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PHYSICO-CHEMICAL WATER TREATED WITH SONIC GENERATOR AND $Al_2(SO_4)_3$ COAGULANT

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ABSTRACT

This paper is a study on the problem of using ultrasound in the treatment of raw water. It highlights the effect of ultrasounds produced by the experimental sonic ultrasound generator through the physico-chemical analysis of raw water, as well as of the treated water, namely turbidity, pH and dissolved oxygen. Also, to reduce the dose of coagulant used in water treatment plants, we studied the influence of ultrasound on water treated with coagulant based on the physico-chemical parameters analysis.

The aim of this paper was to determine the effects of ultrasound and of the coagulant on the physico-chemical parameters of water by treating raw water with ultrasonic gas-dynamic generators, or by adding coagulant, with reference to water quality before treatment. We followed the environmental impact by allowing the use of the sonic generator technology treatment leading to significant reduction in the amount of chemicals commonly used in water treatment stations in view of clotting suspension.

KEYWORDS: water treatment, physico-chemical, sonic generator

1. Introduction

This paper treats the problem of developing new methods of water treatment using ultrasound gas-dynamic generators. Ultrasound production facilities [1] can be used in processes taking into account construction, media used, working frequency, acoustic intensity, irradiation time. In analyzing any process related to the application of ultrasound technology, the first problem that arises is to produce ultrasonic vibrations of a determined frequency and intensity [2]. Generators produce ultrasounds in certain areas of propagation for certain frequency ranges [3] and therefore for each technological process a type of ultrasonic generator is used. Based on the analysis of the types of generators, the best gas-dynamic generator type was Hartmannrod with rod [4], which is stable in operation and can ensure high enough work gas flow, as required in water treatment.

2. Experimental stand and working methodology

The gas-dynamic axial sonic generator used (Fig. 1) was chosen because of its construction characteristics that determine operating parameters corresponding to laboratory conditions [5].

Thus, to study water treatment using a sonic generator (ultrasonic and concomitant bubbling) a hydro-pneumatic scheme [5] of the experimental facility it was achieved (Fig. 2).

The plant can use compressed air or oxygen as working agent to generate ultrasounds depending on technological needs.

In our case, the system uses air as working medium for sonic generator power, which leads simultaneously to producing ultrasonic waves and to aeration-bubbling phenomenon, thus ensuring the sonic treatment of the technologic liquid.

Air, as working medium for generating ultrasound, was taken from an air compressor with a capacity up to 6 bars.

They collected water samples from the Danube according to the appropriate standard and samples of 1 liter of fresh water were used as samples and treated with a sonic generator under certain conditions.

The experimental stand operated at a supply pressure of 0.4MPa generator, or frequency ν=27.4kHz and acoustic intensity level L = 131.0dB.

Also, during water treatment with sonic generator varied in the range of 5-40 seconds.

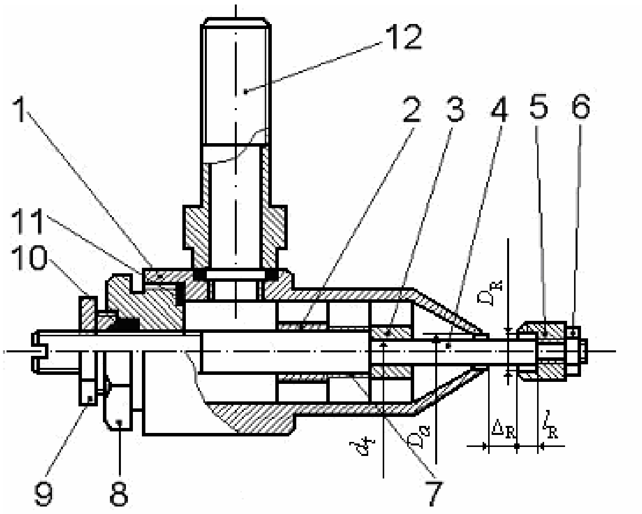

Fig. 1. *Axial gas-dynamic sonic generator: 1 - nozzle, 2, 3 - cross support; 4 - rod, 5 - resonator, 6 - nut, 7 - bush, 8 – cover, 9 - nut, 10 - gasket, 11, 13 - ring; 12 - socket; D_a- nozzle diameter, d_t - rod diameter, D_R, L_R - diameter and depth resonator, D_r - distance granting resonator*

