THE CHEMISTRY OF THE RAW WATER TREATED BY AIR-JET ULTRASOUND GENERATOR

ANCA ŞTEFAN, GEORGE BĂLAN

Abstract. The paper presents the sonic treatment effect on the main chemical indicators of the raw water. Also, the paper presents the air-jet ultrasound generator and the experimental laboratory installation for sonic treatment, as well as the working methodology.

Key words: air-jet generator, ultrasound, chemistry, water.

1. INTRODUCTION

In the process of water treatment, a major issue is the loading with suspended solids and organic substances which lead to disruption of water and determine the need to increase the oxygen and air content of water.

In order to obtain clean water from raw water it can be used the sonic technology [1]. That allows its use in a continuous loop, ensuring environmental restoration of natural and artificial elements [2].

The primary device that enables the sonic technology is the air-jet generator, which is emitting ultrasound and produces airflow at certain acoustic and gas dynamic parameters [3]. Using the air-jet generators in water treatment allows the combination of two mechanisms of treatment – coagulation of particles due to acoustic waves produced by ultrasound generator and bubbling working air resulted of its operation.

2. THE EXPERIMENTAL INSTALATION FOR SONIC TREATMENT OF RAW WATER

The research of sonic treatment (both with ultrasound and bubbling) requires certain technical requirements to ensure the technological process conveyance and control, provided within the experimental facility. The air from the compressor 1 (Fig. 1) at a pressure of 0.6÷0.8 MPa, it is stored inside a accumulator tank 2, which is designed to eliminate pressure fluctuations generated by this compressor and to provide the desired flow and working pressure during the sonic treatment [4]. The

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“Dunărea de Jos” Galați University, Romania

accumulator tank is emptied regularly through valve V1, which ensures the elimination of condensate part. After opening the valve 2, the compressed air from tank passes through the pneumatic reducer 3, where its pressure drops to a value of 0.1 ÷ 0.3 MPa, required to operate the sonic generator 7.

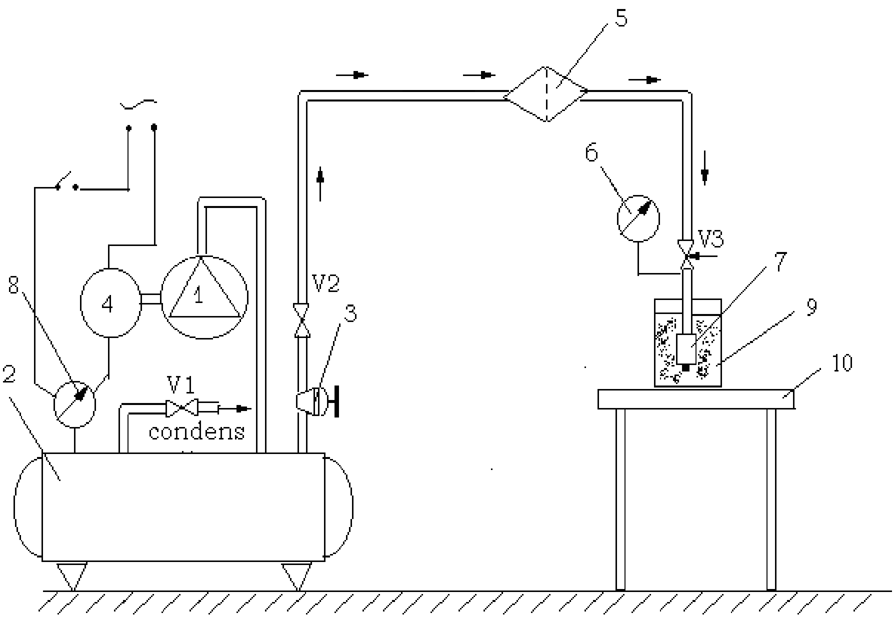

Fig. 1 – Experimental layout for raw water treatment: 1 – compressor, 2 – accumulator tank, 3 – pneumatic reducer, 4 – electrical engine, 5 – air filter, 6 – manometer, 7 – ultrasound air-jet generator, 8 – manometer, 9 – working tank, 10 – working table, V_1 – drain valve, V_2 – valve, V_3 – regulating valve.

Adjusting accurately the input gas pressure into the generator is done with regulating valve V_3. Working pressure of generator and the generator flow (air intake) is controlled using high precision pressure manometer 6. The air-jet ultrasound generator 7, positioned inside the working tank 9, produces concomitant ultrasound waves and bubbling, thereby achieving the water sonic treatment.

Based on the calculus method [3] it was designed and constructed the air-jet axial generator with the following dimensions: $D_a = 4.0$ mm, $d_t = 3.0$ mm, $D_R = 4.0$ mm, $l_R = 2.5$ mm, $\Delta_R = 1.4 \pm 0.5$ mm, as presented in Fig. 2.

