Surface Water Treatment Pilot using Micro Hydraulic Technology Combining Ozone and Activated Carbon

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The technological line proposed in the research process is a combination of Micro Hydraulic reaction technology combined with Ozone and activated carbon filtration. The processing line will be simulated by a test model with a capacity of 5 cubic meters per hour. Installation location at Nhi Thanh Water Supply Plant, Long An Province. The Pilot will operate in 9 different stages, in order to comprehensively evaluate the Pilot.
The results of water quality analysis after the operation showed that the DO index increased from 3ppm to 7ppm, the pH remained stable at 7, turbidity (NTU) after treatment is always very low and averages at 0.01 NTU, Permanganate index after treatment is lower than 2 mg/l, average iron content is 0.05 mg/l, average manganese content is lower than 0.2 mg/l. Most of the water quality indicators are within the allowable limits according to QCVN 01-1: 2018/BYT, National technical regulation on Domestic Water Quality. This result will be compared with the quality of clean water after treatment at the Nhi Thanh water supply plant. Thereby, we can see the advantages and disadvantages when comparing the two water treatment technologies.

Keywords: *water treatment, micro hydraulic, activated carbon filtration, oxidation tower, ozone*

Introduction

The Nhi Thanh Water Plant Project from Module I was built with a capacity of 30,000 cubic meters per day and came into operation in April 2020. Module I of the Plant has maximized the water supply capacity in a short time to serve the needs of people using clean water for daily life and production. However, the water use situation tends to increase very high and it is forecasted that the demand for water will exceed the capacity of the plant to meet. In a short time, it will increase to 60,000 cubic meters per day and will reach 120,000 cubic meters per day in the period 2025–2030.

Due to high consumption demand, it requires an early investment in Module II of Nhi Thanh Water Plant by an additional 30,000 cubic meters per day, for the total capacity of the plant to reach 60,000 cubic meters per day, when water quality is good and successful. For streets in need, it can reach 70-75,000 cubic meters per day. From the results of analysis and assessment of the quality of raw water, as well as the treatment efficiency and water supply capacity of Nhi Thanh – Module I, there are still many problems that are difficult to overcome. Therefore, there is a need for a new treatment technology line more suitable to the characteristics of the water supply, limiting the amount of chemicals used during operation and the treatment efficiency still meeting the requirements according to QCVN 01-1: 2018/BYT, National technical regulation on Domestic Water Quality.

The main goal of the testing process is to find the right specifications and use them as the baseline for: Evaluate the effectiveness of the oxygen tower in increasing dissolved oxygen and pH in raw water. Evaluate the processing capacity after the Flocculation/ Coagulation process in the Micro Hydraulic cluster. Evaluation of performance when combining Ozone technology with activated carbon, during treatment of Permanganate, Manganese, Ammonium, Iron, Color.

From the evaluation results, the testing process will get complete and accurate information, helping to make decisions and plan a more realistic and feasible test. At the same time, detecting possible problems with the system, thereby changing, giving timely adjustment directions, by the actual conditions and continually improving technology transmission lines to ensure quality the amount obtained after the treatment is the most optimal.

Experimental model operation process: In order to achieve accurate figures and specifications, the model will be operated in 2 phases.

Phase I: 10 different test cases.

Phase II: Period of bad raw water quality and low pH.

For Phase II of the test, since you already know the right specifications, only change the number of chemicals used during treatment.

Materials and Methods

Process water treatment technology of experimental model

Raw water will be directed from the raw water pipeline of Nhi Thanh Water Plant to the Oxygen Tower. Raw water is led down from the top of the tower. During the flow, water will be mixed with Pall Ring in the tower. At the same time, using a centrifugal fan to supply air directly inside, increase oxygen content in water, reduce CO_2, increase pH without using chemicals.

