INTEGRATED ADSORPTION AND ULTRASONIC TECHNOLOGY FOR WATER TREATMENT PROCESSES

M. Malovanyy[1], V. Starchevskyy[2], N. Vronska[1], I. Koval[2]

[1]Department of Ecology and Environmental Protection,
[2]Department of General Chemistry. Lviv Polytechnic National University, 79013 Bandery 12, Lviv, Ukraine (E-mail: mmal@polynet.lviv.ua)

ABSTRACT
Current status of water sources and central water supply systems of Ukraine did not ensure the required quality of drinking water. Research focused on the problem of drinking water preparation. The aim of this work is to study the process of water treatment from mechanical and chemical pollution and pathogenic microflora by adsorption and ultrasonic methods. Proposed technology reduces bacterial contamination and purifies water from organic pollutants, increasing water quality.
Disinfection of water under the influence of ultrasound is carried out by cavitation process during insonation, i.e. formation, growth and destruction of gas bubbles in the liquid. Uniform dispersion of gas in water is provided at simultaneous action of ultrasound and gas on polluted water, which is a factor in the intensification of the decontamination processes. To achieve the desired low microbial number and high water quality additional treatment method is required. In this study the most common natural sorbents (zeolites, glauconites, palygorskite, bentonite) were used for further increasing water quality. Use of natural sorbents in the purification technology does not require its regeneration, so water treatment using sorbents is promising and relatively inexpensive method.
Chemical oxygen demand (COD) and microbial number were used as criteria of water treatment and were analyzed for incoming water, after ultrasonic treatment and after application of natural sorbents.
It was found that interaction of ultrasound and adsorption allows achieving a high quality of drinking water.

KEYWORDS: natural sorbents, ultrasound, adsorption

INTRODUCTION

Any water reservoir or water source is an integral part of the surrounding environment. It is influenced by formation conditions of surface or underground water runoff, various natural phenomena, industry, construction engineering, transport, human economic and domestic activity. The emergence of new unusual substances pollutants which deteriorate the water quality in the water environment is the result of such influences.

Pollutions affecting the water environment are classified depending on approaches, criteria and tasks. As a rule chemical, physical and biological pollutions are differentiated.

The main sources of natural waters pollution are:

- atmospheric waters carrying a significant amount of pollutants that are washed out of the air and mainly have the industrial origin. When flowing down the slopes, atmospheric and melt-waters grasp additionally a significant amount of substances. Runoff from city streets and industrial sites are especially dangerous, so far as they carry a significant amount of oil products, phenols, various acids;
- city waste waters which include mainly sanitary wastewaters containing excrements, detergents, and microorganisms among which are pathogenic ones;

- industrial waste waters formed in various manufacturing fields; among them ferrous metallurgy, chemical, timber-chemical, and oil refining industries consume water most extensively.

Often that the level of waters pollution is very high, thus without implementation of new technologies it will not be possible to receive water for economic and domestic needs that meets sanitary and hygienic requirements.

Therefore, nowadays in water treatment processes the special attention is given to the application of:

- physical methods for natural waters disinfection,
- ultrasonic cavitation which provides the fast inactivation of microorganisms,
- natural sorbents reducing the concentration of organic pollutants (Mason et al 2003, Grim 1967, Avidon 1968).

METHODOLOGY

Ultrasonic action is used in practice for water treatment due to the high efficiency of water purification from chemical pollution, biological objects; saprophytic and pathogenic microorganisms, viruses, animalculines etc. Ultrasonic is an effective reagentless highly ecological method of water purification from organic and microbiological components (Melkumova A. S. et al 1975).

During the cavities collapse the emitted energy causes the processes of microorganism destruction. The pathogenic microflora is destructed and active radicals are formed around the collapse points. Cavities develop in the ultrasonic emitter chamber with the frequency of several tens of kilohertz mainly on inhomogeneities that are represented by spores of mushrooms and bacteria (Mokryy E. M. et al 1993).

In the first stage of research used the synthetic solution of Bacillus bacteria. It was put into the ultrasonic reactor (Drawing 1). The ultrasonic oscillations (frequency 22 kHz, power 35W, intensity W/ cm^3 per volume unit) from the UZDN-2T generator are transmitted with the help of magnetostrictive emitter immersed into the test water (V 150 cm^3) (Fridman V. M. 1967, Margulis M. A. 1986).

During the whole process CO_2, O_2, He, and Ar were bubbled through the test water. The reactor was cooled constantly by the current water. The experiments conditions are the following: T= 298 K, P= $1 \cdot 10^5$ Pa, ν_{us}= 22 kHz, process time - 2 hours.