The compressed gas passed through the nozzle 1 reaches the resonator 5 fixed on the rod 4, which is installed inside the generator's nozzle (Fig. 2) and it is able to move. Supersonic gas jet exiting the nozzle loses its stability by interaction with the resonator cavity and emitting high frequency shock waves [3].

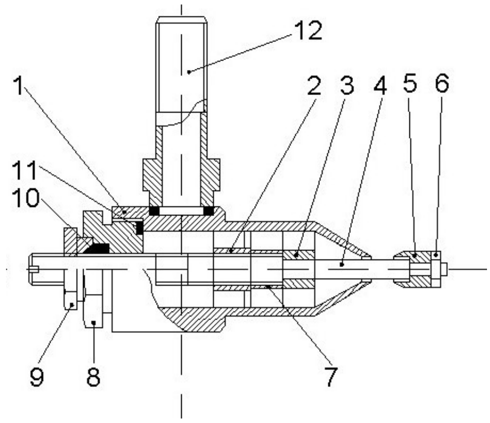

Fig. 2 – The axial air-jet sonic generator: 1 – air nozzle; 2, 3 – cross support; 4 – rod; 5 – resonator; 6 – screw-nut; 7 – sleeve; 8 – cover; 9 – locking nut; 10 – gasket; 11, 13 – ring; 12 – fitting.

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The acoustical parameters: sound intensity level and generator's frequency were determined according to the air pressure at the generator entrance and air mass flow. The result of generator's acoustical and gas dynamic measurements are presented in Table 1.

Table 1

The air-jet ultrasound generator's acoustical and gas dynamic dates

Working pressure, p [MPa]	0.1	0.15	0.2	0.30	0.4
Air mass flow, $\dot{m}_a$ [g/s]	3.51	4.38	5.26	7.01	8.76
Working frequency, f [kHz]	23.2	25.1	26.8	27.4	27.2
Sound intensity level, L [dB]	72.2	96.4	118.6	122.2	131.0

The sound intensity level and the working frequency of the generator can be adjusted according to the supply pressure, in the frequency range $f = 23 \div 27.5$ kHz and sound intensity range $L = 72 \div 131$dB.

3. THE EFECT OF SONIC TREATMENT ON THE PHYSICO-CHEMICAL PARAMETERS OF RAW WATER

In order to asses the quality state of raw water compared with the one of sonic treated water, were determined the basic physical-chemical indicators as provided in Rumanian STAS: the dissolved oxygen with the sodium thiosulphate method [5]; pH by potentiometer method [6]; turbidity by colorimetric method [7]. The working methodology within the experimental research was as follows [8]:

– it was used a sample of one liter of raw water from the Danube;

– the raw water sample is sonic treated with the air-jet generator and the treatment duration was between 5÷40 seconds.

The compressed air pressure ranged between 0.1÷0.5 MPa, and the samples were subjected to the sound intensity of 70÷131dB, within the frequency range of 23÷27.5 kHz.

It was studied first the evolution of the dissolved oxygen, pH and turbidity according to the supply pressure of the ultrasound air-jet generator.

As in Fig. 3, the increase of the dissolved oxygen is held up to the pressure of 0.15 MPa, reaching 10.24 mg O_2 per liter, after which the maximum pressure of 0.4 MPa is reduced with 0.3 mg O_2/l as the initial value was 9.6 mg O_2/l.

The research results on the dissolved oxygen content in water according to the working pressure [8] confirm that the sonic treatment of raw water produces two different processes: bubbling, which provides aeration, respectively cavitation, which causes water degassing.

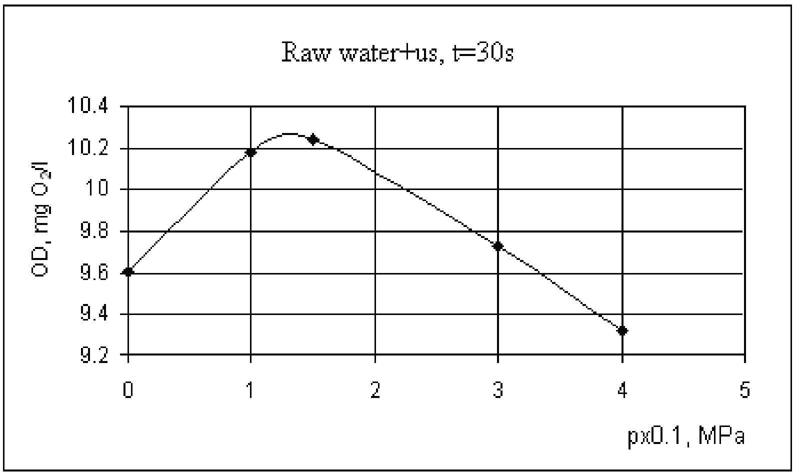

Fig. 3 – The dissolved oxygen variation depending on the supply pressure of the ultrasound air-jet generator.

