motes forming and further rising of solid phase. As a result, the coarsely dispersed deposit of poorly soluble salts is extracted on the surface of polymer fibers, and ions concentration in the solution, passed through the sorbent, decreases. Due to this fact the hydrophobic fibrous polymeric materials may be used for water and drains purification from metal ions. They are cheap, available, and capable of regeneration and may be easily utilized.

REFERENCES

1. Pat. 2117719 RF. ICI D01D 5/08, D04H 3/16. The way of obtaining fibrous material from thermoplasts and installation for its realization / V.V. Bordunov, G.G. Volokitin. Reported 1996; Received 26.06.97, Bull. № 23. 1998.
2. Sirotkina E.E., Novoselova L.Yu. Materials for sorption water purification from oil and petroleum products // Himiya v Interesah Ustoichivogo Rasvitiya. – 2005. – V. 13. – № 3. – P. 359–377.
3. Arefieva R.A., Bordunov V.V., Bordunov V.G., Sobolev I.A. Polymeric fibrous sorbents for sewage water purification // Kachestvo – Strategiya XXI Veka: Mater. of the V International Theoretical and Practical Conference. – Tomsk, 2000. – P. 91–96.
4. Bordunov V.V., Bordunov S.V., Sobolev I.A. Perspective material for petroleum products gathering from water surface // Kachestvo – Strategiya XXI Veka: Mater. of the VI International Theoretical and Practical Conference. – Tomsk, 2001. – P. 73–74.
5. Arefieva R.A, Bordunov V.V., Bordunov S.V., Pilipenko V.G., Sobolev I.A. Application of fibrous polymeric materials for drinking water supply // Kachestvo – Strategiya XXI Veka: Mater. of the VI International Theoretical and Practical Conference. – Tomsk, 2001. – P. 62–64.
6. Petrova E.V., Otmahov V.I., Gapeev V.A., Volokitin G.G., Otmahova Z.I. The research of sorption property of fibrous sorbent obtained from polypropylene wastes for its using in water purification // Analitika i Kontrol. – 2004. – V. 8. – № 2. – P. 112–117.
7. Bulatov M.I., Kalinkin I.P. The practical book of photometric method of analysis. – Leningrad: Himiya, 1986. – 432 p.

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TECHNOLOGICAL AND HYGIENE-SANITARY ASPECTS OF USING BIOLOGICALLY PURE PROCESS WASTE WATER IN THE SYSTEMS OF TECHNICAL WATER SUPPLY

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According to sanitary-toxicological factors biologically purified waste water of chemical enterprise are referred to low-toxic substances, are not allergens, do not posses irritant action on mucous tunics and skin and are suitable for recycling water system makeup. Crucial factors of reusing these waters are their corrosive activity, susceptibility to mineral salt accumulation and bioaccretion.

The systems of industrial water supply and water draining of industrial enterprises influence negatively both directly and indirectly the environment. It concerns both water diversion capacity from natural water sources and their contamination with sewage water. Therefore, such systems should operate according to the requirements of environmental control [1]. Measures in environmental control, water resources conservation [2] and environmental safety support should be provided. Industrial water supply should stipulate maximal rotation of process sewage water for water losses compensation [3]. Biologically purified sewage water (BPSW) is one of the sources of water compensation in the systems of industrial water supply at chemical and by-product coke enterprises [4, 5]. The possibility of BPSW using is based on the conformity principle of used water quality to the conditions of its further application. This principle demands the choice of industrial water supply system, where BPSW will be used, and the range of factors both of technological and hygiene and sanitary character should be taken into account.

Service water systems may be direct-flow and reverse according to the mode of water use. The direct-flow systems propose single water use with further purification of contaminated sewage water before its discharge into municipal sewage or surface reservoirs. Such technology of using water, quite often high-quality drinking one, is not only wasteful, but also potentially harmful for the most part of population. The direct-flow water use for industrial water supply is permitted only at justification of unreasonableness of reverse water supply systems or impossibility of their creation.

The reverse systems are divided into local, centralized and mixed. At local systems water is used after reduction (regeneration) in one or several technological processes. At centralized water supply water passes the purification in a single flow and returns to the production after being used for different purposes. At mixed water supply water of one reverse system is used in another one (water of cooling system is used in technological one; water of technological system is used in transporting one etc.).

There are technological, transporting and cooling service water systems according to the character of water use in the technological processes. At technological system operation, and in some cases at transporting system operation, reverse water is contaminated with specific industrial product. Process water, contaminated with chemical compounds, may be harmful for a person and environment at its disposal to the surface reservoirs (in the form of concentrated bleed water) and its further use.

