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The Implementation of Micro/Nanobubbles (MNBs) Technology to Treat Basin Water as The Primary Water Source for Hydroponics in Greenhouse

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ABSTRACT

The greenhouse plays a pivotal role in creating an ideal environment for hydroponic cultivation. The greenhouse has utilized rainwater and basin water as a source of raw water for hydroponic farming. Presently, the water quality of Leuwi Padjadjaran basin fails to meet the standards required for hydroponics due to its turbidity, sediment content, discoloration, pH levels exceeding 7, and low dissolved oxygen (DO) concentration of 2.2 mg/l. The micro/nanobubbles (MNBs) technology stands as a viable method for water treatment owing to its capacity to bind impurities via radical OH. The application of MNBs for the treatment of basin water involves the use of a hydrodynamic cavitation MNBs generator with a dual-chamber rotating flow nozzle. The parameters evaluated in this research encompass DO concentration, MNBs stability, microbubble size, and the visual response to MNBs application. MNBs treatment was conducted with three different gases: air, oxygen, and ozone. Microbubbles were measured using the particle image velocimetry (PIV) method. The DO concentration reaches 21.6 mg/l when employing oxygen-based MNBs. On the third day post-generation, MNBs stability still maintains DO concentrations above the initial levels. Thus it can be used as hydroponic raw water.

1. INTRODUCTION

Greenhouses play a crucial role in hydroponic cultivation by creating an ideal environment for plant growth through microclimate control. With greenhouses, farmers can regulate temperature, humidity, light, and air circulation precisely according to plant requirements. This allows hydroponic plants to grow more optimally without depending on external weather conditions. In this controlled environment, plants can experience faster growth, higher production, and better harvest quality (Tando, 2019). Greenhouses have significant potential to utilize various raw water sources, including rainwater and reservoir or basin water. With the right technology, rainwater can be collected and stored for irrigation purposes in greenhouse hydroponic cultivation. Meanwhile, basin water can also be utilized as an alternative raw water source due to its continuous flow regardless of weather factors (Wagiono *et al*., 2022).

Currently, the water from Leuwi Padjadjaran Basin, which is the subject of this study, cannot be used for hydroponic greenhouse needs because its quality does not meet raw water quality standards. The water is turbid, muddy, and brownish in color, especially during the rainy season. Measurement results show that the pH level is above 7, whereas good water is neutral (pH=7) (Presiden RI, 2001). The pH value of raw water used affects plant growth, where plants can grow optimally in the pH range of 5.5-6.5 (Karoba *et al*., 2015). Measurement results of dissolved oxygen (DO) content are still low at 2.2 mg/L compared to the minimum requirement of 4 mg/L for hydroponic plants. DO is an important parameter for hydroponic plant growth. Therefore, the DO level in the nutrient solution must be adequately maintained for hydroponic plant needs (Safira *et al*., 2023).

Raw water is water used and utilized for various purposes such as drinking water, livestock, industry, and agriculture (Kementrian PUPR, 2018). Raw water itself plays a significant role in hydroponics, which has various application systems. Hydroponic system itself is a cultivation system without using soil as the planting medium but by adding nutrient water as a nutrient source. This makes raw water one of the main supporting components in hydroponics, where the nutrient solution will be mixed into the raw water. The content and quality of raw water will affect macro and micro elements in the nutrient solution used (Amalia *et al*., 2021).

Micro/nanobubbles (MNBs) technology is one method that can be utilized in water treatment because it has OH radicals that can bind dirt (Ghadimkhani *et al*., 2016). MNBs help to separate dirt through flotation processes that occur in the application of micro/nanobubbles for wastewater, effectively reducing coagulant doses (Liu *et al*., 2010). The addition of ozone gas to micro/nanobubbles production has also been proven to disinfect drinking water to eliminate bacteria and prevent the growth of microorganisms (Batagoda *et al*., 2018). The advantages of applying MNBs in water treatment are high gas transfer efficiency, organic and pathogen disinfection oxidized with direct reactions to trigger bond cleavage in wastewater and indirect reactions utilizing hydroxyl radicals, and can be produced by hydrodynamic cavitation methods in wastewater (Lyu *et al*., 2019). MNBs research in wastewater treatment has been proven to reduce COD and BOD levels, eliminate odor and color, reduce TSS, and neutralize pH (Liu *et al*., 2010). Therefore, the research aims to apply MNBs technology for Leuwi Padjadjaran Basin water treatment as hydroponic raw water, so its quality can be improved, especially in dissolved oxygen (DO) concentration and stability.