In Fig. 4, the pH evolution was determined based on the generator working pressure, which decreases at $p = 0.15$ MPa and then returns back to its initial value ranging in pH = 6÷8.

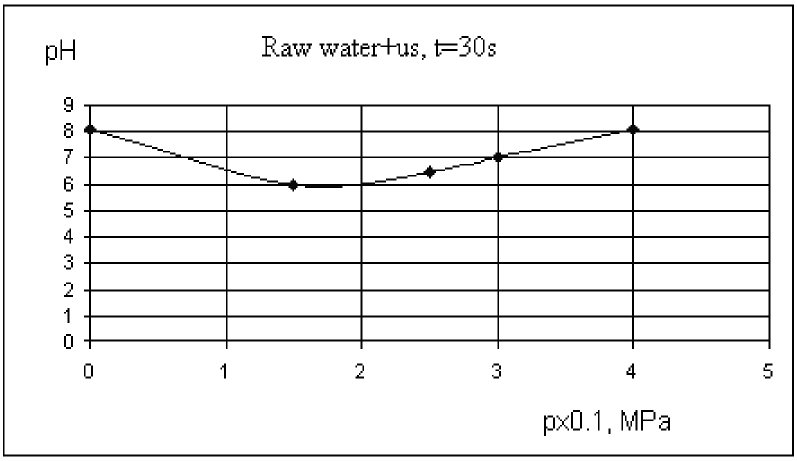

Fig. 4 – The pH variation depending on the supply pressure of the ultrasound air-jet generator.

In Fig. 5, the decrease effect of turbidity is observed from the generator working pressure $p=0.15$ MPa, after which the turbidity indicator slowly decreases.

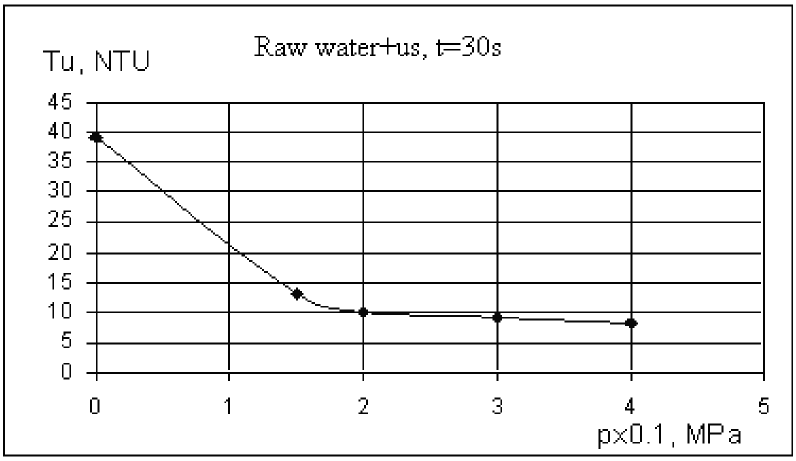

Fig. 5 – The turbidity variation depending on the supply pressure of the ultrasound air-jet generator.

In order to compare the effect of sonic treatment at different water temperatures, was studied the evolution of physical and chemical parameters at a temperature of 16 °C, respectively 21 °C.

The two graphs representing dissolved oxygen versus time (Fig. 6) show that at lower temperature variations are greater, but the values are within the quality limits. Thus, the variation of dissolved oxygen content at a temperature of 16 °C has a maximum after 5–10 s of treatment, and a minimum at 20 s.

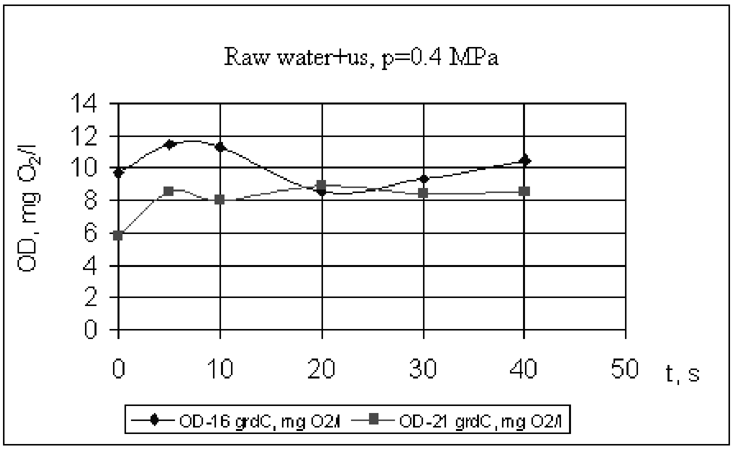

Fig. 6 – The dissolved oxygen variation depending on the sonic water treatment duration ($L = 131$ dB, $f = 27.2$ kHz).