Tab. 1. Operation process of the experimental model – Phase I

Tab. 1. Proces eksploatacji w modelu eksperymentalnym – Faza I

Experiment	Time (day)	Water flow (m^3/h)		Application of experimental model operation				
		Q_1	Q_2	Centrifugal fan	Ozone (mg/l)	Chlorine for preliminary treatment (g/m^3)	PAC (g/m^3)	NaOH (g/m^3)
1	2	5	5	YES	< 0,4	NO	13,6	NO
2	2	5	5	NO	NO	NO	10,5	NO
3	6	5	5	YES	NO	NO	15,7	NO
4	3	5	5	YES	< 0,4	1	15,7	NO
5	5	5	5	YES	1 - 2	1,6	15,7	NO
6	2	5	5	YES	>2	1,9	15,7	NO
7	2	5	3,6	YES	>2	2	16,8	NO
8	2	5	2,5	YES	NO	2	16,8	NO
9	5	5	2,5	YES	2	2	13,6	NO
10	2	5	1,5	YES	NO	2	15,7	NO

Tab. 2. Operation process of the experimental model – Phase II

Tab. 2. Proces eksploatacji w modelu eksperymentalnym – Faza II

Experiment	Water flow (m^3/h)		Application of experimental model operation				
	Q_1	Q_2	Centrifugal fan	Ozone (mg/l)	Chlorine for preliminary treatment (g/m^3)	PAC (g/m^3)	NaOH (g/m^3)
17/6/2020	5	5	YES	> 2,3	1,3	15	NO
19/6/2020	5	5	YES	> 2,3	1,6	26	268
22/6/2020	5	5	YES	> 2,3	1,5	24,7	321
23/6/2020	5	5	YES	> 2,3	1,9	19	295
25/6/2020	5	5	YES	> 2,3	3	26,1	268
26/6/2020	5	5	YES	> 2,3	8,5	31,8	214
29/6/2020	5	5	YES	> 2,3	11,4	12,4	NO
02/07/2020	5	5	YES	> 2,3	14,7	17,5	NO
06/07/2020	5	5	YES	> 2,3	21,9	20,6	NO
07/07/2020	5	5	YES	> 2,3	21,4	14,2	NO

Notes:
Q1: Flow of raw water into the experimental model
Q2: Flow of water into the ozone mixing tower

Tab. 3. Symbols of sampling dates

Tab. 3. Oznaczenia próbek I daty pobierania próbek

No	Date	No	Date	No	Date
Day 1	March 2	Day 15	March 25	Day 29	June 19
Day 2	March 5	Day 16	March 26	Day 30	June 22
Day 3	March 6	Day 17	March 27	Day 31	June 23
Day 4	March 7	Day 18	March 30	Day 32	June 25
Day 5	March 10	Day 19	April 1	Day 33	June 26
Day 6	March 11	Day 20	April 6	Day 34	June 29
Day 7	March 12	Day 21	April 8	Day 35	July 2
Day 8	March 13	Day 22	April 9	Day 36	July 6
Day 9	March 16	Day 23	April 14	Day 37	July 7
Day 10	March 17	Day 24	April 15		
Day 11	March 18	Day 25	April 28		
Day 12	March 19	Day 26	April 29		
Day 13	March 23	Day 27	June 17		
Day 14	March 24	Day 28	June 18		

Raw water after going through the Oxygen Tower will automatically flow through the Micro Hydraulic treatment cluster. At the pipe position before entering Micro Hydraulic, the chlorine will be injected directly into the water to oxidize organic compounds after the pH has been raised, and at the same time, a quantity of PAC is added to support the flocculation process.

Water after filling with chlorine and PAC will flow through the Static mixer, which is designed with many small compartments inside when the water flows through it will create a turbulent flow, which will disturb and increase the optimization of the chemical.

After the flocculation has been dissolved in the water, the individual particles need to be bonded together. To create the flocculation reaction, it is necessary to add energy to the system (eg stir) according to the dfloc flocculation pattern and time T shown in Figure 1. The energy required to make the cotton is written by the formula:

The mixing of flocculant and flocculant is the most important in the surface water treatment line. If the floc does not precipitate well and the flakes are not large, the sedimentation and filtration are ineffective, the output water quality is poor and the system does not reach the design capacity and consumes a lot of chemicals. With innovative mixing and reaction technology combining lamel inclination technology and Leopold knitting filter plate, we will exploit the maximum capacity of the existing site and structure and the best water quality. The amount of chemicals used will also be much lower.

