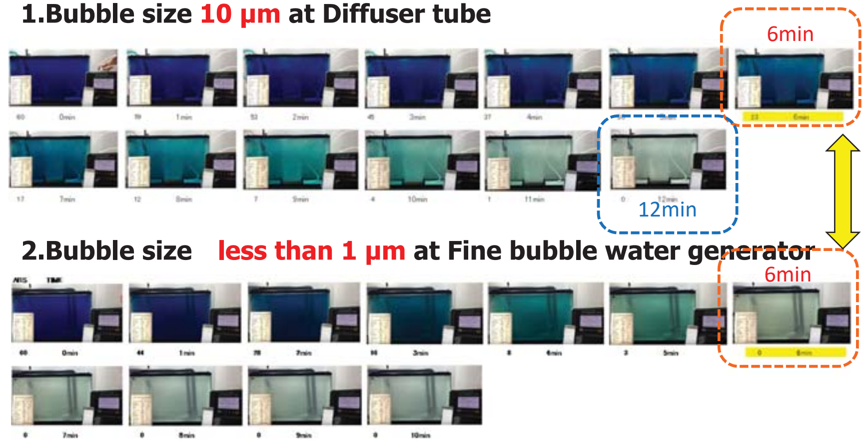


Comparison between Diffuser tube and fine bubble water generator

Time course of methylene blue color at 1 minute intervals

1.Bubble size 10 µm at Diffuser tube

2.Bubble size less than 1 µm at Fine bubble water generator



APEC-WS 2 presentation

"b) Introduction to dissolved air floatation (DAF) process and DAF bubble bed

Dr. HJ. KIM
IrehEnvit Corp., Tanhyeon-myeon, Paju-si, Gyeonggi-do, Korea
and Dr. CG. KIM
Professor at INHA University, Incheon, Korea

September 9(Thu), 2021

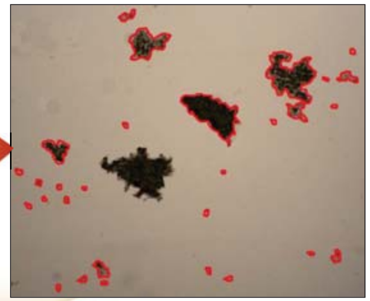
Example: Average Absorbance vs time elapsed data: Three FB generating systems are compared with Diffuser.

in sec. Time	Difuser	Un	System A	Un	System B	Un	System C	Un
0	62.5	1.7	62.1	2.1	63.3	2.7	63.3	1.05
60	58.6	2.7	43.6	2.1	48.2	1.6	43.2	1.95
120	52.1	3	27.5	1.9	36.5	1.3	26	2.2
360	44.6	2.7	15.1	1.3	25.9	0.7	14.1	1.95
480	37.4	2.4	6.5	0.9	16	1.7	6	1.45
600	30.6	2.1	1.2	0.01	8.3	1.5	1.5	0.01
730	24.5	1.9	0.2	0.01	2.9	0.2	0.2	0.01
840	18.8	1.8	0.2	0.01	1.1	0.1	0.2	0.01
960	13.6	2	0.2	0.01	0.2	0.01	0.1	0.01
1080	9.4	1.5	0.2	0.01	0.1	0.01	0.1	0.01
1200	6	1.2	0.2	0.01	0.2	0.01	0.1	0.01

Introduction to Dissolved Air Flotation (DAF) Process and DAF Bubble Bed

HYOUNGJUN KIM
IREHENVIT CORP.

Solid phase pollutant in water

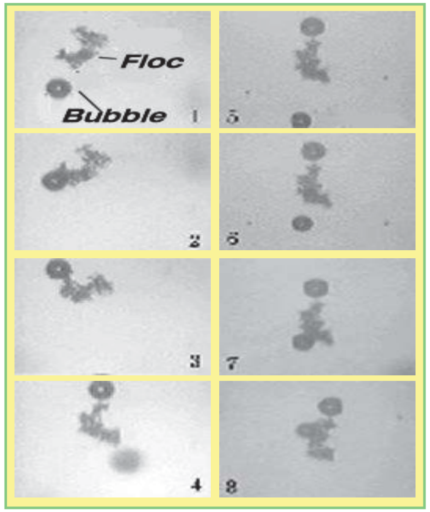


Filtering

Sedimentation

Flotation

Flotation process

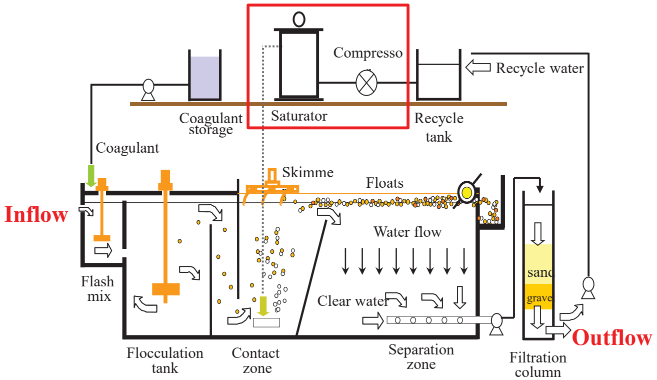


gravity separation process in which gas bubbles attach to solid particles to cause the apparent density of the bubble-solid agglomerates to be less than that of the water, thereby allowing the agglomerate to float to the surface

Dissolved air flotation (DAF)

flotation process by which low density particles are removed from water and wastewater by **using fine bubbles** which are produced by the reduction in pressure of a water stream saturated with air

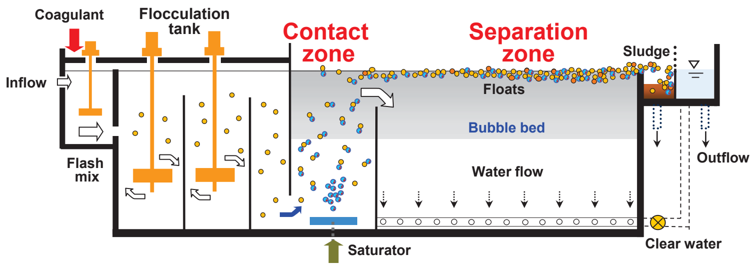
Pressurized solution system (ISO/DIS 20480-3 Fine bubble technology - General principles for usage and measurement of fine bubbles - Part 3: Terminology of fine bubbles in generating systems, subclause 4.5)



Contact zone / Separate zone

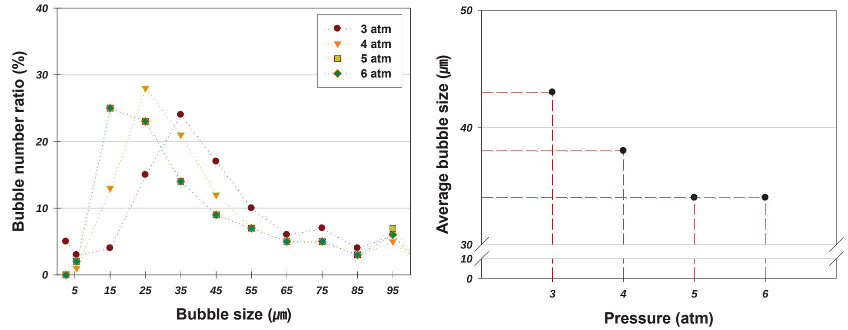
contact zone
zone where the floc particles are carried into and generate the particle-bubble aggregates by contacted with air bubbles

separation zone
zone where aggregates are separated from the water and become concentrated in a float layer at the top of the tank



Saturation pressure

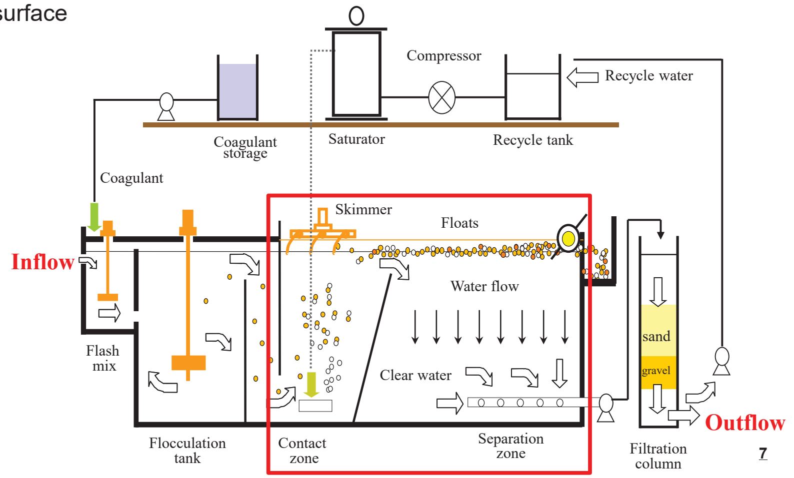
inner pressure of saturator which is used for generating bubble



Contact zone / Separate zone

DAF tank

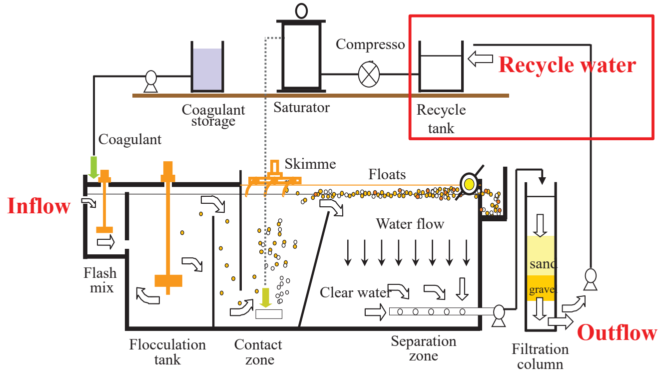
tank that DAF process is performed in and is roughly divided into two compartments containing contact and separation zone according to the step of flotation process: formation of particle-bubble aggregates and rising to the surface



Recycle water / Recycle ratio

recycle water
water used to generate fine bubbles required for the DAF process among the treated water by the DAF process

recycle ratio
ratio of the flowrate of recycle water to the flowrate of inflow to the DAF process



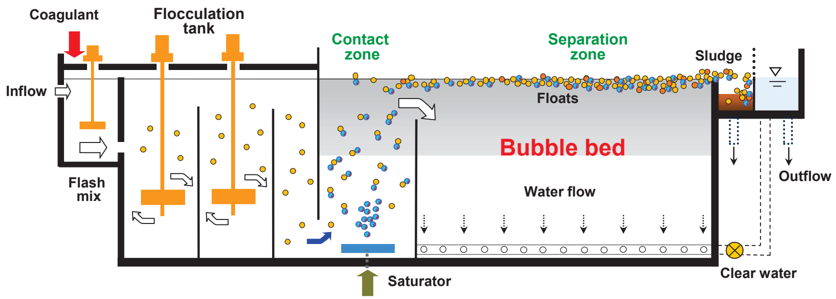
Treatment capacity / Hydraulic loading rate

treatment capacity
capacity that a certain process can handle for a unit time

hydraulic loading rate
index representing the treatment capacity at a limited area, calculated as the ratio of the flowrate to the DAF process to the surface area of the DAF tank

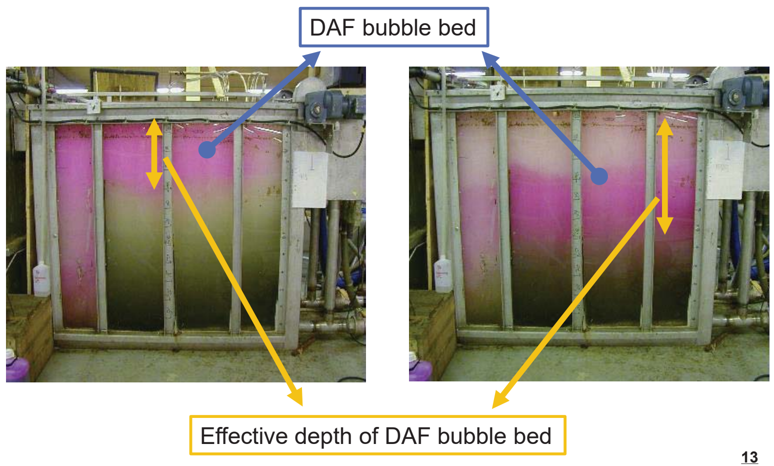
DAF bubble bed

layer generated by fine bubbles in separation zone



Effective depth of DAF bubble bed

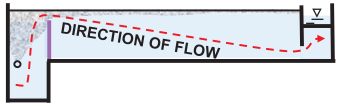
thickness of DAF bubble bed after the DAF process reaches state of equilibrium



DAF tank in plant

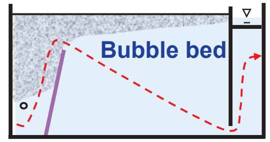
Changes of DAF cell & effective depth of bubble bed

1st Generation



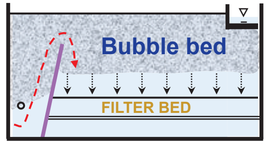
✓ Almost no bubble bed at separation zone

2nd Generation



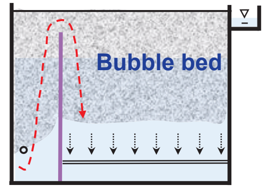
✓ Bubble bed formation at separation zone