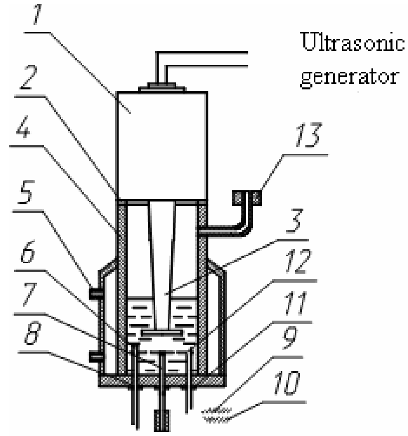

Figure 1. The reactor scheme for water treatment process

1- magnetostrictor; 2,8,9 - thickening; 3 - waveguide, 4 - reactor, 5- heat carrier nozzles, 6 - thermocouple, 7 - gas input nozzles, 10, 11 - cap nuts, 12 - sampler, 13 - gas output nozzles.

In the second part of work used water from natural pond polluted with different microorganisms. Stage I was ultrasonic treatment with use oxygen gas. Parameters of the processes that the same as the first part. Stage II was sorption on natural sorbents. In our studies used three types of sorbents – bentonites, zeolites, glauconites (U. G. Distanov et al 1990, Tsitsishvili G. V. et al 1985). They are the most common natural sorbents that can be used for water treatment.

The application method of natural dispersed sorbents is also very perspective and has the following advantages (Breck D. 1976, Matsievska O. O. et al 1995):

- the natural sorbents are widely distributed all over the Ukrainian territory;
- they are available and inexpensive materials;
- adsorption technologies using natural dispersed sorbents provide the high quality level of water treatment process;
- the used natural adsorbent does not require the regeneration.

The experiment conditions are the following:

sorbent type - bentonite, zeolite, glauconite;

sorbent concentration – 7 g/l, 20 g/l, 35 g/l respectively;

water used – natural water from pond

sorption time – 1 hour;

constant mixing.

Sampling was carried out before the experiment, after the ultrasonic reactor and use of natural sorbent.

Samples were analyzed for Chemical Oxygen Demand (COD) (Nasseri S. et al 2006) and Microbial Number (MN) (Slyusarenko T. P. 1984).

RESULTS AND DISCUSSIONS

The data of water purification of the model substance by ultrasonic is provided below (MN_0 – number of microorganisms, cfu/cm^3)(Tables 1-2, Figure 2).

Table 1. Water disinfection levels (D_d) and effective constants of destruction frequency of Bacillus type bacteria (k_d) ($MN_0 = 8 \cdot 10^2$ n /cm^3)

Process conditions	**D_d, %**	**$k_d \cdot 10^4$, c^{-1}**
Ar/ultrasound	95,9	4,29±0,06
He/ ultrasound	93,6	3,68±0,07
O_2/ultrasound	90,5	3,6±0,07
CO_2/ultrasound	91,1	1,67±0,13

Table 2. Effective constants of dieaway frequency of Bacillus type bacteria and their destruction levels ($MN_0 = 7 \cdot 10^5$ cfu/cm^3)

Ar/ultrasound		**O_2/ultrasound**	
$k_d \cdot 10^4$, c^{-1}	**D_d, %**	**$k_d \cdot 10^4$, c^{-1}**	**D_d, %**
10,1±0,01	99,9	9,76±0,01	99,8

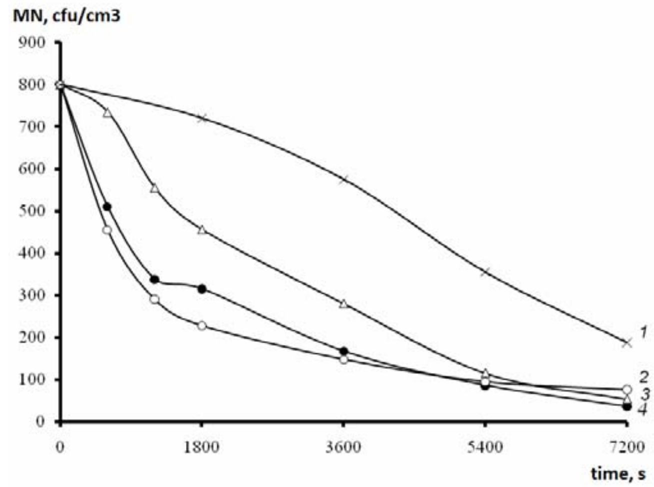

Figure 2. Dependence of changes in number of microorganisms (Bacillus type bacteria) from duration of gas/ultrasound action by bubbling different types of gases: CO_2 (1), O_2 (2), He (3) та Ar (4).