In each compartment, micro-hydraulic eddy currents of varying intensity flow through the deflector, the PAC will be more exposed, creating more flakes. The wiper plates are also designed in a variety of distances and sizes when the water flows, the right hydraulic source will not break the floc. Water continues to flow into the Lamela sedimentation compartment in the direction from below, large patches of cotton will sink, smaller and lighter cotton patches will emerge, but most of them will be retained in the lamen. Water continues to flow back up the serrated trough and is led into the 4 sand filter compartments of the treatment cluster.

Water after being treated in the Micro Hydraulic cluster will flow through the stainless-steel water tank and be pumped into the Ozone mixing tower.

The amount of ozone will be dissolved into the water through many steps such as Ozone mixer, static mixer, Ozone

$$G = \sqrt{\frac{P}{\mu V}}$$

G: gradient average speed (s-1)
P: Energy (Watt)
μ: Dynamic viscosity (Ns/m2)
V: Volume (m^3)

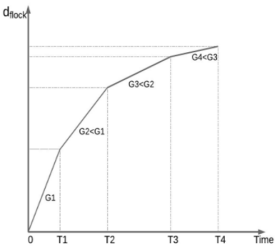
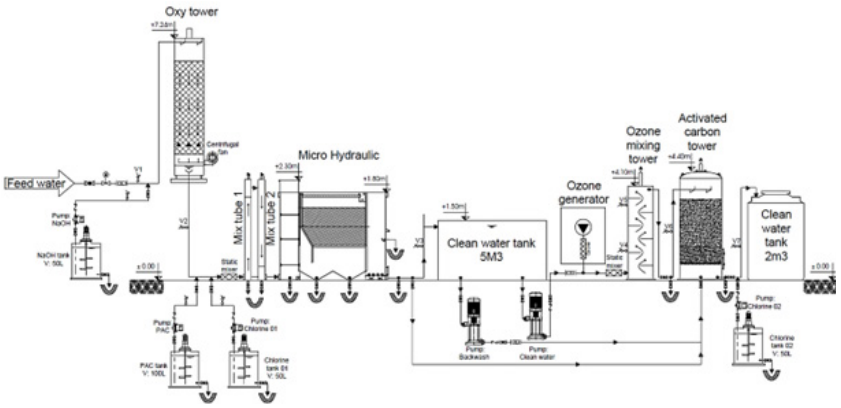


Fig. 1. The rate of floc residue generated over time
Rys. 1. Szybkość generowania pozostałości kłaczków w czasie



Note:
V_1: Sampling point raw water
V_2: Sampling point after crossing the oxygen tower
V_3: Sampling point after cross Micro Hydraulic processing cluster
V_4: Sampling point at ozone mixing tower (below)
V_5: Sampling point at ozone mixing tower (above)
V_6: Sampling point before entering the activated carbon filter tower
V_7: Sampling point clean water

Fig. 2. Descriptive scheme of the system
Rys. 2. Schemat opisowy systemu

mixing tower. Water will rise from bottom to top, in the process of rising water will have to continuously change the flow direction, because the tower is welded with many internal horizontal walls, optimizing the ability to handle O_3 in the water.

After passing the Ozone mixing tower, the water will be led to the activated carbon filter tower, where the water will flow from the top-down, going through the 2.7 m high activated carbon layer, then organic compounds are difficult to decompose and cannot be treated with Ozone will be adsorbed into the capillary pores of coal. The filtration process takes place 3 times a week, to ensure the coal layer is not washed away, the water flow used for the filtration process is 10 m3/h.

After the filtration process, the water will be disinfected with chlorine and led to a clean water tank.

RESULTS AND DISCUSSION

Metrics analyzed during operation include dissolved oxygen, pH, Turbidity, permanganate, Iron, manganese, and ammonium. The quality of the clean water sample will be compared with that of the Nhi Thanh water plant.

