Microbiological Treatment of High-Coloring Natural Waters

T Popova¹, V Golovin¹, P Medved¹
¹Department Engineering Systems of Buildings and Constructions, Far Eastern Federal, University, 8, Sukhanova St., Vladivostok 690950, Russia

E-mail: Popovatyu@dvfu.ru

Abstract. The formation of water quality in water resources depends on a greater number of natural and anthropogenous factors, determining the scheme of water treatment, its manufacturability and reliability at some point. In particular a significant part (over 30%) of surface sources is characterized by a high content of organic substances. This index is integrally estimated by the oxidation and water color. Notably, its magnitude frequently exceeds the maximum allowable concentration (three times or more). The experience of water treatment shows that the processing of such waters is extremely difficult and requires a significant correction of the applied technologies.

1. Introduction
It is commonly known that the organic content, estimated by the color and water oxidability is an important indicator of the natural water pollution, which should be taken into account choosing a purification scheme. In practice, the color of natural water resources are not always determined by the content of dissolved organic matters (DOM). Natural humus is represented by humic and fulvic acids, which give the water a yellow-brown color and form with metals (primarily iron and manganese) oxidation-resistant complex compounds, which are soluble in water. Moreover, DOM basically are represented by salts of organic acids, in particular, humic acids, such as crenic and apocrenic, which add a brownish color to the water. It is often perceived as an increased turbidity.

The experience of sewage treatment plants shows that the most serious water treatment problem for domestic and drinking purposes is the presence of compounds of various metals in stable forms in the type of complex organic compounds in natural waters. In this regard, the main reason preventing the purification of natural waters is that substances like, for example, humates can form complexes with metals, the removal of which from water is not provided by processes used traditionally in water treatment practice (settling with pretreatment reagents, clarification, filtration and etc.). This problem is due to the presence of abundant leaf waste in the process of the washing regime of water resources formation, with the heavy precipitation frequently with acid reaction (pH <7.0). All this has helped to the "leachability" of metals, humic substances and the active formation of organic complex compounds.

2. Conditioning problems with using surface water
New scientific knowledge about the drinking water impact on human health and the requirement for harmonization of Russian regulations with WHO recommendations determined the development and approval of a new normative document for water quality control - SanPiN 2.1.4.1074-01 "Drinking water. Hygienic Requirements for Water Quality in Central Potable Water Supply Systems. Quality
control \textit{”), which provides to set the indicators characterizing the chemical composition of drinking water and subject to continuous production control individually for each water supply system. The requirements of the current regulatory documents significantly change the approach to the problems of natural waters conditioning, not only for the purpose to expand the list of water quality indicators that are monitored during the treatment, according to the final result - in terms of the indicators directly at the water intake place, but also imply the improvement of the water treatment technology itself. The latter is impossible without a deep insight of the processes description that take place in the treatment facilities through the stages and the factors that determine the qualitative parameters of the source water and their intra-annual variability.

As practice of natural waters conditioning shows, the requirements of SanPiN 2.1.4.1074-01 using traditional water treatment technologies cannot be fulfilled, primarily for the reasons indicated above, due to the inability to eliminate complex organic compounds from water, the presence of which is a negative factor that determines a number of problems in the process of water purification and transportation. These problems determine such negative consequences as the decrease in the coagulation effect during sedimentation, clarification and filtration, as an increase depth of colmatation of the filter loading and, consequently, the complexity of its hydraulic regeneration, the formation of toxic organochlorine compounds, the biocorrosion of the metallic elements in the water supply and distribution system (WSDS), etc.

The problems of conditioning when using surface waters are aggravated by the significant variability of their quality indicators seasonably. Water quality monitoring of surface watercourses and reservoirs is currently very limited and, in particular, does not give a complete picture of the forms of various polluting ingredients in such waters. At the same time, often during the organization of domestic and drinking water supply, the justification of the scheme for conditioning of surface waters should take into account not only the presence of certain pollutants in them, but the compounds form in which they are in this water. Particularly, this is a case of the stable organic compounds of various metals, the presence of which is often are ignored, as modern methods of chemical methods for their detection are imperfect or such analyzes are conducted within the time of their natural destruction, that is, after some time it is sufficient for the modification of these compounds. In the process of water treatment, the time at purification plants is much shorter than the natural destruction of organic compounds, which, remaining in the already treated water, are the cause of a negative quality change during transportation and direct usage. In addition, commonly in practice, complex-organic compounds are not considered as polluting ingredients, both in quality monitoring and purification of surface natural waters. Most often complex-organic compounds enter into a complex and highly subjective indicator - chromaticity, determined quite arbitrarily in the degrees of chromaticity of the platinum-cobalt scale (PSC). Frequently it is mistaken in believing that the color of the water is characterized only by the presence of certain species of microalgae, microflora and some similar pollutants.

A high chromaticity is observed for surface water sources when heavy rain falls during the passage of summer typhoons. In this case, the appearance of chromaticity is determined by salt fluviapration of organic acids of the humic series from the soil layer in the river basin. The increased activity of this process is determined by the fact that the precipitates have usually a high dissolving power, since they are characterized by an acidic pH reaction.

