

Studies to reduce biofouling on metal surfaces of abstraction intakes

Anastasia Moskvicheva^{1*}, Ekaterina Fedulova¹, Alexandra Gilgenberg¹, Oleg Kononov¹, and Gulnara Gizzatova²

¹ Volgograd State Technical University (VolgSTU), Volgograd, 400074, Russian Federation

² Volgograd State Agrarian University, Volgograd, 400002, Russian Federation

Abstract. Biofouling is one of the main problems of water industry enterprises; many scientific developments are associated with the prevention of biofouling. It is one of the factors of pollution, a decrease in productivity, and also contributes to the occurrence of serious accidents at abstraction intakes (herein after AI). Scientists dealing with corrosion issues in Russia and research to determine the effectiveness of modern methods that reduce corrosion of metal surfaces have found that the nature of the basic cause of corrosion damage is the formation of material destruction products on the inner surface of the metal due to individual components in waste water. This article presents the results of the microbiological composition analysis.

1 Introduction

According to the relevant services, the average wear rate of abstraction intakes is about 60%, and in some regions, it exceeds 70% (Krasnoyarskiy Kray, Primorskiy Kray, Novgorodskaya Oblast, etc.) [1].

Consequence of AI unsatisfactory condition are colossal losses of treated drinking water, deterioration of the environmental situation in practically all regions of Russia [2,3].

Biofouling is one of the essential causes of ecological imbalance; at the same time, the sector of the biological growth processes negative impact on the natural environment is constantly expanding. Environmental pollution in the framework of the concept defined by UNESCO includes not only the direct, linear introduction of third-party substances or energy into the environment, but also the indirect violation of the ecological integrity of the natural landscape, which leads to rapid or long-term negative consequences for humans and various populations of flora and fauna [4,5].

Not only the environment affects the rate of biofouling processes, but the biofouling process itself creates non-equilibrium conditions in the environment, which, according to the principle of feedback, lead to an increase in corrosion processes intensity. That is why the authors of the article paid special attention to considering the issues of the biofouling processes reciprocal influence and the environment.

Despite the achievements of recent years in the field of biological processes research, the problem of corrosive wear remains in the center of attention of scientists of various fields of

* Corresponding author: viv_vgasu@mail.ru

science: ecologists, chemists, physicists, mechanics, and material engineers, which indicates the relevance of the issue. The issues of ensuring the technospheric and ecological safety of potentially hazardous metal structures in the aquatic environment raised this problem to an even higher level - they are included in the list of priority directions for the development of science, technics and technology of the Russian Federation. [6]

2 Main part

For the construction of headwalls, low-carbon and low-alloy steels are used. In addition to iron, they contain carbon (up to 2%), alloying impurities (chromium, nickel, manganese, copper) and impurities that cannot be completely removed in the metallurgical process (sulfur, phosphorus, oxygen, nitrogen, hydrogen). The inhomogeneous composition of steels favors the formation of corrosive vapors in the corresponding environment [7].

Metal biofouling can be the reason not only for contamination, decrease in the performance of various equipment in production, but also for serious accidents or breakdowns, the cause of which is the metal structures' destruction. Therefore, it is not possible to treat the biofouling of metals as an insignificant phenomenon.

Biofouling is one of the leading problems of modern industry, a lot of scientific developments are associated precisely with biofouling prevention.

The article presents the abstraction intakes headwall functioning gratings biofouling microbiological composition studies 'results. Microscopic analysis of the microflora of the lattice formation showed that the following iron bacteria are dominant in the natural association: from unicellular organisms - various morphotypes «*Siderocapsa*» (*Arthrobacter*) and *Gallionella*; from filamentous forms – *Leptothrix*. The main mass of bacterial formations is made by the representatives of the genus morphotypes «*Siderocapsa*», *Leptothrix* present in an insignificant amount and even less – *Gallionella*. In addition to iron bacteria coated with metal oxides, there are other bacterial cells, algae, and protozoa [8].

Analysis of the microbiological composition of the head walls at AIV Olzhsky town during the period of technical shutdown of water intake (the technological shutdown is associated with repair work or with flushing of filters with a reverse flow of water), showed that the total number of unicellular iron and manganese oxidizing organotrophic bacteria from soil water $(250.00 \pm 8.00) \times 10^6$ kl/ml, anaerobic iron and manganese-reducing bacteria $(8.05 \pm 0.27) \times 10^6$ kl/ml. The counting of the number of microorganisms on the sand load during the three-day technical shutdown of one of the filters showed that the amount of anaerobic iron and manganese-reducing bacteria per 1 g of the lattice reached more than $(2000.12 \pm 74.20) \times 10^6$ kl. The total number of iron and manganese oxidizing microorganisms: organotrophic bacteria $(13.30 \pm 0.53) \times 10^6$ kl/g; unicellular bacteria $(125.33 \pm 4.26) \times 10^6$ kl/g [9].

The data obtained indicate the presence of stagnant phenomena in the headwall and model installation. Therefore, after the start of filtration, the head, which is in a state of stagnant water, has in its composition soluble bivalent iron, which begins to oxidize in the pipes of the city water supply system, and not in the filters of the treatment facilities' water-lifting station.

In this way, as a result of the studies carried out, it was shown that typical representatives of iron bacteria that develop during a neutral reaction of the environment live in the headwall of the model installation. A quantitative account of microorganisms revealed their high content in biofouling of the AI headwall lattice (50 % make up iron bacteria). The important role of iron reducers in the secondary contamination of drinking water with soluble forms of iron was established.