Dissolved oxygen index

Raw water has a very low dissolved oxygen content, ranging from 2 to 3 ppm on average. From the analysis results, it can be seen that the DO index in the clean water sample of the experimental model is higher than that of the clean water sample after the treatment process of the Nhi Thanh Water Plant. The reason for this difference is due to the technological transmission line of the experimental model using an oxygen tower combined with a centrifugal fan, forced air blowing, increasing the amount of dissolved oxygen in the water. Besides, using Ozone technology in the water treatment process also dissolves a large amount of oxygen into the water, increasing the DO index on average from 5-7 ppm. For the treatment system of the plant, after the filtration process, the dissolved oxygen content in the water also increased quite a lot, but the ability was still lower than the test model from 1.5 to 2.5 ppm.

pH index

Raw water has a relatively stable pH when it ranges from 6.6 to 6.8. However, in mid-June, the pH level had a big change and decreased to 4–4.2 (below the allowed limit according to QCVN 08-MT: 2015/BTNMT, column A2). After the treatment of the two systems, it can be seen that the clean water samples of the pH test model are almost equal to 7, and the stability is higher than the treatment system of Nhi Thanh Water Plant.

The pH in clean water samples of Nhi Thanh Water Plant meets the requirements of QCVN 01-1: 2018/BYT, but only fluctuates on average from 6.3 to 6.6. The reason is the chlorine filling process in many places in the system before being pumped into the water supply network.

Turbidity index

From the analysis results, it can be seen that turbidity in raw water sources has many relatively large fluctuations, and changes occur each day. The turbidity has a very low day of only 3 NTU but has a mutation time of more than 18 NTU. The fluctuation range was quite wide, averaging 6-14 NTU. In the early days of the experiment, the model handled the turbidity very well with Micro Hydraulic technology and activated carbon filter, but the turbidity was still much higher than Nhi Thanh Water Plant.

After many experiments, the system operates stably and the operating steps are more optimal. After the processing of the experimental model and the Nhi Thanh Water Plant, the turbidity in the raw water is processed almost entirely, when the results re-

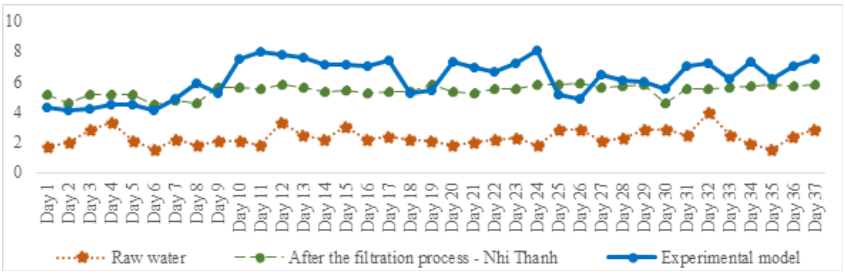


Fig. 3. Analysis results of dissolved oxygen index
Rys. 3. Wyniki analizy wskaźnika tlenu rozpuszczonego

