Giedrė VABOLIENĖ

RESEARCH AND EVALUATION OF THE BIOLOGICAL PHOSPHORUS AND NITROGEN REMOVAL FROM WASTEWATER

Summary of Doctoral Dissertation
Technological Sciences,
Environmental Engineering and Landscape Management (04T)

1471-M

Vilnius LEIDYKLA TECHNIKA **2008**

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Doctoral dissertation was prepared at Vilnius Gediminas Technical University in 2004–2008.

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The dissertation will be defended at the public meeting of the Council of Scientific Field of Environmental Engineering and Landscape Management in the Senate Hall of Vilnius Gediminas Technical University at 9 a. m. on 6 June 2008.

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VILNIAUS GEDIMINO TECHNIKOS UNIVERSITETAS

Giedrė VABOLIENĖ

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1. General characteristic of the dissertation

Topicality of the problem

The excess of nutrients at surface water body causes eutrofication, i.e. mass growth of phytoplankton and water plants. Due to this reason the quality of water is getting worse, some kinds of fish are disappearing and biological variety is decreasing. Eutrofication at water bodies can be prevented by removing nutrients from wastewater. In Lithuania in 2005 there were discharged 192.2 million m^3 of municipal and industrial wastewater into surface water bodies. There were discharged non-efficiently treaded up to permissible concentration according BOD_7, total nitrogen (TN) and total phosphorus (TP) 56.7 million m^3 of wastewater. In order to remove these nutrients from wastewater the technologies of activated sludge process are widely used all over the world. The special micro-organisms of activated sludge that are capable to accumulate and decompose the compounds of nitrogen and phosphorus are applied. However there is a range of changeable factors that affect biochemical processes and activity of micro-organisms. They are composition of wastewater, environmental and technological factors. Most factors have been widely investigated and changeable regularities determined. But nevertheless it is often meet with the non explanatory problem of the decreased efficiency of biological phosphorus removal (BPR).

In Lithuania during the last decade the municipal wastewater treatment plants were intensively reconstructed by introducing nitrogen and phosphorus removal. Not all technologies have been confirmed and have worked reliably after the reconstruction especially biological. As it is not possible to assure the required degree of BPR the chemical method is widely used, which increases the cost of wastewater treatment significantly. Meanwhile, in order to decrease the problem of eutrofication nitrogen and phosphorus removal are meeting stricter and stricter requirements. That's why it is necessary to investigate all the factors that disturb to remove nutrients from wastewater efficiently.

In Lithuania there hasn't been investigated what impact on BPR has temperature of wastewater up to now. The BPR is usually combined with nitrogen removal. The effect of the nitrogen removal has been investigated only from the aspect of nitrates.

Aim and tasks of the work

To determine and investigate factors those disturb to remove nitrogen and phosphorus from wastewater efficiently using biological method under the conditions of Lithuanian climate. To give proposals how to avoid or decrease the effect of these factors changing technological parameters.

Tasks of the work

1. To carry out the analysis of the operation of Lithuanian wastewater treatment plants by evaluating phosphorus removal from wastewater. To determine the regularities of fluctuation of temperature and phosphorus removal.
2. To perform the experimental investigations of the effect of nitrogen removal on the biological phosphorus removal during a warm and cold period of a year. To determine the optimum durations of aeration and reduced aeration for assurance of efficient nitrogen removal evaluating the nitrification and denitrification rates.
3. To investigate the periods when the efficiency of biological phosphorus removal decreases significantly. To determine the means for the restore of biological phosphorus removal efficiency carrying out full-scale experiments.
4. To perform statistical modelling in order to evaluate complexly the impact of factors such as ratio of BOD_7/TP in influent, temperature of influent, the sludge age, the pollution of wastewater according to BOD_7 and the acclimatization period of glycogen accumulating organisms (GAO) on the biological phosphorus removal.
5. To perform the microscopic analysis of the glycogen accumulating micro-organisms. To select the method for determination of glycogen that should be suitable for investigation of activated sludge. To determine the regularities of the fluctuation of concentration of glycogen at the activated sludge when the temperature of treated wastewater fluctuates.
6. Based on research results and their analysis, to give recommendations for assurance efficient phosphorus and nitrogen removal from wastewater.

Scientific novelty

There were determined the causes of the decrease of efficiency of the biological phosphorus removal during warm period of a year under conditions of Lithuanian climate. There have been determined means such as the change of sludge age and the BOD_7/TP ratio in influent for the restore of the biological phosphorus removal efficiency during a warm period of a year. The method of the determination of glycogen at activated sludge has been applied and introduced.

Methodology of research

The basic method of research is full-scale experiments. The analytical methods and the methods of mathematical statistical analysis have been used in the work. There have been applied a method of microscopy of activated sludge

and method of determination of glycogen at activated sludge. Using the method of multiple linear regression analysis there has been selected a model that complexly characterizes the impact of the factors on the BPR and there has been carried out a statistical modelling.