As a rule, water circulating in cooling systems is not contaminated with technological products but it is heated and cooled many times, aerated and partially evaporated [6]. Reverse water, heated in heat-exchange apparatus, is cooled in tower-coolers, water reservoir-coolers, spray ponds or other devices and it is fed again to the cycle by circulating pumps. In the process of circulation the increase of water mineralization and corrosion activity, concentration of chemical contamination and growth of microbiological pollution occurs. In this connection, the part of circulating water is removed from the system and exchanged for makeup water. Cooling systems of industrial enterprises are the largest consumers of makeup water for which biologically purified sewage water may be used.

Table 1. *Makeup water characteristic of the modeling WRC at feeding with biologically purified water of different degree of evaporation*

Name of indices	Notation	Value	
		Makeup water	BPSW
pH	–	8,02	8,16
Alkalinity	mg-equ/l	2,07	7,65
Ca^{2+}	mg-equ/l	1,98	1,54
Mg^{2+}	mg-equ/l	0,62	0,50
Hardness	mg-equ/l	2,57	2,01
Chlorides	mg/l	12,36	136,73
Sulfates	mg/l	17,44	1200
NH_4^+	mg/l	0,45	13,00
Nitrates	mg/l	11,6	708,3
COD	mgO_2/l	18,9	115,0
Salt content	mg/l	180	4000

BPSW application for feeding water supply reverse systems demands the evaluation of a number of processing and hygienic factors. The processing factors are BPSW influence on reverse water corrosive activity; its tendency to hardness salts deposition and biofouling on the surfaces of heat-exchanging and processing equipment. The hygienic factors are stipulated by BPSW pollution. The basis at their estimation is an absolute protection for health of workers and population [7], subjected to direct or indirect influence of BPSW. Besides, harmlessness of chemical composition and favorable organoleptic properties of water for a person should be secured. Compositions of makeup water of water rotation cycle (WRC) and BPSW of the chemical enterprise are presented in Table 1. It follows from these data that the values of the number of BPSW indices (concentration of chlorides, sulfates, nitrates, ammonia nitrogen, COD and salt content) exceed considerably the values of the same indices in makeup water.

The exclusively complex composition of process sewage water, chemical substances transformation as a result of their biological purification do not allow determining theoretically in full the tight coupling between BPSW and the degree of its technological usefulness for reverse systems feeding and man safety. Therefore, the development of guidelines for BPSW use for WRC feeding may be carried out only experimentally. The solution of the given problem should be carried out on the basis of integrated study of BPSW use conditions, methods of polishing and decontaminating, physicochemical, organoleptic and epidemiological parameters, as well as the probable risk level for a man's health, connected with BPSW use in service water systems.

Processing factors, connected with biologically purified sewage water use for feeding waster rotation cycles

It is seen from the characteristic of biologically purified water, presented in Table 1 that it has high salt content and contains a bulk of chlorides, sulfates that may result in intensive corrosion. The presence of biogenic elements, suspensions, presented generally by activated sludge, in water may cause fouling at biologically purified water use in the reverse water supply.

Therefore, the estimation of possibility of biologically purified water use in the reverse water supply includes the study of water corrosion activity, ability to deposition of salts in the conditions of repeated heating and cooling, tendency to form fouling.

Corrosive activity of BPSW was studied in the conditions of its use as the makeup water of WRC. The investigations were carried out at the laboratory setup, modeling WRC. The installation diagram is presented in Fig. 1.

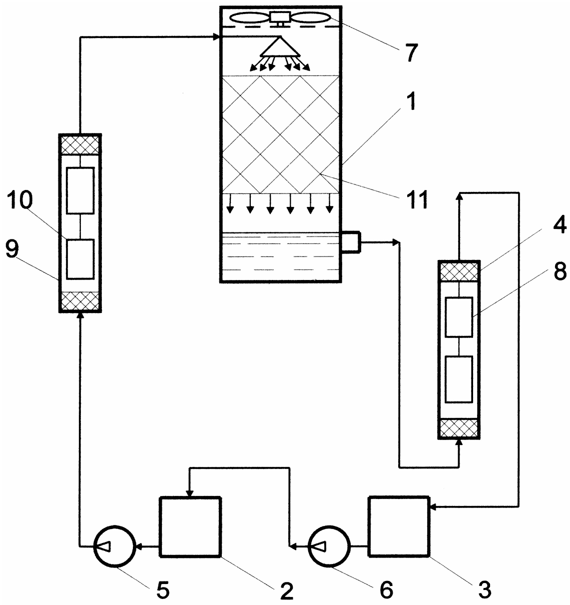

Fig. 1. *The diagram of the laboratory setup, modeling the system of the reverse water supply: 1) the tower-cooler; 2) the capacity with a heater (thermostat); 3) the capacity of chilled water; 4, 9) the glass tube for check samples set up; 5, 6) the pump; 7) the fan; 8, 10) the check samples for research the rate of corrosion, depositions of salts and fouling; 11) the head of Rashing ring*