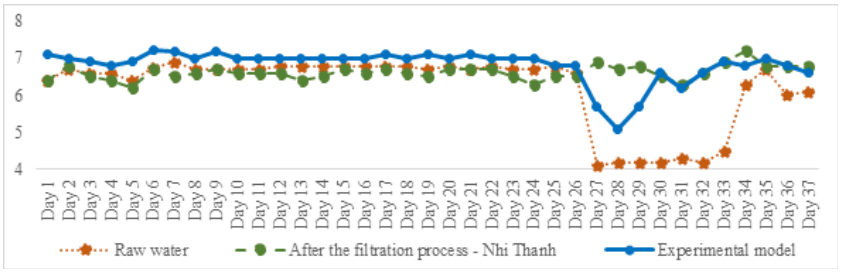


Fig. 4. Analysis results of pH index
Rys. 4. Wyniki oznaczenia wskaźnika pH

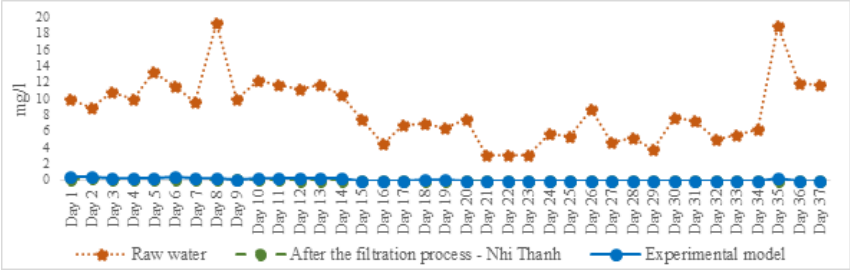


Fig. 5. Analysis results of turbidity index
Rys. 5. Wyniki analizy wskaźnika mętności

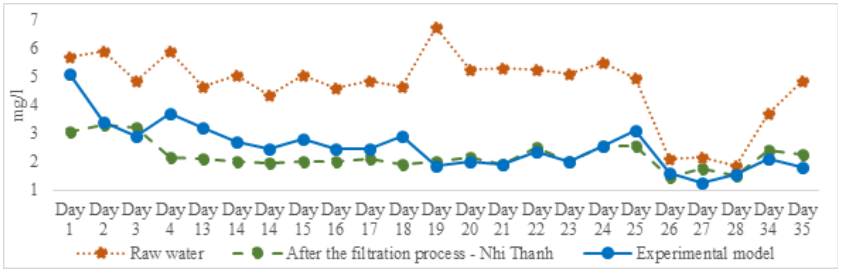


Fig. 6. Analysis results of permanganate index
Rys. 6. Wyniki analizy wskaźnika nadmanganianowego

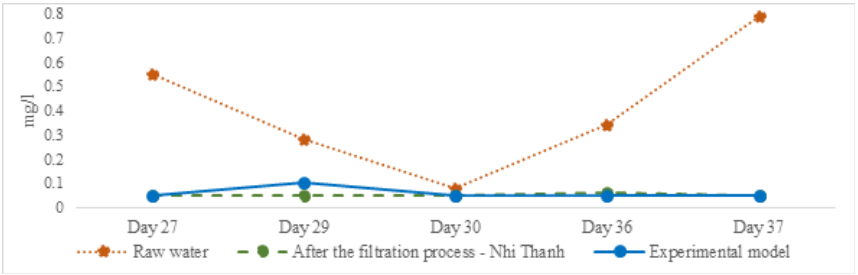


Fig. 7. Analysis results of iron index
Rys. 7. Wyniki analizy wskaźnika żelazowego

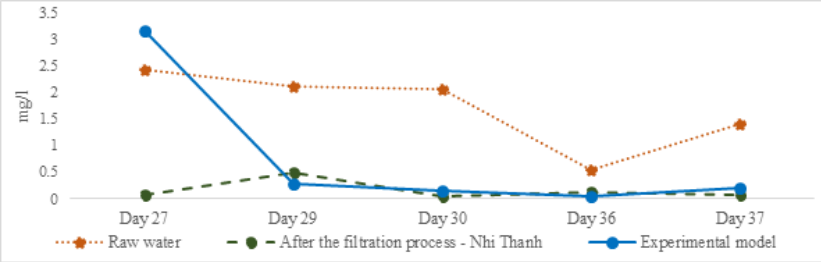


Fig. 8. Analysis results of manganese index
Rys. 7. Wyniki analizy wskaźnika manganowego

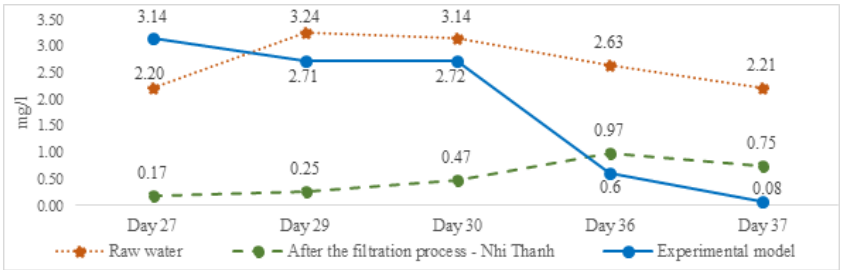


Fig. 9. Analysis results of amoni index
Rys. 9. Wyniki analizy wskaźnika amonowego

corded are mostly <0.01 NTU. Thereby we can conclude, the ability to handle turbidity of both technology lines is equally efficient.