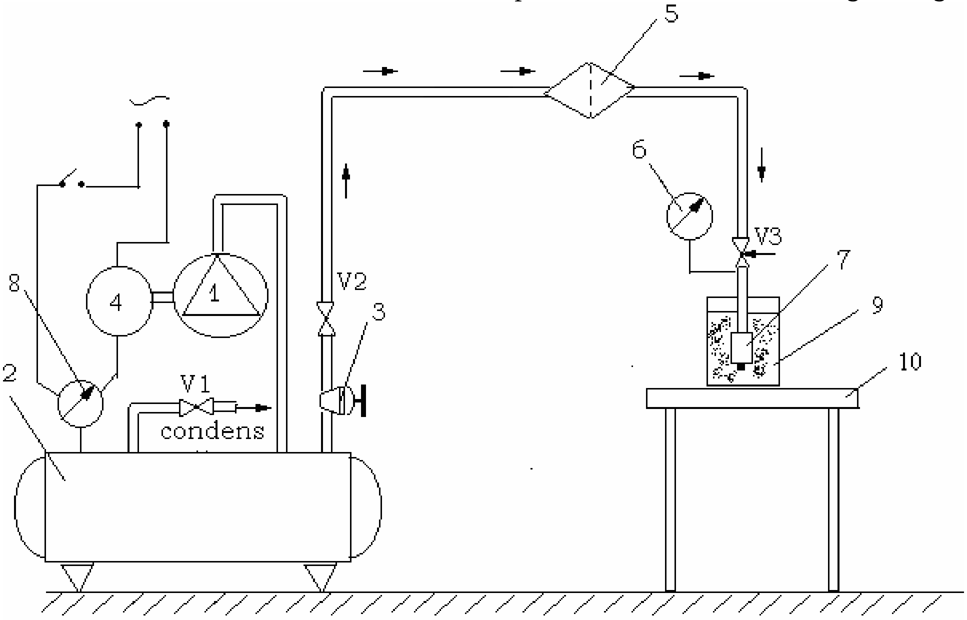

Fig. 2. *Experimental stand for water treatment technology: 1-compressor, 2-tank battery, 3-pneumatic reducer, 4-electric motor, 5-air filter, 6-gauge, 7-gas-dynamic ultrasonic generator, 8-gauge with electro-contact, 9 -cylindrical vessel, 10 - desk, V_1-drain valve, V_2 -valve, V_3-regulating valve*

For comparison and to highlight the effect obtained by using an experimental sonic generator, an aluminum sulfate $Al_2(SO_4)_3$ coagulant was introduced in the raw water sample, before treating the samples with ultrasound.

Water quality has been shown in both studied cases by analyzing some physical and chemical parameters namely: turbidity, pH, dissolved oxygen (DO), according to current standards.

3. Results and discussion

3.1. Dynamics of the water treated with experimental sonic generator

Five one liter of raw water samples were considered each, treated at different periods of time, namely 5, 10, 20, 30, 40 seconds under optimum working regime.

A one-liter water sample was also considered to determine the raw water characteristics and to compare them with the test data submitted to the sonic treatment. The generator operating mode was determined according to the best results obtained from the physico-chemical indicators of the sonic raw water treated at the working pressure of 0.4MPa, to which following acoustic parameters correspond: acoustic intensity L = 131.0dB and frequency ν=27.2kHz [6].

The sonic treatment of raw water leads to a sharp decrease of turbidity (Fig. 3).

The sonic treatment effect occurs from time t=5s treatment [7].

