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PROCESS OPTIMIZATION OF VIBRORESONANCE SEWAGE DISINFECTION

Для процесів кавітаційного очищення стічних вод від органічних домішок розроблено математичні моделі, що адекватно поєднують їх технологічні параметри із показниками якості обробки. У якості стічних вод розглянуто води пивоваріння, молокопереробної промисловості та воду громадського використання.

Ключові слова: технологічні параметри, оптимізація, кавітаційні процеси, органічні забруднення, потік води, вібрація.

Mathematical models which adequately combine their technological parameters with indicators of treatment quality have been designed for the cavitation cleaning processes of sewage from organic admixtures. Water of brewing, milk processing industry and public water use it is considered as sewage.

Key words: technological parameters, optimization, cavitation treatment, organic contaminations, flows water, vibration.

The main source of water contamination is domestic and industrial wastewater. Diversification of their contamination on so much wide, that about application here of any unique method of cleaning it is out of the question. It and biological contamination and contamination of cleansers of domestic waters of flows of settlements phosphates, and organic contaminations by wastes of refineries enterprises, contamination alkalis and acids of processing productions, contamination pesticides and poisons of the ground waters at growing and treatment of agricultural product, by heavy metals at making of casting products of engineer and various products of chemical industry, by a high-toxic chrome at processing of skin and making of wares from her and others like that. Practically this list endless and superfluous time confirms about an urgent necessity not only introduction of the newest environmentally friendly technologies and increase of culture of productions with the purpose of maximal reduction of their wastes and impermissibility of contamination of environment but also about the necessity of perfection of existing and creation of new progressive methods of disinfecting and cleaning of waters of flows.

Among basic methods of water treatment and cleaning of flows, which includes mechanical, chemical, physical and biological methods, it is the most perspective are seemed by the various methods of

the physical water treatment, that predefined by not only their high efficiency but also absence of requirement in separated concomitant the process of water treatment of products. Technology of cavitation water disinfection belongs to such perspective water-purifying technologies.

Laboratory researches and practice of the industrial use are convincingly prove high efficiency of application of the cavitational phenomena in liquids for initiation and activating of various redox processes, including for the operations of water treatment and purification. From other side, it follows to acknowledge that unfortunately, both the simple and economic method of indignation and stable support of cavitation in the pipelines of considerable cuts and productive highly equipment is still absent for his realization in the conditions of production.

That is why actual are researches directed on creation of the modern newest technologies of cavitation treatment, on perfection of existing and creation of new more accomplished from positions of providing of high quality and fitness for industrial application of methods, including new varieties of methods of the cavitation water purification, able to combine high degree of water treatment with the considerable productivity, and equipment for their realization.

The purpose of this research is perfection of cavitational equipment for disinfecting of wastewaters from organic and biological contamination, optimization of his basic structural and technological parameters

The tasks of research are:

– determination of basic structural and technological parameters of vibrocavitators of resonance action, that influence on the productivity of cleansing process and quality of treatment of liquids;

– development of mathematical models of process of vibroresonance of the cavitational disinfecting of waters of flows with biological pollutants, optimization of his basic technological parameters.

Object and article of research were technological charts and operations of water treatment and purification, industrial and experimental equipments for indignation of cavitation in liquids, hydrodynamics in the conditions of cavitational interfusion, kinetic conformities to the law of power influence on disinfecting of water in the conditions of cavitation.

Analysis of previous researches. One of the most ponderable achievements in industry of cavitational water-purifying technologies accrued in the Lviv Polytechnic National University method of vibroresonance of cavitational treatment of substances of liquids. His specific excellent feature is indignation of cavitational processes in the processed liquids tricking into to the resonance hesitating mode of present in liquids embryos of cavitation due to the periodic power influencing on them vibrating in the liquid stream of cavitation perturbation factors, as a rule it is solids. Tricking into to resonance of hesitating motions of embryos of cavitation, here, is provided selection of frequencies of vibrations of cavitation perturbation factors close or multiple own frequencies of vibrations of embryos of cavitation [1, 2]. In a result, in the resonance mode of vibrations of embryos of cavitation treatment of liquids takes place in the mode of active “gas” cavitation, the high is provided, close to ultrasonic, intensity of the cavitation field, and necessary for support of the stable resonance mode energy is outwardly brought minimum. As a result, the method of cavitation vibroresonance treatment of substances of liquids provides the highly productive discrete or continuous processing of liquids, needing only insignificant degree of the specific (on unit of volume of the processed medium) energy brought for his stable support. It opens for him good prospects in the use not only for treatment of substances of liquids of various technological processes, and that especially with authority, for technological water treatment and preparation of water of the domestic use.