Permanganate index

The post-treatment permanganate of both systems is ineffective. Most results are greater than 2 mg/l. But the analysis results of Nhi Thanh water samples from March 6 onwards showed that the maintenance performance was more stable, the difference compared to the threshold was not too large (difference 0.2–0.4 mg/l). The results of analyzing clean water samples in the experimental model, the results were not stable and the difference was quite clear between experiments. But from March 24, the permanganate index began to decline, especially from April 6 to 15, The analysis results of the permanganate index in clean water samples in the model, almost equivalent to the clean sample of Nhi Thanh Water Plant and lower than exceed the permitted threshold (QCVN 01-1: 2018/BYT).

In the phase II experiment, raw water had a permanganate index that was not too high, with a date almost equal to the threshold. So the processing capacity of both systems is very well achieved. The results of the permanganate index in two clean water samples of the two systems ranged from 1.5 to 1.8 mg/l.

Iron index

The iron content in raw water is relatively low and the difference between days is not too great. The lowest iron content was 0.08 mg/l on June 22, and highest on July 7 when the result was recorded at 0.79 mg/l. All analytical results reach limit values according to QCVN 08-MT: 2015/BTNMT, National technical regulations on surface water quality. Oxidation of Fe (II) to Fe (III) is precipitated and eliminated after Lamella deposition and OSF rapid filtration. The clean water sample after the Nhi Thanh Water Plant's filtration process was 0.05 mg /l. Satisfied QCVN 01-1: 2018/BYT. For the test model, a large amount of iron is oxidized at the oxygen tower. More than 50% of the iron content is processed in a Micro hydraulic assembly. The clean water sample after the activated carbon filtration process has an iron content of 0.05 mg/l. Satisfied QCVN 01-1: 2018/BYT.

Thereby, we can see that the iron content treatment efficiency of the two technological lines is the same, but the amount of chemicals consumed by Nhi Thanh Water Plant is much higher.

Manganese index

Manganese is one of the most concentrated ingredients in raw water. The results of Manganese content may be higher than 2 mg/l, 10 times higher than the permitted limit according to QCVN 08-MT: 2015/BTNMT, column A2. From the analysis results of 2 clean water samples, the treatment system of Nhi Thanh factory and the experimental model can be evaluated technically, the treatment capacity is equivalent and the treatment efficiency is acceptable. For the system of the Nhi Thanh Water Plant, the analytical result is much lower than 0.15 mg/l. However, on June 19, the manganese content exceeded the threshold 2 times according to QCVN 01-1: 2018/BYT, National technical regulation on Domestic Water Quality. The reason is that the ammonium content increases, the amount of chlorine in the system are insufficient, and the ability to handle manganese decreases. But the process of overcoming and processing from the Factory takes place very quickly, the manganese content decreases and is stable at less than 0.2 mg/l.

Model testing in the early days of phase II shows that the manganese content in the clean water sample is still very high, the ability to handle manganese is very poor. The reason is that the model has been suspended for a while after running the test in phase I (it takes time for the system to stabilize again). Besides, the absence of NaOH on June 17 was also the main cause of ineffective treatment performance, because during that time the pH in the water was very low, only ranging from 4-4.2, absolutely no. The flocculant and flocculent can be a great hin-

drance in the process of the system. On June 19, after adding NaOH into the system, the concentration of manganese analyzed in the clean water sample decreased sharply to only 0.27 mg/l, lower than the system of Nhi Thanh Water Plant.