The results also show that satisfactory level of dissolved oxygen content of water occurs at lower durations of treatment and must not exceed 10 seconds. In this case, the two processes – degassing and aeration compensate each other [8].

As for dissolved oxygen, pH evolution was determined at a temperature of 16 °C, respectively 21 °C.

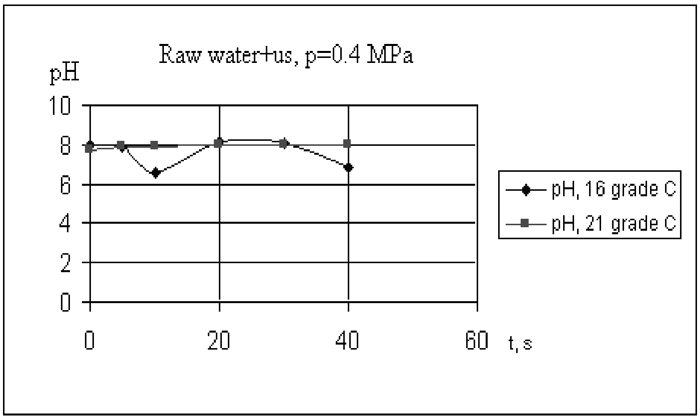

Fig. 7 – The pH variation depending on the sonic water treatment duration ($L = 131$ dB, $f = 27.2$ kHz).

At temperature of 21 °C, the pH is constantly evolving, slightly upward although this increase is only 0.2 units from baseline after the first 5 seconds and of 0.3 units corresponding to the maximum recorded after 40 seconds.

At temperature of 16 °C is observed at the beginning the decrease by 1.2 pH units, then restored and maintained almost unchanged after 30 s and decreases again to 1.6 pH units, thus ranging from the 6.6 to 8.2. Blank baseline was 8.02 and fall within quality limits.

As for turbidity (Fig. 8), the effect of sonic treatment occurs from $t = 5$ s, when is observed a drop of it.

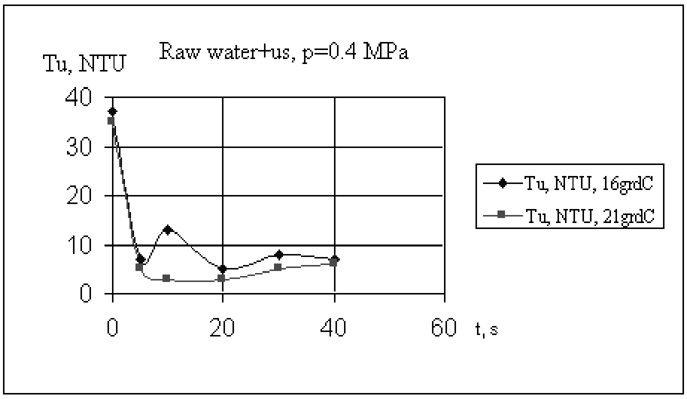

Fig. 8 – The turbidity variation depending on the sonic water treatment duration ($L = 131$ dB, $f = 27.2$ kHz).

With increasing of sonic treatment time, the turbidity varies cvaziperiodic around an average which depends on water temperature, that is $T = 5$ NTU, the initial turbidity was 35 NTU at a temperature of 21 °C and $T = 7$ NTU, the initial turbidity was 37 NTU at 16 °C temperature.

4. CONCLUSIONS

The raw water treatment with ultrasound air-jet generator ($t = 30$ s) led to these results:

– decrease of raw water turbidity by 4 times compared to initial turbidity of 39 NTU;

– pH decrease by 2 units, maintains and restores the initial value of 8.07 units;

– maintaining dissolved oxygen content in water at nearly the initial value 9.61 mg O_2/l with insignificant decrease of 0.3 mg O_2/l.

The study of physical and chemical parameters depending on sonic ($p = 0.4$ MPa, $L = 131.0$ dB, $f = 27.2$ kHz) water treatment duration (5–40 s) for two water temperatures (16 °C, 21 °C) of the one liter sample revealed as follows:

– turbidity decreases 5–7 times, from 5 seconds of treatment with ultrasound air-jet generator;

– pH remains almost constant at water temperature of 21 °C and oscillates around the initial temperature of 16 °C;

– oxygen content of water increases after the first 5 seconds of sonic treatment at a normal value for the given temperature.

Thus, the sonic technology proves to have an influence on the water parameters, the experimental results pointing out the effect on the three tested indicators.

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