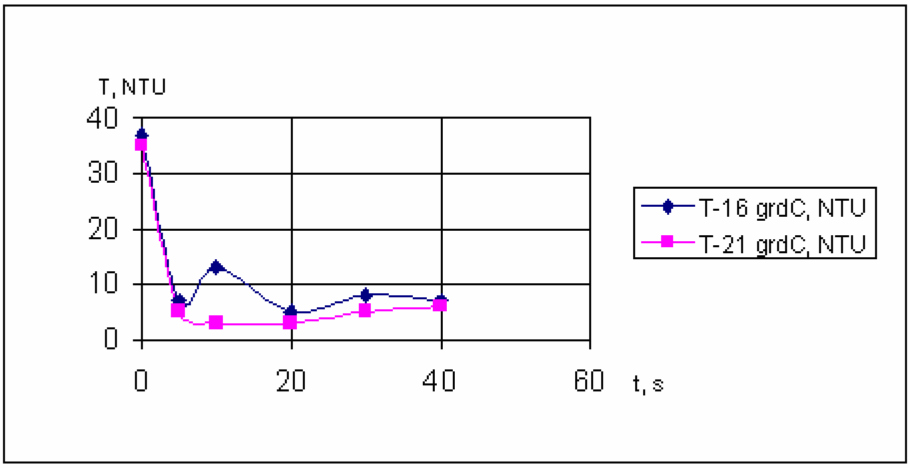

Fig. 3. *Turbidity variation depending on the time of sonic treatment of water*

After an initial turbidity of 35NTU (nephelometric turbidity units) at a temperature of 21^{0}C to 16^{0}C and 37NTU, the same time, with increasing sonic treatment turbidity varies quasi-periodically around an average of T=5NTU (nephelometric turbidity units) respectively T=7NTU. The analysis of the results shows that after 10 seconds of sonic treatment of raw water turbidity reduction occurs on an average of 5-7 times compared with the value determined in untreated raw water.

In the case of pH (Fig. 4), the influence of ultrasonic waves is negligible at both considered temperatures [7] and its evolution is relatively constant.

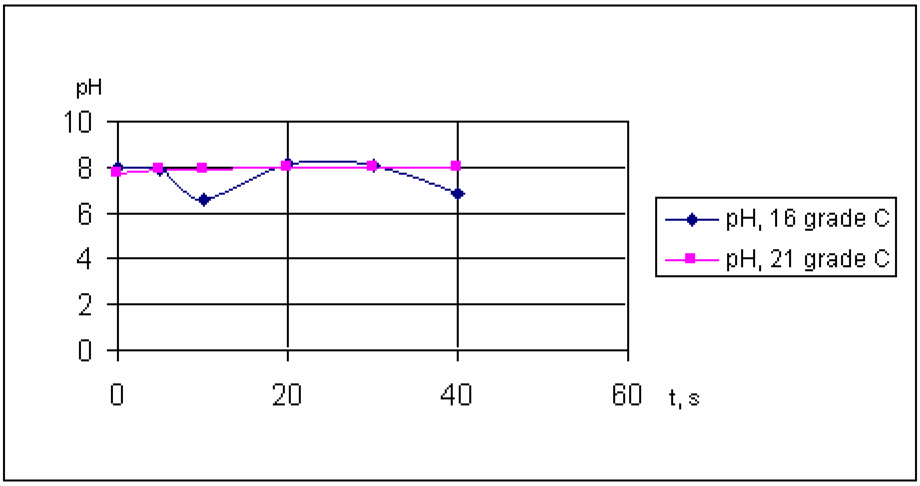

Fig. 4. *pH variation depending on the time of sonic treatment of water*

The initial base value of the control sample was 8.02 and it is within quality limits. From Figure 5 it is noticed that at a temperature of 21^{0}C, the quantity of dissolved oxygen in untreated raw water is 5.8mgO_2/L, so under the limit prescribed by law (7mgO_2/L). However, after the first 5 seconds of ultrasonic treatment, the oxygen level increases to a normal value for a given temperature and the recorded values with increasing treatment time vary between 8 and 9 mg O_2/L.