Thus, complex-organic compounds are very resistant to degradation, and this property determines the complexity of removing such impurities from aqueous medium (natural and waste water). At the same time, dissolved organic matter, which in relation to bacteria is a nutrient substrate, provokes the development of various forms of microorganisms, including pathogens and potentially pathogenic ones. This is especially important to take into account water treatment, because the processes of microorganism development are already quite active in water supply sources. They are in progress at the stage of water transportation from the water supply source to the water treatment complex in the inlet pipeline systems, as well as at the stage of water treatment in the treatment plants. Generally accepted pre-chlorination in practice is not always reliable for protecting water supply system from the
consequences associated with the presence of microorganisms in the water even after purification in the case of stable complex-organic compounds. Moreover, there are formed organochlorine or ozonorganic compounds in the presence of such strong oxidizing agents as chlorine or ozone in the aqueous medium.

The negative consequences of the insufficient effect of surface water cleaning with the stable organic compounds have an effect on the conditioning process and also during the transportation of purified water to the consumer in the water supply and distribution system (Table 1). Such effects are often regular.

Table 1. Negative consequences of incomplete surface water treatment if they contain organic complex compounds.

| In the process of water treatment                                      | When transporting water in the WSDS system                                         |
|----------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| Residual, deep colmatation of filter loading                         | Worsening of water organoleptic properties                                        |
| Biological fouling of drainage filter systems                        | Ironing of cleaned water                                                          |
| Reduction in duration of filter cycling                               | Filtering the formation of highly toxic organochlorine compounds                  |
| Increased costs of purified water for washing                        | Biocorrosion of the WSDS system elements                                          |
| Difficulty of sludge dewatering washing                               | Biocompounding of breeding pipelines                                              |

Surface water has an unsatisfactory quality in the content of dissolved organic compounds. The ferrification characteristics of purified water are appeared in the detection of iron oxides in a relatively small concentration (up to 0.15 mg / dm3) and in a corresponding decrease in transparency. In this case, the nature of the biofouling of steel elements (domed formations on the inner surface) indicates about the active development of iron-oxidizing microorganisms. The latter is the cause of active biocorrosion of the distributing pipelines and the WSDS system as a whole (Fig. 1). This is very common in many water supply systems and is detected when the pipeline repair sections are opened.

Figure 1. Fragment of the internal surface of the pipeline supplying high-colored water from a surface water source with the development of biocorrosion.

In this case biological corrosion leads not only to the accelerated wear of pipeline systems (destruction with the formation of fistulas and suture ruptures), but also to secondary water contamination with the bacteria metabolic products and iron oxides.

At this time the mechanism of biocorrosion is not sufficiently studied. However, the most likely development scheme is outflux of aggressive enzymes by microorganisms whereby the splitting of complex-organic compounds takes place. Microorganisms use organic part of complex molecules to
ensure their metabolism, and the mineral part is stayed in water. In this case, microorganisms tend to immobilize i.e. fixing on the moveless elements of their environment, which in this case is the inner surface of the tube, on which the colonies of these bacteria are formed.

Enzymes released by microorganisms, contacting with the surface of a steel pipe are the cause of biocorrosion. It can be said with certainty that attempts to apply well-known approaches to the processing of high-color natural waters to prevent biocorrosion do not give a reliable result. The experience of pre-chlorination, carbonation, reagent treatment with elevated doses of coagulants only proves the validity of this conclusion.

An effective way to improve biotechnology and to accelerate the purification process of colored natural waters is the purposeful transformation of organic impurities by the selected microorganisms before the feed water is supplied for final purification. Technologically, this problem can be solved by fixing the cells of the microorganism-destructors to water-insoluble carriers, which are non-soluble (immobilization).

Immobilization of bacterial cells and microorganisms can be a natural process or can be caused by chemical or physical means. In particular, the development of methods for controlling artificial or induced immobilization has led to the realization of the advantages of immobilized cells in biological reactors.

Indeed, immobilized cells were used for biological treatment of wastewater for a long time, distributed as a skin over a solid surface of a dropping biofilter. However, this process is an example of naturally occurring immobilization. At present, immobilization of any microbial or tissue cells has become available, that has led to a significant expansion of their application. Even in the case of wastewater treatment, recent advances have significantly improved this traditional process, based on the use of immobilized cells, by increasing the specific surface area of the nozzle in the system.

3. Microbiological cleaning of natural waters

Over the last years, in the water treatment practice it is conducted the active researches on the use of microbiological effects on dissolved organics, which, with respect to bacteria, is a nutrient substrate. In particular, it have been developed a number of technical means (bioreactors) including microbiological decolorization of natural waters with the participation of the authors. The main direction of microbiological purification of natural waters is to ensure thorough and reliable treatment of treated water at a significant flow rate. It is necessary to keep a significant biomass of microorganisms-destructors in the treatment plant, and this can be achieved only by immobilization of microorganisms on the carrier. Immobilized (attached) microorganisms are more resistant to the action of toxicants, reproduce faster than in suspension state, are characterized by increased metabolic activity.

