THE SONIC SETTLER FOR DRINKING WATER TREATMENT PLANTS

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INTRODUCTION

The most common source used in water treatment for drinking water is surface water, but the surface water is turbid [6]. This feature varies by season and river flow. The main phase of water treatment technology is settling, a process of sedimentation that are retained up to 98% of suspensions of any kind, either gravity (which is deposited by gravity) as well as colloidal (to be submitted after a preliminary treatment with anti-coagulant).

Basins for water settling are called settlers. They may be horizontal, longitudinal, radial or vertical, depending on the direction of water flow. Choose the type of sludge is based on a techno-economic study, taking into account the size of treatment plants, local conditions (size of land that can be used, land topography, the soil nature, level and quality of raw water), the cost the investment, operating, and operating difficulties.

Water decanting is recommended for these variants [4]:

- horizontal settlers (equipped with lamellar modules to increase efficiency), and traditional vertical type is suitable for low flow water;
- radial settlers are advantageous for high water flow (but because of the difficulty in operation it is recommended that they be used only pre-settlings).
- vertical settlers can be used in all cases where you must obtain a very good clarification water before the filtration process, effluent treatment for medium and large flows (the advantage of concentration in a single mixing tank construction, the settling of the reaction and leading to a high efficiency water clarification besides a significant savings in investment).

Regardless of the type of construction, the flow chart of a decanter containing: an input system and raw water distribution, marketing and distribution system of coagulant, a settling space, a space decanted sludge sedimentation, water collection system decanted and a collection system and sludge disposal [4].

In this paper we propose a new water treatment technology: the use of sonic generator in the pond. Sonic waves emitted together with the airflow can lead to accelerated sedimentation of particles and to reduce the coagulant dose used.

2. SONIC EXPERIMENTAL SETTLER

To achieve sonic technology to raw water pond it was designed a vertical suspension settler (Figure 1) equipped with a sonic air-jet generator.

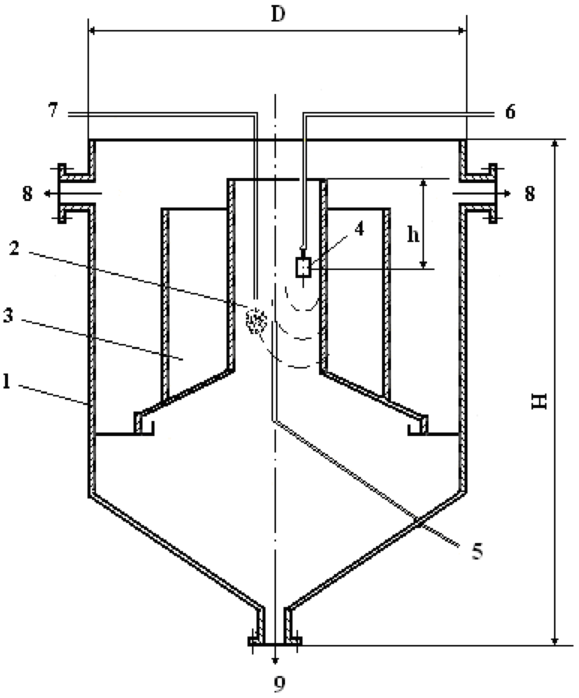


Figure 1. Sonic experimental settler:
1-settler wall; 2-mixing chamber; 3-reaction chamber; 4-sonic air-jet generator; 5-raw water pipeline; 6-air duct work of the generator; 7-coagulant pipeline; 8-decanted water collection; 9-collector sludge disposal; D,H- settler diameter and height respectively; h-generator depth.

Sonic decanter works this way. Raw water, water from the Danube, enters the mixing chamber 2 through the supply pipe 5. There the food arrives by pipeline 7 and the coagulant (aluminum sulfate solution). Sonic generator, powered with air under pressure through the pipe 6, is introduced through the mixing chamber in different positions and deep (depth in the range h = 0-1m), which co-produces and bubbling sonic where, due to air this operation from generator [2,3].