The necessary level of dissolved oxygen content in water occurs at a less time treatment that does not exceed 10 seconds. The sonic treatment time influence on the content of dissolved oxygen [7] indicates that during the sonic treatment two different processes occur simultaneously: the aeration and the degassing of water. Degassing occurs due to ultrasonic cavitation, and aeration occurs after the penetration of the working air resulting from the functioning of the gas-dynamic generator.

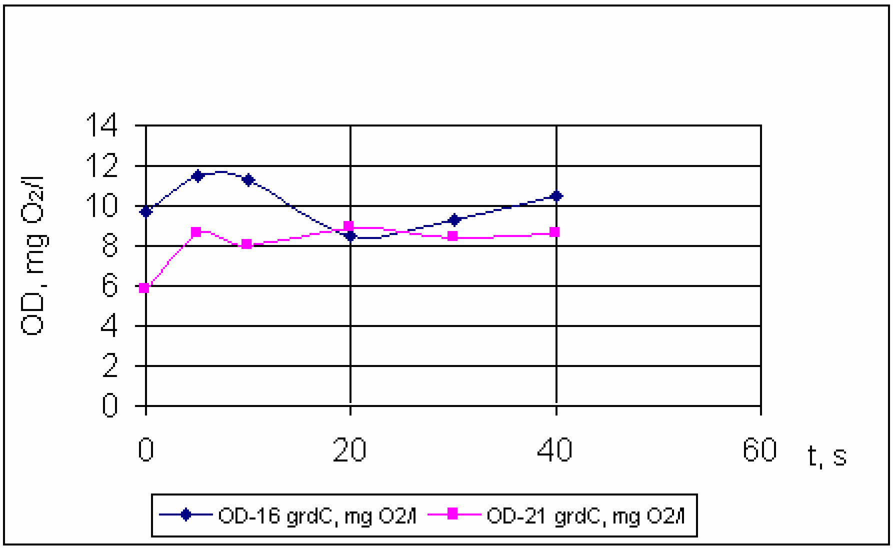

Fig. 5. *Variation of dissolved oxygen with the time of sonic treatment*

In this case, the two processes - degassing and aeration net each other and optimal results are obtained for the required oxygen content necessary in water at certain temperatures.

The results presented above allow us to choose the minimum length of sonic treatment time to which water can get optimal parameters, namely 5-10 seconds for a liter of water sample.

3.2. Dynamics of the water treated with coagulant and experimental sonic generator

The main purpose of using coagulants in water treatment technology [5] is increasing the sedimentation process from decanters. From economic and environmental points of view, solutions to reduce the dosage of coagulants or the use of environmentally friendly technologies are demanded.

We studied the possibility of reducing the dosage of coagulants to protect the environment and public health using an ultrasonic generator, and a coagulant commonly present in sewage systems, aluminum sulphate $Al_2(SO_4)_3$. In the study, it was considered the maximum dose of coagulant of 40 mg/L $Al_2(SO_4)_3$, while the dose of coagulant used at present in the water treatment plants is 40-60 mg/L $Al_2(SO_4)_3$.

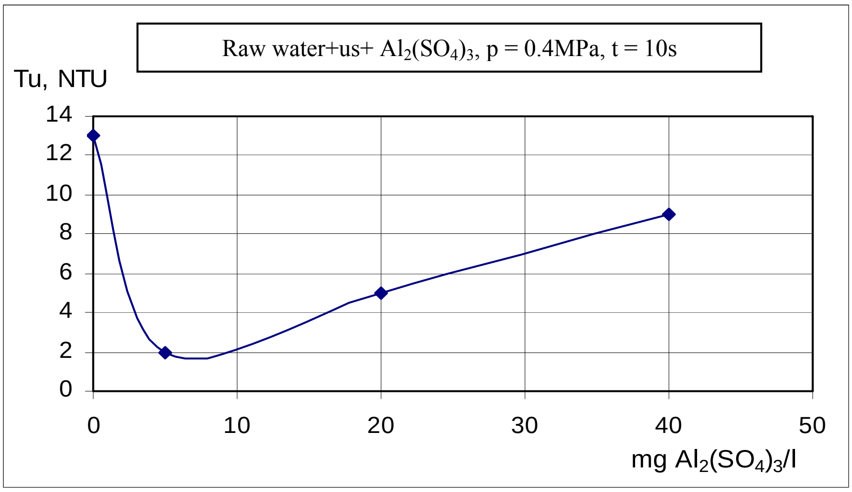

Fig. 6. *Water turbidity variation depending on the dose of coagulant $Al_2(SO_4)_3$*