Exposition of basic material. Among developed low frequency vibrocavitators in Lviv Polytechnic National University the most suitable from positions of providing of high performance of cleansing and disinfecting treatment of waste water is circular vibration electromagnetic cavitator of resonance action [2] and vibrocavitator for treatment of chemically active liquids, liquids under pressure and at the promoted temperatures [3], which is presented on fig.1. Circular electromagnetic vibrocavitator is able to provide the high (to 4.0 m3/h) performance of cavitation treatment due to the considerable to 10 inches transversal

cut of working chamber, vibrocavitators for treatment of chemically active liquids is the commensurate with productivity due to possibility of treatment of liquids under pressure.

By the basic knots of low frequency vibration electromagnetic cavitator for cavitation treatment of chemically active substances of liquids, liquids under pressure to 3.5 – 4.0 kg/cm^2 and liquids at the promoted temperatures a working chamber is hermetically closed with symmetric flanges to which two cylinder corps are added with the union couplings of serve of cool liquid. Into every cylinder stator shell with a puttee and anchor of electromagnets of occasion, which from a working chamber are pressurized flange with the central opening for moving of rod of anchor of electromagnet, is placed. Between an anchor and stator of electric drive the membrane which provides oscillation of anchor with rod added to him with amplitude to 3.5–4.0 mm made from elastic material is set on the rod of anchors of electromagnets deck-perturbation factors of cavitation the flat or conical surface of which is pierced openings for fluid of the processed liquid is fastened. A working chamber is equipped the union couplings for a serve and taking of the processed liquid, concomitant treatment gases or air (in the case of technological necessity). Cavitator from reasonings of accident prevention it is closed protective sheepskin coats which are set on supports. Taking into account, that the resilient pendants of the resonance tuning are absent in cavitators of this type, the regulator of frequency of tension the model of AFC-120 is included in the electric chart of feed of their electromagnets of occasion, which allows the smooth adjusting to change frequency of attracting of anchor of electromagnet to his stator, changing the same frequency of vibrations fastened on the rod of anchor of deck-perturbation factors of cavitation.

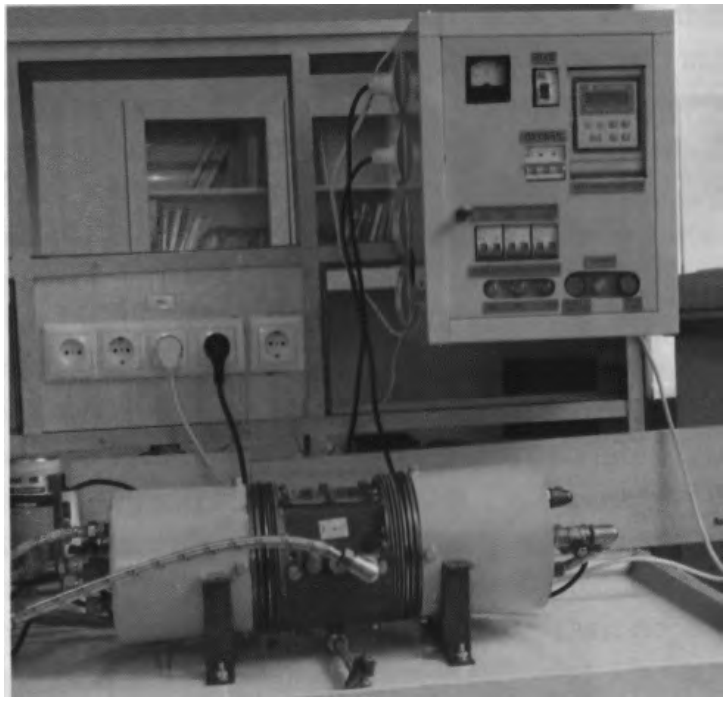

Fig. 1. Electromagnetic cavitator for cavitation treatment of chemically active substances of liquids, liquids under pressure and at the promoted temperatures (with the partly taken off protective elements of sheepskin coat)