Practical value

There has been answered the question that arises at most Lithuanian wastewater treatment plants about the malfunction of the biological phosphorus removal during a warm period of a year. The recommendations for the assurance of the efficient biological phosphorus and nitrogen removal from wastewater have been presented according to the results of the full-scale investigations. The results of the work could be used for the design of new, reconstruction and especially for maintenance of existing facilities for biological phosphorus and nitrogen removal.

Defended propositions

1. The biological phosphorus removal can be disturbed by the activity of glycogen accumulating organisms during a warm period of a year in Lithuania.
2. The impact of nitrogen removal on the biological phosphorus removal clears up only during a warm period of a year due to the activity of glycogen accumulating organisms.
3. The highest efficiency of nitrogen removal when simultaneous nitrification denitrification technology is applied for nitrogen removal is reached under condition when the duration of aeration and reduced aeration are equal to 150 min. each.
4. The decrease of efficiency of the biological phosphorus removal due to the activity of glycogen accumulating organisms can be restore by reducing the sludge age up to 5 days.
5. When the glycogen accumulating organisms prevail in the system of activated sludge, the ratio of BOD_7/TP in influent should be not less than 35.
6. The application of method for determination of glycogen in activated sludge.

The scope of the scientific work

The scientific work consists of the general characteristic of the dissertation, 7 chapters, conclusions and recommendations, list of literature, list of author's publications. The total scope of the dissertation is 125 pages, 65 pictures, 33 tables.

2. Analysis of biological nutrients removal from wastewater

In the chapter there has been overviewed the importance of biological nutrients removal from wastewater, principles, technologies, biochemical and technological processes. The factors that have impact on biological phosphorus and nitrogen removal have been characterised.

The greatest attention has been devoted to the temperature impact on the biological phosphorus removal. The glycogen accumulating micro-organisms, that grow under mezophilic conditions (optimum temperature for their growth is 20–38 ºC) has been analysed. The GAO consumes the volatile fatty acids that could be consumed by the phosphate accumulating organisms (PAO) under anaerobic conditions. Contritely to the PAO, the GAO does not accumulate phosphate under the aerobic conditions and they use glycogen as a source of energy. Due to this reason the efficient of biological phosphorus removal from wastewater is not ensured any more.

The technologies applied in wastewater treatment plants of Lithuania have been analysed linking them with quality of effluent and clearing up the problems of biological nutrient removal from wastewater. According to these problems the tasks have been formulated.

3. Methodology of research

In this chapter the analytical methods have been described that were used for analysis of operation of facilities for biological nutrients removal. There are presented parameters that characterise operation of wastewater treatment plants, methodologies of calculation, microscopy of activated sludge and determination of glycogen concentration.

4. Research of influent temperature impact on biological phosphorus removal in Lithuania

In Lithuania during a warm period of a year the temperature of influent higher than 20 ºC holds from 3 to 4 months (in June, July, August, September and October) in the investigated wastewater treatment plants of Vilnius, Klaipėda, Alytus and Utena cities (Fig 4.1). The maintained sludge age fluctuated from 16 to 30 days. That is why there are favourable conditions for the growth of GAO bacteria.

Meanwhile, during the warm period of a year the concentration of TP in effluent increases at wastewater treatment plants of the largest Lithuanian cities.

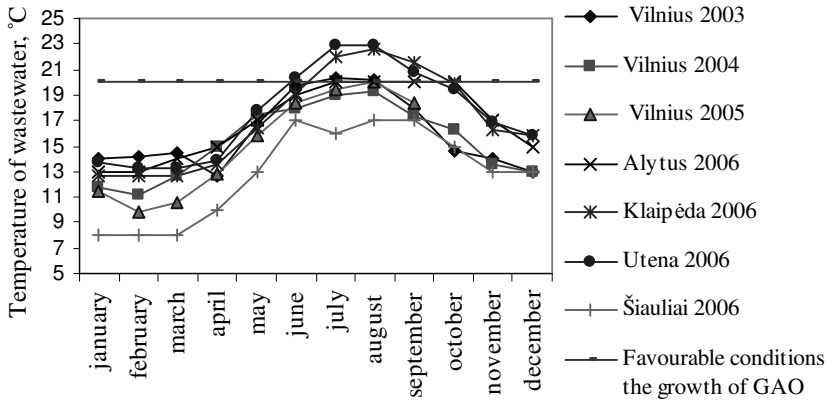

Fig 4.1. Dynamic of fluctuation of influent temperature in wastewater treatment plants of Vilnius, Alytus, Klaipėda, Šiauliai, Utena cities

In order to determine the relationship between the efficiency of BPR and the temperature of influent it was carried out the correlation regression analysis of statistically reliable data (TP concentration in effluent and temperature of influent) of each investigated wastewater treatment plants (Fig 4.2).

