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ONE-SLUDGE DENITRI-NITRIFICATION SYSTEM APPLICATION IN RECONSTRUCTION OF BIOLOGICAL TREATMENT PLANTS IN RUSSIAN FEDERATION

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Abstract: The paper presents the main problems and their solutions in the reconstruction of treatment facilities in the Russian Federation. The results of research aimed the use of the stable system, which is based on nitrification activated sludge appliance, when the sludge contains bacteria-heterotrophic-nitrificators, are shown. The working process after the reconstruction was high effective (about 98% organic compounds removing, and about 99% ammonium nitrogen removing). Analysis of the treatment facilities after reconstruction proves theoretical assumptions about the system. These data confirm the stability of the developed technological schemes and give reasons to recommend it for further implementation of the reconstruction of treatment facilities.

Keywords: wastewater, facilities, reconstruction, biological treatment, nitrogen, biogenic elements.

1. Introduction

Problems of removing biogenic compounds from wastewater are of great concern among scientists from all over the world. In our country commonly used to divide nitrogen compounds norms into three groups: ammonium, nitrites and nitrates. Boundary values for phosphorous content also create a special difficulty in wastewater treatment and discharging into the receiver (Gogina et al., 2014; Salomeyev et al., 2010; Wang and Shammas, 2009). One of the ways to solve the problem is the modernization of WWTPs. Modernization serves to restore or to increase the effective work of WWTPs without involving great investments. About 3 mln m^3/d of sewage are run off from Moscow region to wastewater treatment plants. The majority (2.4 mln m^3/d) are treated amongst 880 WWTPs in the surrounding Moscow region while only 0.6 mln m^3/d are treated in WWTPs situated in Moscow. Moreover, biological technologies being used in waste water treatment facilities in Russian Federation do not meet the effective nitrogen and phosphorous compound's removal standard parameters for sewage discharged to the receivers. In particular, ammonium nitrogen removing accounts for 20-40%, while scientists have proved effectiveness not less than for 80-90%. There are similar solutions for phosphorous concentration decreasing in wastewater as well. With the use of modern technologies, the existed facilities may take part in sewage treatment intensification process. For more than 10 years scientists from Water Disposal Department of Moscow State Construction University have been making experiments on developing and practices different technologies in modernization of WWTPs. Experiments with high efficiency removal of nitrogen and phosphorus were carried out in the science laboratory called "Water disposal systems – reconstruction and renovation". An example of Kolomna WWTP (Moscow region) modernization is presented in this paper.

2. Methods and description of research object

Active use of bacteria-heterotrophic-nitrificators began at the end of the last century (Hao et al., 1996; Hu et al., 2002; Krishna et al., 1999; Spanjers and Vanrolleghem, 1995; Surmacz-Górska et al, 1996). In a basic technological scheme of Kolomna WWTP the special biological process was applied for modernization. For this purpose, the existing traditional aeration chamber was divided into four zones (anoxic and aerobic) to obtain high efficiency of nitrogen removal. After biological treatment secondary sedimentation tank was applied to achieve recirculation of return sludge and discharge sewage after biological treatment (Salomeyev et al., 2010). Parameters of activated sludge treatment may be changed due to requirements. It's possible to change the amount of zones (aerobic and anaerobic) and treatment time in each zone. Such a scheme was applied in Kolomna

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WWTP.

The sewage flow to biological treatment was in average 60000 m^3/d. The quality of sewage to be treated in aeration tank is mostly homogeneous. Due to own research basic parameters were: BOD – 72 mg O_2/dm^3, ammonia nitrogen 18 mg $N\text{-}NH_4/dm^3$ and phosphorous – 2.7 mg P/dm^3. Average value of BOD was low and ammonium nitrogen concentration was high. The modernization was based on one-sludge system with denitri-nitrification in one chamber. An existing aeration tank was divided into aerobic and anoxic zones. The first zone contains dissolved and chemical bounded oxygen, and the second one contains only chemical bounded oxygen. Basic parameters (parameters after biological treatment and limits) are presented in Table 1.

3. Results and discussion

It is not correct to estimate nitrogen compounds removal without taking into account two inorganic nitrogen contaminants: nitrites and nitrates. In the regard system the concentration of nitrites nitrogen was close to zero while concentration of nitrates was high. This fact stamps that two stages of nitrification processes in the aeration tank are flowing correctly when denitrification is not carried out fully. It also happens for the second nitrification stage to flow back. This means that secondary nitrite formation may happen because of the high concentration of nitrates nitrogen and low denitrification process. In regard with the data obtained during research it became possible to make calculations and conclusions about the biochemical system.

According to the calculations the treatment period for sewage in aeration tank was about 8 hours. The sludge concentration in aeration tank was about 3.5 g/l in average, ash content was about 0.3. The oxidation velocity was calculated as for heterotrophic one-sludge system. According to the data obtained an average oxidation velocity for the particular treatment period was 6.9 mg BOD/gh. The activated sludge load for the regarded system amounted to 167 mg BOD/gd. These parameters' values obtained due to calculations were too small for biological treatment process to be carried out.