In general for the cavitational processes of vibrations there is a number of factors which are added modifications and adjusting and have a ponderable influence on the eventual parameters of quality of cleansing treatment. They are divided into technological and structural and their changes in a greater or less degree, but show up on the changes of the state of the processed liquid. The parameters of technological cleansing equipment belong to the structural factors, in particular:

– amplitude-frequency features (AFF) of cavitator;

– power of occasion of revolting cavitation of hesitating elements, i.e. specific power inputs are on cleaning of unit of volume of the processed liquid;

It follows to take to the changed technological parameters of processes of the кавітаційного cleaning of liquids;

– terms of realization of cavitational of cleansing process, which are represented pressure and temperature of liquid;

– state of the processed liquid which is characterized the parameters of its contamination, namely by the chemical oxygen demand (ChOD, mg/dm3), microbial number (MN, CFU/cm3) and hydrogen index (pH);

– duration of cavitational cleansing treatment, τ, s.

The optimum values of structural parameters most ponderable from which is AFF of occasion and his power determine on the initial stages of industrial introduction of cavitational cleansing process. Exactly here by the developed device [4] experimentally for concrete proper cleansing treatment of muddy liquid determine the ranges of frequencies of resonances of vibrations of present in a muddy liquid of cavitation kernel. On the basis of these information appoint frequency and amplitude of vibrations of perturbation factors of cavitation and power of realizing of their occasion.

The list of basic technological parameters of processes of the vibrocavitational disinfecting is set and to cleaning of wastewater from organic contaminations, their intercommunication between itself and with the basic quality indexes of cavitational treatment enables optimization of technological parameters to apply the well-known theory of planning of experiment [5]. The finished good of theory of planning of experiment is a construction of mathematical models which not only adequately describe and represent a certain process or phenomenon but also allow to optimize the ways of achieving a maximal eventual effect – qualities of cleaning of flows.

The theory of planning of experiment foresees a reflection as certain mathematical dependences of intercommunications between the so-called variables of entrances – technological parameters of treatment in our case, and by the parameters of the eventual state – dependency variables, functions of review, by the parameters of optimization and others like that. In the case of the biological disinfecting and cleaning of wastewater from organic contaminations by facilities of cavitational treatment the indexes of ChOD and MN of the processed water can be used in quality of basic indexes of cleansing treatment. Exactly these two indexes, both for muddy liquids in the initial state and their modifications both in the process of treatment and after its completion most objectively represent the high-quality state of muddy or cleared liquid. Their correlation between initial and eventual values can be interpreted as a degree of cleaning or disinfecting of liquid is certain. Ponderable is and те, that the indexes of ChOD and MN of liquids with organic admixtures (by contaminations) indissolubly interrelated and change one necessarily causes changes other.

As variables parameters, so-called “variable factors”, appropriately to choose the next in this case:

– duration of treatment, τ, s;

– temperature condition of the processed liquid medium of T ^{0}C ;

– hydrogen index pH of the processed liquid;

– one of the higher noted indexes of quality and state of the processed liquids, that one of indexes of ChOD or MN.

Each of the noted variable factors owns numeral values which outline the range of his definition, and answers all requirements to the parameters of in-outs, namely:

– subject measuring and can be set an amount;

– consonant with other functional variables;

– substantially influences on the function of review.

Intercommunications between the function of review and functional variables here represented as mathematical models of the explored process.

Most comfortable and simple in application among methodologies constructs of mathematical models of the various phenomena and processes there is planning of complete factor experiment (CFE) as CFE of 2^k, where k is variable factors (factors). CFE plans are symmetric, rationed, orthogonal.

