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EVOLUTION OF MICRO/NANO BUBBLES DISTRIBUTIONS

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ABSTRACT

In this study, a laser light scattering method was used to measure size distribution of a desk-top RMUTL MNB generator (KVM-10; 1 l/min at 200-270 kPa). For evolution of MNB size distribution, size distribution of consecutively generated MNB water was evaluated when the MNB generator switch on and switch off. The size distributions are measured from the initial micro bubble rich distributions into nano bubble distributions by MNB analyzer Horiba LA-960A. The results show relatively short time (about 20 minutes) to reach stable nano bubble distributions from the initial microbubble distributions. The oxygen is studied.

Keywords : micro/nano bubble size distribution, laser light scattering method.

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1. INTRODUCTION

The micro/nano bubble (MNB) technology is rapidly emerging now in various fields as an innovative advanced technology with outstanding and versatile effects (Fig.1). The MNBs have huge surface areas, high pressures inside, bubble surface negatively charged, which can show amazing effects for applications[1]

Fig.1. versatile applications of Micro/Nano Bubbles (Courtesy Toshihiko EGUCHI)

Because of The properties of MNB like high inertial pressure, high gas-liquid interfacial area, negatively charged surface and high gas dissolution rate makes them extremely suitable for various applications[2,3]. MNB has been used for a source of high temperatures when activated by ultra-sonic in chemical reactions and to increase oxygen delivery in fermentation process[4,5]. MNB is used to drive mixing on a chip in microelectromechanical devices[6]. MNB is being developed to also use as ultrasound contrast, drug delivery agents[7]. When considering the agriculture and aquaculture applications of MNB, it is very important to evaluate based on scientific principles, from an academic standpoint and to compare MNB technology with existing technology both in terms of its functional quality and effectiveness. Thus it becomes very necessary to examine clearly the superior physical characteristics like size distribution, number concentration, residence time and lifetime of MNB When MNB generator switch on and after switch off.

However, since 2015, when Prof. Dr. Kiyoshi Yoshikawa started as research advisor to the President of Rajamangara University of Technology Lanna (RMUTL), Chiang Mai, Thailand, and opened "Center of Excellence of High Voltage, Plasma and Micro/Nano Bubbles. Application for Advanced Agricultural and Aquaculture, MNB technology was found that is very innovative and promising with great potential to the improvement of Thai society. For this reason, from the beginning, RMUTL researcher joined and doing research and development of MNB generators, as well as applications of MNB generators. The development is ongoing as shown in Fig. 2. Mainly 2 kinds of MNB generators have been developed, namely, KVM-10 is a desktop MNB generator for academic research (flow rate; 1L/m), and KVM-20 is a medium size MNB generator for practical applications (flow rate; 20L/m) both for almost 10% cost of Japanese equivalent MNB generators. So far, we have already improved up to version 10 in the past 1.5 years. Recently, Oxygen MNB density as high as 5×10^{11} bubbles/ mL have been succeeded, measured by Horiba LA- 960A which was introduced last December to RMUTL.

Now the effects of MNB of such as air, Oxygen, Nitrogen, and Ozone gases on the versatile applications were evaluated. For examples, as in Thai, due to its extremely high temperature and humidity, illegal formalin is being used for fish preservation, as well as fruits and vegetables, which causes 10 times higher cancer-risk to kids under 2 years old compared with the adults, according to United States Environmental Protection Agency, EPA in 2010. To drastically ban formalin from food preservation, Nitrogen MNB generators were developed which can reduce the dissolved Oxygen from 7mg/L down to 0.1 mg/L for 100L water in 15 minutes, resulting in Oxygen-free MNB water(OFW). In this water, live fishes immediately die, and also aerobic bacteria cannot survive longer, which results in long fish preservation. So far, RMUTL conducted successful trial experiments in collaboration with private sectors in Thailand, such as, long shelf fish preservation by oxygen-free MNB water (OFW) without formalin, coconut milk and boiled shrimp sterilization by Ozone MNB water (OZW), fruits and vegetable preservation by Oxygen rich MNBs water (ORW), high DO MNB water injection into rearing ponds, and so on. RMUTL has been developing MNB technology since 2015 to present as shown in Fig. 3.\

However, in order to clear the various MNB functions in the applications, the knowledge of distribution and the number density of the MNB are essential. The MNB is found to change its distribution from microbubble rich water into nano bubble dominant water in relatively short times, and the latter becomes very stable with a slight temporal reduction of the MNB number density measured by HORIBA 960-A, which can measure both micro and nano bubble distributions and densities continuously

2. MATERIALS AND METHODS

Pure water was used to produce micro- and nano-bubbles. This water was obtained using a water purification system (ROM-250-100T, Treat Chemical Co., Ltd., Thailand), which is equipped with a reverse osmosis cartridge and modules of ion-exchange resins and activated carbon. The main gas used to produce MNB was oxygen (O2, purity 99.999%, Mae Ping oxygen, Ltd., Chiang Mai, Thailand).