Samples were analyzed for chemical oxygen demand (COD) and microbial number (MN) (Tables 3-5, Figures 3-4).

Table 3. Changes in COD and MN when C= 7 g/l

	COD_0 mg/dm^3	COD after ultrasound mg/dm^3	COD after sorption mg/dm^3	MN_0 cfu/cm^3	MN_0 after ultrasound cfu/cm^3	MN after sorption cfu/cm^3
Bentonite	256	192	224	22 000	45 000	10 700
Zeolite	320	224	192	25 000	33 000	9 000
Glauconite	288	192	176	76 500	55 000	25 000

Table 4. Changes in COD and MN when C= 20 g/l

	COD_0 mg/dm^3	COD after ultrasound mg/dm^3	COD after sorption mg/dm^3	MN_0 cfu/cm^3	MN_0 after ultrasound cfu/cm^3	MN after sorption cfu/cm^3
Bentonite	256	240	128	22 000	41 200	3 000
Zeolite	320	224	160	25 000	30 800	2 000
Glauconite	288	192	160	76 500	60 000	5 000

Table 5. Changes in COD and MN when C= 35 g/l

	COD_0 mg/dm^3	COD after ultrasound mg/dm^3	COD after sorption mg/dm^3	MN_0 cfu/cm^3	MN_0 after ultrasound cfu/cm^3	MN after sorption cfu/cm^3
Bentonite	128	96	64	22 000	39 000	2 000
Zeolite	320	160	96	15 000	23 000	7 000
Glauconite	288	192	96	61 000	53 000	4 000

As seen from figure 3, all three types of sorbent purified water, but best results obtained in purification of water by bentonite (C=35 g/L).

At the first stage of purification MN increases due to cavitation during insonation. At the second stage, when we added sorbent, best results in purification of water were obtained by ceolite (C=20 g/L). The research results showed that the combination of ultrasound and absorption methods can significantly increase the quality level of water purification.