The mathematical design of processes of cavitational disinfecting and cleaning from organic admixtures was carried out for waters of flows three the most common types of contaminations, namely;

– wasretwater of brewing production on the example of muddy waters of "Kumpel" brewing;

– suckling whey as basic component of waters of flows of milk processing production;

– urea as one of basic organic pollutants of reservoirs of the public use – pools, water parks and others like that.

For comfort of the use the mathematical models of these cleansing processes as the so-called equalizations of regression, function of review and value of variable factors are presented in table 1.

Table 1

Mathematical design of cavitational cleansing processes (CFE 2^3)

№	Name of process cleansing	Parameter of optimization (Y function)	Technological parameters (variable factors)			Mathematical model (regression equation)
			X1	X2	X3	
1	2	3	4	5	6	7
1	Vibrocavitational treatment of wastewater of "Kumpel" brewing production under nitrogen medium	ChOD mg/dm^3	MN, CFU/cm^3 $(MN)_{min}$=10000 CFU/cm^3; $(MN)_{max}$ = 9.76 ·10^6 CFU/cm^3	Medium temperature T, C Tmin=200C; Tmax=500C	Treatment duration τ, s. $\tau_{min=60s}$; $\tau_{max=7200s}$	Y=(ChOD) =1200+ +9.3·10^5(MN)- -16.4(T)+0.08(τ)
		MN, CFU/cm^3	ChOD, mg/dm^3 $ChOD_{min=}$ 300 mg/dm^3 $ChOD_{max}$ = 2000 mg/dm^3	Medium temperature T, C Tmin=200C; Tmax=500C	Treatment duration τ, s. $\tau_{min=60s}$; $\tau_{max=7200s}$	Y=(MN)= =475765+ +53.7(ChOD)- -2714(T)- -11.5(τ)
2	Vibrocavitational processing of whey	ХСК, mg/dm^3	MN, CFU/cm^3 $(MN)_{min}$=10000 CFU/cm^3; $(MN)_{max}$= 500000 CFU/cm^3	Treatment duration τ, s. τ_{min}=60$_s$; τ_{max}=7200$_s$	hydrogen index pH, pH_{min}=4.0; pH_{max}=6.0	Y=(ChOD)= -9218+ +0,015(MN)- -0.87(τ)+ +2664(pH)
3	Vibrocavitational processing of model medium of urea+water at the ratio of 1:10 under nitrogen atmosphere	ChOD mg/dm^3	MN, CFU/cm^3 $(MN)_{min}$=16000 CFU/cm^3; $(MN)_{max}$= 32000 CFU/cm^3	Treatment duration τ, s. $\tau_{min=60s}$; $\tau_{max=7200s}$	Hydrogen index of pH pHmin=2.63; pHmax=5.8	Y=(ChOD)= +118.15+ +3.25·10^{-3}(MN)- -33.2 ·10^{-3} (τ)+ +5.1(pH)

The results of graphic reflection of the got mathematical models are represented on figures. So on fig. 2 and fig. 3 influencing of basic technological parameters of process of the vibrocavitational cleaning of wastewater of "Kumpel" brewing production is graphicly represented, namely to duration of treatment τ, s and medium temperatures T, C on such indexes of cleaning quality as ChOD (fig. 2) and MN (fig. 3). At the reflection of influencing of technological parameters on ChOD changing in the process of the vibrocavitational cleaning was fixed $MN_{average}=5\cdot10^6 CFU/cm^3$ and MNmax=10^7 CFU/cm^3) values of MN of the processed water (fig. 2), i.e.

$$y = (ChOD) = f(T, \tau) \rightarrow (MN)i = Const.$$

And at the researches of their influence on MN changing was fixed ChODmax=2000 mg/dm^3 (fig. 3), i.e.