2. MATERIALS AND METHOD

The tools and materials used in this study are a hydrodynamic cavitation MNBs generator system with rotating flow nozzle channel, Sony RX-100 IV digital camera, 635 nm laser diode, water purification machine to produce reverse osmosis water, QLY-5 L oxygen concentrator (Qili Environmental, China), ozone concentrator, Lutron WAC-2019SD DO sensor, aquarium, and Leuwi Padjadjaran Basin water.

2.1. Characterization of MNBs Generator

The MNBs generator (Figure 1) used utilizes a hydrodynamic cavitation system that utilizes a rotating flow nozzle with a dual-chamber channel. The MNBs generator consists of a submersible pump WD-101 E and a nozzle connected using PVC pipes. The nozzle used has a self-suction system to flow gas into the nozzle chamber, so air for MNBs production does not require air injection. Characterization of the MNBs generator was carried out in an aquarium to facilitate observation of the microbubbles produced by the generator. The aquarium used has a capacity of 20 liters of water, allowing testing of the MNBs generator in 20 liters of water.

Characterization needs to be done to observe the mass transfer of gas to liquid and the size of microbubbles produced by the MNBs generator. The water used for generator characterization uses reverse osmosis water produced from a water purification machine. This aims to ensure that the water used is free from other particles, so when analyzing the detected size of microbubbles, only microbubbles are truly detected. The purpose of characterization is also to see how long the MNBs generator takes to produce the highest dissolved oxygen (DO) concentration. Measurement of microbubble size is carried out to detect the presence of nano-bubbles, based on the relationship between microbubbles and nano-bubbles. Nano-bubbles are formed after the generation of microbubbles and can be said to be residues or shrinkage of microbubbles smaller than 50 µm (Yasui *et al*., 2018).