The results were obtained using modern methodology, in particular, a JEOL JSM-6380 LV scanning microscope with an INCA Energy-250 energy dispersive attachment and X-ray spectral analysis with a microprobe analyzer in a transmission microscope of the company "JEOL" JEM 100 C.

A comprehensive study of the elemental composition of the biofouling of the VCD headwall lattice revealed the presence of various chemical elements: C, O, Na, Mg, Al, Si, S, Cl, K, Ca, Mn, Fe, Cu, Zn, P, Mo. The dominant number of heavy metals atoms (Mn, Fe) is associated with their biological sorption on the headwall elements and glasses as a result of the activity of iron and manganese oxidizing microorganisms. It can be seen from the data that such elements as C, O, Si, Fe are present in all studied samples, and with an increase in iron content, a proportional increase in the atomic percentage of C, Fe, Ca is observed. The atomic percentage of oxygen changes insignificantly, while the atomic percentage of Si decreases, which is most likely associated with an increase in the metal ions' sorption intensity on the surface of the headwall fragment and due to the activity of microorganisms capable of oxidizing bivalent forms of iron and magnesium with the deposition of oxides on the surface of these metals. The presence of Mn on the lattice fragments of the headwall also confirms the presence of oxidative processes in the filtered water associated with the conversion of compounds of this metal into an insoluble form. Atomic percentages for Na, Mg, Al remained at the same level. Such elements as P, Cl, Mo were identified only once in different samples, and it is difficult to judge about any dynamic processes from them [10].

In this way, the presence of elements Fe, Mn and other heavy metals on the formations of specimen slides and photographs of their surface made it possible to conclude that iron and manganese oxidizing microorganisms actively participate in the functioning of the model setup.

In biofilms formed on the water supply systems' surfaces with iron bacteria, other microorganisms can actively proliferate.

Even if biofilms are formed from completely harmless, oligotrophic species, the emergence in a nutrient-poor system of local zones enriched with biomass contributes to the emergence and development of epidemiologically dangerous organisms - pathogenic bacteria, viruses, fungi, protozoa.

Thus, in biofilms formed by iron bacteria, *Escherichia coli*, bacteria of the genus *Pseudomonas*, and also enteroviruses were found.

The bacterial density of such microorganisms in the biofilm can range from 10⁷ to 10¹¹ CFU/mg biofilm masses. The separation of microorganisms from the biofilm occurs, as a rule, haphazardly and can be caused by a number of factors, from which it is necessary to isolate:

- an increase in the biomass of growth to a certain "critical" value;
- changes in environmental conditions (concentration of nutrients, switching to another source of water supply, quality composition of biocenosis, temperature, pressure, oxygen concentration, etc.);
- the occurrence of alternating flows in the pipeline.

Microorganisms are torn out of the biofilm by a stream of water as more or less continuously (constantly), so they are torn off by a "flap". Therefore, water samples in no way can show where and in what quantity biofilms are formed [11].

An important criterion for assessing the formation is the potential of microbiological contamination created by them (in foreign literature - contamination potential).

A conditional representation of the biomass quantitative parameters, which exists as a potential for bacterial contamination in individual areas of the drinking water supply system, can be obtained on the basis of an approximate (approximate) calculation.

This estimate is very rough, since it does not take into account the growth rate of microorganisms in the biofilm (and all parameters affecting it), hydrodynamic conditions of operation, colonized material, etc., nevertheless, it assumes a possible additional biological system for unloading water.

As a result of the vital activity and the withering away of microorganisms, the quality of drinking water decreases: turbidity and color increase, and organoleptic indicators deteriorate.

The presence of sulfate reducers in the system causes the appearance of a hydrogen sulfide odor, and when interacting with iron leads to the formation of iron sulfide, which has a black color.

The presence of odors in the water is also associated with the development of actinomycetes in biofilms.

Many types of bacteria are active corrosive agents. The most important are the groups of bacteria involved in the transformation of iron and sulfur.

The role of microorganisms in corrosion processes is reduced to accelerating the depolarization of the cathode by enzymatic transfer of electrons, the release of corrosive metabolic products, and the formation of differential aeration vapor. Depending on the conditions, the mechanism of microbiological corrosion can be explained by one of the listed processes or their combination [12].

Iron bacteria of the genera *Gallionella*, *Crenothrix*, *Leptothrix* are the active participants in the corrosion of iron in the aquatic environment. Microbial aerobic corrosion of water pipes is associated with their activity. Settling in pipes, bacteria form mucous accumulations on their walls, possessing high mechanical strength and therefore not being washed away by the current of water. The strength of these formations is due to the fibrous structure of the iron bacteria shells.

Corrosion starts with the formation of yellow or dark brown deposits or cavernous deposits on the pipe inner surface, consisting of ferric hydroxide. Caverns are formed, as a rule, on irregularities. The pipe sections under the caverns are isolated from water and the access of oxygen to them is difficult. And on the contrary, the areas washed by water are aerated well. Thus, the development of iron bacteria leads to the formation of zones with a different degree of aeration on the pipe surface. The occurrence of a corrosive current is caused by the formation of differential aeration pairs with different values of the electrode potentials, which are established in areas covered with caverns and free from them. The areas under caverns function as anodes, and at well-aerated areas with a higher potential, a cathode depolarization reaction occurs [13].

3 Conclusion

The studies on biofouling presented in the article have shown an undeniable effect on the destruction of the headwall structures' material, the ambient temperature. It was proved that polyethylene is the most affordable in terms of cost characteristics, and the chemical composition of water supplied to AI plays an important role, since it includes pollution of organic and inorganic origin, that is why it is necessary to pre-prepare (purify) the water.

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