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METHODS OF MICROORGANISMS INACTIVATION IN THE TECHNOLOGICAL LIQUIDS

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МЕТОДЫ ИНАКТИВАЦИИ МИКРООРГАНИЗМОВ В ТЕХНОЛОГИЧЕСКИХ ЖИДКИХ СРЕДАХ

In article allocated the main methods of liquids disinfecting. Water disinfecting is an example. We considered features of impact different methods of disinfecting on microorganisms. Shown these disinfecting methods of impact on a human organism. Marked out advantages and shortcomings of the most widespread methods water disinfecting. We carried out the comparative analysis of the specified methods of disinfecting. Shown the physical method of disinfecting as the most perspective. Formulated requirements to the ultrasonic equipment, which applied to disinfecting of liquids.
Keywords: cavitation, cavitation processing of liquids, disinfecting, disinfection use of chlorine, application of ultrasound, application of an ultraviolet, application of boiling, use of silver, use of ozone for disinfecting.

Introduction

Efficiency and quality of many technological processes, using technological liquids, depends on degree of infection with their microorganisms harmful and hazardous to health of the person.

Methods of disinfecting of liquids, which are now, can be divided into four main groups. They essentially differ in the mechanism of an inactivation of microorganisms:

- chemical, connected with application of strong oxidizers. As oxidizers use chlorine, chlorine dioxide, sodium hypochlorite, ozone, manganese-sour potassium, iodine, bromine, peroxide of hydrogen [1];
- thermal, realized at the expense of boiling and freezing [2];
- a water saturation method ions of precious and non-ferrous metals – silver, copper, etc., possessing bactericidal action [3];
- physical, realized by means of ultraviolet rays, ultrasound, radioactive radiation [4].

Each of the listed methods has the features of impact on microorganisms, has advantages and shortcomings.

The purpose of the offered article is the analysis of known disinfecting ways of technological liquids for possibility of creation the high-efficiency technological equipment which realizes process of microorganisms inactivation.

Main material

Chemical methods of disinfecting of liquids.

In the most widespread and effective method of disinfecting, especially large volumes of water is chlorination and ozonation [1].

Thanks to the oxidizing properties and the preserving effect of an after-effect preventing reproduction in water of various microorganisms, chlorine is almost universal remedy for processing drinking and sewage (fig. 1).

Kinds of water disinfecting method by chlorination is use of hypochlorite of NaClO sodium, dioxide of ClO2 chlorine and NH2Cl chloroamine [1].

Chlorination of water is a well-tried remedy. This process prevents distribution of epidemics. The majority of pathogenic bacteria, for example, typhoid bacilli, causative agents of dysentery, cholera vibrios, viruses of encephalitis are very unstable in relation to chlorine. However, spore-forming bacteria and some viruses, for example, jaundices, chlorine doesn't destroy, that is one of shortcomings of this disinfecting method.

Long-term experience of chlorine using for disinfecting of water allowed to reveal separate shortcomings of this method [5]:

- the increased requirements of safety to treatment plants using chlorine for disinfecting because chlorine is strongly toxic agent;
- need of an exact chlorine dosage control. The insufficient amount of substance won't give necessary bactericidal action. The excessive dose of chlorine will lead to deterioration of tastes of water;
- considerable dependence of disinfecting efficiency on a chemical composition of water;

- need of ensuring good mixing and sufficient duration of chlorine contact with water (not less than 30 minutes);
- need of a large supply storage of chlorine at stations imposes need to provide measures of the service personnel protection from harmful chlorine effect;
- need of by-products removal chlorination process – connections which halogen contain which most part is made by trihalomethane, chlorine organic compounds, connections which halogen contain [6].

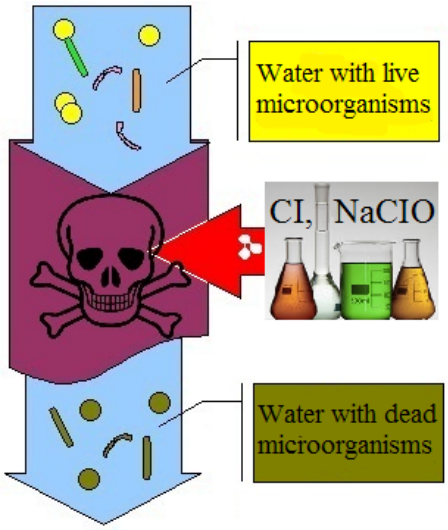

Fig. 1. Scheme of liquids disinfecting in the method of chlorination

Chlorine and by-products of chlorination in drinking water can constitute big danger, than microorganisms which are destroying by them. Accumulation of chlorine-containing connections in a human organism leads to diseases of internals, and also atherosclerosis, a cancer, anemia and allergic reactions [6]. Chlorine can destroy proteins and have adverse impact on an integument and hair, even small concentration of chlorine-containing substances will make negative impact on a human organism, as they will collect in various fabrics. Formation of by-product chemical compounds in water is one of the main reasons for search of new technologies and means of disinfecting of drinking water. Water purification with ozone is considered the most environmentally friendly and universal method of its processing (fig. 2.) [7].