In the carried out experiments the water under study had been heated to the preset temperature (35...40 °C) in the thermostat – 2 and was given to the top of the tower-cooler – 1, made of organic glass (the diameter of the column was 0,2 m, the height was 0,64 m) by the pump – 5. In the tower-cooler the water was given to the irrigation of the head – 11 of the Rashing rings by means of an atomizer. Draining down the head, the water contacted with air stream, which was produced by the fan – 7. As a result, the water was chilled and entered by gravity to the capacity – 3. The chilled water was given to the thermostat – 2, from the capacity – 3 by the pump – 6, where it was heated again and given to the tower-cooler for cooling.

The corrosion rates of carbon steel in the chilled and heated water, rates of deposition of mineral salts and fouling, species composition of fouling were determined in the carried out experiments. The corrosion rate was determined periodically by the diminution of carbon steel samples weight (St. 3) from the moment of their contact with water. The rate of the deposition of mineral salts and fouling was determined by the increase of stainless steel samples weigh. Species composition of fouling was determined by microexamination of the glass samples.

Influence of biologically purified water on the corrosion activity of the circulating water of the modeling water rotation cycle

Firstly, the experiments were carried out at the modeling setup of WRC. Water from service water supply of a chemical enterprise (clarified river water) with salt content of 180 mg/l and BPSW with the content of 4085 mg/l was used as the water under investigation.

It follows from the data of Table 2 that substitution of makeup water with the river one for biologically purified water results in increasing the corrosion rate of carbon steel in the circulating water of WRC. This phenomenon is quite undesirable as it is connected with the increased corrosion of heat-exchange and processing equipment.

The possibility of BPSW using as an addition to the makeup river water was studied at the next stage. The series of the experiments, where the mixture of river water and BPSW with different salt content was used as the researched water, was carried out for this purpose. The obtained data are presented in Table 2. It is seen from this figure that the dependences of corrosion rates on salt content of river water and BPSW mixture have rather complex structure and characterized by maximums and minimums.

Table 2. *Corrosion rate of carbon steel (St 3) in circulating water of modeling WRC*

Water	Samples contact time of with circulating water, h	Corrosion rate, $g/(m^2 \cdot h)$	
		In heated water	In chilled water
River	120	0,43	0,37
Biologically purified	120	0,65	0,43

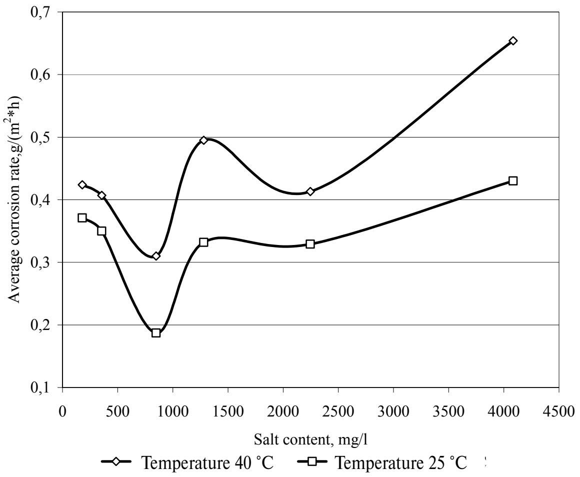

Fig. 2. *Dependence of corrosion rate of carbon steel (St. 3) in circulating water of modeling WRC on salt content of makeup water*

The first minimum of values of corrosion rate corresponds to salt content of circulating water of 750...850 mg/l. And the value of corrosion rate, corresponding to this salt content, is lower than the value of corrosion rate for river water. The second minimum corresponds to salt content of circulating water of 2200...2300 mg/l. The value of corrosion rate, corresponding to this salt content, is at the level of corrosion rate for river water. The most probable reason of this phenomenon may be the following one. Two processes -deposition of salts and corrosion – compete with each other in aqueous medium at the carbon steel samples (St. 3). As the experiments were carried out at the same conditions (hydrodynamic and temperature regime), the decrease of corrosion at water mineralization of 750...850 mg/l was connected with partial shielding of sample surface owing to film formation from deposits of mineral salts and biomaterials. The existence of such film results in diffusion problems at water contact with sample surface and, as a result, in the decrease of corrosion rate.

