SONIC TECHNOLOGY FOR OBTAINING DRINKING WATER

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Abstract .The paper presents the results of experimental research at the Water Plant in Braila. The purpose was to achieve the practical installation for the sonic treatment of raw water in the continuous operating mode in industrial level and determine the operating modes for which the effect of application of sonic technology is maxim. We evaluated the physical-chemical and microbiologic indicators in different operating regimes of the sonic settling. Creating a new technology of sonic treatment for raw water allows removal of disinfection phase, and is preferred for environmental reasons.
Keywords: sonic settler, water, physical and chemical indicators, microbiologic indicators

Introduction

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 [1] and they can 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. In this paper we propose a new water treatment technology: the use of sonic settler, which is equipped with air-jet sonic generator [2].

1. Sonic settler and research methodology of water sonic treatment

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.

On the platform of Braila water treatment plant the experimental installation [2,3] for treat the raw water was made, that contains : vertical settler, two- frequency sonic-ultrasonic type air-jet generator, and necessary systems for raw water supply, for air pressure, for coagulant solutions. Sonic decanter works at this way (Fig. 1). Raw water enters in 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.

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 in the bottom cone during of settling certain period time and is discharged through the sludge outlet spout 9. Experimental sonic settler has the following overall rate: D = 1.6 m, H = 2.56 m.

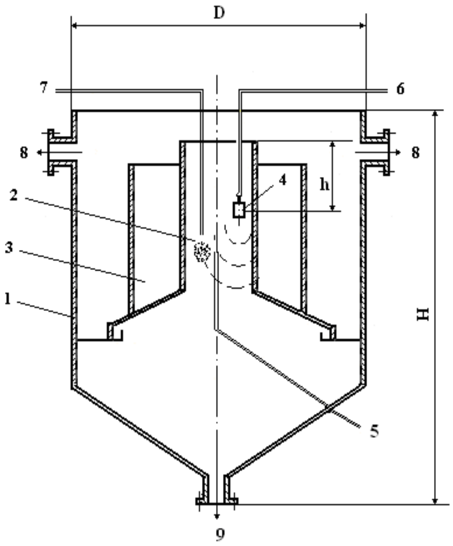


Fig. 1. Sonic experimental settler: 1-settler wall; 2-mixing chamber; 3-reaction chamber; 4-sonic air-jet generator; 5-raw water pipeline; 6-air duct work of the generator; 7-coagulant pipeline; 8-decanted water collection; 9-collector sludge disposal; D, H- settler diameter and height respectively;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

As sonic air-jet generator it was used the hydrodynamic unit P. Dumitras from Institute of Applied Physics of Academy of Science of Moldova [4,5].We determined the acoustic parameters of the generator on air working pressure p = 0.05 MPa, which were conducted experimental research settling. Acoustic spectrum of sonic air-jet generator revealed two working frequency [5]: the sonic frequency of f_I = 10.76 kHz and ultrasonic frequency of f_{II} = 21.520 kHz as well as similar character of variation of intensity levels. Methodology in experimental research work was:

- establishing working dates for installation, where water flow is a constant (raw water flow rate of 0.9144 m^3 / h , speed raw water ascension 0.145 mm / s);

- 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).

2. Influence of operating modes of sonic settler on physical-chemical and microbiological parameters of quality of raw water

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 sonic settler.

2.1. Turbidity Index.

Turbidity variation was investigated depending on operating modes of the sonic settler at different values of the o*peration time ratio* t_{rap}, which describe the generator operating conditions:

$$t_{rap} = \frac{t}{t_0}, \qquad (1)$$

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

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

- 0 minutes operation / 60 minutes break, $t_{rap} = 0$;
- 5 minutes operation /15 minutes break, $t_{rap}= 0.33$
- 10 minutes operation /10 minutes break, $t_{rap} = 1.0$
- 20 minutes operation / 10 minute break, $t_{rap} = 2.0$

The depths to that sonic generator was placed were: h = 0, 0.25, 0.5, 0.75 and 1.0 m toward exit mouth of Sonic settler reactor (see *Fig.*1). From Figure 2 is observed that the minimum value of turbidity is obtained on the depth h = 0.75 m:

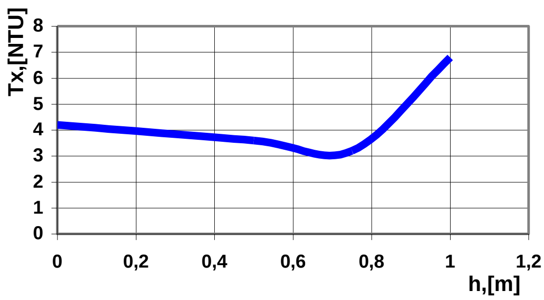


Fig. 2. Sonic decant water turbidity T_x according to the depth h (generator acoustic intensity level 109.88 dB /108.09 dB, frequency: 10.76 kHz / 21.520 kHz, operating time ratio t_{rap} = 0.33)