The MNB generator (KVM-10, RMUTL, Thailand) was used for the production of MNB. Oxygen was introduced in the inlet part of the diaphragm pump while the water was suctioned. Then, the mixture of water and gas was subjected to a high pressure in a pressurized tank to increase the dissolution of gas in the water. When the water was released at the atmospheric pressure, the de pressurization of gas-supersaturated water led to nucleation of the bubbles, which were expelled and dispersed through a nozzle at the outlet.

The bubble size distributions were evaluated by a laser scattering particle size distribution analyzer (LA-960A, Horiba, Ltd., Japan). Which detects the light intensity distribution pattern emitted from the particles. The range of particle size which can be detected is from 10 nm to 5000 μm. The refractive index of material of the particle was set to 1.0003, corresponding to the oxygen. The measurements were performed at 25 °C.

Fig. 2. History of MNB Technology development by RMUTL.

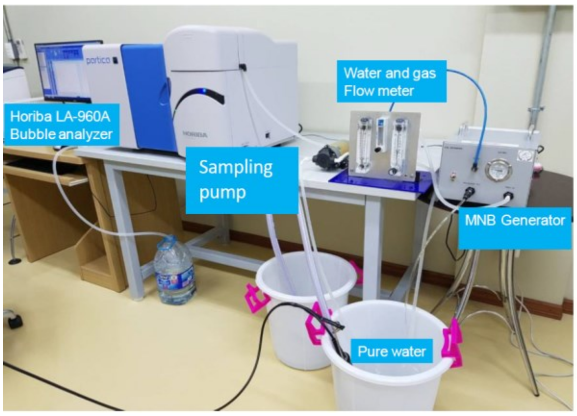

Fig. 3. The experimental set up for evolution of MNB distributions.

In this study, the measured continuously the evolution of MNB distributions and number densities as condition in Table 1.

The experimental setup is shown in Fig.3. The production of Oxygen MNB water, a MNB generator (RMUTL KVM-10) and commercial oxygen gas (purity 99.5%) were used. Flow rates of water and oxygen gas were controlled and measured by flow meter, the water was circulated in this system for 20 min at 25 °C. In this study, this procedure in referred to as micro/nano bubble water, indicating the water in which micro and nano bubbles were introduced.

MNB measuring system, MNB water was introduced in the inlet part of a sampling pump for 1 L/min while the MNB generator switch on. Then, the consecutively generated MNB water was subjected to HORIBA MNB analyser LA960-A, the water was circulated to a water tank loaded, the size distributions were measured every 5 minutes without generator switch off until, 20 minutes, the sampling pump and size distributions measurement still proceed for 60 minutes. MNB water were kept in 2L bottle at room temperature for every day measurements in 5 days continually.

Table 1. experimental condition.

Pure Water	5 liters, pure water from revers-osmosis filter system Water temperature = 25 ~ 27 degree C
UFB Generator	KVM-10 with nozzle Operating condition Water flow = 1~2 L/min Gas flow = 0.05 L/min Exit pressure = 200~270 kPa[G] Generation time = 20 minutes
Gas	Oxygen
Measurement Method	Laser Scattering Particle Size Distribution Analyzer HORIBA LA-960 with sampling pump

3. RESULTS AND DISCUSSION

Measurement of consecutively generated MNB water, in the initial microbubble dominant states (for example, in Fig.4, t=5 min, mode size of bubble is 24 μm and number concentration is 5733 (bubble/ml), microbubbles are unstable and possible to measure by a sampling system. According, measurements must be performed by Horiba LA-960A directly to MNB generator and water tank loaded with microbubbles.

When MNB generator switch off, bubble generation processes stopped, MNB bigger than 24 μm floating up to the surface quickly for 5 min and MNB 24 μm remains in the water for 15 min, after that MNB 0.223 μm has been detected as shown in Fig. 5.

The measurement was continued for 35 and 45 min after the MNB generator switch off, MNB about 1 μm with 5.9181E+07 bubble/ml of number concentration was detected as shown in Fig.6.

MNB water was kept in room temperature(25°C). After 3 days, the bubble size reduced from about 1 μm to 0.107 μm whereas the number concentration increased from 5.9181E+07 bubble/ml to 6.08961E+10 bubble/ml. In addition, the size distribution of MNB water was measured after 4 and 5 days as shown in Fig.7.