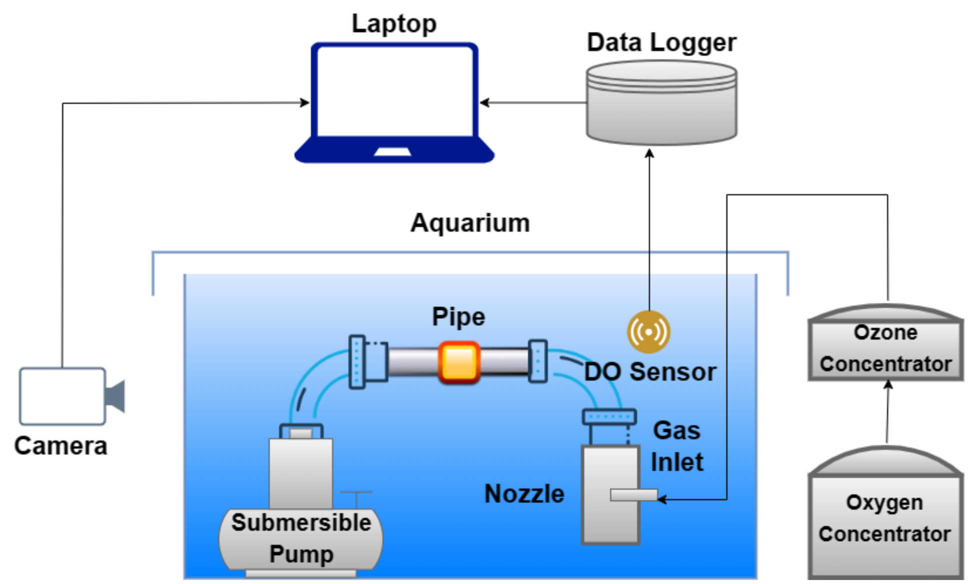


Figure 1. Scheme of MNBs generator testing

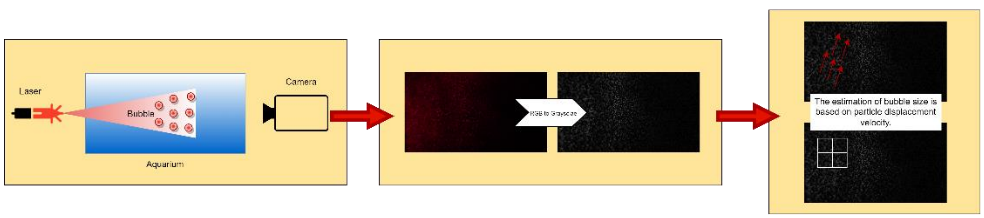


Figure 2. Scheme of particle image velocimetry testing

2.2. Particle Image Velocimetry

Analysis of microbubble size using the particle image velocimetry (PIV) method. PIV testing (Figure 2) begins with video recording of bubble rising movement, image acquisition and extraction or pre-processing, particle/bubble displacement calibration (pixels to micrometers), displacement to particle velocity measurement, particle size estimation, and bubble size distribution (Redhyka, 2017). To produce microbubble images during generation, PIV testing requires a high-speed camera or frame rate. Microbubbles that appear shortly after MNBs generation will be visible with an indication that MNBs water is milky white. Microbubbles will disappear immediately after the generator is turned off, so the video recording process for microbubble measurement is done quickly. The video results are taken using a Sony RX-100 IV camera with a 240 fps mode to capture slow-moving bubble videos. Characterization of microbubbles is important in research because it produces free radicals during bubble breakdown processes needed for disinfection in water treatment systems.

2.3. Leuwi Padjadjaran Basin Water Treatment

The treatment of Leuwi Padjadjaran Basin water using Micro/nanobubbles technology is carried out with three gas treatments, namely free air, oxygen, and ozone. Parameters observed from the application of the MNBs generator in basin water treatment are DO concentration, pH/ORP changes (for ozone gas), and conductivity. After the generator is turned off, microbubble recordings will be made to analyze the size of microbubbles produced by the three gases used in basin water treatment. Samples from each treatment with different gases will be measured for 3 days after micro/nanobubbles generation to see changes in DO concentration, pH/ORP, and conductivity. Measurement of DO concentration stability becomes one of the parameters to see the duration of MNBs staying in the water, because the higher the DO concentration, the longer the bubble stability in the water (Ushikubo *et al*., 2010).

3. RESULTS AND DISCUSSION

3.1. Characterization of MNBs Generator

The characterization results of the MNBs generator show the optimal time for producing micro/nanobubbles in liquid. There is an increase in dissolved oxygen (DO) concentration along with a decrease in DO concentration during MNBs generation. The water temperature during generation also experiences a more stable increase compared to DO concentration. The graph of DO concentration increase and temperature increase is shown in Figure 3. The initial DO concentration before MNBs generation was 3.8 mg/l, with a final DO concentration at the end of generation of 6.55 mg/l. The highest DO concentration point occurred at the 10th minute of MNBs generation, reaching 6.75 mg/l, followed by a decrease after the 10th minute. This indicates the optimal time for MNBs generation with the used MNBs generator is 10 minutes. The temperature decrease after the 10th minute occurred due to the water temperature factor, which increases as MNBs generation continues. The temperature increase during the 16-minute generation was 0.7°C. These results indicate that temperature can affect DO concentration, where temperature is inversely related to gas-to-liquid mass transfer or can be said that an increase in temperature will be followed by a decrease in DO concentration (Michailidi *et al*., 2020).

3.2. DO Concentration, pH/ORP, and Conductivity

Gas-to-liquid mass transfer or DO concentration was measured in the study to observe water responses using different gases, namely free air, oxygen, and ozone. ORP (Oxidation Reduction Potential) is the tendency to obtain electrons that can be reduced, while pH indicates the degree of acidity or alkalinity of a solution. Water conductivity values were also measured to observe the water's ability to conduct electricity or to see the mineral content in the water. Changes in DO concentration, pH, ORP, and conductivity values are shown in Figure 4.