To determine the minimum dose of coagulant, to which the effect is observed, the influence of coagulant concentration was studied and the ultrasonic produced by the ultrasonic generator on turbidity, at the working pressure of 0.4MPa and treatment duration of 10 seconds (Fig. 6). It is observed from sonic generator water treatment, the reduction water turbidity of 7.5 times the initial value of raw water.

Also, by getting the lowest turbidity value at the lowest dose used, we conclude that the coagulant dose decreased by 8 times, respectively, from 40mg/L to 5 mg/L $Al_2(SO_4)_3$.

Given this result, we studied the influence of the treatment time (Fig. 7) on turbidity at a dose of 5mg/L $Al_2(SO_4)_3$, the same supply pressure of 0.4MPa generator.

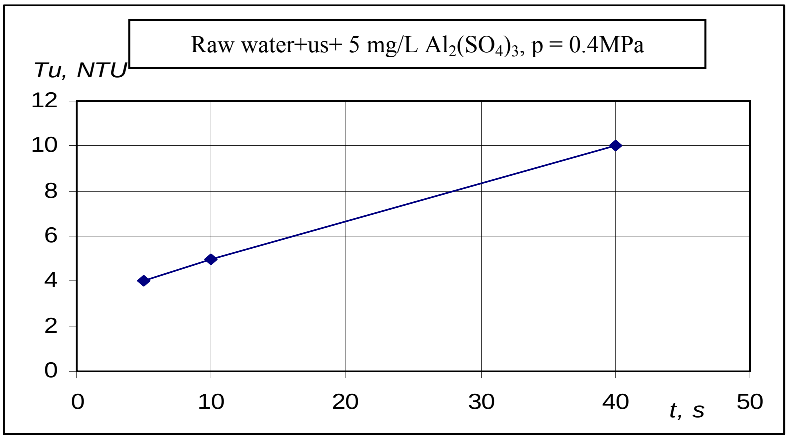

Fig. 7. *Water turbidity variation depending on the time of treatment at a dose of 5 mg/L $Al_2(SO_4)_3$*

The graphic from Figure 7 shows that turbidity increases with increasing treatment time, the treatment time required to achieve minimum turbidity being 5 seconds.

Given the amount of raw water turbidity (Fig. 6), adding minimal coagulant dosage with ultrasounds produces a significant reduction in turbidity. It is noted that at a treatment duration of 5 seconds and 10 seconds, respectively, to register turbidity values as indicated in the standards are recorders (Tu≤5NTU).

Next, we studied the influence of the coagulant dose and the ultrasound on the pH, at the same parameters as for turbidity (Fig. 6).

The dose of coagulant $Al_2(SO_4)_3$ in water does not affect the pH values, as shown in Figure 8.