3rd Generation



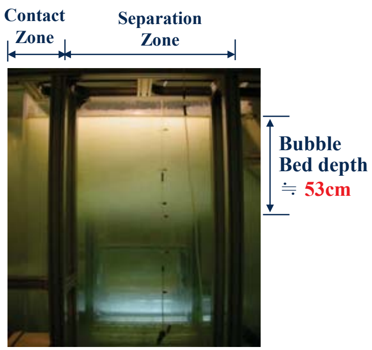
✓ Deep bubble bed formation at separation zone

4th Generation

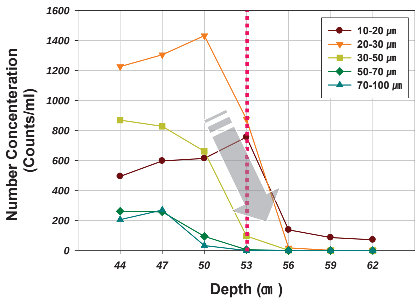


✓ Increased tank depth and bubble bed

Effective depth of bubble bed at pilot plant



Pressure: 5atm, Recycle ratio:50%



- The depth of bubble bed can be observed around 53 ± 3 cm
- 10~50 ㎛ size bubbles were measured as decreasing rapidly around 53cm by using on-line particle counter

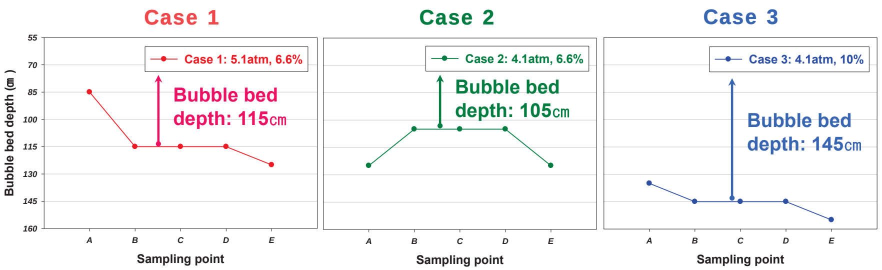
Development of DAF technology

Description	1st generation (prior 1960)	2nd generation (1960's ~1970's)	3rd generation (1980's)	4th generation (1990's)
Hydraulic loading rate (m/hr)	2~3 less than	3~8	5 ~12 until 1990	20 ~ 25 in 1996 expand to 40
Separation conditions	Turbulent flow	Laminar flow	Laminar flow	Turbulent flow
Effective depth of bubble bed (m)	Not Available	0.1 ~0.7	0.1 ~1	2.5 ~3.5
Active time for floc-bubble collisions (min.)	Not Available	NA	0.5 ~3	5 ~20

❖ Water treatment capacity ⬆ ➡ Hydraulic loading rate ⬆ ➡ DAF efficiency ⬇
➡ Square DAF cell ➡ Separation zone bubble bed depth, time for floc-bubble collisions ⬆
➡ DAF efficiency ⬆

※ 3rd, 4th generation DAF systems Increased tank depth ➡ Bubble bed was important

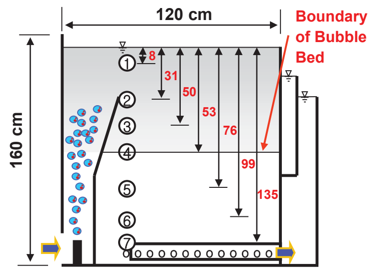
Effective depth of bubble bed at full scale field



<The depth of bubble bed at case 1, 2 and 3>

- Pressure change (Compare with Case 1 and Case 2)
  : the higher pressure, the deeper bubble bed depth
- Recycle ratio change (Compare with Case 2 and Case 3)
  : the higher recycle ratio, the deeper bubble bed depth
- ❖ Bubble volume concentration ⇧ ➡ Bubble bed depth ⇧

Effective depth of bubble bed at water treatment plant

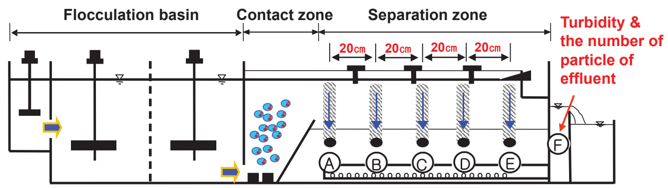


<Characteristics of raw water>

Turbidity	Alkalinity	Temp.	pH
2.4 NTU	26 mg/L as $CaCO_3$	7.5 ℃	7.7

<Operation conditions >

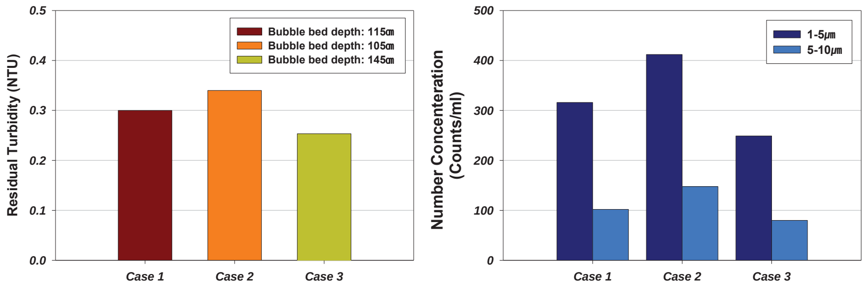
Pilot plant	Full scale field	Pressure (atm.)	Recycle ratio (%)
Pressure: 5atm Recycle ratio: 50%	Case 1	5.1	6.6
	Case 2	4.1	6.6
	Case 3	4.1	10.0



<Sampling points at the pilot plant and fullscale field>

- Sampling point (depth)
  - ① 55cm
  - ② 75cm
  - ③ 95cm
  - ④ 105cm
  - ⑤ 125cm
  - ⑥ 155cm

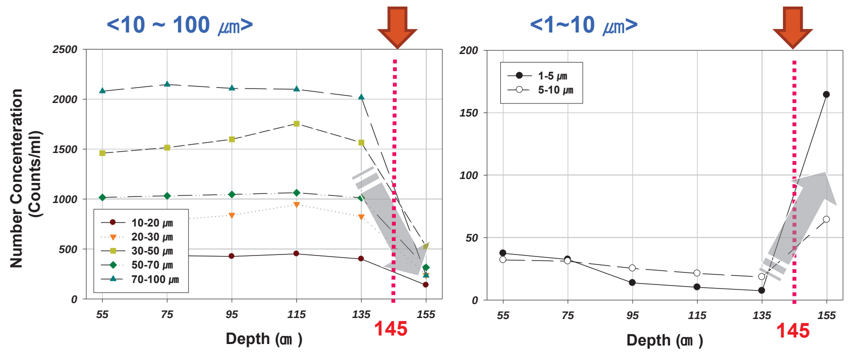
Effective depth of bubble bed at full scale field



<Residual turbidity and size distribution at effluent (sampling point F)>

- The depth of bubble bed depth affects the turbidity,
  but the result is less 0.5 NTU ➡ It is difficult to estimate an efficiency
- A lot of particle in effluent at Case 2
- A little of particle in effluent at Case 3

Effective depth of bubble bed at full scale field



<Bubble & particle size distribution at Case 3 (4.1atm, 10%), Point C>

- Middle and large particles were decreased under bubble bed
- Small particles were increased under bubble bed

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Fine Bubble Technology for Sustainable Development Goals

Ms. NISHIMURA Sahori,
National Institute of Technology and Evaluation (NITE), Japan

September 16, 2021

TC › ISO/TC 281

ISO/TR 24217-2:2021

Fine bubble technology – Guideline for indicating benefits — Part 2: Assignment of Sustainable Development Goals (SDGs) to applications of fine bubble technologies

This document provides guidelines for suppliers to show in which part of the Sustainable Development Goals fine bubble technologies can contribute to users.

This document also provides guidelines for document writers to assess the contribution of their documents related to fine bubble technology to the Sustainable Development Goals.

It also enables users to understand the benefits of using fine bubble technologies.

(Reference)https://www.iso.org/standard/78107.html?browse=tc

DAF bubble bed compactness

index indicating the degree to which the DAF bubble bed is saturated with bubbles at state of equilibrium

$$C = \frac{V_{bubbles}}{V_{bb}} \times 100 = \sum_i (n_i \times i) \times 100$$

Where

C	is DAF bubble bed compactness (%)
V_{bubble}	is the volume of bubbles in DAF bubble bed, calculated as the sum of each bubble volume (m^3)
V_{bb}	is the total volume of DAF bubble bed, calculated by multiplying surface area and effective depth of DAF bubble bed (m^3)
i	is the volume of a bubble (m^3/EA)
n_i	is the bubble number concentration whose volume is i (EA/m^3)

Thank You !

Benefits

- Improve reliability of fine bubble technologies
- Promote the user's understanding of the benefits of using fine bubble
- Promote investment activity

What are SDGs?

Case: Cleaning Application

Cleaning restroom floor in large facilities

West Nippon Expressway Company Limited, Fine Bubble Industries Association

Background

Cleaning Restroom Floor

Using fine bubble

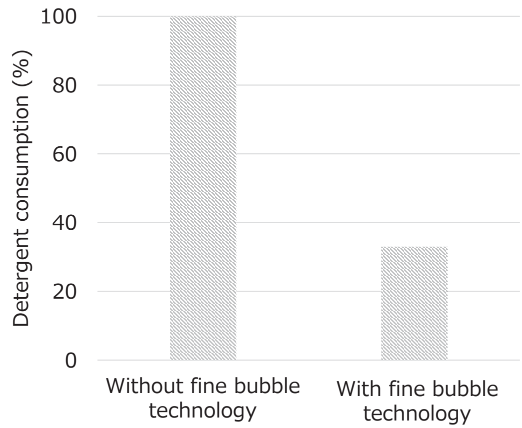
↓

Improving cleaning effect

↓

Reducing detergent

Examples of Data Comparison



➡ Reducing detergent

Cleaning Restroom Floor

Using fine bubble

↓

Improving cleaning effect

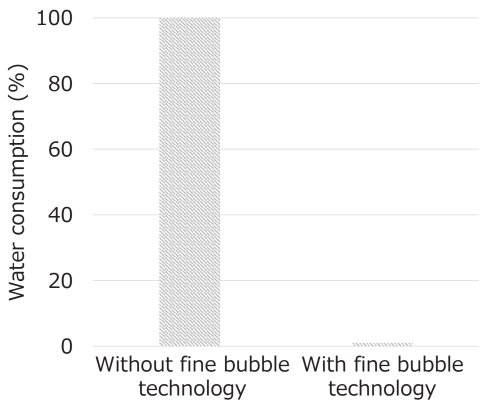
↓

Reducing detergent

↓

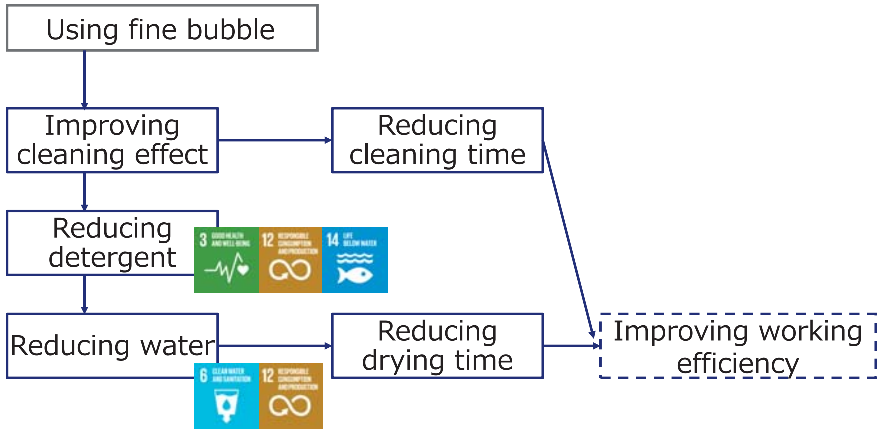
Reducing water

Examples of Data Comparison

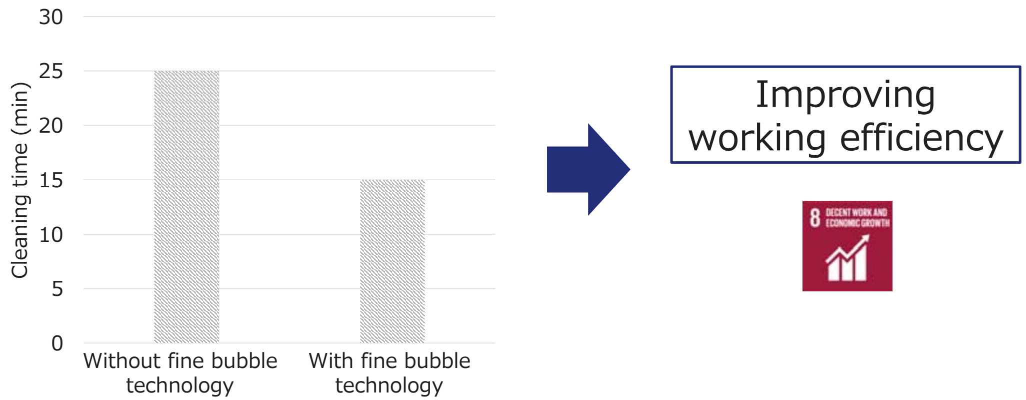


➡ Reducing water

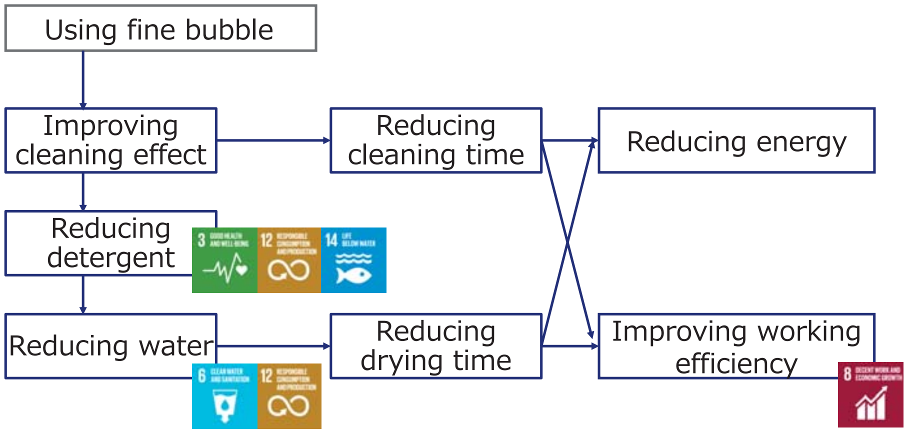
Cleaning Restroom Floor



Examples of Data Comparison



Cleaning Restroom Floor



Identifying Key Elements

Goals for fine bubble technologies (extract version)