Ozone processing of water promotes improvement of its taste and a smell.

Ozone effect on microorganisms consists in oxidation of the organic substances which are in intracellular substance. The active form of ozone is capable to oxidize the mineral connections and chemicals which are in the liquids. It allows to use this technology in the course of purification of underground waters, sewage of the enterprises, and also in systems of circular water supply of pools of big productivity.

Unlike chlorination, ozone using in systems of water treatment doesn't involve harmful to the person the derivative of chlorine [6].

Formation of some chemical compounds which arose in the course of ozonization on the contrary promote strengthening of process of an inactivation of microorganisms.

High oxidizing ability of ozone imposes some restrictions on the equipment to which have contacts with liquids enriched with ozone. In the course of disinfecting, it is necessary to use the equipment and materials possessing high corrosion resistance, these are pipes, reactors and capacities from PVC, stainless steel or concrete.

Ozonization - a chemical method of disinfecting and its efficiency substantially depends on chemical and physical composition of water, and also technological parameters of process. Change of liquids temperature and its acidity also involves deterioration of dynamics process of inactivation microorganisms.

Formed in the course of ozonization of such oxides as peroxide, epoxide, formaldehyde, acetaldehyde, etc. Can negatively will be reflected in quality of an output product. The assimilated oxidized components formed in the course of disinfecting by ozone are ideal food for microorganisms. It need additional use of biologically active filters [8].

Realization by ozonization demands high initial costs of the equipment and training of the service personnel.

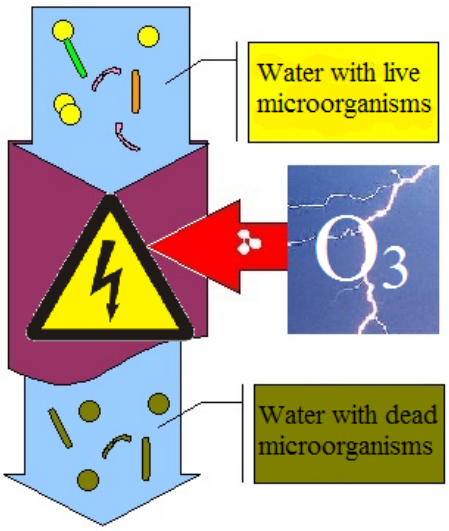

Fig. 2. Scheme of liquids disinfecting in the method of ozonization

High initial costs of the equipment applied at ozonization process, and need of the qualified service personnel are limited of use this method disinfecting. Fast decomposition of ozone excludes effect of an after-effect, therefore it application as a final stage of water purification extremely doubtfully. Introduction to the liquid a large amount of ozone which is strongly polluted by organic impurity involves formation of a specific smell and taste.

Together with chlorination and ozonization in the course of disinfecting of water there is known application of iodine-containing connection (fig. 3). As bactericidal means iodine is applied long ago. In the course of water treatment are most often used its connections in because of low solubility of pure iodine [9].

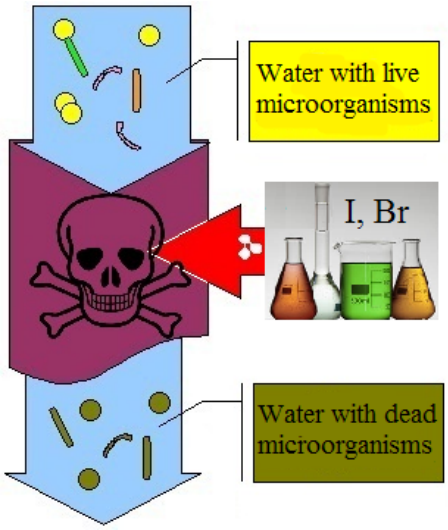

Fig. 3. Scheme of liquids disinfecting in the method of iodination and bromination

HI is the most active iodine-containing connection which is applied in the course of water disinfecting. Iodine unlike chlorine is chemically neutral to ammonia and other chemical reagents. The technology of iodination of water gained the greatest distribution at an inactivation of microorganisms in small volumes [9]. Simplicity of application of this method allows to use it for individual water disinfection in marching conditions. Also iodination found the application at disinfection of swimming pools.