As it is known, the technological possibilities and efficiency of the purification plants, performed in accordance with traditional concepts, are rather limited. In this connection, the development of methods for intensifying purification processes based on the use of highly effective microorganisms-destructors becomes high priority. The development of the microbiological principles for the purification of natural waters has confirmed the idea of the possibility for replacing traditional treatment facilities with technologies of cleaned cultures not only in laboratory but also in working conditions. It should be noted that microbiological purification is economical, it does not require large capital and operating costs, local treatment plants occupy small areas, and they are simple and reliable in maintenance.

The usage of bioreactors with highly active bacteria-destructors fixed on the carrier allows purifying of high-colored natural waters characterized by different composition and concentration of pollutants efficiently. Here, the immobilization by adsorption and aggregation is the most acceptable. Organic and inorganic carriers like various polymers, ceramics, clay and others can be used as adsorbents. In recent years large-pored carriers attract special attention.

The responsible stage in ensuring the reactor operation with the fixed microorganisms is the choice of the carrier. The carrier for immobilization must be easily permeable and able to protect
microorganisms from mechanical, aerodynamic and hydrodynamic influences, abrupt changes in pH, temperature, concentration of pollutants.

In the practice of microbial water purification, the usage of "viy" nozzles and glass cleaner are widespread as a carrier of microorganisms, as well as mesh carriers made of polymer mesh. Recently, new polymeric carriers of microorganisms have been developed. Among them, special interest is caused by materials in the shape of form-stable fibrous of non-woven elements, which are produced by pneumatic-sputtering of melts of thermoplate polymers.

The most important moment in this case is the right choice of microbiological preparations, which should contain noncompeting microorganisms of broad action, environmentally clean and absolutely harmless to humans. For example, it is possible to place "AQUA-EM-1" to such specimens. Currently, the base "AQUA-EM-1" (EM - effective microorganisms - in the edition of the legal owner) specimen, created by EMRO (Japan) on the basis of the "Kyusei" specimen is produced in 59 countries and is used in more than 130 countries. "AQUA-EM-1" is an aqueous medium in which microorganisms are safe and healthy for humans and environment. It is used pure water without suppressing components (chlorine, etc.) and strains of non-pathogenic bacteria and fungi to prepare the specimen. The finished product is a brown liquid with a slight oily odor, after fermenting the organisms.

The main constituents of the microorganisms contained in the "AQUA-EM-1" specimen are sour-milk bacteria, yeast fungi, yeast fungi and other microorganisms similar to them have been used for a long time by mankind in the preparation of bread, cheeses, yoghurts, wines and other products subjected to fermentation. According to the manufacturer's safety data sheet, it is a mixture of 84 types of effective microorganisms and fungi that are not antagonistic to each other.

Thus, all microbes present in AQUA-EM-1 are existed in the natural ecosystem and are used mainly in the food industry. They are not toxic to people, animals, plants and the environment, AQUA-EM-1 solution is not dangerous and not radioactive and does not contain genetically modified organisms.

The mechanism of action "AQUA-EM-1" specimen is based on the fact that lactic acid bacteria process organics by fermentation, and lactic acid, according to Japanese researchers, prevents the vital activity of harmful microorganisms. Other metabolic products of lactic acid microorganisms are also suppressed competing bacterial species, especially specific enzymes. Such enzymes are quite aggressive to organic substances dissolved in water, since they contribute to their mineralization and removal from solution. Yeasts are also involved in the decomposition of organic substances and produce biologically active substances such as hormones and enzymes that promote the cleavage of complex organic molecules.

Microorganisms of the EM specimen can be attributed to photosynthetic bacteria that have the property of consuming hydrogen sulphide, ammonia and processing them into substances that later serve as a "food" for microorganisms. Getting into the environment, these three groups of basic bacteria interact with bacteria that are already contained in this environment, suppress competitors and destroy organic substances of various natures.

Thus, a microbiological specimen containing non-pathogenic microorganisms, when introduced into an aqueous medium, is capable not only to destruct organic impurities, but also to suppress competing bacteria species. This is due to the fact that nonpathogenic microorganism, release specific enzymes and other metabolic products which are unacceptable to competitors. In such a situation, competing species are gradually suppressed, which ensures the water disinfection in the water body. Besides that, the suppression of competitors is provided by the numerical advantage of non-pathogenic species with more active mineralization of organic matter contained in treated water, and thus the pathogenic bacteria and viruses are deprived of nutrition.

At present, in the world practice there is already quite a lot of positive experience in the use of EM technologies for the purification of water in natural water bodies. The international experience of using such technologies proves their effectiveness even in the most unfavorable ecological terms. They found the greatest application in Japan, South Korea, Nicaragua, Uzbekistan and other countries of the world.
4. Conclusion

During recent years, studies have shown that microorganisms of specimen such as "AQUA-EM-1" destructively impact on many organic impurities contained in aqueous media, in particular, in natural waters (marine areas, rivers, reservoirs). The content of suspended substances, petroleum products, metal salts of organic acids, which determine the water color and the concentration of other contaminants are decreased when entering the "AQUA-EM-1" specimen.

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