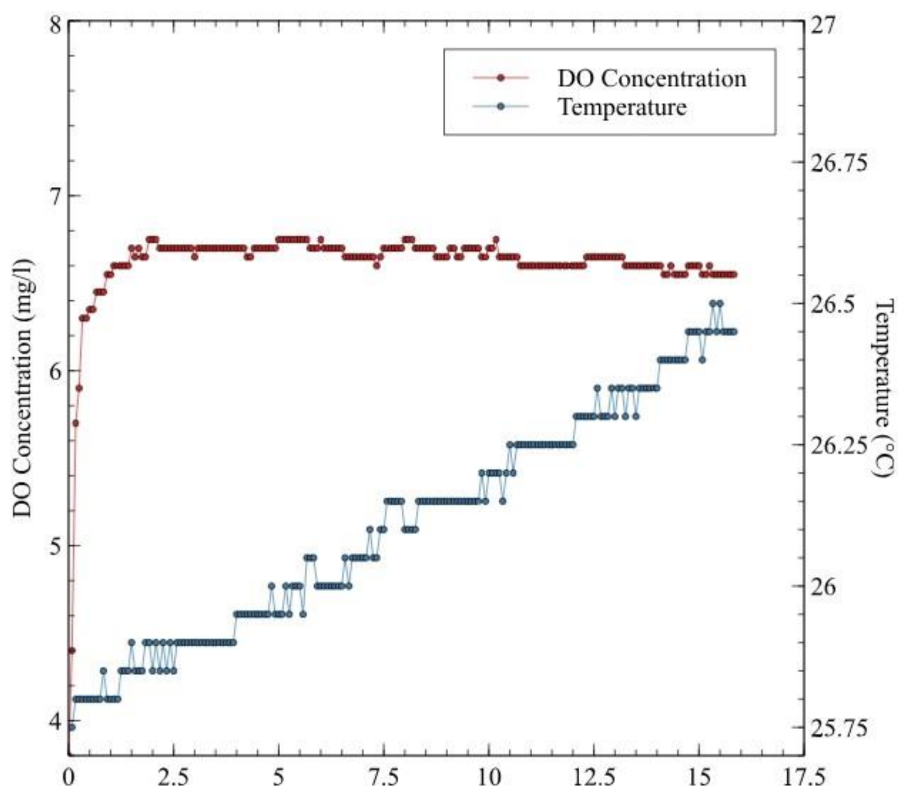
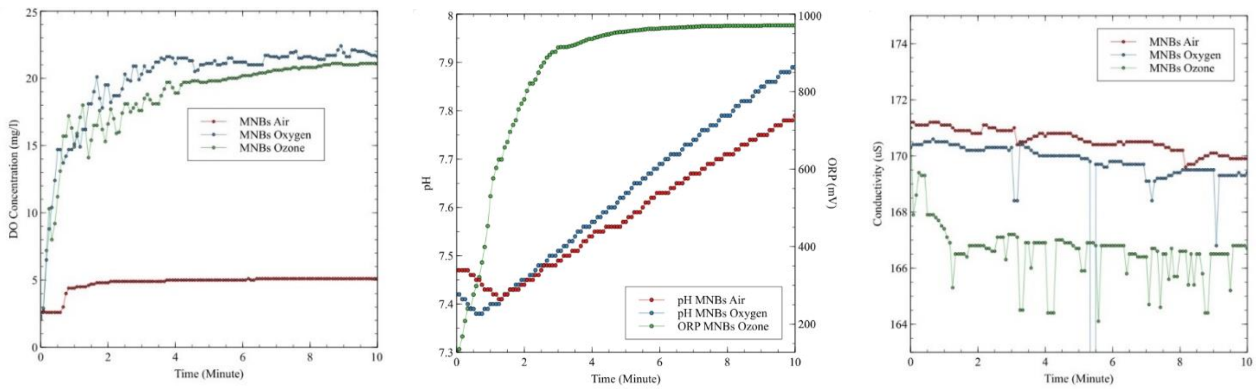
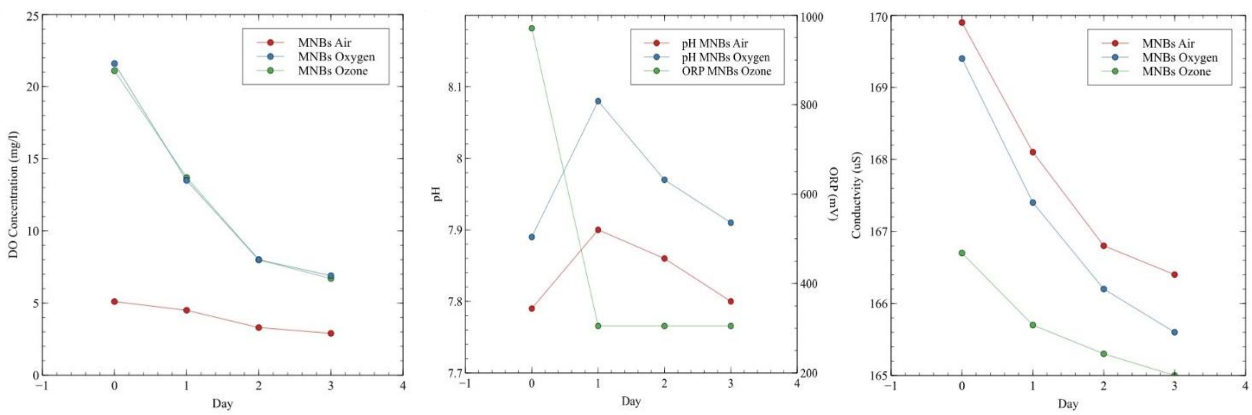