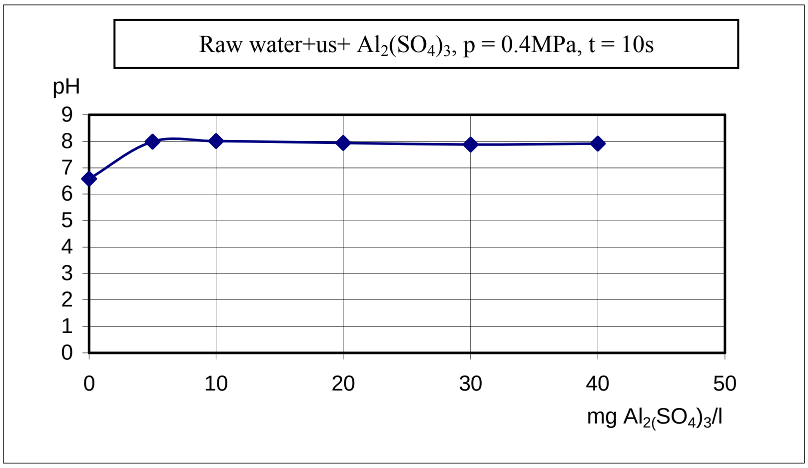

Fig. 8. *pH variation depending on the dose of $Al_2(SO_4)_3$ coagulant*

If in both cases, the pH is not influenced by ultrasound, or by the presence of coagulant and ultrasound, for pH variation depending on the duration of water treatment with 5 mg/L $Al_2(SO_4)_3$, at the working pressure p = 0.4MPa, an increase with 2 units of pH occurs (Fig. 9). It can be concluded that to obtain a neutral pH, under the conditions considered above, a duration of treatment of 20-40seconds it is required.

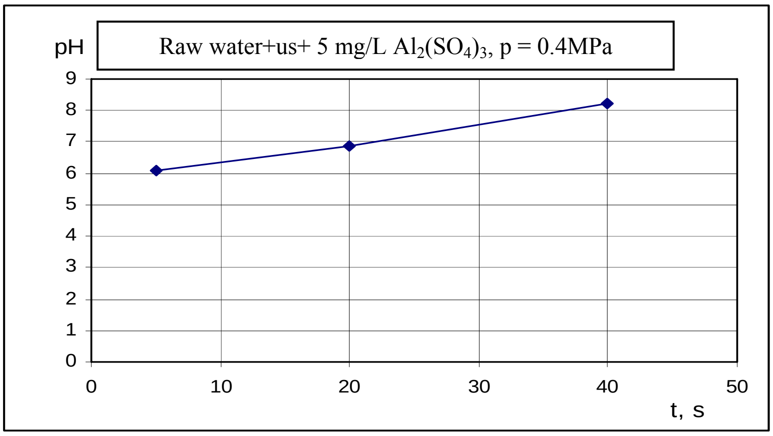

Fig. 9. *pH variation depending on the water during treatment with 5 mg/L $Al_2(SO_4)_3$*

Regarding the evolution of dissolved oxygen content in water in the presence of coagulant and ultrasound, at the same operating parameters previously established for other indicators, a clear change could noticed.

Thus, by increasing the dose of coagulant, the oxygen content (Fig. 10) decreases from 11.2mgO_2/L to 10.5mgO_2/L, so the coagulant dosage with ultrasounds affect the content of dissolved oxygen, in water but to a lesser extent.

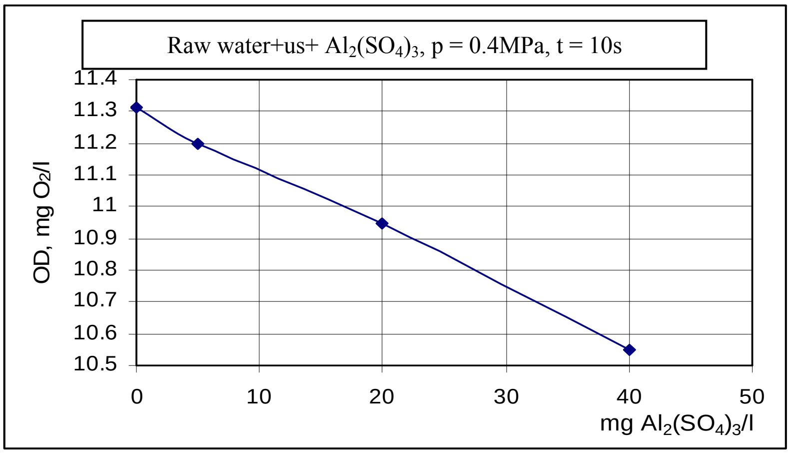

Fig. 10. *Dissolved oxygen variation depending on the dose of $Al_2(SO_4)_3$coagulant*