Bubbling (aeration) performs a mixture of raw water and coagulant. Effects of sonic generator and enters the reaction chamber 3 which amplifies the coagulation-flocculation process.

Decanted water is collected by collecting eight stacks. The suspension is deposited on the bottom (cone) during of settling certain period time and are discharged through the sludge outlet spout 9. Experimental sonic settler has the following overall rate: D = 1.6 m, H = 2.56 m.

3. SONIC AIR-JET GENERATOR AND ACOUSTIC PARAMETERS

Sonic air-jet generator [1,8] payment experimental rectangular shaped and contains two resonators with the whirlwind. Design casing 3 is milled with a fork inside a rectangular channel which is located one and two identical resonators housing (Figure 2).

Resonators are flat and each has read a cylindrical chamber with a diameter d_R transverse to create a certain frequency pulsations. Top resonator 2 has rounded bottom and a rectangular opening to the axis of symmetry of the generator. Lower resonator 3, is top with rounded rectangular opening. Their replacement with rounded sides facing each other creates a central channel for passing the working fluid.

The generator works as follows. The fluid (air or gas) under pressure enters through a nozzle on the right side of the housing in a rectangular channel made of two resonators and the cylinder walls. Every resonator has the cylindrical cavity , the fluid creates a vortex that produces as many oscillations of a certain frequency depending on the speed gap flow which depends on δ, and the fluid pressure inside the vortex cavity. Because the cavity diameters are equal, the interference occurs which improves amplitude oscillations and allows generating strong high-frequency waves, including ultrasonic.

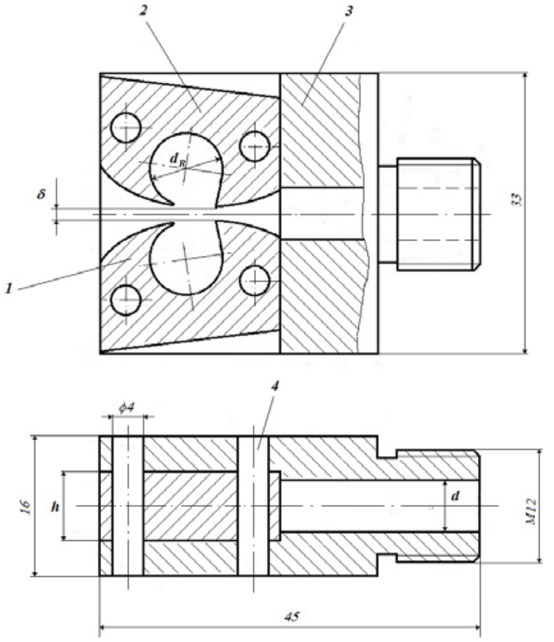


Figure 2. Experimental air-jet generator with two resonators: *1-housing; 2-top resonator; 3-lower resonator;4- pin;* d_R*=8 mm-diameter resonator cavity; d=7 mm -input channel diameter; h =8 mm-length of the nozzle; δ =1,2 mm - slot of the nozzle.*

To determine the acoustic parameters of the sonic air-jet generator was used experimentally by two chains system of measuring noise and vibrations of the Laboratory of the Polytechnic University of Bucharest (Figure3).

The first chain contains a sound level meter measurements in 2250 produced by Brüel and Kjær allowing forward current reading sound levels expressed in dB on the entire frequency spectrum (denoted by Z value expressed in dB, weighted value-weighted curve (denoted by value He expressed in dB (A)) and sound intensity levels values in bands 1 / 3 octave with center frequencies mentioned (12.5, 16, 20 ....) in the field of audio frequencies (10Hz-20kHz).