Figure 3. Graph of MNBs Generation Characterization



(a) (b) (c)

Figure 4. Graph during MNBs Generation: a) Dissolved Oxygen (DO) Concentration, b) pH and ORP, c) Conductivity



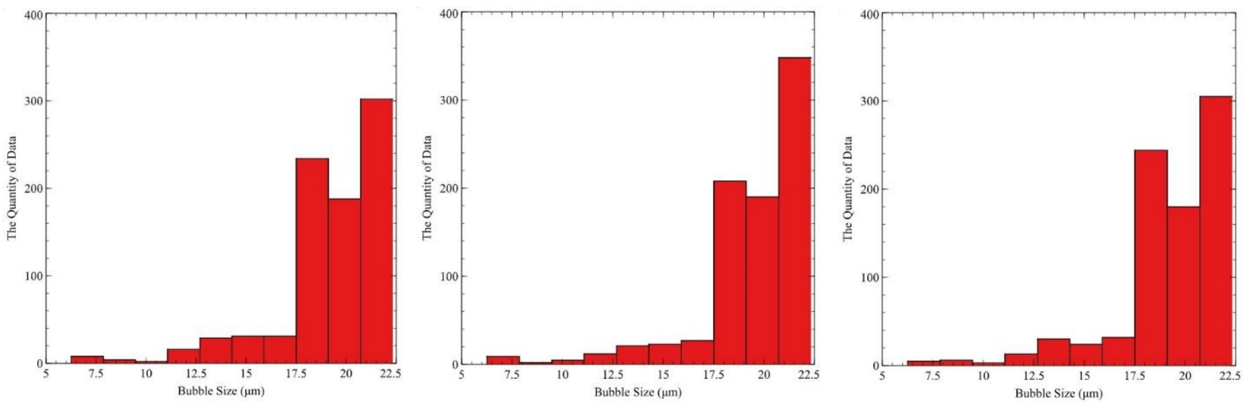
(a) (b) (c)

Figure 5. Measurement of MNBs Stability: a) Dissolved Oxygen (DO) Concentration, b) pH and ORP, c) Conductivity