Goal No.	Examples of key elements
Goal 3	— Sterilization methods — Improve water quality by reducing pollution and minimizing the discharge of hazardous chemicals and materials
Goal 12	— Reducing the environmental impact — Reduce discharging chemicals and wastes to the water and the soil
Goal 14	— Development of fisheries and aquaculture — Prevent and reduce marine pollution of all kinds

APEC Workshop II

20:20-20:40

"d) Cleaning of Salt on Surface of Iron Structure by using Ultrafine Bubbles"

Dr. Akira YABE

Special Advisor & Researcher Emeritus of National Institute of Advanced Industrial Science and Technology (AIST), Japan

September 16(Thu), 2021

Other Applications' Achievements

nite

Cleaning application e.g. Cleaning salt (NaCl)-stained surfaces	6 CLEAN WATER AND SANITATION	7 AFFORDABLE AND CLEAN ENERGY	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	11 SUSTAINABLE CITIES AND COMMUNITIES
Agriculture application e.g. Promotion of hydroponically grown lettuce	2 ZERO HUNGER	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	14 LIFE BELOW WATER	15 LIFE ON LAND

ISO/TS 21256-1:2020(E)
Fine bubble technology — Cleaning applications—
Part 1: Test method for cleaning salt (NaCl) -stained surfaces

You Tube Video

nite

Online NITE Seminar 6. Applications of Fine Bubble Technologies and SDGs

YouTube

NITE official
チャンネル登録者数 2.36万人

General principle/

Uniformity of UFB in supplied water for jet

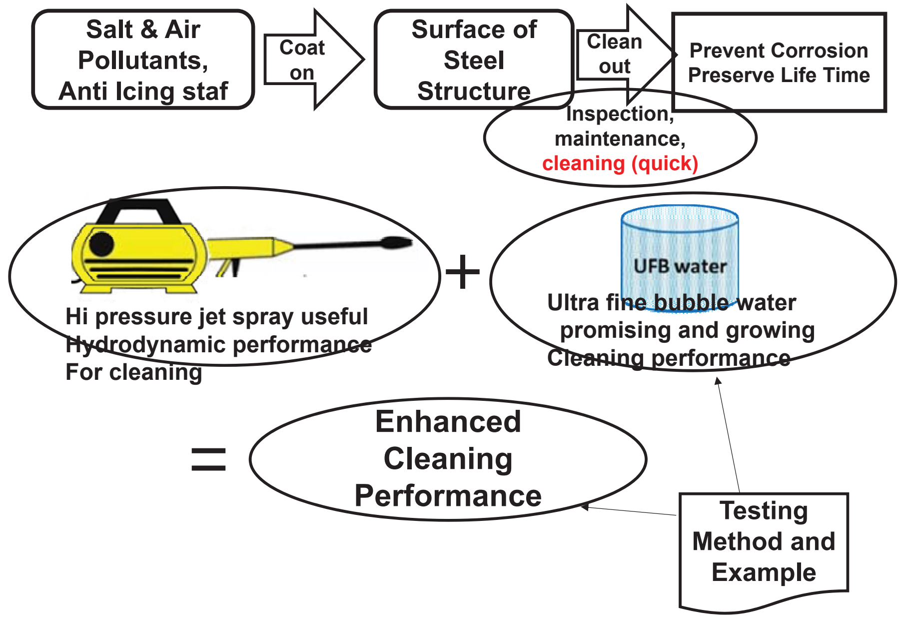
Characteristic of UFB water:
Average Diameter and Number concentration of UFB

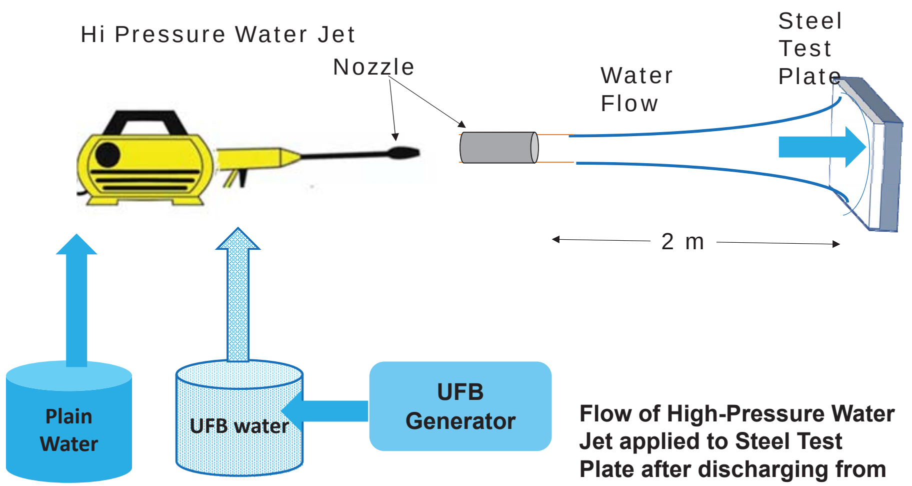
Cleaning performance depends of UFB original performance, hydrodynamic performance and property of salt stain

Fixed are; Specification of High pressure water jet, Properties of salt stain and test environment.

Modified are; Characteristics of UFB water

Introduction: Back Ground and Brief Senario of the Document





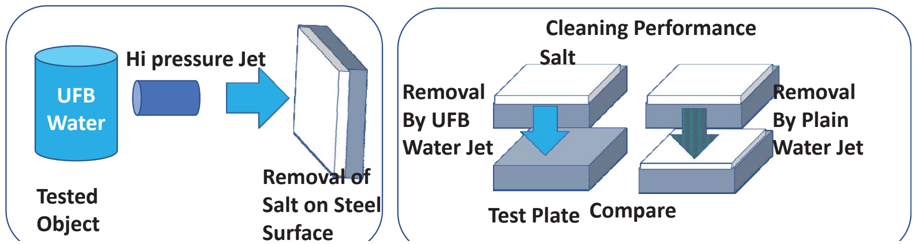
Flow of High-Pressure Water Jet applied to Steel Test Plate after discharging from its Nozzle

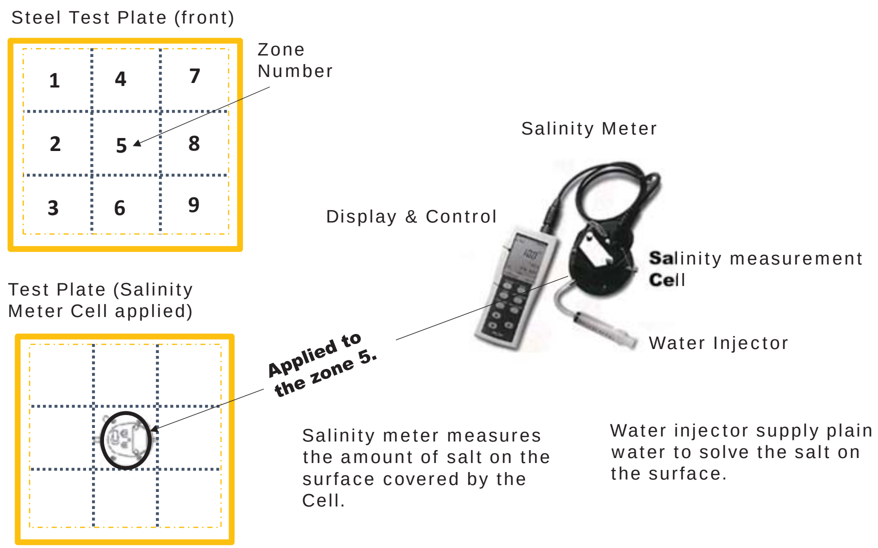
Alternatively
With UFB or Without UFB

ISO/TS 21256-1:2020(E) ISO/TC 281/WG3
Fine bubble technology — Cleaning applications — Part 1: Test method for cleaning salt (NaCl) -stained surfaces

Scope

A test method to evaluate the cleaning performance of ultrafine bubble water in high-pressure water jet to remove salt-stained steel surfaces.
The evaluation is to measure and compare removals of salt-stain on surface of a test plate with the ultrafine bubble water to control plain water.





Testing equipment

Hi Pressure Water Jet:
Discharges water through small nozzle by high pressure, namely with high speed.

Nozzle diameter: 6 mm at exit

Water temperature: 15℃ -25℃

Pressure at exit: 5 -9 Mpa

Flow rate at exit: 300 – 400 L/h

Cleaning profile at test plate: 250 -300 mm and stable

Supply of cleaning water: Continuous

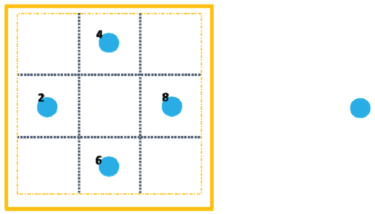
Testing equipment

Test Plate
Simple in shape (eg. Flat plate)
Material: carbon steel
Dimension 530 x 530 mm x 10 mm(t)

Procedure (Before cleaning)

S(initial) =((S(2) +S(4) +S(6) +S(8))/4

S(initial): initial adherent average density (in mg/ m^2)

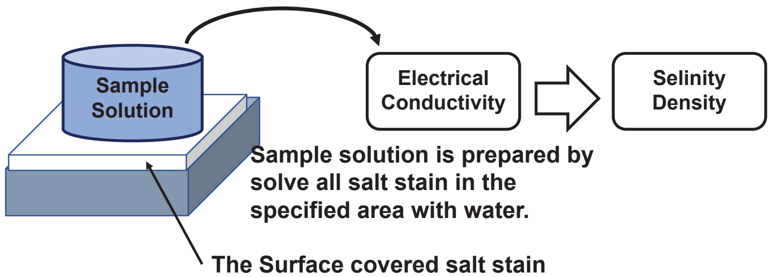


Testing equipment

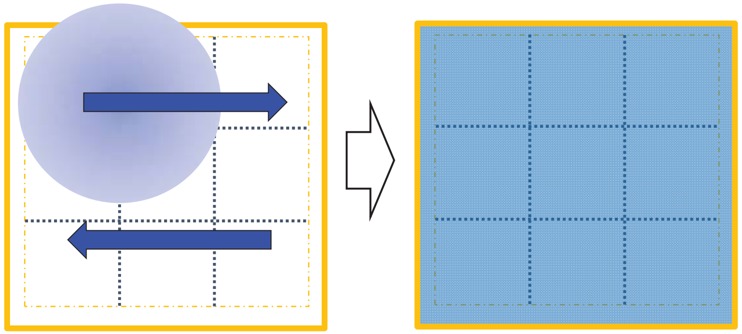
Surface Salinity Meter

Method: Surface salinity density
← Electrical Conductivity of sample solution (ISO 8502-9)

Precision ±1 % at temperature 0 -50℃

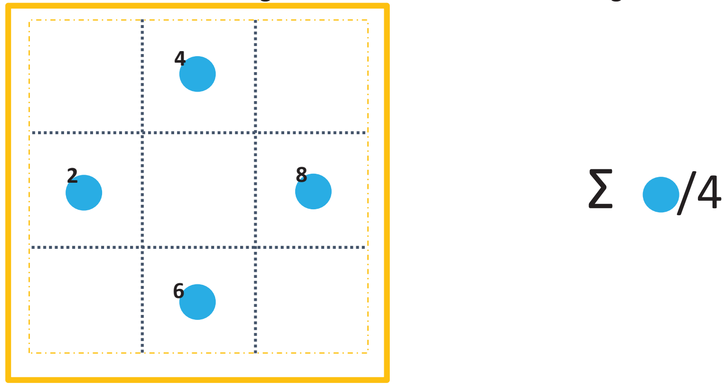


Cleaning Procedure on the plate



One round stroke takes approximately 1 second.
20 round strokes are sufficient.

Initial averaged concentration before washing



Blue spot: indicate the zone with salinity meter applied.

Out puts of salinity meter are averaged over the zones with even number.