Temperature of liquids, its acidity, iodides existence in water and hydrocarbonates has a great influence on efficiency and speed of disinfecting process when using chemical reagent of iodine [10].

The water which passed processing by the preparations containing iodine can have an unpleasant smell and specific taste. It is connected with formation of the substance HOI which can react with organic components that forms organic chemistry of iodine.

To iodination shortcomings, as well as any other chemical disinfecting method, it is worth referring of complexity control of reagent concentration during process of an microorganism's inactivation. The insufficient dose of reagent can not give bactericidal effect. Surplus of reagent can lead to serious diseases.

Behind application, frequency in the course of disinfecting along with iodine there has application chemical bromine reagent (fig. 1.3). The principle of action this substance on microorganisms is similar to chlorine effect, but unlike it bromine less active oxidizer.

The bromination technology gives a by-product - bromine-organic compounds. These bromine-organic compounds is an dioxine group - strong poisons [11]. After process of disinfecting it is necessary to carry out removal of by-products.

Small distribution of disinfecting by means of iodine and bromine is connected with the high cost of reagents in comparison with chlorine. For this reason they are applied generally to disinfection of liquid in small volumes [9].

Thermal methods of disinfecting of liquids.

For realization of a thermal method of liquids disinfecting has use high-temperature plasma, an open flame, hot air, superheated steam and also low temperatures in the course of freezing (fig. 4.) [12].

The easiest thermal method of disinfecting is boiling. The bactericidal effect of this method is reached after several minutes of liquids boiling. Thus, the majority of microorganisms has irreversible processes which lead to their death [2].

Advantages of boiling at deactivation of microorganisms it:

- small extent of influence on process of a physical and chemical composition of liquids;
- simplicity of control process;
- possibility of automation.

Shortcomings of this disinfecting method:

- big cost because of considerable expenses of the electric power or fuel materials;
- small productivity;
- absence of effect an after-effect;
- possibility of secondary bacterial pollution. Boiling as method of disinfecting, it is expedient to apply to household use or in the conditions of the developed epidemic situation.

Freezing as disinfecting method, should be taken into account only conditionally as low temperatures lead only to weakening of active reproduction of various microorganisms, but not to their death. At temperatures close to zero bacterium still keep ability to reproduction, but intensity thus considerably decreases. Use of low temperatures can be used as a method of extension the shelf life of pure water.

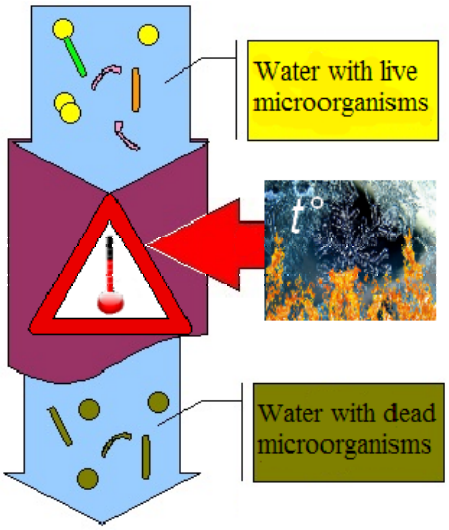

Fig. 4. Scheme of liquids disinfecting in the thermal method

Method of liquids saturation with ions of precious and non-ferrous metals.

The special attention by consideration of this method of disinfecting should be paid to use of silver and copper. It is the most extended elements for an inactivation of microorganisms (fig. 5) [13].

Bactericidal effect of precious and non-ferrous metals (copper and silver) happens at the molecular level. Their particles get into intracellular substance and interact with sulfur-containing amino acids of microorganisms. They participate in photosynthesis process. Therefore process of photosynthesis becomes impossible and the cage dies off [13].

Disinfecting of water by saturation ions of silver has effect of an after-effect [3]. It gives the chance to use this technology for long storage of drinking water.

Antimicrobic effect of silver, as well as any reagent method of disinfecting, substantially depends on the physic and chemical composition of water [14]. In this regard it is necessary to exercise constantly control of dispensing of reagent and to control quality of an output product. The bactericidal effect of silver is possible at concentration of reagent of 0,125 mg/l that much more admissible norms [14]. At smaller values, it is possible to constrain reproduction of microorganisms only. The silver that applied to an inactivation of microorganisms is expensive reagent. Besides, it is capable to collect in a human organism, thereby to promote development of a disease under the name argyria – poisoning with silver. At long-term the use of "silver" water could be inflammations of a mucous membrane of a digestive tract, manifestation of a renal failure are possible, there can be an ataxy, paralysis of respiratory system, etc. [15].