DO concentration during MNBs generation using different gases showed different concentration increase rates. Figure 4a shows the highest concentration during a ten-minute generation by applying MNBs using pure oxygen gas injection with a final DO concentration of 21.6 mg/l, while air MNBs resulted in a final DO concentration of 5.1 mg/l. Treatment with oxygen MNBs showed a higher final DO concentration compared to ozone and air treatments, which is consistent with Ushikubo *et al*.'s research (2010), where oxygen nanobubble DO concentration is higher than DO concentration produced by air nanobubbles. Air and oxygen MNBs treatments based on Figure 4b showed an increase in pH at the end of the ten-minute generation, but the oxygen treatment showed a higher increase compared to the air treatment even though the initial pH was lower. ORP was measured for ozone MNBs application, where at the end of the generation, the ORP value significantly increased from 127 mV to 971 mV. The increase in pH value in MNBs technology application is a good indication in water treatment or can be said to play an important role in flotation, as efficiently basic pH values will increase ammonia removal in water (Liu *et al*., 2010). The increasing ORP value indicates a greater amount of hydroxyl radicals, thereby increasing oxidation ability (Chu *et al*., 2007).

3.3. MNBs Stability

Bubble stability in this study was seen from the measurement of dissolved oxygen (DO) concentration, pH, ORP (for ozone MNBs), and conductivity. Bubble stability was measured in five-liter jugs for three days after MNBs generation. DO concentration measurement was conducted to see the duration of staying time for each MNBs treatment. The DO concentration decrease graph of oxygen and ozone MNBs treatments looks similar when seen in Figure 5a. The oxygen and ozone MNBs DO concentration on the third day after generation was still above the initial concentration before MNBs generation, and also above the final DO concentration after MNBs generation. This indicates that the higher the DO concentration, the longer its stability (Ushikubo *et al*., 2010). The pH value of air and oxygen MNBs from stability measurement for three days after generation looks similar in the decreasing graph from Figure 5b, but differs in value where the MNBs pH is higher than the air MNBs pH value. The ORP value of ozone MNBs from the first day to the third day after generation remains stable at 300 mV. This number is still higher than before ozone MNBs generation. Figure 5c shows the decreasing stability graph of air, oxygen, and ozone MNBs conductivity values. The conductivity value of MNBs treatments decreases during generation and measurement after generation. Unlike DO, pH, and ORP concentrations, where during generation the values of DO, pH, and ORP concentrations increase but decrease during stability measurement. The conductivity value of the basin water after MNBs treatment shows a decrease in electrical conductivity, indicating a decrease in minerals contained in the water (Etchepare *et al*., 2017).



(a) (b) (c)

Figure 6. Distribution of Microbubble Sizes: a) Air MNBs, b) Oxygen MNBs, c) Ozone MNBs

3.4. Microbubble Size

Microbubble size is one of the parameters measured to detect the presence of nanobubbles in this study. Microbubbles are present during MNBs generation using MNBs generator with a hydrodynamic cavitation system utilizing a rotating nozzle with two-channel flow. Basin water treatments for air, oxygen, and ozone MNBs were successfully analyzed for their microbubble size, where all gas treatments had sizes <50 µm. Air MNBs had an average microbubble size of 19.24 µm, oxygen MNBs had 19.27 µm, and ozone MNBs had 19.48 µm. Distribution of microbubble sizes are shown in Figure 6. Different gas treatments did not significantly affect the average microbubble size. The noteworthy result is that all MNBs treatments had an average microbubble size of <50 µm, indicating the presence of nanobubbles in the water after MNBs generation (Yasui *et al*., 2018). This result can be confirmed in the literature on MNBs generation which successfully measured microbubble sizes <50 µm, which then successfully detected nano bubble sizes <200 nm using the Zeta Size Nano ZS with Dynamic Light Scattering (DLS) method (Alam *et al*., 2022).