Ammonium index

Ammonium is not only very difficult to treat ingredients in raw water but also fluctuates at a very high level from 2.2 to 3.2 mg/l. The analysis results show that the Ammonium content exceeded the limit from 7 to more than 10 times according to QCVN 08-MT: 2015/BTNMT, column A2.

Through the results presented in Figure 9, we can evaluate the ammonium processing capacity of the two technological lines.

The results showed that there are contradictions. For the treatment system of Nhi Thanh Water Plant, the analysis results of the clean water samples were very good on the 17th and 19th were below the limit. However, the results recorded in the following days tended to increase gradually, highest on July 6 when the Ammonium in clean water samples was at 0.97 mg/l (exceeded the limit of allowed folding 3 times).

The test model is gradually showing stability and very good handling of the system. Although in the first days of Phase II testing, the Ammonium treatment capacity is very low, with the right chemical increase and more and more stable operation, the Ammonium treatment efficiency is achieved post-processing is very high. Results were recorded on July 7 at 0.08 mg/l (3.75 times lower than the threshold).

Conclusions

Micro-hydraulic technology combining ozone and activated carbon filtration is technically feasible, the analysis results show that the parameters of DO, pH, turbidity, permanganate, color, iron, manganese, sulfate, and ammonium all change in a positive direction. Clean water samples meet QCVN 01-1: 2018 / BYT standards for the quality of clean water for domestic use. Although the first test results were not really as expected, the difference between the Nhi Thanh water treatment system and the experimental model was almost equal. In the tests, after the system gradually stabilizes and goes into orbit, combining calculation and choosing the right chemical charge rate, the processing efficiency of the experimental model increases very high. Besides, Ozone technology has not been applied much for the treatment of supply water with such a large volume of water in Vietnam, so it takes a longer time to study. The quality of activated carbon is very important in the treatment of mechanical pollutants.

When using ozone to treat water, it is necessary to ensure that ozone is aerated into the water for enough time necessary to create ozone dissolved water with enough concentration of sterilization and chemical decomposition. Avoid sniffing, direct inhalation of ozone gas often in the air because it will harm the respiratory tract due to ozone having strong oxidizing properties. Therefore, the ozone pipes must be regularly checked, maintained, and replaced if a leak is detected. Also, the risk of fire is a top priority when using Ozone technology in the treatment process.

For activated carbon filtration, additional tests are required with better-activated carbon and higher iodine content. Thereby, we can better evaluate the processing ability of the experimental model.

Acknowledgment

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Pilotażowe oczyszczanie wód powierzchniowych z wykorzystaniem technologii mikrohydraulicznej łączącej ozon i węgiel aktywny

Zaproponowana w procesie badawczym linia technologiczna jest połączeniem technologii reakcji Micro Hydraulic połączonej z filtracją ozonem i węglem aktywnym. Linia technologiczna będzie symulowana przez model testowy o wydajności 5 metrów sześciennych na godzinę. Miejsce instalacji w zakładzie wodociągowym Nhi Thanh w prowincji Long An. Instalacja pilotażowa będzie działała w 9 różnych etapach. Wyniki analizy jakości wody po procesie wykazały, że wskaźnik DO wzrósł z 3 ppm do 7 ppm, pH utrzymywało się na stabilnym poziomie 7, mętność (NTU) po uzdatnianiu jest zawsze bardzo niska i średnio 0,01 NTU, wskaźnik nadmanganianowy po uzdatnianiu jest niższy niż 2 mg/l, średnia zawartość żelaza wynosi 0,05 mg/l, średnia zawartość manganu jest niższa niż 0,2 mg/l. Większość wskaźników jakości wody mieści się w dopuszczalnych granicach zgodnie z QCVN 01-1: 2018/BYT, krajowymi przepisami technicznymi dotyczącymi jakości wody użytkowej.

Wynik ten został porównany z jakością czystej wody po uzdatnieniu w wodociągu Nhi Thanh. W ten sposób pokazano zalety i wady dwóch technologii uzdatniania wody.

Słowa kluczowe: *uzdatnianie wody, mikrohydraulika, filtracja węglem aktywnym, wieża utleniająca, ozon*