$$y = (MN) = f(T, \tau) \rightarrow (ChOD)i = Const.$$

The general tendency of changes of ChOD both at the mean and at maximal values of MN of initial water under vibrocavitational cleaning of wastewater of "Kumpel" brewing production (figs. 2, 3) is the factor, that than higher is ostensible ChOD and MN of initial water, that than greater is organic and biological contamination, the below is a degree of its eventual cleaning, that below is a cleansing effect. So at the initial MN value of polluted water $MN = (4{,}5 \div 5{,}0) \cdot 10^6\, CFU/cm^3$ after treatment of 2 hours (τ =7200s) at the medium temperature of T=250C lowering of ChOD of water is provided from 1200 mg/dm^3 to 700-750 mg/dm^3, that the degree of its cleaning is achieved under the conditions (38–42 %) (fig. 2). At the substantially higher initial value of MN=(9,5-10)·$10^6\, CFU/cm^3$ за similar terms of cleansing treatment lowering of ChOD of polluted water is provided from 1800 mg/dm^3 to 1200 mg/dm^3, that cleaning degree equal 33.3 % (fig. 2). Cleaning degree here and in subsequent determined after formulas:

$$\frac{ChOD_{in} - ChOD_{end}}{ChOD_{in}} \cdot 100\% \text{ or } \frac{MN_{in} - MN_{end}}{MN_{in}} \cdot 100\%$$

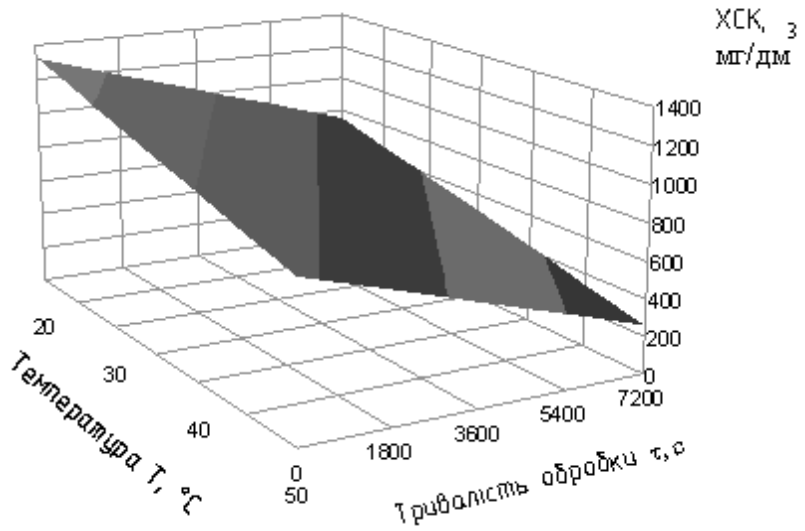

Fig. 2. Graphic reflection of influencing of technological parameters on the indexes of quality of the vibrocavitational cleaning of wastewater of "Kumpel" brewing production from organic contaminations under nitrogen medium at $МЧ_0 = 5 \cdot 10^6 \frac{CFU}{cm^3}$

Similar conformity to the law was observed and at researches of influencing of technological parameters (T and τ) on changing of MN of the same polluted water in the process of its vibrocavitational cleaning. Here researches conducted at the fixed values $ChOD_{max} = 2000\, mg/dm^3$. Dependence of degree of disinfecting from the initial state of polluted water is here opposite a previous case: for less muddy water an accessible degree of cleaning is within the limits of 16.5 % (fig. 3), and for more polluted equal 31 %, i.e. almost higher at twice. Thus, here obviously there is certain conformity to the law – worsening of degree of cleaning on the measure of swift growth of degree of muddiness. By an exit from this situation there can be application of the frequent discrete cleaning or of long duration cleaning in the reserved technological loop.