3.5 Visual Response of MNBs Application

The study of MNBs application in the basin water is one study to observe the responses that occur in the basin water. MNBs become one of the technologies used in mineral separation, so this study visually presents MNBs application as shown in Figure 7. A significant visual response is seen in ozone MNBs, where the basin water changes color to yellow-brown. The color change of basin water after ozone MNBs generation is clear due to the effect of ozone gas administration, or often called ozonation (Moris *et al*., 2022). The change in basin water color to yellow-brown after ozone MNBs generation indicates that the basin water contains metals, thus causing a color change after ozone gas administration (Widyasari *et al*., 2014). These results differ from ozone application in wastewater treatment which has been widely applied, where it functions to clean colored water or reduces the turbidity level of wastewater (Rosalina,

(a) (b) (c)

Figure 7. MNBs Generation Process: a) Air MNBs, b) Oxygen MNBs, c) Ozone MNBs

2018). Therefore, further study is needed regarding the response of color changes in water after ozone MNBs application in basin water. Based on observations, basin water that has been treated increases its DO concentration and stability, making it suitable for hydroponic raw water. However, further research is needed on the filtration process.

4. CONCLUSIONS

The application of micro/nanobubbles (MNBs) technology using a hydrodynamic cavitation system MNBs generator utilizing a rotating nozzle with two-channel flow in basin water treatment can increase the DO concentration for air MNBs, oxygen MNBs, and ozone MNBs respectively by 5.1 mg/l, 21.1 mg/l, and 21.6 mg/l. The stability of MNBs on the third day after MNBs generation remains above the DO concentration before MNBs generation. The microbubble size in basin water treatment with MNBs application was successfully detected at sizes <50 μm. Color changes occur in basin water with ozone MNBs turning yellow-brown. Further studies are needed regarding the color changes that occur and measuring the COD and BOD levels before and after the application of MNBs technology in basin water.

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REFERENCES

Alam, H.S., Sutikno, P., Soelaiman, T.A.F., & Sugiarto, A.T. (2022). Bulk nanobubbles: Generation using a two-chamber swirling flow nozzle and long-term stability in water. *Journal of Flow Chemistry*, ***12***(2), 161–173. https://doi.org/10.1007/s41981-021-00208-8.

Amalia, A.F., Dalapati, A., Firdaus, J., Haryono, P., & Rachmawatie, E. (2021). Pengaruh konsentrasi air baku terhadap pertumbuhan tanaman selada pada budidaya hidroponik. *J-PEN Borneo : Jurnal Ilmu Pertanian*, ***4***(2), 1–6. https://doi.org/10.35334/jpen.v4i2.2092.

Batagoda, J.H., Hewage, S.D.A., & Meegoda, J.N. (2018). Nano-ozone bubbles for drinking water treatment. *Journal of Environmental Engineering and Science*, ***14***(2), 57–66. https://doi.org/10.1680/jenes.18.00015.

Chu, L.B., Xing, X.H., Yu, A.F., Zhou, Y.N., Sun, X.L., & Jurcik, B. (2007). Enhanced ozonation of simulated dyestuff wastewater by microbubbles. *Chemosphere*, ***68***(10), 1854–1860. https://doi.org/10.1016/j.chemosphere.2007.03.014.

Etchepare, R., Oliveira, H., Nicknig, M., Azevedo, A., & Rubio, J. (2017). Nanobubbles: Generation using a multiphase pump, properties and features in flotation. *Minerals Engineering*, ***112***, 19–26. https://doi.org/10.1016/j.mineng.2017.06.020.

Ghadimkhani, A., Zhang, W., & Marhaba, T. (2016). Ceramic membrane defouling (cleaning) by air nano bubbles. *Chemosphere*, ***146***, 379–384. https://doi.org/10.1016/j.chemosphere.2015.12.023.

Karoba, F., Nurjasmi, R., & Suryani, S. (2015). Pengaruh perbedaan pH terhadap pertumbuhan dan hasil tanaman kailan (*Brassica oleraceae*) sistem hidroponik NFT (nutrient film technique). *Jurnal Ilmiah Respati Pertanian*, ***7***(2), 529–534.