Turbidity value in this case is 3.2 NTU, value less than at traditional decanters (value ranging between 4.2 and 4.6 degrees NTU). Based on the water turbidity determinations we can said that operating time ratio is the base time parameter from the settler sonic operation is depends directly. Turbidity variation depending on operating mode of sonic settler is presented in Fig. 3:

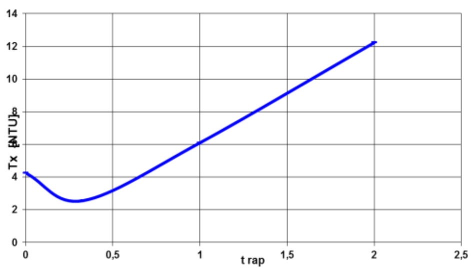


Fig. 3. Sonic decanted water turbidity T_x according to operating time ratio t_{rap} (acoustic intensity level 109.88 dB /108.09 dB, frequency: 10.76 kHz /21.520 kHz, depth h = 0.75 m)

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.

Polynomial approximation for water sonic treated turbidity dependence, depending on the operating mode of the sonic settler to optimum depth of generator immersion (h*= 0.75 m) has the formula:

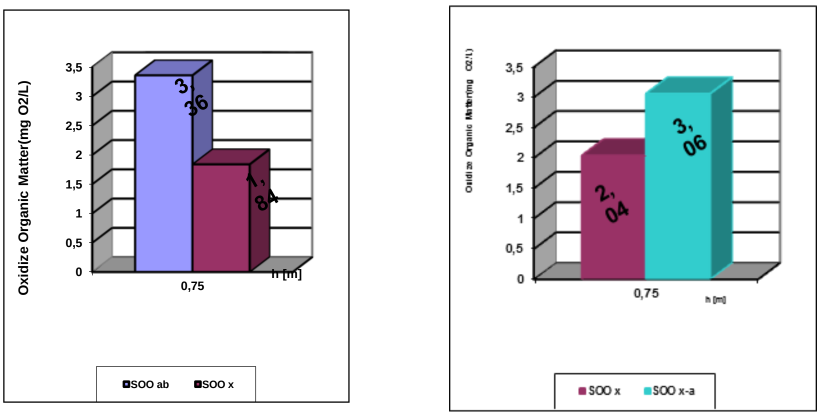
$$T_X = - 4.9368\, t_{rap}^3 + 16.94\, t_{rap}^2 - 10.144\, t_{rap} + 4.242, \tag{2}$$

where: T_x ,[NTU] is turbidity and t_{rap} is operation time ratio of sonic generator.

Further maintained sonic settler operating regime where water turbidity is minimal : 3 cycles of 5 minutes of actual generator operation followed by 15 minutes of rest (operating time ratio t_{rap} = 0.33) at optimal depth of generator immersion.

2.2. Oxidability index.

The figure below illustrates the influence of sonic treatment and bubbling on the content of oxidability substances in water:



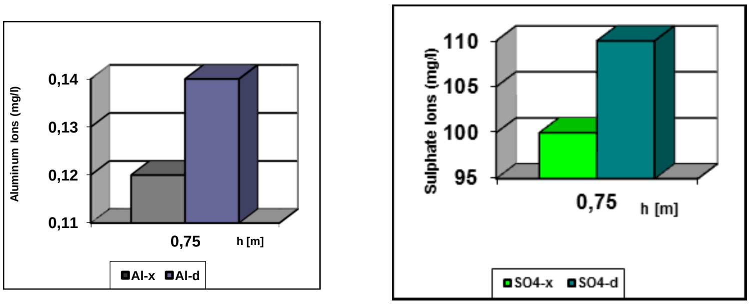
a *b*

Fig. 4. Sonic settling water oxidability (generators acoustic parameters: $L_{f\,I}$ = 109,88 dB/ $L_{f\,II}$ = 108,09 ; f_I =10,76 kHz/ f_{II} =21,520 kHz), compared with raw water (a) and with bubbling treated water (b): SOOab - oxidability organic matter of raw water; SOOx – oxidability organic matter of settling water at sonic treatment; SOOx-oxidability organic matter at aeration

It is noted that the value of water decanted oxidability at sonic treatment decreases being 1.826 times lower than the value determined for raw water(fig. 4, *a*). Sonic generator replacement with an aerator showed increase of the average water oxidability (fig.4.6, *b*). Oxidability value of settled water when sonic generator was replaced with an aerator is: SOOx-a = 2.40 mg O2/ liter. This value is 1.3 times higher than the one obtained when using sonic generator, which indicates that for sonic treatment two distinct processes occur-acoustic cavitation producing water degassing leading in decreased oxidability, and air bubbling leading to water aeration, respectively to oxidability increase.