For each measurement is that the annexation spectrogram. The second chain contains a sound level meter measuring Brüel and Kjær 2209 classic that has allowed the registration of the acoustic signal in time on a laptop and FFT spectral analysis in the 0-25 kHz frequency range of these signals with a program LABwiev [5] Spectrograms obtained for each

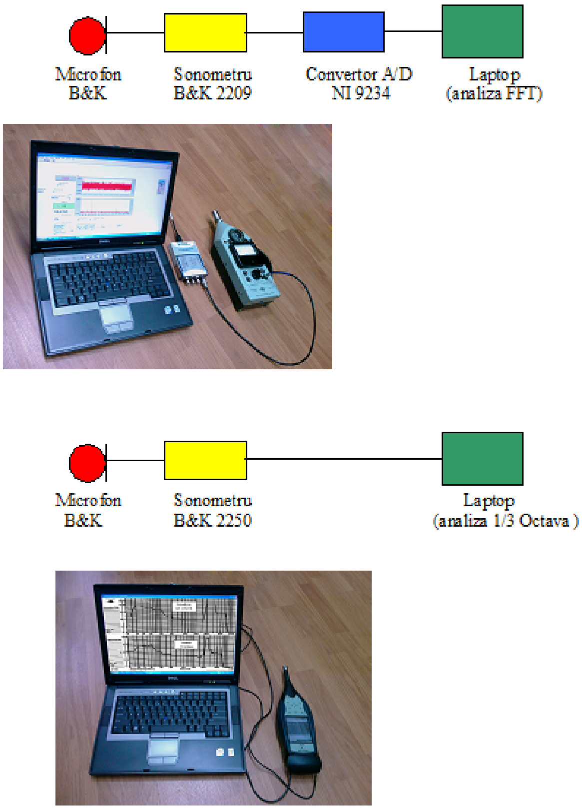


Figure 3. Noise measuring system in two chains.

measurement method were presented to highlight ZOOM precisely resonant spectral values.

Acoustic measurements were conducted in compliance with noise emission standards SR EN

ISO 3744/2009. Determination of sound power levels of noise sources using sound pressure.

The experimental generator was located horizontally at a distance of 2 m from the floor and 3-6 m from the walls in a soundproof room. Background noise in the room during the research did not exceed 48 dB, which is much smaller compared with the intensity of sound produced by the sonic generator.

The microphone is in the horizontal plane normal to the axis of the generator at a distance of 1m, so the microphone axis to pass through the center working area of the generator (Figure 4).

We determined the acoustic parameters of the generator on working pressure p = 0.05 MPa, which were conducted experimental research settling.

Acoustic spectrum of sonic generator experienced bands 1/3 octave (Figure 5) revealed two radial generator working frequency: 10 kHz frequency first and second frequency of 20 kHz.

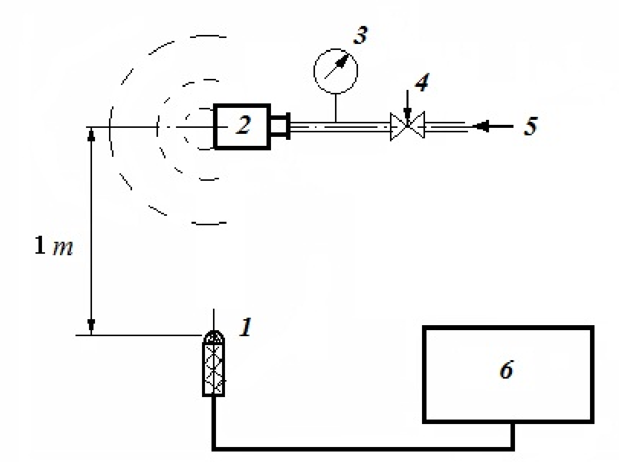


Figure 4. Scheme to perform acoustic measurements: *1-mcrophone, 2- air-jet generator 3-manometer, 4-regulator pressure, 5- air intake, 6 - noise measurement system.*

Intensity level at the first frequency acoustic emission (L_{fI} = 109.88 dB), which is in the sonic field, is moor on the 1.8 dB in compared with acoustic intensity for the second frequencies (L_{fII} = 108.09 dB, which already belongs to the field of ultrasound, the overall intensity level is:

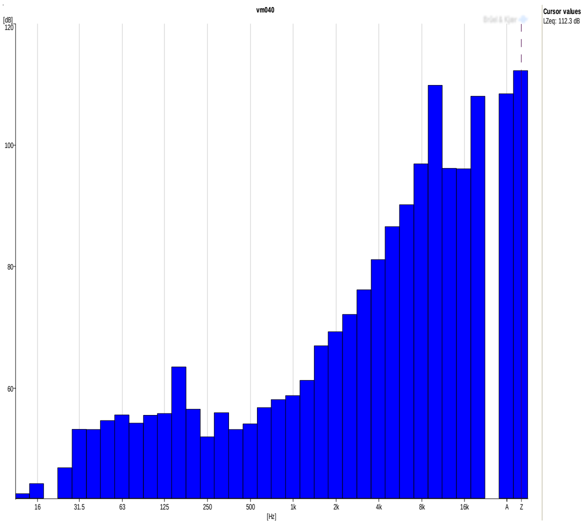


Figure 5. Acoustic spectrum in 1/3 octave produced by two resonators air-jet generator

$$L_z = 112.32\ dB. \qquad (1)$$

Below are shown (Figure 6) measured acoustic pressure pulses in real time during generator operation and is given at the Figure 7 FFT spectral analysis of this signal with LABview program.

Finding work two frequencies: the frequency of f_I = 10.76 kHz sonic (Figure 7 *a*, *b*) and ultrasonic frequency f_{II} = 21.520 kHz (Figure 7 *a*) as well as similar character of variation of intensity levels. Acoustic shows that the experimental generator (Figure 2) is one bi-frequency, being the sound-ultrasound type.

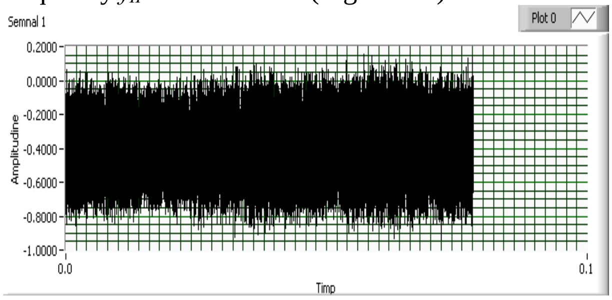
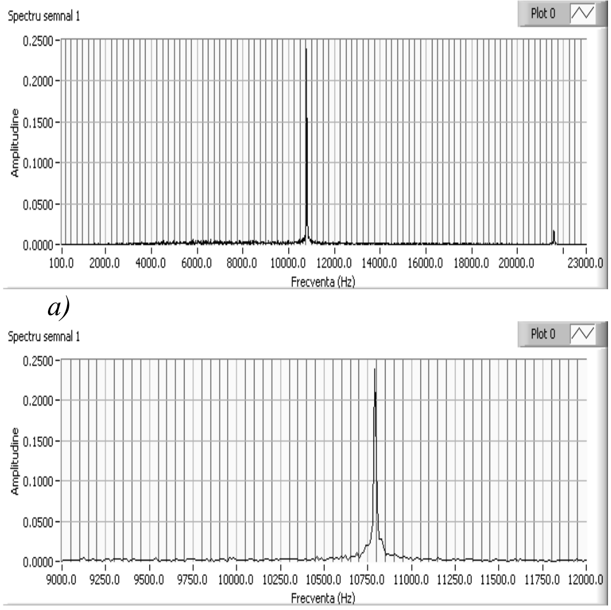


Figure 6. Sound pressure pulses in real time produced by two resonators air-jet generator.



a)

b)

Figure 7. LABwiev FFT spectral analysis software spectrum of acoustic pressure pulsation: *a- in narrow band; b- ZOOM in the zone of interest*

4. THE EXPERIMENTAL AND RESEARCH METHODOLOGY OF THE SONIC SETTLER

Research sonic treatment (ultrasound and simultaneous aeration) of raw water from a surface source requires certain technical requirements for controlling and monitoring the technological process, which are provided in the experimental facility, built on the platform of water treatment plant in Braila.