Influence of biologically purified water on depositions of mineral salts and suspensions in circulating water of the modeling water rotation cycle

The rate of deposition of mineral salts and suspensions was determined on the samples of stainless steel simultaneously with determination of corrosion rate of carbon steel in the experiments. The obtained data are presented in Fig. 3, the data of which also show the complex structure of deposition rate dependence on salt content of circulating water. First of all, it follows from Fig.3 that the rate of mineral depositions and suspensions for river water is 0,013 $g/(m^2 \cdot h)$, and for BPSW it is considerably higher – 0,03 $g/(m^2 \cdot h)$, i. e. it growths at BPSW content increasing in used water. However, the curve in Fig. 3 has the minimum, corresponding to salt content of 1200...1300 mg/l, at which the deposition rate conforms to river water.

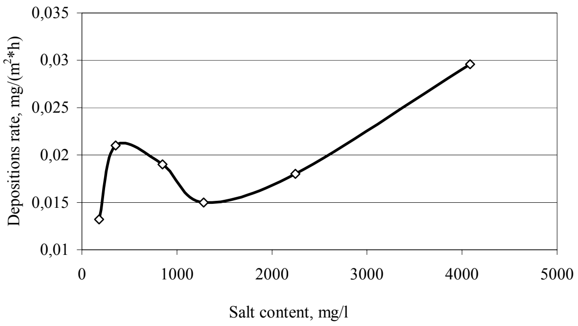

Fig. 3. *Dependence of depositions rate in circulating water of modeling WRC on salt content of makeup water*

There are no worms in river water; in the mixture of river and biologically purified water with salt content of 1200...1300 mg/l there are worms in small quantity. In biologically purified water with salt content to 4000 mg/l there are «very many» worms. River water, the mixture of biologically purified with river water, biologically purified water, having salt content to 4000 mg/l promote the intensive evolution of green bacteria. Therefore, the germicidal treatment of circulating water is necessary at using BPSW for WRC feeding.

Sanitary-toxicological characteristic of biologically purified sewage water of a chemical enterprise

The requirements of sanitary-toxicological and epidemiological safety of BPSW are the most important criteria at developing guidelines for BPSW use in open service water systems and first of all for WRC feeding [7]. At the same time, water should have favorable organoleptic properties and safe chemical composition. High quality of BPSW by organoleptic indices is important not only as indirect evidence of its safety, but from the point of view of psychological barrier overcoming, occurring automatically in the process of such water use in the technologies with open water surface.

Determination of sanitary-toxicological parameters of BPSW of a chemical enterprise was carried out by the specialists of Kemerovo State Medical Institute according to «Methodical aids on scientific justification of harmful substances maximum concentrations in basin water» № 1296-75, 15.04.75, Moscow, 1976. The investigations of determining average-lethal doses (LD_{50}), BPSW irritant action on mucous tunics, skin-irritant and sensitizing BPSW action were performed. The experiments were carried out at nonlinear rats and mice as well as at cavies. The obtained results allowed for a conclusion that BPSW is a low toxic substance, possessing no irritant action on mucous tunics, cutaneous covering and without allergic effect.

Conclusion

Biologically purified sewage water of the chemical enterprise (Kemerovo «Azot» corporation) relates to low toxic substances, is not an allergen, does not possess irritant action on mucous tunics and skin and it is useful by sanitary-toxicological indices for feeding the reverse water supply systems. By the engineering indices (corrosion activity, tendency to mineral salts deposition and fouling) this water is recommended to be used in the mixture of makeup river water. Using biologically purified sewage water for feeding water rotation cycle the treatment of circulating water with germicides is necessary for suppressing fouling.

REFERENCES

1. Federal Law «Environment Protection» № 7-F3 of 10.01.2002.
2. Water Code of Russian Federation № 167-F3 of 16.11.1995.
3. Water resources conservation / Yakovlov S.V., Prosorov N.V., Ivanov E.N., Gubiy I.G. – Moscow: Vysshaya skola, 1991. – 400 p.
4. Koganovskiy A.M., Semenyuk V.D. Reverse water supply of chemical enterprises. – Kiev: Budivelnik, 1975. – 231 p.
5. Grigoruk N.O., Puckerev G.P. Water supply, sewage system and sewage purification of chemical-recovery enterprises. – Moscow: Metallurgya, 1987. – 119 p.
6. Kucherenko D.I., Gladkov V.A. Reverse water supply. – Moscow: Stroyizdat, 1980. – 169 p.
7. Federal Law «About Sanitary-Epidemiological Welfare of Population» № 52-F3 of 30.03.1999.

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