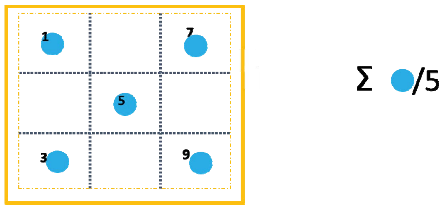
Measurement of salt stains after cleaning

After each cleaning stroke calculate:

S(aw) =((S(1) +S(3) +S(5) +S(7) +S(9))/5

S(aw): adherent average density after cleaning(in mg/ m^2)

Terminate of cleaning: Either density reading zero
or specified number for stroke attained.



Cleaning Procedure

Automatic stroke of jet mechanism is recommended.
(Example of manual operation is given in the document.)

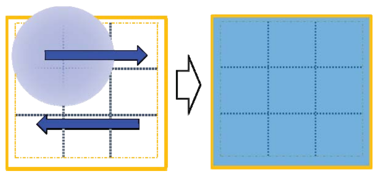
Distance of water jet: kept 2 m

Test piece: fixed tightly and kept normal to jet stream

Stroke: round trip, may less than 20 strokes for a cleaning.

Round trip: approximately 1 second

A cleaning is repeated for a testing with UFB and control waters.



Test Report

TEST REPORT

a) Applied environmental conditions, cleaning water, cleaning machines, measuring instrument influential to the test result;

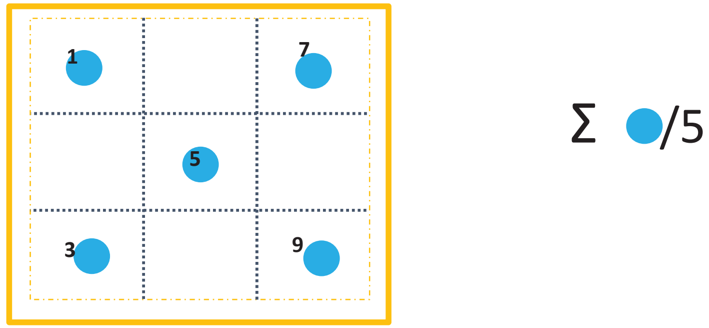
b) Meteorological environment (eg temperature, humidity, air pressure);

c) test conditions (parameter settings on pre-treatment, cleaning machine, washing water, measuring instrument);

d) test results (cleaning stroke number , initial adherent density of salt, and measured adherent density after cleaning and removed quantity or salt removed ratio);

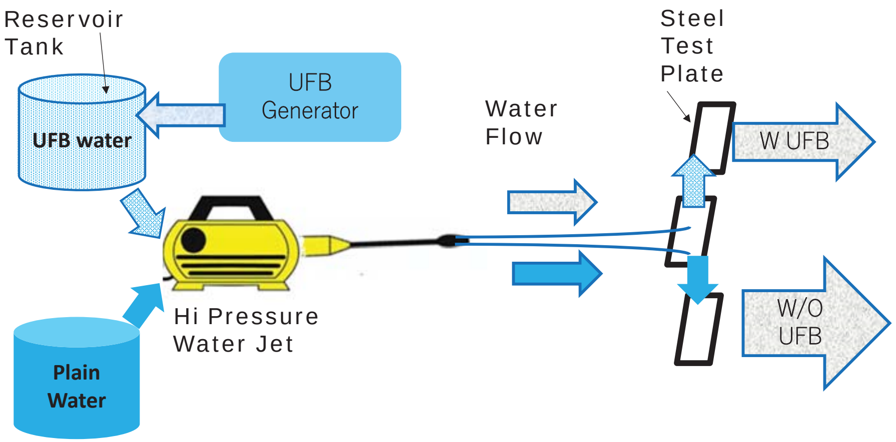
e) any deviations from the procedure described in this document;

Averaged concentration after the washing process.



Blue spot: indicate the zone with salinity meter applied.

Out puts of salinity meter are averaged over the zones with odd number.



Comparative Testing
With UFB and Without UFB

Calculation of removed salt stain

Salt removal ratio or removal quantity: to be reported.

Salt removal ratio

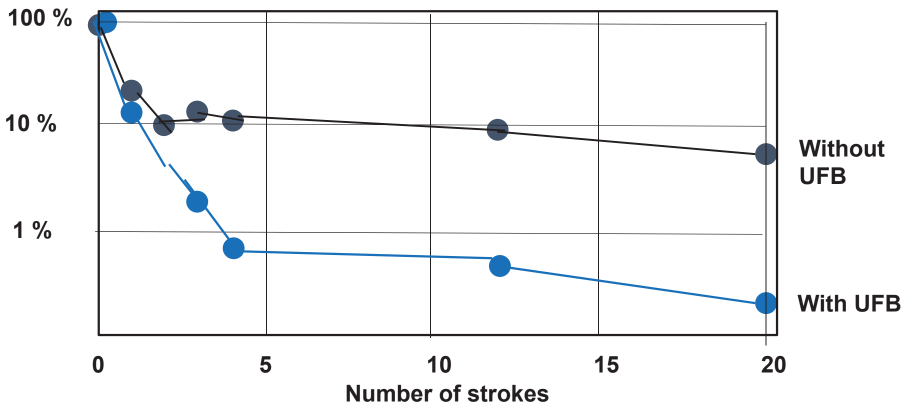
R(asr) = (S(initial) –S(aw))/S(initial)

R(asr): Salt removal ratio
S(initial): initial salinity density
S(aw): salinity density after cleaning

Salt removal quantity

Q =S(initial) –S(aw) : (mg/ m_2)

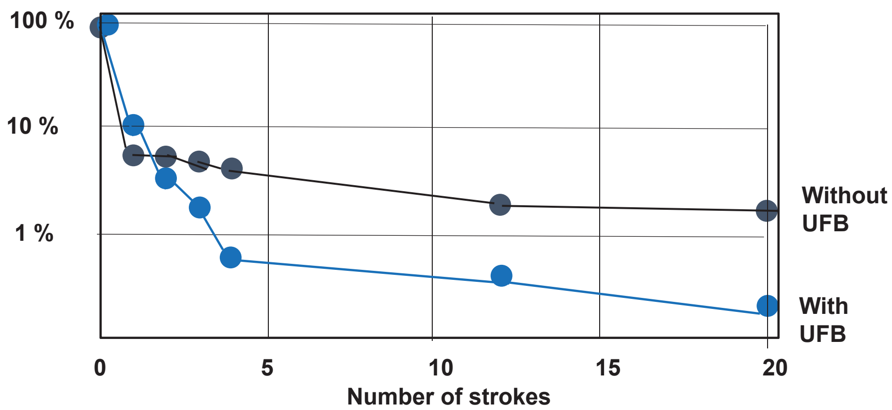
Reduction of relative residual density example 1



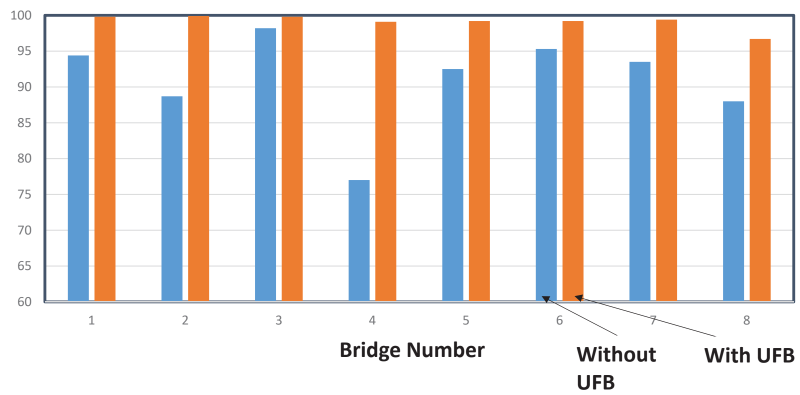
Example; Removal quantity

	control	control	control	UFB	UFB	UFB
	initial (mg/m2)	After	Remv rate	initial (mg/m2)	After	Remv rate
Mibu	88.8	5	94.4	96.6	0.2	99.8
Takata	48.8	5.5	88.7	93.4	0.1	99.9
Miwa	82.2	1.5	98.2	107.1	0.2	99.8
Fukatani	17.4	4	77	21.3	0.2	99.1
Kouchi Rvr	38.5	2.9	92.5	25.6	0.2	99.2
Hinokami Rvr	64.2	3	95.3	93.9	0.7	99.2
Bcchu Rvr	64.3	4.2	93.5	54.3	0.3	99.4
Hokubo JCT	67.5	8.1	88	81.4	2.7	96.7

Reduction of relative residual density example 2



Relative Residual Salinity Density in %



APEC Workshop II

(e) "The standards for elimination method of fine bubble"

Ms. Hirona Kobayashi,
National Institute of Technology and Evaluation(NITE)
Japan

September 16, 2021

Topics

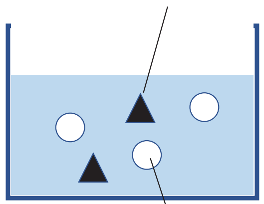
- Introduction
- Elimination method for sample characterization – part1: Evaluation procedure
- Elimination method for sample characterization – part2: Elimination techniques

Introduction

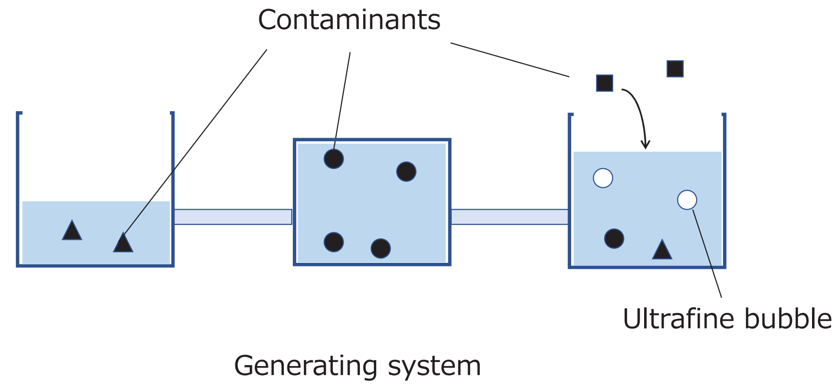
To measure ultrafine bubbles

①APEC Workshop I : Handling

②APEC workshop II

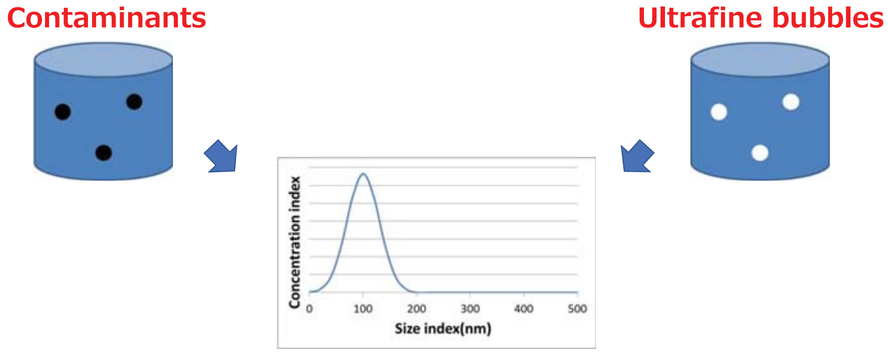


Ultrafine bubbles and contaminants in water



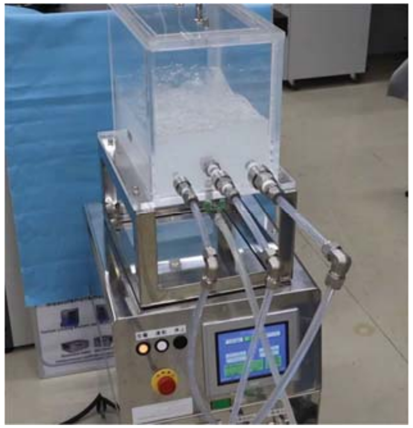
Measurement for ultrafine bubbles

Measurement results of ultrafine bubbles and contaminants



Elimination method for sample characterization – part1: Evaluation procedure

Clean generating system



TC › ISO/TC 281

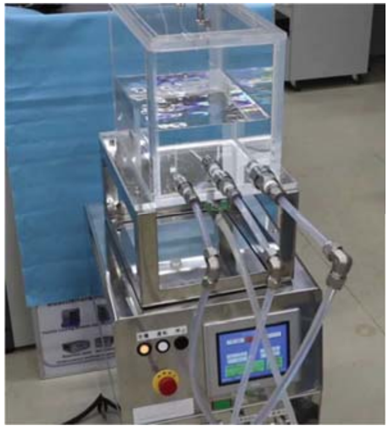
ISO 24261-1:2020

Fine bubble technology — Elimination method for sample characterization — Part 1: Evaluation procedure

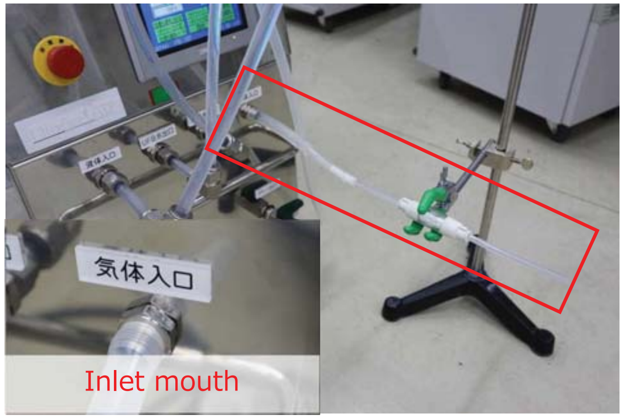
This document specifies the evaluation procedure of fine bubble elimination for fine bubble dispersion in water. This document is applicable only to fine bubbles without shell.