Experimental plant outside of sonic settler- I comprises different systems: the second raw water supply- II , air supply system of the sonic generator- III, the sewage system suspension decanted - IV, clarified water collection system - V (figure 8).

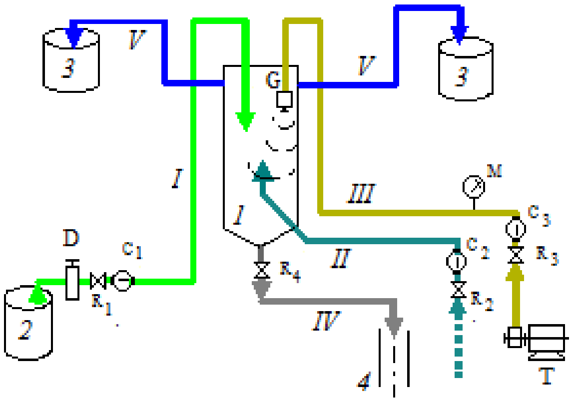


Figure 8. The experimental installation for research sonic settler: *1-settler, 2-coagulant tank, 3-decanted water tank; 4-sewer; G-sonic generator; D-coagulant dosing; R_1-coagulant flow control valve; C_1-coagulant monitoring meter ; R_2-tap raw water control; C_2-meter raw water monitoring; T-turbocharged; R_3-pressure air control valve; M-gauge; R_4-regulating valve outlet mud.*

The water from plant raw system is pumping in the sonic settler 1 , raw flow water is monitored by valve R_2 and water controlling C_2. Aluminum sulfate solution from tank 2, reached in the system through dispenser D, and the flow of aluminum sulfate solution come to sonic settler is monitored by valve R_1 and the controlling C_1.

Sonic generator working air produced by the turbocharger T, discharge pressure of 0.05 MPa and the maximum flow rate of 220 m³/h, is set by regulator R_3 and monitored by manometer M. Sonic generator G, positioned inside the settler, ensure water clarification by simultaneously produces aeration and acoustic waves.

Methodology in experimental research work was:

- establishing working dates for installation, where water flow is a constant (raw water flow rate of 0.9144 m³ / h , speed raw water ascension 0.145 mm / s);

- setting the flow dose gelling agent solution (aluminum sulfate AL_2 (SO4) $_3$) in terms of 40-60 g/m³;
- setting intermittent work cycle of sonic generator (actual generator operation period of 60 minutes, alternated with periods break for the 5,10,15 or 20 minutes).

To evaluate the effectiveness of sonic settling were measured turbidity of raw water treated in experimental settler and in a classical water treatment technology, in accordance with relevant legislation [4,7].

Determination of turbidity was taken immediately after sample collection. In the MERCK type turbidimeter (Figure 9) was introduced 20 ml vial containing water to be analyzed and is expected to stabilize the device.

Figure 9. MERCK type turbidimeter.

Turbidity determination is based on Tyndall effect, according to the water becomes cloudy bright if is crossed by a light due to suspended particles diffuse.

Turbidity value is displayed electronically on the turbidimeter screen in Nephelometer Turbidity Units (NTU). 1 NTU = 0.13 degrees of silicon, silicon degree of turbidity is the dispersion of the incident beam passing them through a suspension containing one milligram of silicon dioxide in a cubic decimeter of water - a level of turbidity corresponds to 1 mg SiO_2 / l of water.

5. EFFECT OF SONIC TREATMENT ON THE TURBIDITY OF RAW WATER DECANTED

Given that the operating conditions of sonic settling is discontinuous (with breaks), to assess how effective both during operation and during the break, but the depth and position of the sonic generator placed in the mixing chamber, experiments were performed dive depth according to different operating modes of the generator while the generator.

