Efficient phosphate removal by biological corrosion method

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Abstract. Water quality deterioration in water bodies is directly related to the development of anthropogenic eutrophication processes. To resolve this complex issue, one needs to minimize biogenic discharge of nitrogen and phosphorus compounds into the water bodies. The article presents relevant information in the field of phosphate-removing wastewater treatment, describes the most effective biological and biological-chemical methods of phosphate-removing wastewater treatment. The article presents the results of research on phosphate-removing wastewater treatment methods using iron-bearing reinforced feed material (biological corrosion method, biogalvanic method). The placement of reinforced feed material in a standard air tank allowed to significantly increase the efficiency of organic contamination-removing biological wastewater treatment. The biological process activation ratio due to the use of reinforced feed material amounted to 1.78. The placement of reinforced feed material in the bioreactor, which operates without activated sludge return, allowed to achieve complete phosphate removal from the waste water. The maximum effect of phosphate removal (99 %) with the concentration of phosphate in treated water below the detection limit was achieved after 4 to 6 hours of wastewater treatment in the bioreactor, with the concentration of organic contamination in the incoming wastewater from 150 to 300 mgBOD/L and the concentration of phosphate upstream of the bioreactor from 4 to 6 mg PO4/L. Based on the research carried out, it was concluded that the use of biological corrosion method allows to achieve high efficiency of phosphate removal, as well as to intensify the biological process of organic contamination removal from waste water.

1 Foreword

In order to solve the issue of deterioration of the water quality of water bodies, it is necessary to minimize the discharge of nutrients (nitrogen and phosphorus compounds).

Today, many methods are used to remove nutrients, including phosphates. Which are removed by chemical, physico-chemical, biological, biological and chemical methods.

Of greatest interest are biological methods, since its use uses the biological potential of activated sludge to the maximum extent possible, but the use of the standard method of

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biological treatment achieves the removal of phosphates by only 20 - 40%, which is not enough to ensure the required cleaning effect (at least 95%).

The methods Phostrip, A / O (Anaerobic – Oxic), EASC (Extended Anaerobic Sludge Contact process) and others have been developed and are successfully used to remove phosphates.

Compounds of phosphorus and nitrogen are simultaneously removed using the methods of UCT, Bardenpho, Phoredox, etc.

The UCT method is most effective in removing nitrogen and phosphorus at the same time.

To reduce the effect of nitrates formed in the aerobic process, various modifications of the above methods are used [1].

Bardenpho is a stepwise biological treatment method with alternating aerobic and anoxic zones [2].

The organization of recirculating flows is a feature of all the schemes under consideration.

Japanese and Chinese scientists have investigated the process of intensification of nitrogen and phosphate removal using thermophilic fermentation suspension from food waste (fsfw) as an external carbon source. The efficiency of this technology in phosphorus-removing wastewater treatment exceeded 98 % [3].

Efficient phosphate removal (92.8 ±6.7) was achieved in the sequencing batch reactor (SBR) – the ASSR system [4, 5].

Stable operation and high efficiency of phosphate-removing wastewater treatment (99.1 %) was achieved by applying the biological process AAO-SBSPR [6].

Russian scientists, in their works, have carried out the estimation of potential efficiency of phosphorus compounds removal from waste water by biological method. Scientists have come to the conclusion about the possibility of phosphate removal and that certain technological parameters of biological treatment allows to meet strict requirements for phosphate removal [7].

The simultaneous removal of nitrogen (98.7 %) and phosphorus (83 %) was achieved in a study of the effectiveness of a new two-stage aerobic anoxic continuous action reactor (CFBCR) [8].

Scientists in the USA conducted the study of the reactor series (SBR) for the simultaneous removal of nitrogen and phosphorus. The reactor operating conditions for achieving high phosphate removal rate (> 99 %) were determined [9].

Modern research is aimed not only at improving recirculation processes and flows, but also at genetic modification of activated sludge bacterial composition to intensify biological phosphate removal [10, 11].

The combination of biological and chemical cleaning processes leads to the greatest cleaning effect of phosphate removal. These methods of biological and chemical cleaning differ in the place of introduction of the reagent and the composition of the reagent used.

2 Study of biological corrosion method for deep phosphate removal

We conducted research on the use of the biological corrosion method (biogalvanic method) to remove phosphorus compounds and intensify biological wastewater treatment.

2.1 Air tank – precipitation tank diagram

The placement of reinforced feed material in a standard air tank (the plant operation diagram is shown in Fig. 1) allowed to significantly increase the efficiency of organic contamination-removing biological wastewater treatment. The biological process activation ratio due to the use of reinforced feed material amounted to 1.78.

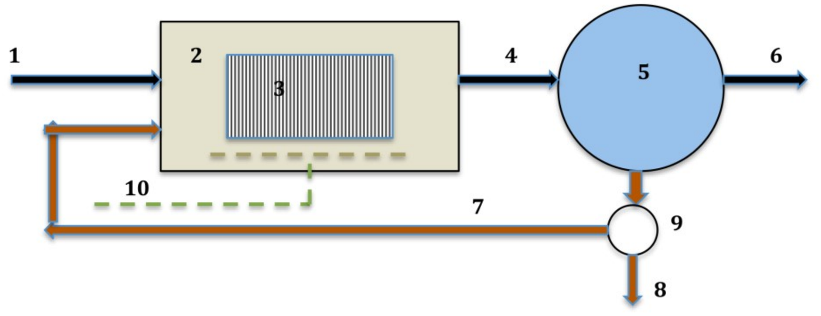

Fig. 1. Air tank with reinforced feed material operation diagram.