In our experimental, MNB size distributions were measured by a laser light scattering method, the bubbles of diameter in the range from 10 to 100 bigger μm were observed. Large bubbles (diameter more than 24 μm and number concentration is around 5733 (bubble/ml)) stayed still during when MNB generator switch on. Because of scattered light intensity from large bubble higher than small bubble then the distribution shows only large size and low number concentration. Whereas, when the MNB generator switch off, the production process stop, large bubble floats to water surface quickly and they disappeared in after 15 min. After that, MNB smaller than 1 μm and high number concentration was observed and stayed still in the last 3 days, because of the floating speed of the small bubble is very low. Even so, it disappeared within three days and then the bubble size about 100 nm (6.08961E+10 bubble/ml) was observed.

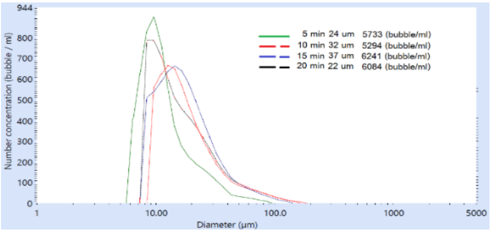

Fig. 4. The size distribution of MNB for 5, 10, 15, 20 after MNB generator switch on.

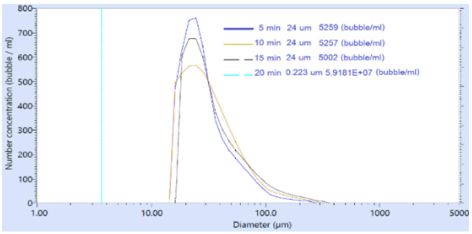

Fig. 5. The size distribution of MNB for 5, 10,15,20 min after MNB generator switch off.

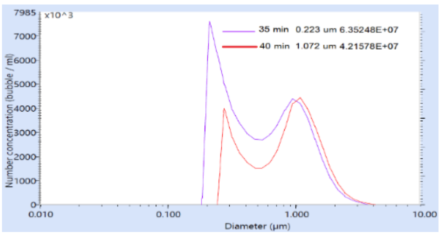

Fig. 6. The size distribution of MNB for 35,40 min after MNB generator switch off.

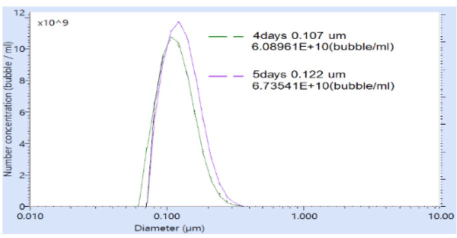

Fig. 7. The size distribution of MNB for 4 and 5 days after MNB generator switch off.

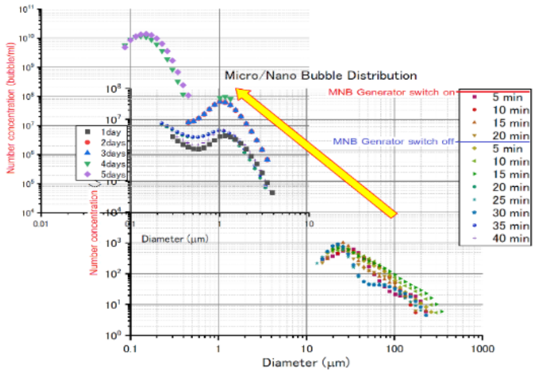

Fig. 8. Evolution of Micro/Nano bubbles distributions measured by Horiba LA-960A.

4. CONCLUSION

During the generation (MNB generator switch on) of MNB in the water, the water showed a white milky appearance. The bubble concentration rapidly increased to values of approximately 5733 to 6084 bubble/ml. Micro bubbles of mode diameter of 22 to 37 µm were detected through laser light scattering method.

After stopping the bubble generation (MNB generator switch off), the milky water gradually disappeared, becoming to transparent. The micro bubble bubbles were no logger detected after some minutes after MNB generator switch off but bubble in nano scale were detected.

The laser light scattering method detected bubble approximately 200 nm diameter in number distribution. The residence time of the nano bubbles was evaluated by the measurements of bubble size distribution along the time. In this study, the bubble could be detected for 3 to 5 days.

In summary, Evolution of MNB bubble distributions with the use of laser light scattering method, during generation, the large bubble with low number concentration was observed. After stopping the bubble generation, the bigger bubble floats to water surface quickly and the smaller bubble with high number concentration was observed, stayed still more than 3 days.

5. ACKNOWLEDGMENTS

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