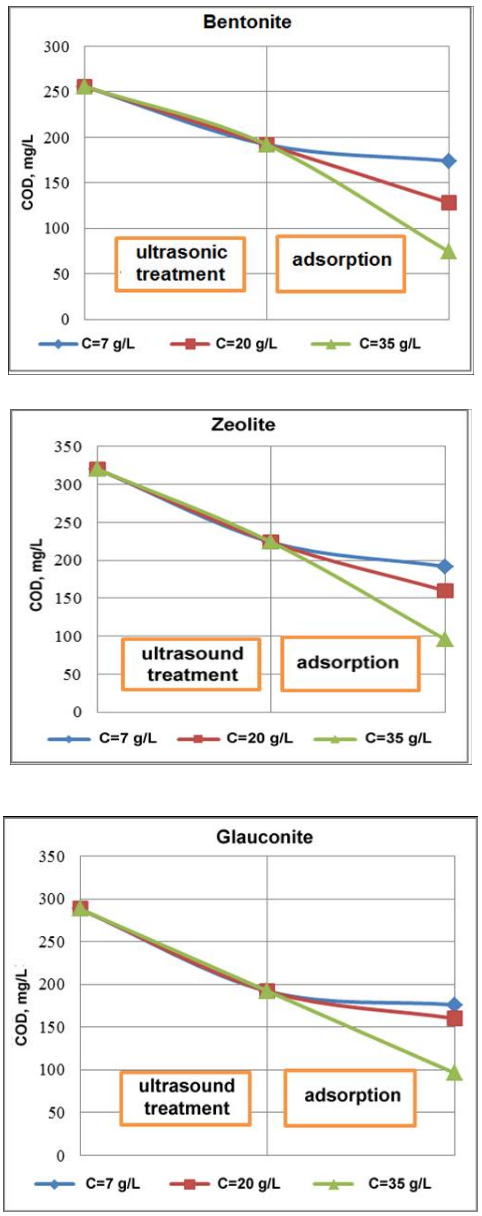

Figure 3. Changes in COD

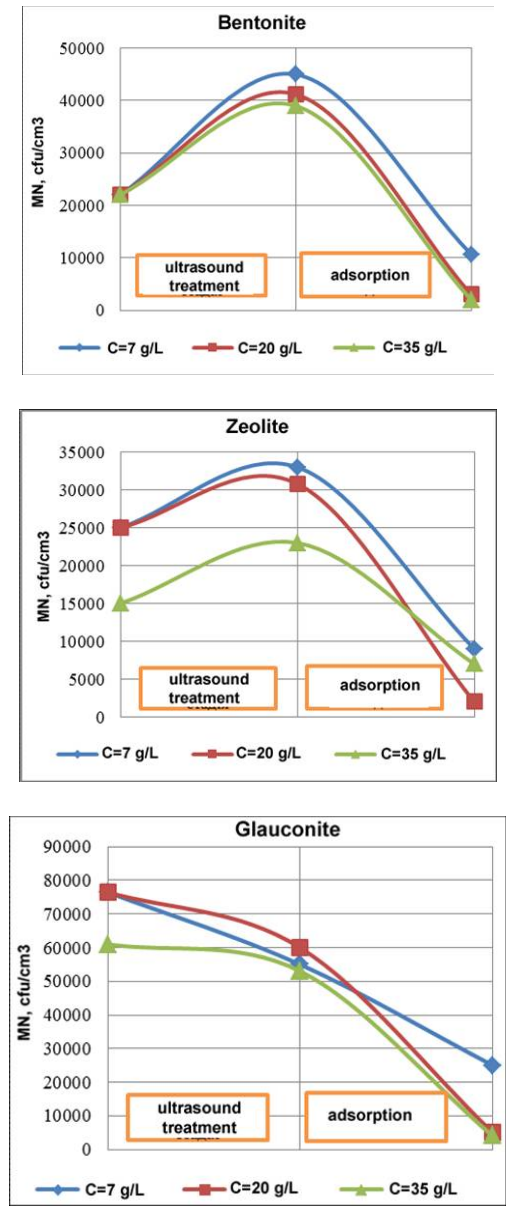

Figure 4. Changes in MN

CONCLUSIONS

The use of ultrasonic cavitation energy allows intensifying water treatment and is an effective method of water sanitization.

The application of dispersed sorbents in water treatment allows further decreasing both COD and microbial number after ultrasonic cavitation step.

The main advantages of the use of natural minerals are: large geological reserves, low-cost exploitation of minerals, easy preparation for transportation and usage, possibility to reuse sorbents in other technologies, thus eliminating the need of expensive regeneration.

REFERENCES

Mason, T.J., Joyce, E., Phull, S.S., Lorimer, J.P. (2003) Potential uses of ultrasound in the biological decontamination of water. Ultrason. Sonochem., 319-323.

Melkumova A. S., Lisichkina Z. S., Gorshkov S. I. (1975) Ultrasound [in Russian]. Moscow, Medicina, 344 p.

Fridman V. M. (1967) Ultrasonic chemical equipment [in Russian]. Moscow, Mashynostroenie, 212 p.

Margulis M.A. (1986) Sound chemical reactions and sonoluminiscence [in Russian]. Moscow, Chimiya, 286 p.

Mokryy E. M., Starchevskyy V. L. (1993) Catalytic reaction in cavitation. Monograph [in Ukrainian]. Lviv, Svit. 72 p.

U. G. Distanov, A. S. Mihajlov, T. P. Konyuhova et al (1990) Natural sorbents of the USSR [in Russian]. Moscow, Nedra, 208 p.

Tarasevych J. I., Ovcharenko F. D. (1975) Adsorption on clay minerals [in Russian]. Kyiv, Naukova dumka, 351 p.

Grim R. E. (1967) Mineralogy and practical use of clay [in Russian]. Moscow, Mir, 511 p.

Avidon V. P. (1968) Preliminary experiments on clays in field condition [in Russian]. Moscow, Nedra, 168 p.

Breck D. (1976) Zeolite molecular sieves [in Russian]. Moscow, Mir, 778 p.

Tsitsishvili G. V., Andronickashvili T. G., Ckirov G. N., Filizova L. D. (1985) Natural zeolites [in Russian]. Moscow, Chimiya, 224 p.

Matsievska O. O., Granops M. M., Shnerch S. S. (1995) Carpathian use of zeolites in water treatment processes [in Ukrainian]. Proceedings of IV Scientific conference "Problems of construction and environmental engineering". Rzeszov (Poland), 99-104.

Nasseri S. and al. (2006) Environ. Health Sci. Eng. Vol. 3, №2, 109-116.

Slyusarenko T. P. (1984) Microbiology laboratory workshop on food production [in Russian]. 208 p.