1 – incoming wastewater; 2 – air tank; 3 – reinforced feed material; 4 – sludge mix; 5 – secondary precipitation tank; 6 – treated wastewater; 7 – recirculated activated sludge; 8 – excess activated sludge; 9 – sludge chamber; 10 – air.

However, the main goal, which was deep phosphate removal, was not achieved, because after the reinforced feed material was placed in the air tank, the efficiency of phosphate removal rose to 99 %, but decreased to ≈ 60 % after 15 days. In the course of the experiment, the 30% decrease of the free-floating activated sludge amount resulted in 99% increase of phosphate removal. The "younger" the activated sludge, the more intensively it increases, the more phosphorus is consumed while removing it from the waste water. Since young, developing activated sludge stimulates effective phosphate removal, in order to achieve the most complete phosphate removal from the wastewater by means of reinforced feed material, it is necessary to maintain a low sludge age in the air tank by completely removing the returning activated sludge from the system maintaining sufficient amount of biomass attached to the reinforced feed material.

2.2 The bioreactor without activated sludge return diagram

On the basis of the conducted research, the diagram without activated sludge return was developed (the plant operation diagram is shown in Fig. 2).

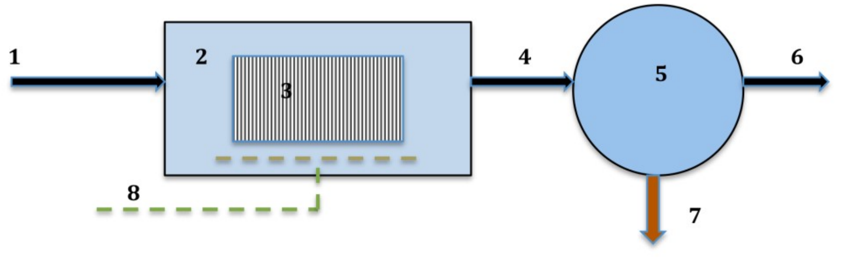

Fig. 2. Bioreactor with reinforced feed material operation diagram.

1 – incoming wastewater; 2 – bioreactor; 3 – reinforced feed material (in reference model – unreinforced); 4 – purified wastewater and biofilm mix; 5 – secondary precipitation tank; 6 – treated wastewater; 7 – excess activated sludge; 8 – air.

The maximum effect of phosphate removal (99 %) with the concentration of phosphate in treated water below the detection limit was achieved after 4 to 6 hours of wastewater treatment in the bioreactor, with the concentration of organic contamination in the incoming wastewater from 150 to 300 mgBOD/L and the concentration of phosphate upstream of the bioreactor from 4 to 6 mg PO4/L. The main data of the experiment (with aeration duration of 4–6 hours) are given in Table 1.

Table 1. Basic data from the experiment.

Parameters	Incoming drain liquids	Treated drain liquids	
		Studied	Reference
Phosphates, mg/L	4–12	BLD*–1	4–12
Iron, mg/L	BLD* – 0.3	BLD* – 0.1	-
BOD5, mg/L	100–250	3–10	10–30
Ammonium nitrogen, mg/L	15–25	8–12	15–25
Nitrites, mg/L	-	0.5–4	0.4–3
Nitrates, mg/L	-	3.5–15	BLD* – 4
Suspended substances, mg/l	60–150	BLD* – 20	15–30
Activated sludge characteristics			
Dose of biofilm attached, g/L	-	3–5	1.8–3.0
Dose of suspended sludge, g/L	-	0.1–1	0.2–0.5
Biofilm ash content	-	0.5–0.6	0.1–0.12
Sludge ash content	-	0.35	0.1

	Studied model	Reference model
Organic contamination specific oxidation rate, mgBOD/g·h	13.47–35.4	9.6–25.5
Load of organic contaminants on biomass, mgBOD/g·day	323.3–849.6	230.4–612
Phosphate specific oxidation rate, mgPO4/g·h	0.43–1.9	0–0.19
Load of phosphate on biomass, mgPO4/g·day	10.32–45.6	0–4.56

BLD* – below limit of detection

The use of the method of biological corrosion at the stage of domestic wastewater tertiary treatment showed positive results of deep phosphate removal. However, studies have shown that deep phosphate removal is mainly due to physicochemical processes of phosphate coagulation with ferrous ions, the source of which is the metal in the feed material, which is subjected to processes of electrochemical corrosion. When the biofilm loading becomes overgrown, the contact of the metal surface area with water decreases, and the purification effect decreases. After regeneration of the load, the efficiency of phosphate removal increased to its previous level.

3 Conclusions

Prospectivity of using biological and biological-chemical methods of phosphate removal from waste water has been proved. Studies have shown that the method of biological corrosion (biogalvanic method) significantly increases the efficiency of removal of phosphates and organic impurities contained in wastewater. This method can be used not only to intensify phosphate removal processes, but also for intensification of biological purification of organic contamination (BOD) in order to reduce the volume of air tanks or to intensify their operation without construction of additional sections, thus reducing the time of stay while maintaining the effect of BOD purification.

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