2.3.Content of aluminum ions and sulfate ions.

Test results [3] have shown that the average aluminum ions content (Fig. 5 a) decanted water through experimental sonic settling (Al^{-}_{x} = 0,12mg/l) is 1.66 times smaller than the average value obtained in classic settling (Al^{-}_{d}= 0,14 mg/l). It should be emphasized that the effect of reducing aluminum ion content of sonic treated water is beneficial for aquatic ecosystems and human health.



a *b*

Fig. 5. Aluminum ions content value (a) and sulfate ion content (b)at sonic treatment (generators acoustic parameters: $L_{f\,I}$ = 109,88 dB/ $L_{f\,II}$ = 108,09 ; f_I =10,76 kHz/ f_{II} =21,520 kHz) compared to classical technology

Experimental results showed that the average of sulfate ion content (fig. 5, *b*) of experimental sonic settling (SO4-x =100 mg/l) is smaller than average value determined for classic settling (SO4-d = 110 mg/l), which shows an economic effect.

2.4.Microbiological indicators.

Given that the settler sonic operating mode is discontinuous was monitored bacterial load of treated water for all operating modes of sonic settler (t_{rap} = 0; 0,33; 1,0; 2,0) [7]. Were determined: aerobic mesophilic bacterial count at 37 º C (mesophilic), probable number of coliforms bacteria (total coliforms), thermo-tolerant probable number of coliform bacteria (fecal coliform), probable number of fecal streptococci.

Mesophilic bacteria are microorganisms that grow at 22 º C and 37 º C, able to form visible colonies on nutrient media under certain culture conditions (UFC).

Coliform bacteria (total coliforms) are mobile bacilli, Gram-negative non-sporulated which ferment lactose at 37 ± 0.5 ° C and is identified by the characteristic appearance of colonies formed on selective media.

Thermo-tolerant coliform bacteria (fecal coliform) have lactose fermentation characteristic in lactose liquid medium and acid gas at 44 ± 0.5 ° C.

Fecal Streptococci are spherical or oval cocci, Gram-positive, immobile, seated in pairs or short chains isolated which grows at a temperature of + 44 ± 0.5 ° C in the presence of 40% bile salts and sodium azide.

Table 1 presents the results of sonic treated water bacteriological load in the experimental settler depending on its trap operating mode. The research was conducted in two seasons: summer and autumn water temperatures ranging from 14-16 ° C and from 24 to 26.5 º C.

Table 1. Microbiological indicators depending on operating mode of the sonic settler

Operation Time Ratio t_{rap}	0	0,33	1,0	2.0
Aerobic mesophilic bacterial count at 37ºC (germs), [No./1 ml]	92	0	0	0
Probable number of coliform bacteria (total coliforms) [No./100 ml]	140	0	0	0
Thermo-tolerant probable number of coliform bacteria (fecal coliform) [No./100 ml]	33	0	0	0
Probable number of fecal streptococci (Streptococcus) [No./100 ml]	5	0	0	0

Table 1 shows that starting with Operation Time Ratio t_{rap}=0.33, all microbiological indicators analyzed reaches zero, which allows us to choose the optimal treatment sonic regime - 5 minutes operation / 15 minutes break. Sonic treated water bacteriological charging not vary with depth that sonic generator is immersed and also starting with t_{rap}=0.33 remains zero [129]. To generalize the results according to sonic treatment regime and acoustic field intensity, has proposed a new sonic criterion [7]. It is the ratio of the acoustic intensity level produced by a generator and water flow passed through the sonic settler:

$$Cs = \frac{L \cdot t}{Q(t + t_0)}, [\frac{dB \cdot s}{l}], \qquad (3)$$

where: L, [dB] is the overall level of sound intensity produced by the generator ; t, [s] – generators working time ; t_0, [s] – pause time of generator operating cycle ; Q,[l/s]=$Q \cdot 10^{-3}$ [m^3/s] – treated water flow.