According to the literally data and a great experience in working with the biological systems for wastewater treatment it is known that for the effective working of the biological system and for the activated sludge to be maintained in a working condition those two parameters should reach: the oxidation velocity more than 10 mg BOD/gh, and the activated sludge load about 300 mg BOD/gd. According to the actual standards (building standards and limits) for the aeration tank with long aeration the oxidation velocity amounted 6 mg/gh (while the sludge concentration was 3 g/l and ash content was 0.35). A comparison of the parameters of the regard system to these data reveals that the oxidation velocity, which is the basic factor to show the sludge working, is extremely low. The data obtained reveals the fact that activated sludge in this system has a load-illness (it is so called "hungry" sludge). Such conditions may result in activated sludge flocs destruction, activated sludge bacteria colonies destruction, which leads to microorganism's dysfunction in biological treatment process. Also systems are characterized by normal wastewater efficiency (BOD) due to heterotrophic bacteria and by ammonium nitrogen treatment due to bacteria-autotrophy-nitrificators. This system operating in the regard WWTP works stable only with parameters to be constant: hydraulic load, inclusions quality, sludge concentration, and others. Therefore, with the use of all basic aeration tank parameters, it becomes possible to determine nitrification and denitrification velocity. For this purpose a calculation method recommended by the reference book to the actual Building Norms and Standards for the systems with nitrification heterotrophic-bacteria was used.

The results obtained revealed the fact that nitrification and denitrification velocities were very small – 3.8 and 3.5 mg/gh, consequently. This fact speaks about nitrification process coming through not deep enough, in spite of the high sludge age in the system. This may be caused by lack of carbon feeding, which is very important for nitrification-autotrophy bacteria taking part in nitrification process. Low nitrification velocity may also cause the reverse process, which was partly confirmed by sanitary and chemical analyses. Backward nitrification makes denitrification reaction low down,

Tab. 1. Basic parameters of research installation- Kolomna WWTP.

Parameters	Parameters of treated sewage with a new technology (mg/dm^3)	Limits for sewage discharged to fishery water (mg/dm^3)
Ammonium nitrogen	0.06-0.2	0.39
Nitrates nitrogen	0,0	0.01
Nitrites nitrogen	7.5-9.1	9.1
Total phosphorous	1.0-1.3	0.2
BOD_5	1.5 to 3.0	3.0
COD	20-65	No limits

Own research

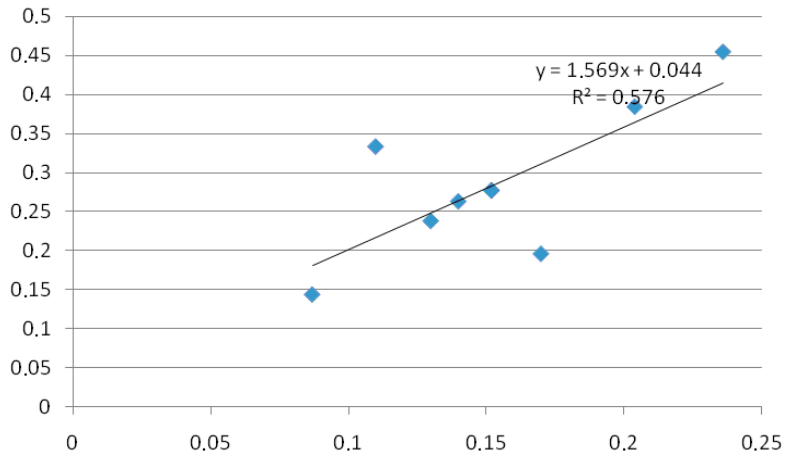

Fig. 1. Double opposite magnitudes relation $1/\rho = f(1/Lex)$; (ρ – specific oxidation velocity, mg/h, *Lex* – BOD of purified waste water, mg/l).

which was also confirmed by obtained data. Moreover, the effective denitrification coming over also requires carbon feeding for heterotrophic bacteria. Lack of carbon feeding occurs even at the stage of denitrification process in spite of the wastewater addition into three corridor of the aeration tank. This fact was also caused by a lack of BOD load and a large sludge concentration. In order to confirm the calculation results graphic relations were performed, for characterizing the biological treatment process with nitrification and denitrification carrying out. Recently this and other similar methods have been observed by other authors (Daigger et al., 2014; Fernandez-Fontaina et al., 2014, Harun et al., 2014; Ikumi et al., 2014; Janeczko et al., 2014; Su et al., 2014; Jemaat et al., 2014; Jenni et al., 2014; Ofiţeru et al., 2014). Figure 1 presents points field for double opposite magnitudes relation design: $1/\rho = f(1/Lex)$; (ρ – specific oxidation velocity, mg/h, *Lex* – BOD of purified waste water, mg/l). Evidently, the point's field looks rather organized and may be subjected to a mathematical description. This fact proves this biological systems stability, which has prevalence in regard to biological foaling oxidation.