Kementrian PUPR. (2018). *Prasarana Air Baku Air Minum Sumber Hujan*. Accessed on 12 January 2024 from: https://simantu.pu.go.id/epel/edok/016e2_Modul_10_Perencanaan_Air_Baku_dari_Air_Hujan.pdf

Liu, S., Wang, Q., Zhai, X., Huang, Q., & Huang, P. (2010). Improved pretreatment (coagulation-floatation and ozonation) of younger landfill leachate by microbubbles. *Water Environment Research*, ***82***(7), 657–665. https://doi.org/10.2175/106143010x12609736966522

Lyu, T., Wu, S., Mortimer, R.J.G., & Pan, G. (2019). Nanobubble technology in environmental engineering: Revolutionization potential and challenges. *Environmental Science and Technology*, ***53***(13), 7175–7176. https://doi.org/10.1021/acs.est.9b02821.

Michailidi, E.D., Bomis, G., Varoutoglou, A., Kyzas, G.Z., Mitrikas, G., Mitropoulos, A.C., Efthimiadou, E.K., & Favvas, E.P. (2020). Bulk nanobubbles: Production and investigation of their formation/stability mechanism. *Journal of Colloid and Interface Science*, ***564***, 371–380. https://doi.org/10.1016/j.jcis.2019.12.093.

Moris, A.O., Nur, M., Setyatwan, H., & Setiawan, I. (2022). Pengaruh pemaparan gas ozon terhadap kadar air, lignin, selulosa dan hemiselulosa pada *Azolla pinnata*. *Jurnal Ilmu Ternak Universitas Padjadjaran*, ***22***(1), 1-5. https://doi.org/10.24198/jit.v22i1.38037.

Presiden RI. (2021). *Peraturan Pemerintah tentang Pengelolaan Kualitas Air dan Pengendalian Pencemaran Air*.

Redhyka, G.G., Bahrudin, B., & Alam, H.S. (2017). Estimation of bubble size distribution using spatial digital image correlation. *Proceedings of the 2nd International Conference on Automation, Cognitive Science, Optics, Micro Electro Mechanical System, and Information Technology* (*ICACOMIT 2017*): 123–127. https://doi.org/10.1109/ICACOMIT.2017.8253399

Rosalina. (2018). Studi pengaruh jenis warna, dan waktu ozonasi terhadap penurunan kekeruhan pewarna. *Warta Akab*, ***42***(2), 1–8.

Safira, M., Yusuf, A., Salim, T.I., & Alam, H.S. (2023). Design and implementation of IOT-based monitoring system on nanobubble -based hydroponics farming. *Jurnal Teknik Pertanian Lampung*. ***12***(2), 470–483. https://doi.org/10.23960/jtep-l.v12i2.470-483.

Tando, E. (2019). Review : Pemanfaatan teknologi greenhouse dan hidroponik sebagai solusi menghadapi perubahan iklim dalam budidaya tanaman hortikultura. *Buana Sains*, ***19***(1), 91-102. https://doi.org/10.33366/bs.v19i1.1530.

Ushikubo, F.Y., Furukawa, T., Nakagawa, R., Enari, M., Makino, Y., Kawagoe, Y., Shiina, T., & Oshita, S. (2010). Evidence of the existence and the stability of nano-bubbles in water. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, ***361***(1–3), 31–37. https://doi.org/10.1016/j.colsurfa.2010.03.005.

Wagiono, M, & Fitriani, R. (2022). Pengaruh penggunaan air hujan hasil pemanenan air hujan pada pengembangan sumber air pertanian perkotaan terhadap pertumbuhan dan hasil tanaman kale (*Brassica Oleraceae* Var. Acephala) kultivar curly Gruner. *Agrotek Indonesia*, ***7***(1), 58–65.

Widyasari, E.N., Tjahjanto, R.T., & Khunur, M.M. (2014). Pengaruh laju alir udara pada ozonisasi dalam oksidasi emas. *Kimia Student Journal*, ***1***(2), 220–226.

Yasui, K., Tuziuti, T., & Kanematsu, W. (2018). Mysteries of bulk nanobubbles (ultrafine bubbles): Stability and radical formation. *Ultrasonics Sonochemistry*, ***48***, 259–266. https://doi.org/10.1016/j.ultsonch.2018.05.038.