(Reference) https://www.iso.org/standard/78232.html

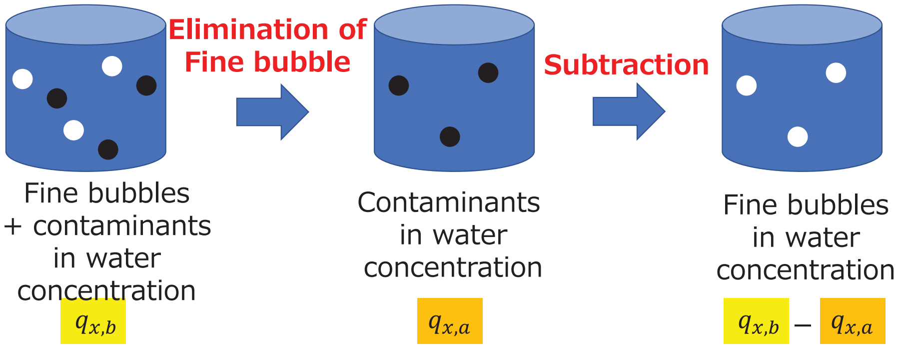
Generate ultrafine bubbles



Prepare water and gas



Elimination efficiency



Number reduction rate(%) $r_0 = (q_{0,b} - q_{0,a})/q_{0,b} \times 100$

Volume reduction rate(%) $r_3 = (q_{3,b} - q_{3,a})/q_{3,b} \times 100$

Prepare measurement devices

An example of reduction rate

	Number concentration (/ml)
Before elimination	7.1E+08
After elimination	1.5E+07

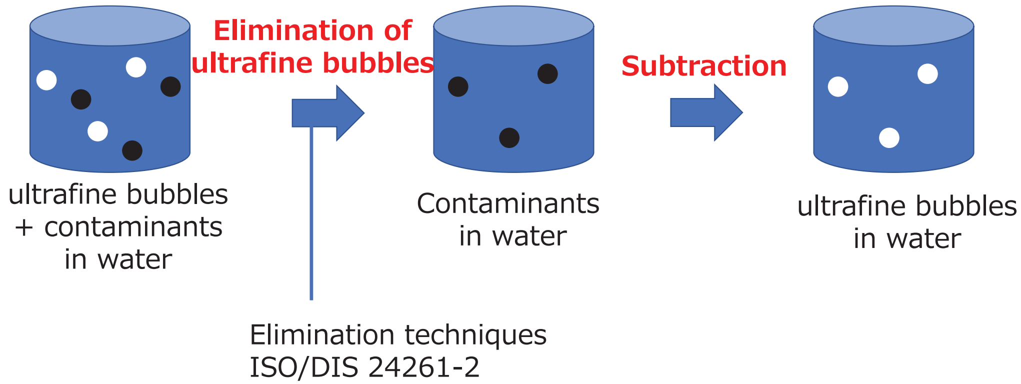
Number reduction rate (%)

$r_0 = (q_{0,b} - q_{0,a})/q_{0,b} \times 100$

= (7.1E+08 − 1.5E+07) /7.1E+08 ×100

= 98 %

Evaluation procedure



Elimination method for sample characterization – part2: Elimination technique

nite

TC › ISO/TC 281

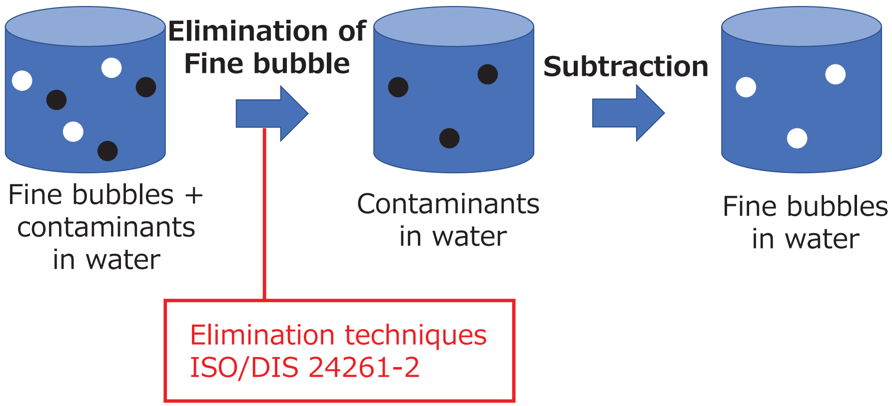
ISO/DIS 24261-2

Fine bubble technology — Elimination method for sample characterization — Part 2: Fine bubble elimination techniques

(Reference) https://www.iso.org/standard/80020.html

Evaluation procedure

nite

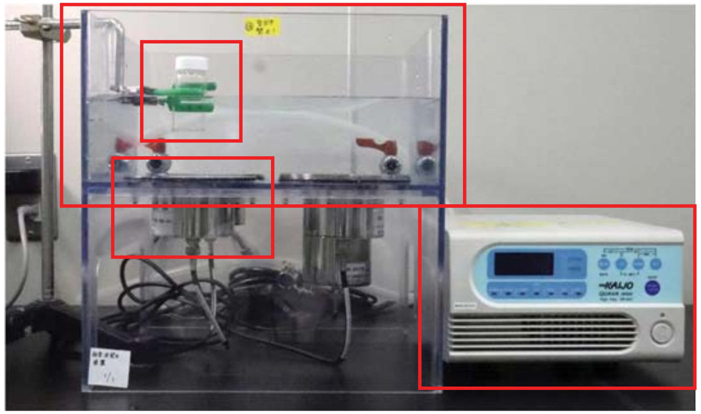


Elimination techniques

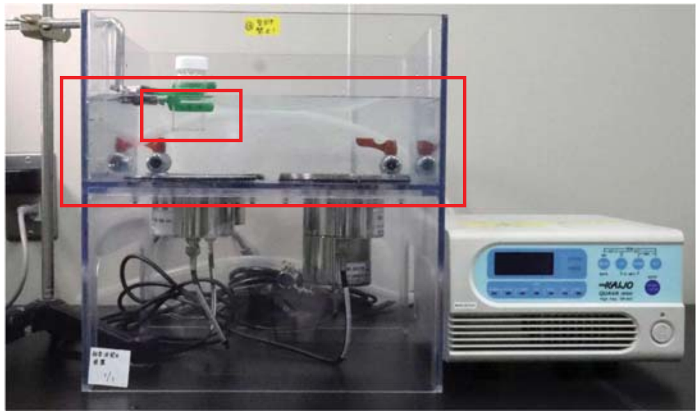
nite

- Ultrasonication method
- Ultracentrifugation method
- Freeze and thaw method

Ultrasonication method



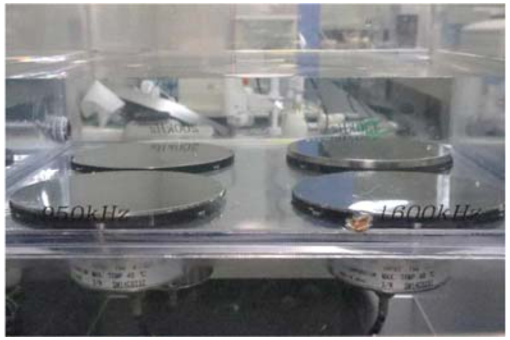
Ultrasonication method



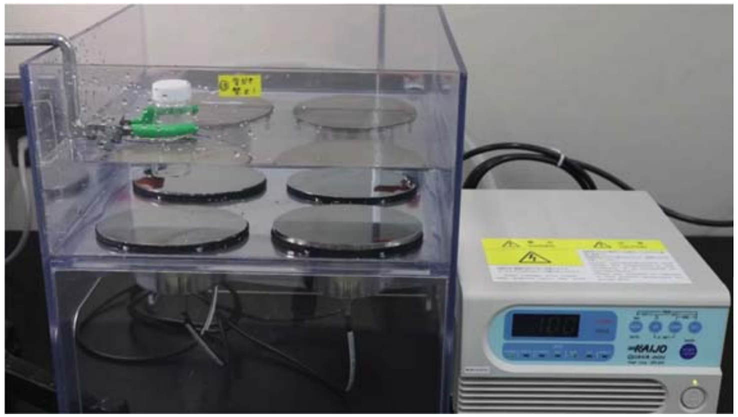
container

Sampling

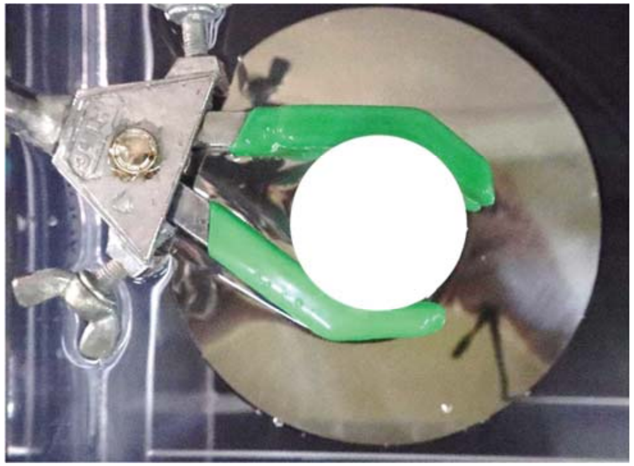
The parameters of ultrasonic device



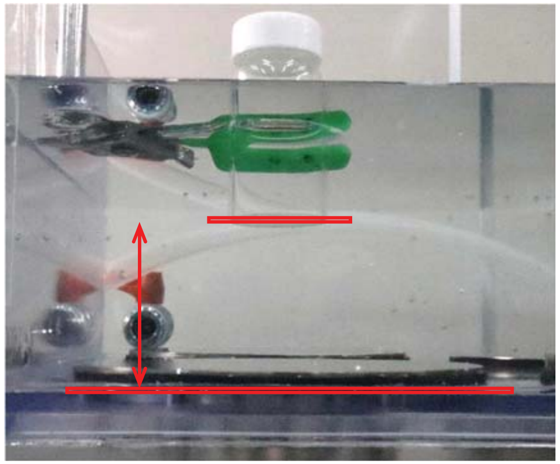
Irradiation by ultrasonic wave



The position of container

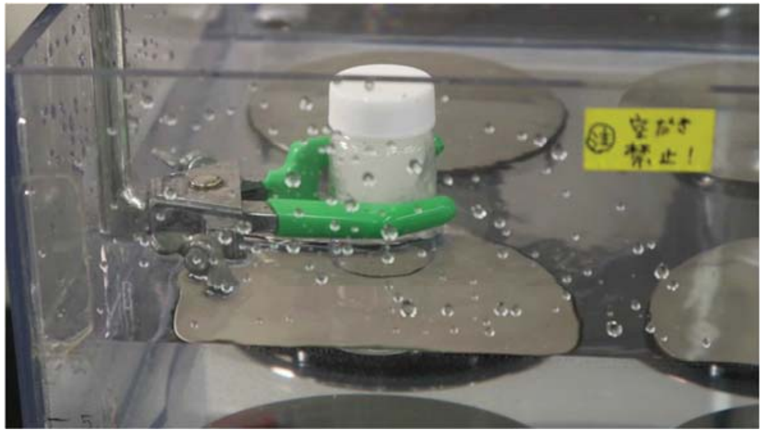


The position of container



Irradiation by ultrasonic wave

nite



An example of results with appropriate conditions

nite

conditions

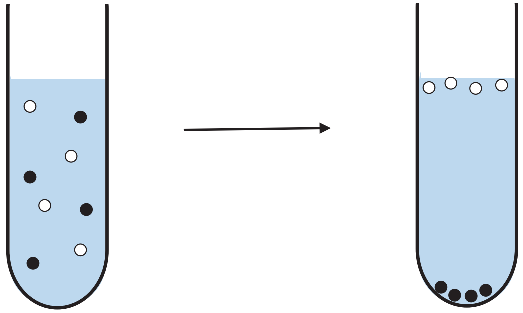
	Conditions
Frequency (kHz)	1600
Driving power (W)	100
Irradiation time (min)	15

Results

	Results
Number reduction rate (%)	90
Number concentration before elimination process (particles/ml)	5.4 × 10^8
Number concentration after elimination process (particles/ml)	5.4 × 10^7

Ultracentrifugation method

nite

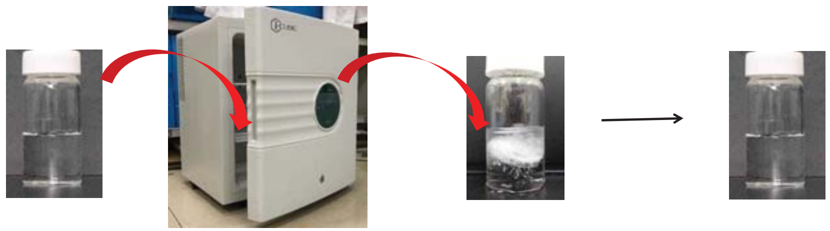


Ultracentrifugation method

nite

rotor

Freeze and thaw method



An example of results with appropriate conditions

conditions

	Conditions
Sample volume in each tube (ml)	1
Temperature (℃)	25
Relative centrifugal force (g)	1,050,000
Ultracentrifugation time (min)	15

Results

	Condition
Number reduction rate (%)	66
Number concentration before elimination process (particles/ml)	3.4×10^8
Number concentration after elimination process (particles/ml)	1.3×10^8

An example of results with appropriate conditions

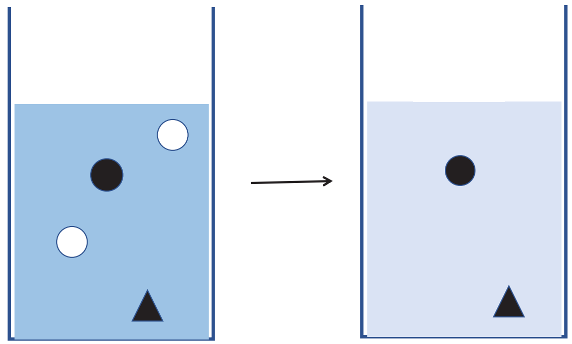
conditions

	Conditions
Freezing time (h)	24
Temperature (℃)	-18

Results

	Condition
Number reduction rate (%)	90
Number concentration before elimination process (particles/ml)	3.0×10^8
Number concentration after elimination process (particles/ml)	2.8×10^7

Freeze and thaw method



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4. 