4. Conclusions

Relying on the analyses carried out for the biological system working in the Kolomna WWTP we can make a conclusion about the successful experiment carried out with the use of the stable system, which is based on nitrification activated sludge appliance, when the sludge contains bacteria-heterotrophic-nitrificators. Therefore, treatment stations reconstruction and new methods of deep wastewater treatment methods may solve the problem of waste water discharged into the receivers of Russian Federation without treatment. WWTP reconstruction must be based on the state-of-the-art science achievements with the use of hi-tech solutions, building materials, reagents in condition of using the existing volume of a treatment plant with minimum investments in new construction and with reaching the maximum treatment effect. This way we can decrease pollutants load discharged to the environment.

References

Daigger G.T., Littleton H.X. (2014). Simultaneous biological nutrient removal: A state-of-the-art review. *Water Environment Research*, Vol. 86, No. 3, 245-257.

Fernandez-Fontaina E., Carballa M., Omil F., Lema J.M. (2014). Modelling cometabolic biotransformation of organic micropollutants in nitrifying reactors. *Water Research*, Vol. 65, 371-383.

Gogina E.S., Ruzhitskaya O.A., Yantsen O.V. (2014). Investigation of the processes of nitrification and denitrification in wastewater treatment. *Advanced Materials Research*, Vol. 919-921, 2145-2148.

Hao O.J., Huang J. (1996). Alternating aerobic-anoxic process for nitrogen removal: process evaluation. *Water Environment Research*, Vol. 68, No. 1, 83-93.

Harun H., Anuar A.N., Ujang Z., Rosman N.H., Othman I. (2014). Performance of aerobic granular sludge at variable circulation rate in anaerobic-aerobic conditions. *Water Science and Technology*, Vol. 69, No. 11, 2252-2257.

Hu Z.-R., Wentzel M.C., Ekama G.A. (2002). Anoxic growth of phosphate-accumulating organisms (PAOs) in biological nutrient removal activated sludge systems. *Water Research*, Vol. 36, No. 19, 4927-4937.

Ikumi D.S., Harding T.H., Ekama G.A. (2014). Biodegradability of wastewater and activated sludge organics in anaerobic digestion. *Water Research*, Vol. 56, 267-279.

Janeczko A.K., Walters E.B., Schuldt S.J., Magnuson M.L., Willison S.A., Brown L.M., Ruiz O.N., Felker D.L., Racz L. (2014). Fate of malathion and a phosphoric acid in activated sludge with varying solids retention times. *Water Research*, Vol. 57, 127-139.

Jemaat Z., Suárez-Ojeda M.E., Pérez J., Carrera J. (2014). Partial nitritation and *o*-cresol removal with aerobic granular biomass in a continuous airlift reactor. *Water Research*, Vol. 48, 354-362.

Jenni S., Vlaeminck S.E., Morgenroth E., Udert K.M. (2014). Successful application of nitritation/anammox to wastewater with elevated organic carbon to ammonia ratios. *Water Research*, Vol. 49, 316-326.

Krishna Ch., Van Loosdrecht M.C.M. (1999). Substrate flux into storage and growth in relation to activated sludge modeling. *Water Research*, Vol. 33, No. 14, 3149-3161.

Ofiţeru I.D., Bellucci M., Picioreanu C., Lavric V., Curtis T.P. (2014). Multi-scale modelling of bioreactor-separator system for wastewater treatment with two-dimensional activated sludge floc dynamics. *Water Research*, Vol. 50, 382-395.

Salomeyev V.P., Pobegaylo Yu.P., Gogina E.S., Ruzhitskaya O.A., Ryzhkov A.D., Shipitsin M.N. (2010). Patent napoleznuyu model: "Ustanovka dlya biologicheskoy ochistki stochnykh vod ot organicheskikh zagryazneniy i ammoniynogo azota", Nomer patenta: 91715, Strana: Rossiya; Data registratsii: 03.03.2009, Nomer zayavki: 2009107450/22.

Spanjers H., Vanrolleghem P. (1995). Respirometry as a tool for rapid characterization of wastewater and activated sludge. *Water Science and Technology*, Vol. 31, No. 2, 105-114.

Su J.-J., Chang Y.-Ch., Huang S.-M. (2014). Ammonium reduction from piggery wastewater using immobilized ammonium-reducing bacteria with a full-scale sequencing batch reactor on farm. *Water Science and Technology*, Vol. 69, No. 4, 840-846.

Surmacz-Gorska J., Gernaey K., Demuynck C., Vanrolleghem P., Verstraete W. (1996). Nitrification monitoring in activated sludge by oxygen uptake rate (OUR) measurements. *Water Research*, Vol. 30, No. 5, 1228-1236.

Wang L.K., Shammas N.K. (2009). Single-Sludge Biological Systems for Nutrients Removal. W: *Advanced Biological Treatment Processes, Series: Handbook of Environmental Engineering, L.K. Wang, N.K. Shammas, Y-T Hung (eds.)*, Vol. 9, 209-270.