Turbidity variation was investigated in depth h, depending on the working time of the generator at different values of the operation time ratio t_{rap}, which describe the generator operating conditions:

$$t_{rap} = \frac{t}{t_0}, \qquad (2)$$

where : t is the operation time and t_0 is the break time from a cycle.

To determine the optimal values for the depth h and the ratio of time t_{rap} have watched the following:

- 0 minutes operation / 60 minutes break, $t_{rap} = 0$;
- 5 minutes operation /15 minutes break, $t_{rap} = 0,33$.

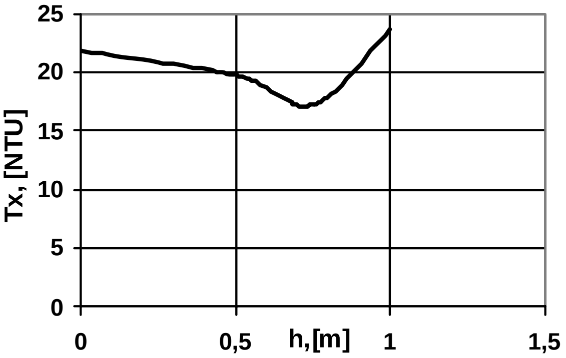


Figure 10. Decanted water turbidity T_x depending on the generator depth h (operating time ratio $t_{rap} = 2.0$)

Raw water turbidity for the Danube, at the time period analyzed, ranged from 8.7 NTU to 12 NTU, water temperature in degrees Celsius it was from 25.5 to 26.5.

- 10 minutes operation /10 minutes break, $t_{rap} = 1,0$
- 20 minutes operation / 10 minute break, $t_{rap} = 2,0$

Figure no. 10-12 are presented graphically clarified water turbidity results depending of the sonic generator depth on which is placed.

From the graph in Figure 10 can be seen as a minimum turbidity occurs at the *h* = 0, 75 m, but its value T_x = 17.22 NTU exceeds the initial value the 12 NTU for raw water.

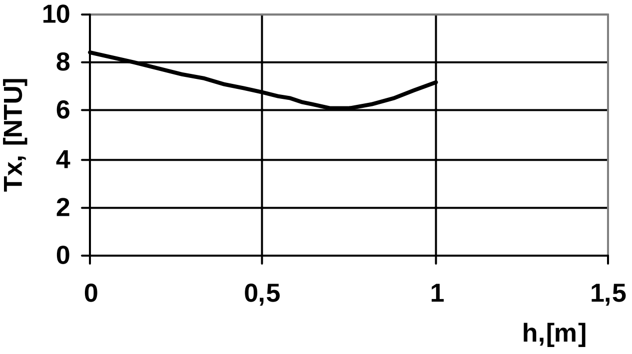
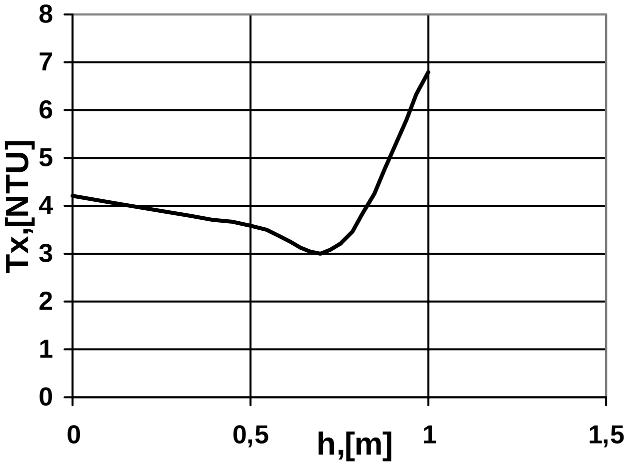


Figure 11. Decanted water turbidity T_x depending on the generator depth *h* (operating time ratio t_{rap} = 1.0).