Ultrafine Bubble Measurement Method

5. 

Microbubble Measurement Method

Ultrasonics Sonochemistry 71 (2021) 105366

Contents lists available at ScienceDirect

Ultrasonics Sonochemistry

journal homepage: www.elsevier.com/locate/ultson

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Destabilization of ultrafine bubbles in water using indirect ultrasonic irradiation

Shunya Tanaka [a], Hirona Kobayashi [b], Seika Ohuchi [b], Koichi Terasaka [c,*], Satoko Fujioka [c]

[a] School of Science for Open and Environmental Systems, Graduate School of Science and Technology, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan
[b] National Institute of Technology and Evaluation (NITE), 2-49-10 Nishihara, Shibuya-ku, Tokyo 151-0066, Japan
[c] Department of Applied Chemistry, Faculty of Science and Technology, Keio University, 3-14-1 Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522, Japan

ARTICLE INFO

Keywords:
Ultrafine bubble
Nanobubble
Defoaming
Zeta potential
Particle tracking analysis

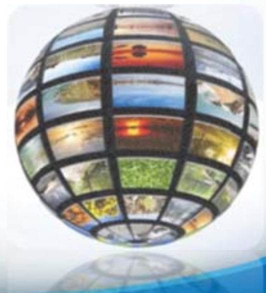
ABSTRACT

Ultrafine bubble (UFB) is a bubble with a diameter of less than 1 μm. Little attention has been paid to the defoaming and removal of UFBs. This study proposes a method to destabilize UFBs by using indirect ultrasonic irradiation. Besides, the destabilization mechanism of UFB was investigated. The ultrasonic frequency was 1.6 MHz and the dissipated power was 30 W. UFB dispersions were prepared using two different types of bubble generators: pressurized dissolution method and swirling liquid flow method. The effects of ultrasonic irradiation on the stability of UFBs were evaluated by particle tracking analysis (PTA) and electrophoretic zeta potential measurement. Results showed that the indirect ultrasonic irradiation for 30 min reduced the number concentration of UFBs by 90% regardless of the generation method. This destabilization was attributed to a decrease in the magnitude of zeta potential of UFBs due to the changes in pH and electrical conductivity. These changes in the electrochemical properties were caused by the formation of nitric acid. To study the destabilization mech-

APEC Workshop II

FBIA

21:15-21:35
"f) Inter Laboratory Comparison of Ultra Fine Bubble Measurement "



Dr. M. TANAKA
Certification Coordinator, Fine Bubble Industries Association, Japan

September 16(Thu), 2021

YouTube – Online NITE Seminar

nite

1. 

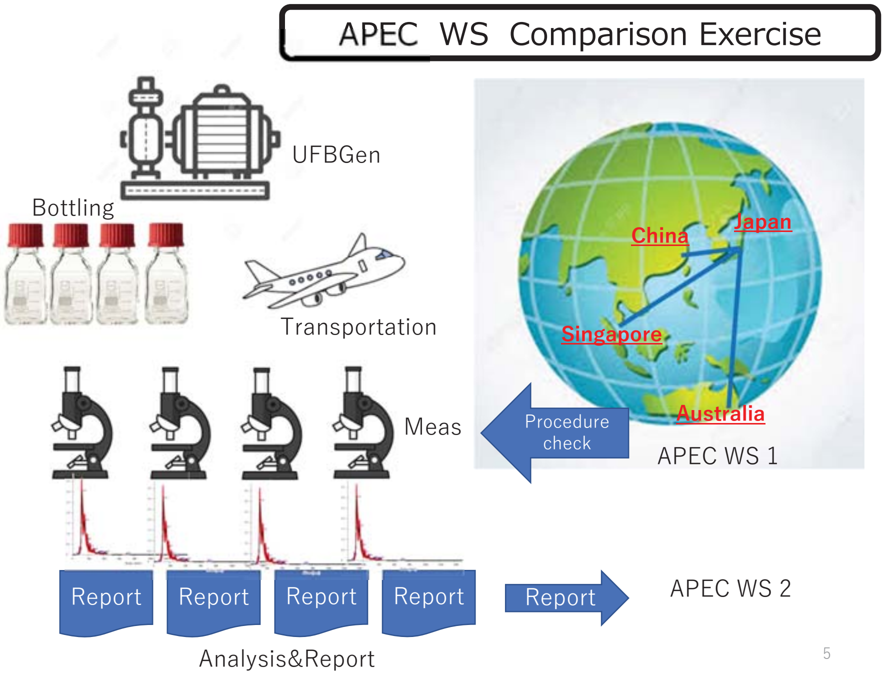
The Outline of Fine Bubble

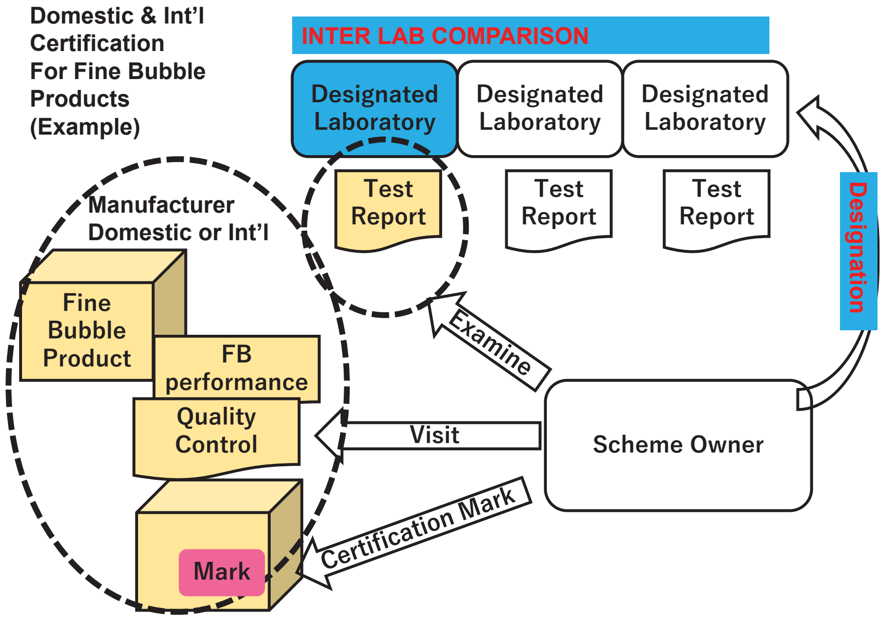
2. 

Measurement items for Fine Bubble
－Size, Concentration and Size Distribution

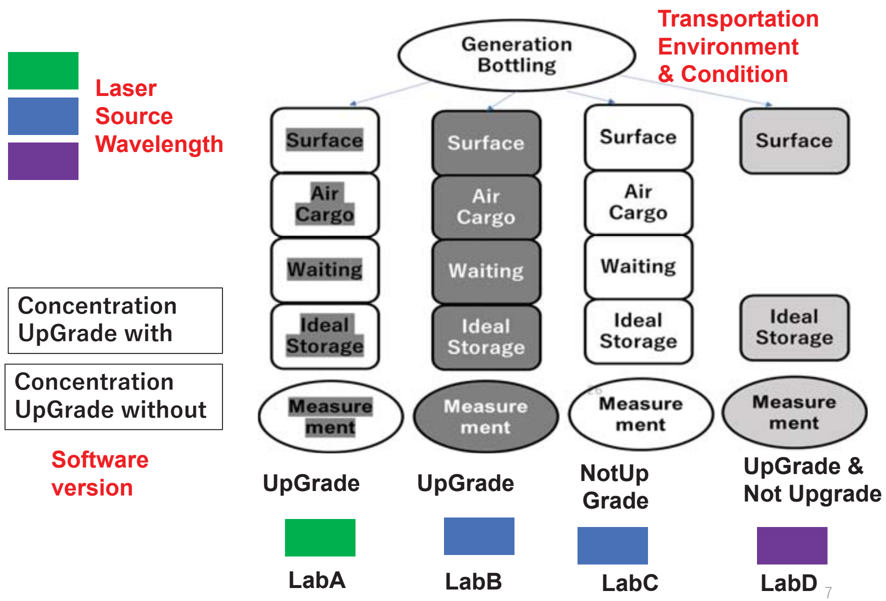
3. 

Measurement items for Fine Bubble
－Other items





Comparison Condition
(Measurement method (PTA) and instrument type identical.)



2021 Jan 21 (Wed)
Proposal of international comparison of UFB water measurement (APEC –WS 1)

1. **Call and participation of Australia, China, Japan and Singapore**

Australia (National Metrology Institute of Australia (NMIA))
Dr. JAMTING, Dr. COLEMAN

China (Shanghai Advanced Research Institute)
Dr. ZHANG and Ms. YUAN

Japan (National Institute of Technology and Evaluation)
Ms. KOBAYASHI, Ms. OHUCHI

Singapore (Temasek Polytechnic)
Dr.YAP, Mr.Wang

(Alphabetical order of economies)

A Set of UFB and Blank water bottles transported to each laboratory

A few drops of water were leaked out from a sealed bottle. (Red Circle)

Packed by plastic buffer sheets and polystyrene box

Box is put in a corrgated paper box and sign of “fragile” with transportation document.

2. Planning

2.1 Defining Measurement Recipe
Explanation on bilateral Zoom meeting,
Referring to Lecture on UFB measurement at APEC WS 1 (See IS 20298-1)

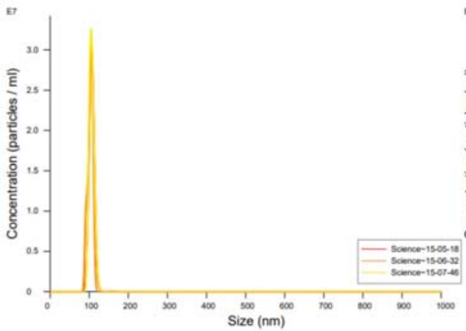
2.2 Plan for Generation of bottled sample,
Cooperation Laboratory for Generating system manufacturer
Experience on preparation for domestic comparison
Measurement within a day or two after generation Unstable

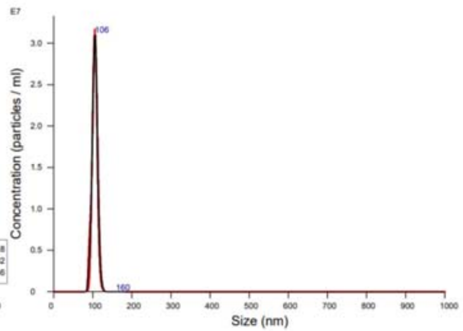
2.3 Plan for transportation of bottles,
Freezing season not acceptable because of reduction of UFB significantly
Hand carry is the best solution but impossible due to the pandemic
Only air cargo looks feasible with soft package for fragile object,
Experience on surface transportation for domestic comparison

2.4 Exchange of information for measuring instruments,
NS300, Nanosight, Green, Blue and Violet laser
Software upgraded version and not upgraded

2.5 Consideration on the bottles,
Glass quality, shape and packing lid
especially at full charging of UFB water up to top. (See IS 2125)

Measurement by Using PTA instrument
Example of typically ideal output data for a UFB water sample





Mean Diameter: 105.1 +/- 1.3 nm
Number Concentration: 5.08e+008 +/- 1.27e+007 /ml

3. Experiments

	Sample 1 (∼4E+8 /mL)	Sample 2 (∼1E+8 /mL)
3/30	Produced	
3/31		
4/1		
4/2	EC1(NUG)	
4/3		
4/4		
4/5	EC1 (NUG)&(UG)	
4/6		
4/7	EC2(UG)	
4/8		
4/9		
4/10		
4/11		
4/12		
4/13		
4/14		Produced
4/15		
4/16		
4/17		
4/18		
4/19		
4/20		EC1 (NUG)&(UG)
4/21		EC3 (NUG)
4/22		
4/23		
4/24		
4/25		EC1 (NUG)&(UG)
4/26		EC 4 (UG)

Because of availability of measuring instrument for one of participation economies, Sample 1 was prepared and dispatched in advance to the Sample 2.