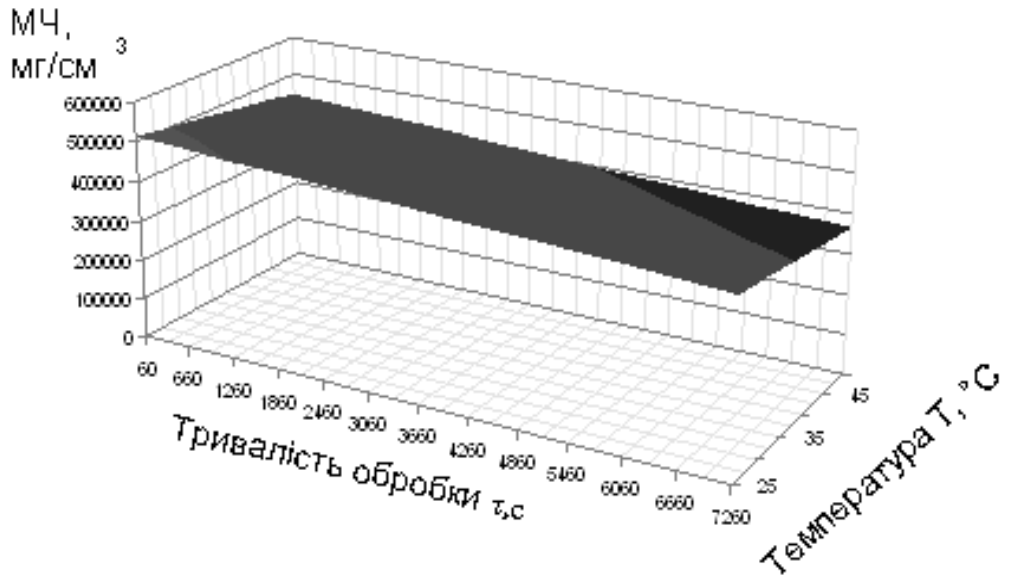

Fig. 3. Diagram of technological parameters impact of the vibrocavitational disinfection of wastewater of "Kumpel" brewing production under nitrogen medium at $ChOD_{in} = 2000 \frac{mg}{dm^3}$

Another from conformities to the law, that is expressly traced from the mathematical models of process of the vibrocavitational cleaning of wastewater from brewing production is the dependence of eventual indexes of cleaning degree from the temperature of medium, which is brightly expressed. So at promoted to T=45-50^{0}C temperatures for all considered terms of treatment of polluted water (fig. 3) cleaning degree 40-45 % arrived at already for the first 10-15 minutes of treatment, swiftly growing in subsequent on the measure of growth of duration of treatment.

The influencing of treatment duration is less brightly expressed here because of cleaning degrees of contaminated water from organic admixtures (fig. 2) and from biological contamination (fig. 3) proportionally increased with increasing treatment duration. At the ranges of changes of technological parameters and terms of treatment appointed here do the maximally accessible degrees of cleaning, depending of muddiness degree of initial water from organic contaminations equal 60-80 % and from biological contaminations equal 30-35 %.

The construction of mathematical model of process of vibrocavitational treatment of wastewater of milk plant, namely wheys, was carried out at a choice in quality of technological parameters of in-outs of treatment duration and pH value, the scopes of varying of which appointed in the range of pHmin =4.0 – pHmax =6.0 (fig. 4).

As well as in previous cases, eventual indexes of cleaning degree dependency upon of contamination degrees of initial wasterwater of organic and biological pollutants. At the normal terms of treatment at the values of MN of initial flow water of MN=$MN_{average}$ =2.5·10^5 CFU/cm^3 with the mean value of pH=5.0 for the first 10–15 minutes treatments a cleaning degree is provided 30-35 %, and at MN=MNmax =10^5 CFU/cm^3 iqual 23 – 25 %. On the measure of multiplying duration of treatment a cleaning degree grows from organic admixtures, attaining 80-85 %. However, decreases sharply pH value (3.8–4.0), that acidity of whey grows swiftly. Predefined it, obviously, by maintenance of acids in the wasterwater.