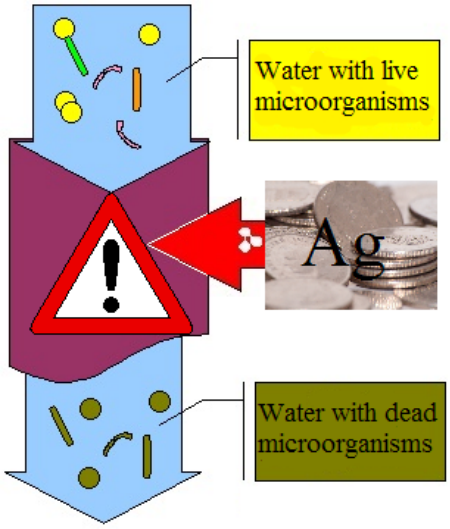

Fig. 5. Scheme of disinfecting liquids in the method of saturation by silver ions

In the course of liquids disinfecting were found application by copper ions. The principle of their action on microorganisms is similar to effect of silver, but for an inactivation necessary big concentration of ions of copper [16].

Any reagent method of liquids disinfecting needs removal of collateral chemicals [6].

Physical method of liquids disinfecting.

In the course of water treatment was widely adopted the method of disinfecting with application of ultra-violet (UV) exposure [4] (fig. 6). Bactericidal action of UV radiation is expressed in ability of rays to get into intracellular substance. Operating on genetic level, destroying chains of molecules of DNA and RNA, interfering with their activity and further reproduction [17].

The technology of water treatment by physical methods with application of UV exposure has a number of advantages before chemical methods:

- there is no need of removal and control of by-products of chemical reactions from the processed liquid due to the lack of those;
- there is no need of application special actions for safety measures in transit, storage and work with toxic materials;
- there is no need continuous purchase of reagents for process of microorganisms inactivation;
- there is no need of the highly skilled personnel involvement, respectively there is no need for carrying out actions for preparation and check of their knowledge and abilities.

The listed advantages of this disinfecting method favourably distinguish it from others. Despite advantages of UV method liquids disinfecting should be noted also its shortcomings [18]:

- liquid after processing can give in to secondary pollution due to the lack of effect of an after-effect;
- UV installation are sensitive to differences tension in a network. It can cause shutdown of a bactericidal lamp. Respectively there is some time when installation isn't capable to disinfect, and liquid continues to arrive to the consumer;
- the bactericidal effect of UV installation substantially depends on a turbidity of liquid and mechanical pollution;
- the beams which are let out by UV lamps quickly lose the efficiency in the thickness of water. Therefore the effect of disinfecting is carried out only near a lamp;
- low efficiency of UV lamps (less than 8.5%). It can be explained so - UV the lamp radiates all diapason, but for disinfecting only its part is used;
- complexity of carrying out an operating control for efficiency of disinfecting and quality of the received product;
- rigidity of liquid can lead to incrustation on a surface UV lamp.

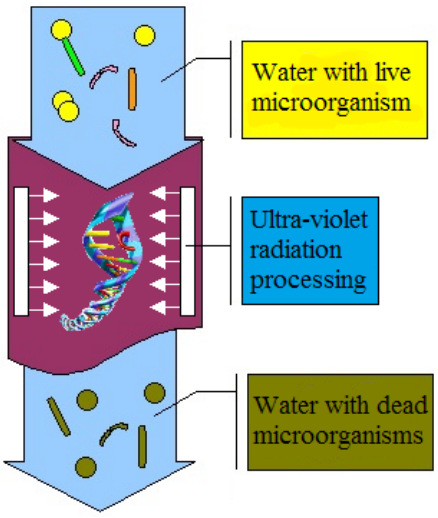

Fig. 6. Scheme of liquids disinfecting in the method of ultra-violet radiation

It leads to decrease in efficiency of installation.

The method of water disinfecting by means of ultrasound gains ground. (fig. 7).

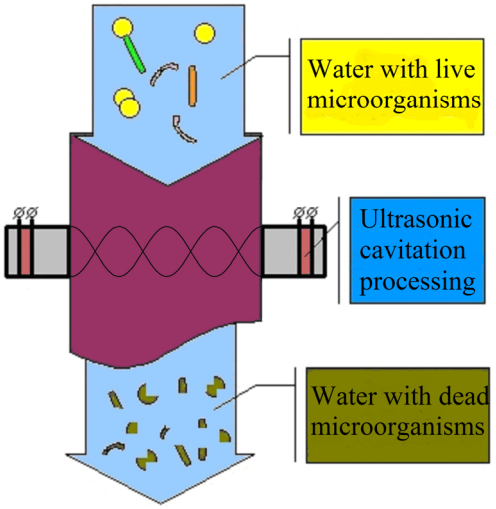

Fig. 7. Scheme of liquids disinfecting in the method of ultrasonic cavitation

Bactericidal properties of this method are realized at the expense of [19]:

- mechanical destructions of a microorganism due to emergence of a cumulative jet directly inside or near a microorganism;
- the local temperature increase at a collapse of cavitation bubbles leading to thermal destruction;
- difference of pressure on the microorganism length in a standing ultrasonic wave leading to violation of integrity of microorganism structure;
- activization of chemical oxidizing processes due to free radicals emergence;
- intensifications of chemical reactions due to hashing at the molecular level of reagents in liquid.

The specified advantages of UV method and belong to the ultrasonic method. To list also it should be added that [20]:

- the devices used to disinfecting of liquids have big service life;
- provide stable quality of processing;
- don't demand service by highly qualified specialists;
- high-speed performance of ultrasonic installations which are applied to an inactivation of microorganisms, allows to use them for processing of liquids, both in tank, and in a stream;
- for ultrasonic cavitation processing it doesn't matter the water turbidity, its chemical and physical composition;
- owing to destruction in the cavitation environment of a crystal lattice of salts on internal surfaces of cavitation devices incrustation isn't observed;
- ultrasonic cavitation processing of liquid can be applied along with of filtration technology. Thus the filter element, placed in a cavitation zone, constantly clears itself, providing stability of the characteristics.

The version and quantity of microorganisms, which can be inactivated in the course of ultrasonic cavitation processing, directly depends on the intensity of ultrasonic wave entering into liquid. Experimental studies show that for achievement of high efficiency process of microorganisms inactivation with method of ultrasonic cavitation processing it is necessary to provide the level of ultrasound intensity higher than 20 - 30 W/cm^2. Introduction to liquid a wave of small intensity (less than 2 W/cm^2) is observed the intensification of microorganisms reproduction process [19].

Conclusions

Analysis allowed to reveal advantages and shortcomings of known ways of disinfecting of technological liquids. The preference can be given to an ultrasonic cavitation way of an microorganisms inactivation. Numerous testings of the ultrasonic cavitation way of microorganisms inactivation of various sizes and types confirmed its high efficiency [19 - 22].

For creation the effective equipment realizing of specified inactivation way it is necessary to provide possibility of introduction to liquids of ultrasonic fluctuations with intensity more than 30 W/cm^2 at the density of energy more than 0,2W/cm^3.

The similar equipment for achievement of high-level efficiency has to meet to a number of specific requirements [23]:

- maintenance of the developed mode of cavitation in all volume of the technological camera;
- ensuring high efficiency of introduction to liquid of ultrasonic energy;
- ensuring concentration of ultrasonic energy in liquid to the demanded intensity level;
- ensuring durability of work of ultrasonic installation;
- application possibility of additional methods increasing of cavitation intensity: increase of static pressure; artificial saturation of water cavitation bubbles; regulation of temperature of liquid; low-frequency modulation of an ultrasonic signal.

Аннотация. *В статье выделены основные методы обеззараживания жидких сред на примере обеззараживания воды. Рассмотрены особенности воздействия различных методов обеззараживания на микроорганизмы. Показано воздействие этих методов обеззараживания на организм человека. Выделены преимущества и недостатки наиболее распространенных методов обеззараживания воды. Проведен сравнительный анализ указанных методов обеззараживания. Выделен физический метод обеззараживания как самый перспективный. Сформулированы требования к ультразвуковому оборудованию, которое применяется для обеззараживания жидких сред.*

Ключевые слова: кавитация, кавитационная обработка жидкостей, обеззараживание, дезинфекция, применение хлора, применение ультразвука, применение ультрафиолета, применение кипячения, применение серебра, применение озона для обеззараживания.

Анотація. *У статті виділено основні методи знезараження рідких середовищ на прикладі знезараження води. Розглянуто особливості впливу різних методів знезараження на мікроорганізми. Показано вплив цих методів знезараження на організм людини. Виділено переваги та недоліки найбільш поширених методів знезараження води. Проведений порівняльний аналіз зазначених методів знезараження. Виділено фізичний метод знезараження як самий перспективний. Сформульовано вимоги до ультразвукового обладнання, яке застосовується для знезараження рідких середовищ.*
Ключові слова: кавітація, кавітаційна обробка рідин, знезараження, дезінфекція застосування хлору, застосування ультразвуку, застосування ультрафіолету, застосування кип'ятіння, застосування срібла, застосування озону для знезараження.

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