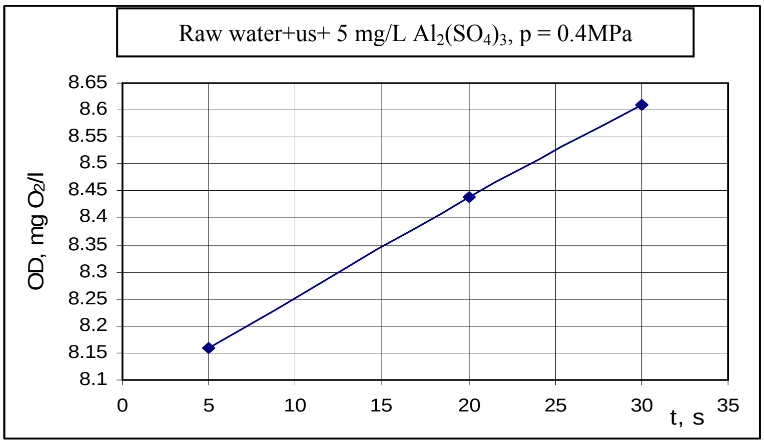

Fig. 11. *Variation of dissolved oxygen according to the time of water treatment with the dose of 5mg/L $Al_2(SO_4)_3$*

The same thing happens in the case of dissolved oxygen variation (Fig.11) according to the time of sonic treatment of water at the dose of 5mg/L $Al_2(SO_4)_3$, the dissolved oxygen concentration increasing from 8.16mg O_2/L to 8.61mg O_2/L.

The parameter variation study highlights the synergistic influence of ultrasound and coagulant, and thus, the possibility of using an ultrasonic generator for reducing chemicals in water treatment plants.

4. Conclusions

By increasing the dose (5-40mg/L) of aluminum sulphate ($Al_2(SO_4)_3$ to sonic treatment (generator working pressure 0.4 MPa, the acoustic intensity L = 131.0dB, frequency ν = 27.2 kHz) with treatment time t = 10s it showed that:

- turbidity increases, so, to obtain minimum turbidity (Tu = 2 NTU), a minimum dose of 5mg/L of $Al_2(SO_4)_3$ is recommended;

- the pH of the water does not change, so it is not influenced by the $Al_2(SO_4)_3$ dose level;

- the content of oxygen in the water decreases from 11.2 to 10.5mg O_2/L.

The influence of the duration (5-40 seconds) of the ultrasound treatment on the physico-chemical parameters of the water, with a coagulant dose of 5mg/L at working pressure of 0.4MPa generator (sound intensity level L = 131,0dB, frequency ν=27.2kHz), was studied and have revealed the following:

- the turbidity increases, which shows that to achieve the best results the treatment time should be considered during treatment to which it is minimal (t = 5 and u = 4 NTU);

- the pH increases by 2 units compared to that determined for untreated raw water (Fig. 8);

- the oxygen content in the water increases from 8.16mg O_2/L to 8.61mg O_2/L with increasing duration of water treatment.

According to limit set of standards (Tu≤5NTU), turbidity reached these values in both cases studied to a minimum coagulant dose of 5mg/L $Al_2(SO_4)_3$ and a treatment duration of 5 to 10 seconds.

The values obtained for water pH in this study are within the limits set by the standards (6.5 ÷ 9.5). In the case of dissolved oxygen, both for its evolution depending on the dose of coagulant and for coagulant according to the duration of treatment and ultrasonic, a decrease is observed in comparison with the value of untreated raw water. This is not desirable because the dissolved oxygen content in the water depends on water temperature and its decrease leads to the loss of water freshness. By contrast, a single action of ultrasound on water increases the dissolved oxygen content, regardless of the temperature of the water sample.

It should be noted that the dose of $Al_2(SO_4)_3$ coagulant recommended in the paper (5mg/L) is 8 times lower than the lowest dose of 40 mg/L $Al_2(SO_4)_3$ used in water treatment plants, which demonstrates the applicability of treatment technology with ultrasonic generator.

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