Below in Fig. 6 is the variation on microbiological indicators of water, depending on the sonic criteria:

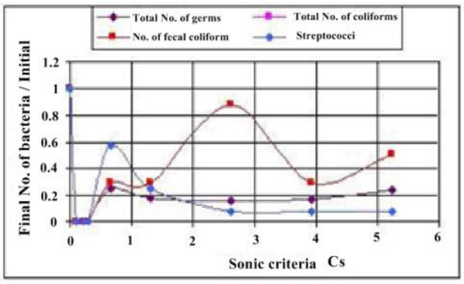


Fig. 6. Microbiological indicators of water depending on the sonic criteria C_s

To understand the curves course must be taken into account that at sonic treatment two processes occur simultaneously: cavitation degassing and aeration by bubbling. The curves in the graph tend to stabilize (see curve streptococci) which confirms the balance between aeration and degassing at sonic treat. Oscillations shown in Figure 6 indicate stress resistance of bacteria which should be studied further. Experimental data processing using MathCAD PLUS, allowed the determination of sonic criteria, where antimicrobial effect is maximum, namely:

$$C_s = 0{,}11 \div 0{,}295, \left[\frac{dB \cdot s}{l}\right] \qquad (4)$$

It is known that destructive influence of ultrasound is a consequence of hydrodynamic forces related to the formation and implosion of ultrasound cavities. Of particular importance is hydrophobic character of the microbiological entity sheath, what makes cavitation phenomenon to take place far away, or closer, the water-microorganism contact area. So the sensitivity of microorganisms, vis-à-vis of the ultrasound effect related to the phenomena which cause cavitation in in their immediate vicinity. Cavity formation within cells is influenced by their structure and composition. Thus, cytoplasm viscosity aggravates a lot the appearance of intracellular cavitation. Due to cavitation bubble destruction, existing gas or vapor within it are adiabatically compressed, temperature can reach to10.000 ^{0}C and forms a shock wave whose intensity increases with increasing ultrasonic pressure. Antibacterial effect obtained by treating water with bi-frequency generator sonic-ultrasonic type, can be explained by a dual bactericidal mechanism [7]:

- in the first phase under the action of sound waves there is microorganisms cell walls awareness through sonic frequency (10.76 kHz).
- in the second phase under the action of low frequency ultrasound (21.52 kHz) bacterial destruction occurs, which is manifested by proteins denaturing, broken capillary walls and cell contents dispersal in the environment.

Conclusions

We studied the influence of sonic settler operating regime on the physico-chemical parameters and microbiological quality of water, experimental acoustic parameters of the generator are: acoustic intensity level $L_{f\,I}$ = 109.88 dB at first frequency emission f_{I} =10.76 kHz (sonic frequency); acoustic intensity level $L_{f\,II}$ = 108.09 dB at second frequency emission f_{II} =21.520 kHz (ultrasonic frequency). Optimal working regime of the generator, in the sonic settler is discontinuous in the cyclical variant: a operating time followed by a long pause. We determined the ratio between the generator operation period and the period of break t_{rap} = 5min/15 min, established in a operating cycle of one hour, where the average turbidity is Tx = 2.56 NTU, and is smaller than the one obtained in the classical settler (value between 4.2 and 4.8 NTU) which proves that sonic settler is 36.415% efficiently against a classic settler. Due to sonic treatment of raw water, the following results were obtained: water oxidability value decreased 1.5 times compared to that obtained by conventional technology and 1.826 times compared to raw water; content of aluminum ions in water decreased of 1.66 times compared to conventional technology; was decreased from 110 mg / l to 100 mg / l water content of sulphate ions compared with traditional settling. Also we studied the influence of working regime of sonic settler on the microbiological quality parameters of raw water: aerobic mesophilic bacterial count (mesophilic), probable number of coliform bacteria (total coliforms), thermotolerant probable number of coliform bacteria (fecal coliform), probable number of fecal streptococci. Sonic treatment of water has a significant bactericidal effect. In all experiments it was observed that at sonic treatment bacteriological indicator values are "0". Behavior of microorganisms under the influence of ultrasound depends on cavitation phenomenon. So if germs and streptococci are destroyed by pressure waves produced by sonic waves, then total and fecal coliforms are resistant to sonic waves, but they destroy at cavitational bubble implosion (the so-called phenomenon "hot spot"). For the first time we introduce the notion of "sono-microbiology" [7], a notion referring to water disinfection using an air-jet sonic generator. In bi-frequency sound field (sonic frequency of 10.76 kHz and 21.52 kHz ultrasonic frequency), there is total destruction of microorganisms in water. Sonic treatment of water includes two physical phases of the classic raw water treatment: settling simultaneously with filtering. Also this treatment eliminates phase of chemical treatment, disinfection. In this context we can speak not by a sonic settler, but sono-biochemical reactor treating water like in a technological cell.

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