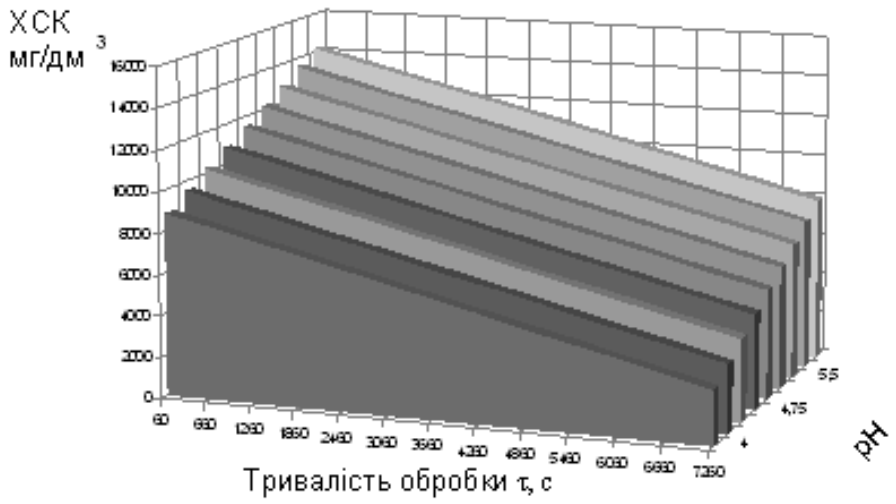

Fig.4. Diagram of technological parameters impact of ChOD values of the vibrocavitational cleaning of wastewater of milk plant from organic admixtures at $MN_{in} = 5 \cdot 10^5 \frac{CFU}{cm^3}$.

Like previous results represented the influence of cavitational treatment on water solution of urea (fig. 5). As well as at cleansing treatment of wastewater from brewing production, on the measure of growth of contamination degree of this model medium a cleaning degree falls down from organic admixtures. So at the initial value of water solution of urea of MN=16000 CFU/cm^3 is a degree of the vibrocavitational cleaning 55–60 %, and at the MN increase up to MN=32000 CFU/cm^3 a cleaning degree reduces to 40–45 %. As well as in the case of wastewater treatment of milk plant, the pH value decreases sharply from 5.8 to 3.5 with increasing the treatment duration units, that testifies about acidity growth.

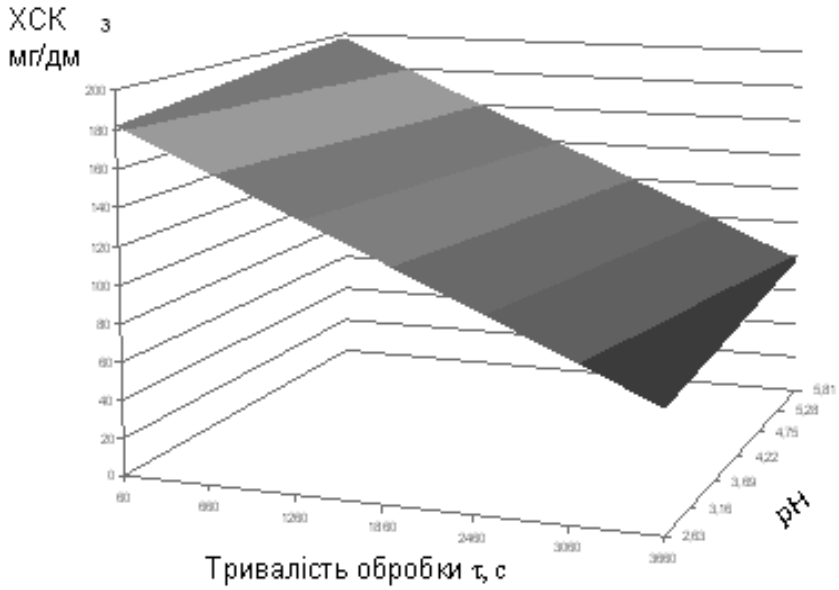

Fig. 5. Diagram of technological parameters impact of the vibrocavitational cleaning of model medium of urinary acid +water at the ratio of 1:10 under nitrogen medium at $MN_{in} = 16000 \frac{CFU}{cm^3}$

Conclusion. Hence, obtained mathematical models in the form of regression equations of cleaning processes of wastewater sufficiently objectively represent relationships with technological parameters of vibrocavitational treatment with the indexes of its quality. Certainly, reproducing models their regressive equalizations are deprived possibility of account of a number of second-rate factors, for example, of character and amount of inorganic admixtures in the processed liquid, ponderable for the cavitation phenomena changes of its viscidity and superficial tension and others like that. However character of influencing of variable factors on the function of review, they represent the basic tendencies of these influencing sufficiently objectively, that confirm the coincidence of design information with experimental information. That is why got mathematical models can be acknowledged such, that adequately describe the process of the vibrocavitational cleaning of liquids and recommended to the use in cases of prognostication of the expected results of this cleansing treatment and optimization of its basic technological parameters.

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