From the graph in Figure 11 may be observed that for *h* = 0.75 m depth have a minimum of 6.1 NTU turbidity, better value about three times the first situation. We effect since the actual operation of the generator was cut in half, from 20 minutes to 10 minutes.



Analyzing the results above, we reduced the generator running time of 2 times the previous case and have increased 1.5 times during the break.

Figure 12. Decanted water turbidity T_x depending on the generator depth *h* (operating time ratio t_{rap} = 0.33).

From figure 12 it can be seen that turbidity decreases with increasing depth up to the limit value of 0.75 m and then rising again.

The minimum value of turbidity is apparent throughout the depth at which submerged generator is 3.2 m and 0.75 NTU, costing less than the traditional settlers (value ranging between 4.2 and 4.6 degrees NTU).

The graph in Figure 10 to 12 it follows that the depth of the 0.75 m (which we call critical depth and *h** we note), it obtained the lowest values of water turbidity decanted in sonic settler.

Based on the water turbidity determinations it made sad that operating time ratio is the base time parameter that settler sonic operation is depends directly.

Turbidity variation depending on the time working regime for *h**= 0.75 m depth is shown in Figure 13.

The minimum turbidity value of T_x =2.56 NTU is obtained for operating time ratio t_{rap} = 0.33 (5 min operation /15 min break). This turbidity value is lower compared the settler classic used (value between 4, 2 and 4.8 NTU), which proves that sonic settler is very good for clarified processes.

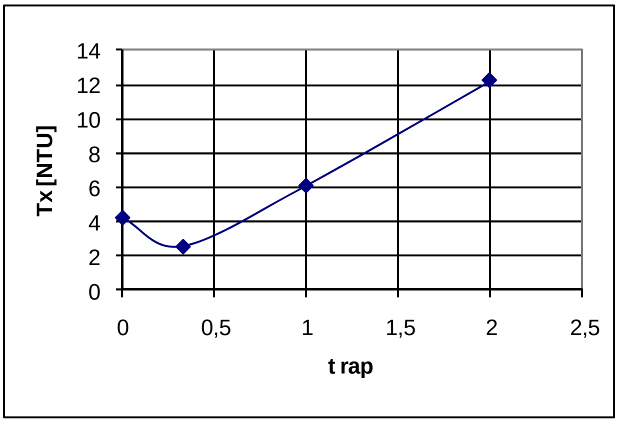


Figure 13. Decanted water turbidity T_x depending on the operating time ratio t_{rap} (generator critical depth *h**= 0.75 m).

CONCLUSIONS AND RECOMMENDATIONS

It was designed and executed the experimental sonic air-jet generator with two resonators.

Acoustic parameters were investigated, the overall sound intensity and frequency spectrum produced by the generator and it was found that the generator is a bi-frequency, having a frequency in the sonic (10.76 kHz) and the other in the field of ultrasonic (21.520 kHz).The respectively overall intensity sound level of L_z = 112.32 dB was obtained on working generator pressure p = 0.05 MPa, which were conducted experimental research of water settling.

It was designed and executed the vertical sonic settler equipped by one air-jet generator with two resonators.

It was studied the turbidity of treated raw water by sonic technology with experimental sonic settler.

In all experiments, the “maximum” water clarified effect is observed when sonic generator is situated on the depth of 0.75 m, what is about a half the height of the settler mixture chamber.

Optimal working time regime of the generator function is discontinuous and cyclic: one for operation followed by a long pause.

Optimal operating time ratio was established between the period of operation of the generator and period of break t_{rap} = 5 minute operation/15 minute break, set in a working cycle for an hour. The clarified water turbidity was T_x =2.56 NTU and this is moor better than obtained at the classic settling (value between 4.2 and 4.8 NTU). This dates proves that efficiency of sonic settler is a better of the 1.6 - 1,8 times.

In research carried out no one add-coagulation is not used, during to classic conventional technology is used as an adjunct a polyelectrolyte coagulation-flocculation.

The sonic settling is new ecological technology, because the less organic chemicals have contained the drinking water.

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