Measurements on identical sample were carried out within a few days, each other.
In order to avoid freezing of UFB water during transportation, the season was carefully chosen.

4. Results of Experiment

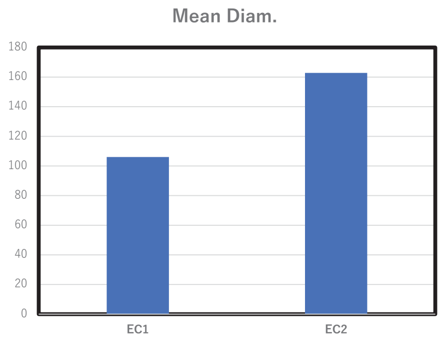
4.1 Bilateral comparison (EC1 vs EC2, EC1 vs EC3 and EC1 vs EC4.
Averaged data for mean diameter and number concentration are compared.
EC1: Participating laboratory in the economy 1.
EC2: Participating laboratory in the economy 2.
EC3: Participating laboratory in the economy 3.
EC4: Participating laboratory in the economy 4.
(Not alphabetical order but arbitrary order)

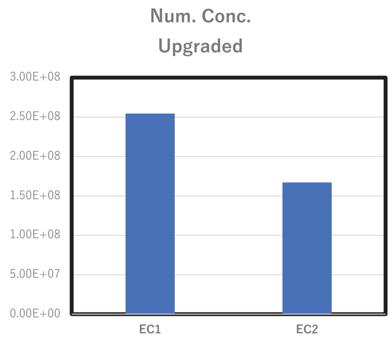
4.2 Result of multi lateral comparison

4.3 Efficiency difference Upgrade version and Non Upgraded version allows to compare number concentrations in different version.
Determination of efficiency ratio by using an UFB water sample applied to both versions at EC1.

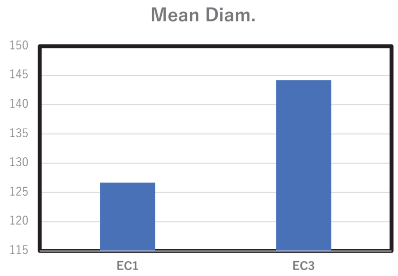
4.1 Bilateral comparison (EC1 vs EC2, EC1 vs EC3 and EC1 vs EC4.
Averaged data for mean diameter and number concentration are compared.

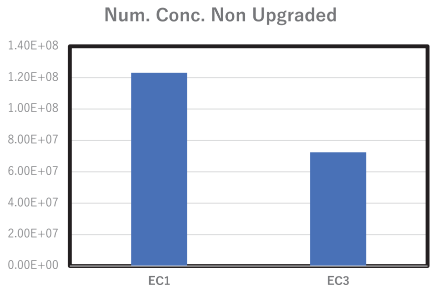
EC1 vs EC2



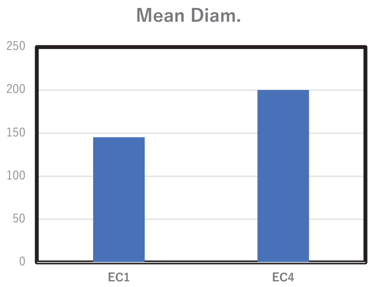


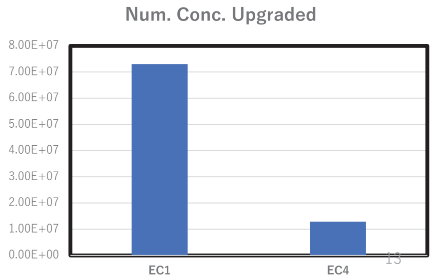
EC1 vs EC3



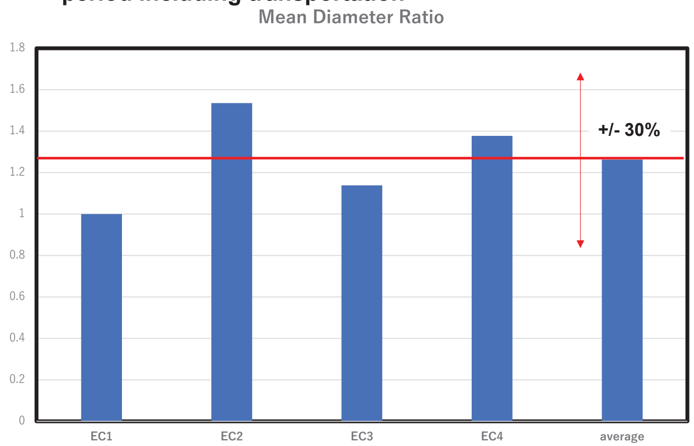


EC1 vs EC4





4.2 Result of multi lateral comparison (mean diameter)
The mean diameters of each labs were normalized to the corresponding mean diameters of EC1 for multilateral comparison.(This does not mean the result of EC1 is correct.)
The time from generation to measurement took around 2 weeks period including transportation

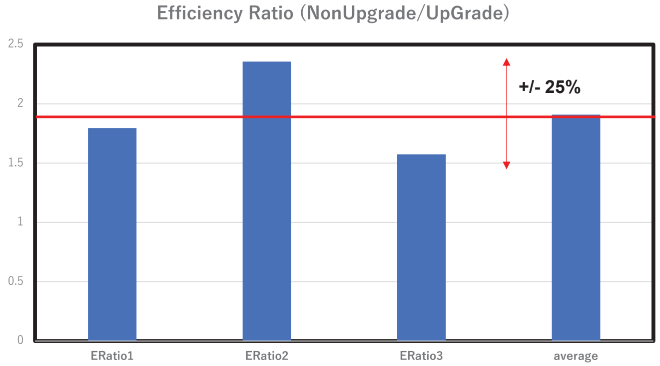


4.3 <u>Efficiency difference Upgrade version and Non Upgraded version</u>

Allows to compare number concentrations of UFB in different version of software of measuring instrument.

Determination of efficiency ratio by using an UFB water sample applied to both versions at EC1.

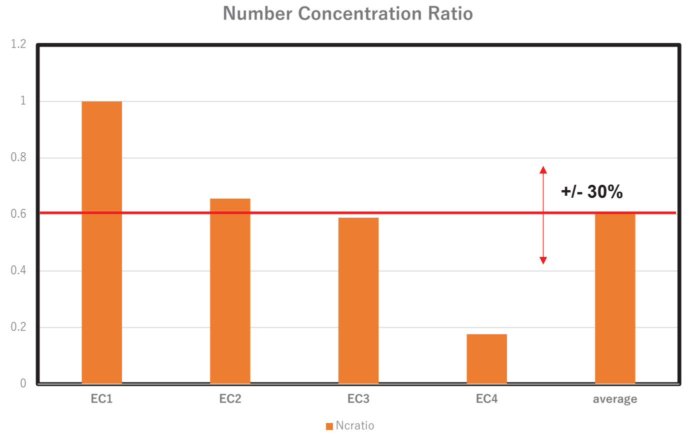
The average shows "1.91" for general efficiency ratio for UFB, while "3.3" had been reported in literature for nano particle.



Result of multi lateral comparison (number concentration)

The number concentrations of each labs were normalized to the corresponding number concentrations of EC1 for multilateral comparison.(This does not mean the result of EC1 is correct.)

The time from generation to measurement took around 2 weeks period including transportation



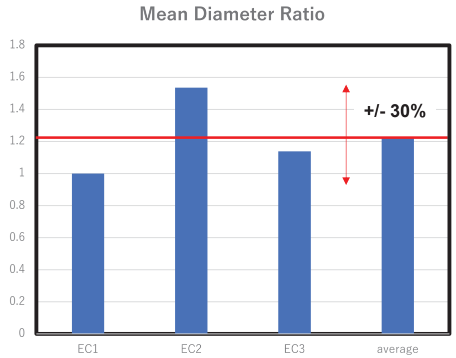
<u>Summary of Comparison exercise</u>

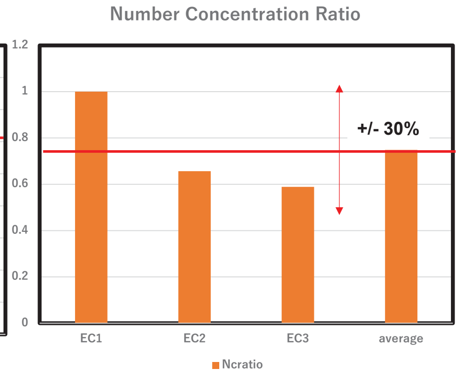
1. UFB water samples should have been prepared once, distributed, and measured within a few days.
   But due to the availability of measurement instruments, UFB water samples were generated twice. (Sample 1 and Sample 2)

2. During transportation some reduction of UFB sample are likely happened. Number concentration distributes over laboratories giving the disagreement more than +/- 30 %.
   The sample giving the least value for number concentration was measured around 2 weeks after the generation.
   For other samples the terms were less than around 1 week.
   The statistics over the latter three results shows the agreement within +/- 30%, although small elimination of UFB due to the term is suspected. The level of agreement is almost consistent with that of domestic comparison using surface transportation.

3. While type of Measuring instruments were identical, software version and wavelength of laser sources were different.
   Since both versions were available on the hardware of instrument and sample, indirect comparison between measurement result from different versions of software was made over all four laboratories.

Result of Tri lateral comparison within around 1 week period (from generation to measurement including transportation)





Conclusion:

Four laboratories participated international comparison exercise for ultra fine bubble measurement.

It consisted of three bi-lateral comparisons and allowed to compare mean diameter measurements and number concentration measurements.

Agreement in +/- 30% were found among the number concentration of three labs on the samples with short transportations in a week. However, it is to be noted that by some unidentified reason some elimination or transformation of UFB may have happened reducing number concentration of UFB. The exposure to long and hard environment for transportation before measurement looks to give significant influence to UFB.

The similar agreements were achieved for mean diameter.

As far as report on the measurement procedures are concerned each laboratory performed sufficiently as specified in agreed procedure.

Acknowledgement to

Australia (National Metrology Institute of Australia (NMIA))
Dr. JAMTING, Dr. COLEMAN

China (Shanghai Advanced Research Institute)
Dr. ZHANG and Ms. YUAN

Japan (National Institute of Technology and Evaluation)
Ms. KOBAYASHI, Ms. OHUCHI

Singapore (Temasek Polytechnic)
Dr.YAP, Mr.Wang

Thank You For Your Attentions!

Mitsuru TANAKA
FBIA

APEC Workshop I

k)19:15-19:30

"Overview of Fine Bubble Technology Development and Application in Agriculture in Chinese Taipei"

Dr. Jong-Shinn Wu[1,2], Dr. Chih-Tung Liu[1,2] and Mr. Shih-Chang Eric Chen[2]

[1]National Chiao Tung University

[2]Fine Bubble Industries Association in Chinese Taipei

January 21, 2021

Outline

- FBT Applications in Agriculture of Chinese Taipei
  - ✓ Fruits and Vegetables
  - ✓ Aquaculture
  - ✓ Chinese Medicine
- Overview of Plasma-Activated Microbubbles (PAMBs)
  - ✓ Plasmas & PAMBs
  - ✓ Preliminary Results & Discussion
- Conclusion & Future Work

FBT Applications in Agriculture of Chinese Taipei

Strawberry Growth

Ozonated fine bubbles (FB):

- Culture solution treatment
  - ✓ Antibacterial (intermittent treatment)
  - ✓ Oxygenation (continuous treatment)
- Leaf treatment (spray)
  - ✓ Insect pests decrease
  - ✓ Bacteria sterilization (*Fusariun spp., Colletotrichum spp., E. coli, C. albicans* & *Trichophyton spp.)*
  - ✓ Pesticide decomposition
- Harvest increase
  - ✓ Harvest amount per unit area improved
  - ✓ Harvest duration extended

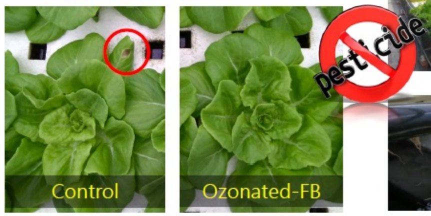
Bacteria ↓ + Insect Pests ↓ + Oxygenation ↑

→ Harvest ↑

Hydroponic Growth - 1

Ozonated fine bubbles (FB):

- Culture solution treatment
  - ✓ Antibacterial (intermittent treatment)
  - ✓ Oxygenation (continuous treatment)
- Leaf treatment (spray)
  - ✓ Insect pests decrease
  - ✓ Bacteria sterilization



Bacteria ↓ + Insect Pests ↓ + Oxygenation ↑

→ Harvest ↑ + Electricity ↓

Hydroponic Growth - 2

Tradition – Pump + Air oxygenation + O_3 sterilization

Electricity: 3ϕ3w 220V
Current: 12 A
Power: 4.57 KW (6HP)
Daily operation: 8 hr
Operation: 16 pools working simultaneously
Pool size: 5m * 25m
Daily power consumption: 4.57 kW*8 hr = 36.56 kWh

FBs – FBs Tech. + O_2 oxygenation + O_3-FB sterilization

Electrici...
Curr...
Power...
Daily op...
Operation: 1... turn, 1 hr for each
Pool size: 5...
Daily power con...mpti...n: 1.68 kW* 16 hr = 26.88 kWh

26.5% Electricity Saving!!

Bacteria ↓ + Insect Pests ↓ + Oxygenation ↑

→ Harvest ↑ + Electricity ↓

Sweet Potato Growth

- FBs washing
  - ✓ outstanding cleaning capability w/o harming sweet potato
  - ✓ sold at > 3000 convenient stores in Chinese Taipei currently

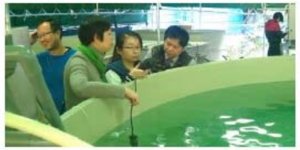
Pesticide Removal

- Strong decomposition of pesticide remaining on leaves
- O_3-FBs technology
  - ✓ insect pests prevention
  - ✓ environmental control
  - ✓ nutrition solution sterilization
  - ✓ leading to time preservation (3~20 times)

Pesticide	Removal (%)		
	Conventional O_3 water	O_3-FBs	Efficiency (times)
Diazinon (大利松)	5.56% ± 0.08	18.75% ± 0.10	3.37
Methyl-parathion (甲基巴拉松)	7.74% ± 0.05	35.68% ± 0.16	4.6
Parathion (巴拉松)	6.21% ± 0.08	30.18% ± 0.12	4.86
Cypermethrin (賽滅寧)	1.32% ± 0.02	28.63% ± 0.02	21.6

Aquaculture Enhancement

- High water temperature (e.g., summer)
  → low dissolved oxygen (DO) in water
- Traditional big bubbling aeration method
  → poor efficiency in oxygenation
  → high power consumption
- FBs technologies
  → large quantity
  → long retention time
  → large surface area significantly
  → DO increase in water
- O_2-FB + O_3-FBs
  → control DO and oxidation/reduction potential (OPR)
  → a better living environment
  → high stocking density
- O_3-FBs
  → effective bacteria sterilization
  → less use of antibiotics



Bacteria ↓ + NH_3-H ↓ + Oxygenation ↑
→ Stocking density ↑ + Anti-biotics use ↓

Chinese Medicine Treatment

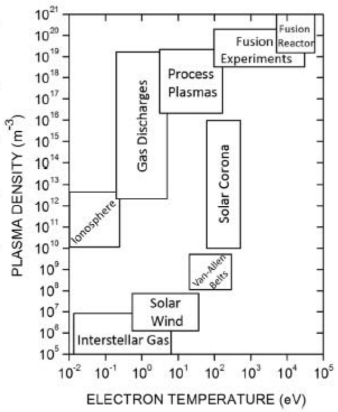
- **Growth Promotion**
  - ✓ Increase oxygenation at ginseng roots
- **Cleaning Effect**
  - ✓ O_3-FBs → bacteria sterilization
  - ✓ O_3-FBs → clean/bleach many kinds of Chinese herbs, even on tortoise plastron & deer antler.

Overview of Plasma-Activated Microbubbles (PAMBs)

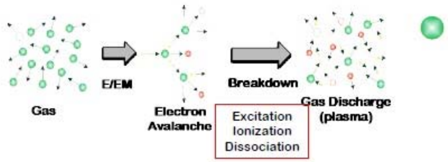
What Is Plasma?

✓ The forth state of matter

State	Example	Temperature	Molecules Structure
Solid	Ice (H_2O)	Cold T < 0°C	Molecules Fixed in Lattice
Liquid	Water (H_2O)	Warm 0 < T < 100°C	Molecules Free to Move
Gas	Steam (H_2O)	Hot T > 100°C	Molecules Free to Move, Large Spacing
Plasma	Ionized Gas $H_2 \rightarrow H^+ + H^+ + 2e^-$	Hotter T > 100,000°C	Ions and Electrons Move in Large Spacing



✓ Laboratory LT Plasma (Discharge)



1 eV = 11600 K

Why PAMBs?

Plasma & PAW

- Pros:
  - ✓ Short-lived species, e.g., $OH^{\cdot}$ and $O_2^{\cdot-}$ (strong oxidative ability, unique)
  - ✓ Long-lived species, e.g., H_2O_2 and O_3 (environmentally friendly)
  - ✓ Strong sterilization effect
- Cons:
  - ✓ Difficult to scale-up PAW

+

FBs

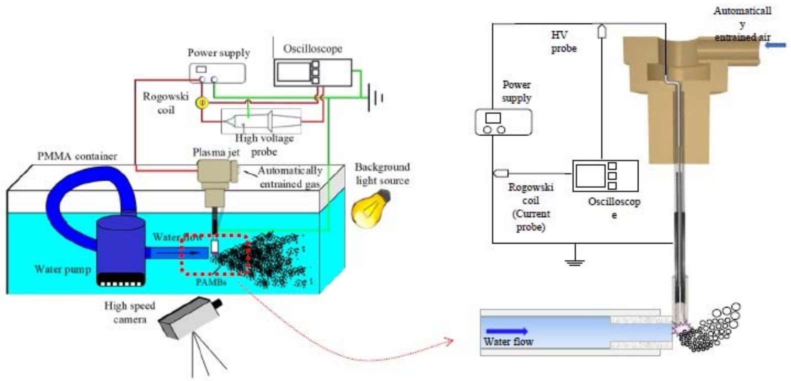
- Pros:
  - ✓ Outstanding cleaning capability
  - ✓ Large interfacial area
  - ✓ Longer residence time
- Cons:
  - ✓ Relative low sterilization effect

⬇

PAMBs

- Pros:
  - ✓ Short-lived and long-lived species
  - ✓ Outstanding cleaning capability
  - ✓ Larger interfacial area
  - ✓ Longer residence time
  - ✓ Easy to scale-up

PAMBs Experimental Configuration*



*M.-C Wu *et al.*, J. Phys. D: Appl. Phys. 53 (2020) 485201; collaborated with Prof. Takehiko Sato of Tohoku University.

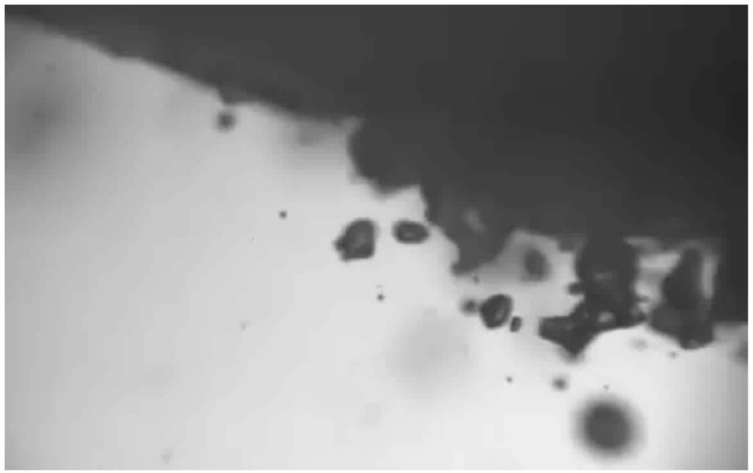
PAW vs. PAMBs

PAW

PAMBs

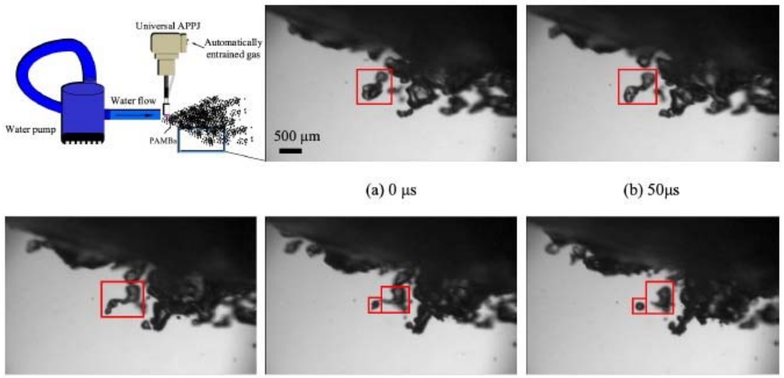
- ✓ Both short-live species and long-live species were applied in PAW and PAMBs cases.
- ✓ Plasma gas in PAW case floated onto the water surface immediately.
- ✓ Plasma gas in PAMBs case stayed and reacted in the solution for longer time.
- ✓ Big-bubbles were stretched and sheared into small-bubbles.

Bubbles Breakup Process -1



Snapshots of Bubbles Breakup Process

- **Imaging Conditions:**
  - ✓ exposure time: 20 μs
  - ✓ speed of camera: 20,000 fps
- **Mechanism:**
  - ✓ velocity gradient (shear stress)
  - ✓ turbulence effect (eddies)

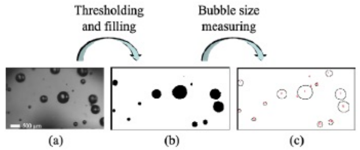


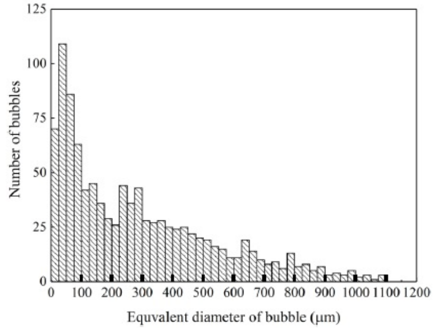
(a) 0 μs (b) 50μs (c) 100μs (d) 150μs (e) 200μs

Distribution of Bubbles Size

For bubble size measurement:

- ✓ exposure time : 50 μs
- ✓ speed of camera: 200 fps
- ✓ For high speed motion of PAMBs
- ✓ exposure time: 20 μs
- ✓ speed of camera: 20,000 fps
- ✓ Bubble size measurement: $D = 2\sqrt{\frac{A}{\pi}}$
- ✓ Circularity ($\frac{4\pi A}{perimeter^2}$): over 0.8

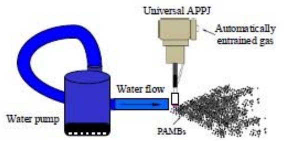




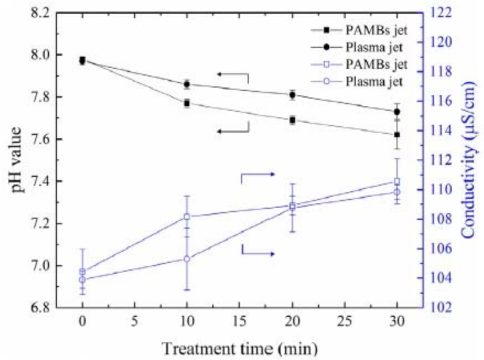
- 1030 individual bubbles were counted
- Detection limit: 13.5 μm
- 32 % bubbles size are less than 100 μm
- Average equivalent diameter: 290 μm

pH Values & Conductivities

(PAW vs. PAMBs)



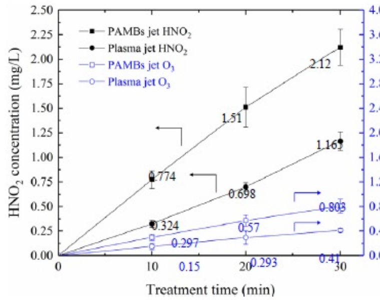
Treatment volume: 10 L (tap water)

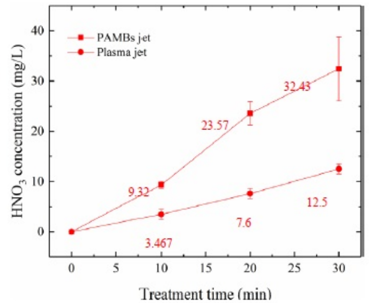


- ✓ pH value of the PAMBs water lower than the large-volume PAW for the whole period of treatment time.
- ✓ The conductivity showed the opposite results. It was because that HNO_2 and HNO_3 were dissolved in the water.

Concentration of Nitrate/Nitrate & Ozone

(PAW vs. PAMBs)





- ✓ Both the nitrite & ozone concentration in the PAMBs were nearly two times higher than those in PAW.
- ✓ Nitrate concentration in PAMBs was three times higher than that of large PAW.
- ✓ It may be because that plasma generated RONS were encapsulated by the microbubbles.

Conclusion & Future Work

Conclusion & Future Works

Summary:

- FBs technology in agriculture applications in Chinese Taipei
  - ✓ Many practical applications with FBs technology have been presented.
  - ✓ Daily consumer goods such as hydroponic vegetables, aquaculture products and sweet potato with FBs/O_3-FBs treatments are already sold in the market.
  - ✓ High-end products, such as strawberry and Chinese medicine, are treated by FBs/O_3-FBs tech. with remarkable cleaning and sterilization effect.
- PAMBs
  - ✓ An innovative approach of combining plasma and MBs technologies to increase the concentration of chemical species in the water has been invented and characterized preliminarily.
  - ✓ Mean diameter of PAMBs is estimated to be 290 μm which can enhance the dissolution of plasma-activated gases into water.
  - ✓ The results showed that the concentration of nitrite & ozone in the PAMBs water were about twice as high as that in the large-volume PAW.

Future Work:

- ✓ To promote FBs technology in other high-end products.
- ✓ To develop a PAMBs system with much finer FBs size and study the flow dynamics in the system.
- ✓ To develop a simple, accurate and automatic method to measure size distribution and concentration of fine bubbles following ISO-21910-1:2020(E).

Thank you for listening

國立交通大學 National Chiao Tung University

Tohoku University MAIL MAGAZINE 東北大学 メールマガジン

科技部 Ministry of Science and Technology

新竹國泰綜合醫院 Hsinchu Cathay General Hospital

台大醫院 新竹分院