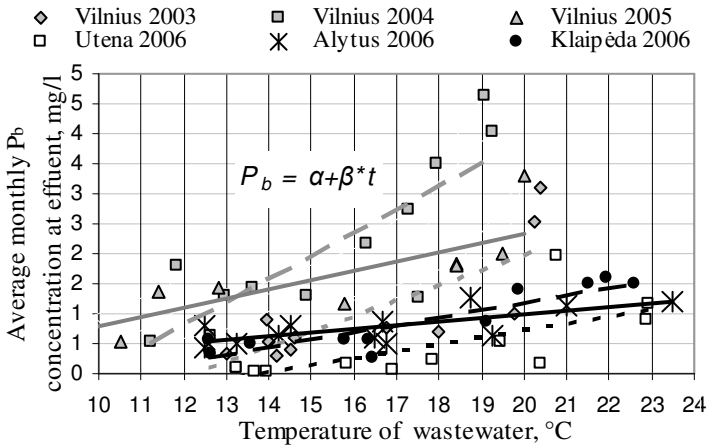

Fig 4.2. Relationship between temperature of influent and concentration of TP (or phosphate) in effluent of wastewater treatment plants in the largest cities of Lithuania

The relationship between analysed parameter is best characterised by a linear regression model selected according to the highest R-squared values that fluctuate from 0.5 up to 0.83. The highest R-squared value (R^2 = 0.83) was obtained in Klaipėda wastewater treatment plant. In other wastewater treatment plants was determined a less percent of TP values, that are affected by temperature value (50.3–68.8 %). Meanwhile regressive data analysis of Šiauliai wastewater treatment plant showed a very weak correlation relationship between analysed parameters (R^2 = 0.37). It is explained that the highest temperature of influent in this WWTP (17.5 ºC) doesn't reach 20 ºC, i.e. there are no favourable conditions for the growth of GAO.

5. Research of impact of biological nitrogen removal on phosphorus removal

One of the factors that have effect on the BPR is compounds of nitrogen as the BPR is combined with nitrogen removal usually. Evaluating the results of investigations of the aeration impact on the phosphate release that were carried out during a warm period of a year, the tendencies of the increase of phosphates in the aeration zone cleared up: there were determined increased concentrations of ammonium nitrogen when the nitrification process was incomplete at the aeration zone and there were determined increased concentrations of nitrates at the anaerobic zone when the denitrification process was incomplete (Figs 5.1 and 5.2).

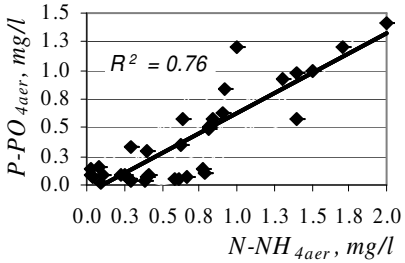

Fig 5.1. Relationship between phosphates and ammonium nitrogen at the aeration zone during a warm period of a year

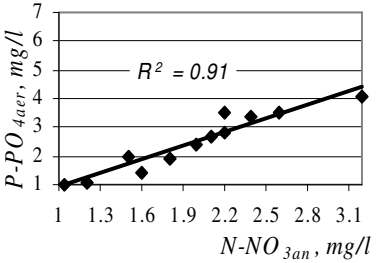

Fig 5.2. Relationship between phosphates in the aeration zone and nitrates at the anaerobic zone during a warm period of a year

There were determined relationships according the obtained results:

$$P\text{-}PO_4\ aer = 0.7 \cdot N\text{-}NH_4\ aer - 0.07, \quad (5.1)$$

$$P\text{-}PO_4\ aer = 1.61 \cdot N\text{-}N0_3\ an - 0.7, \quad (5.2)$$

here $P\text{-}PO_4\ aer$ – concentration of phosphates in the aeration zone, mg/l, $N\text{-}NH_4aer$ – concentration of ammonium nitrogen in the aeration zone, mg/l, $N\text{-}N0_3an$ – concentration of nitrates in the anaerobic zone, mg/l.

Analysing the results of investigations that were carried out at the cold period of a year there wasn't detected any increase of phosphates tendency at the aeration zone. Then the concentration of TP in effluent didn't exceed 0.71 mg/l. Even when the concentration of ammonium nitrogen reached 2.2 mg/l, the increase of phosphates wasn't determined at the aeration zone.

After the calculation of the denitrification rates and analysing them in the aspect of temperature of wastewater it was determined the relationship between analysed parameters ($R^2 = 0.99$, Fig 5.3). It was obtained exponential regression model:

$$\rho_{DN} = 0.5 \cdot e^{0.05 \cdot \tau}, \qquad (5.3)$$

here ρ_{DN} – denitrification rate, mg N/(g MLVSS·h), τ – temperature of wastewater, °C.

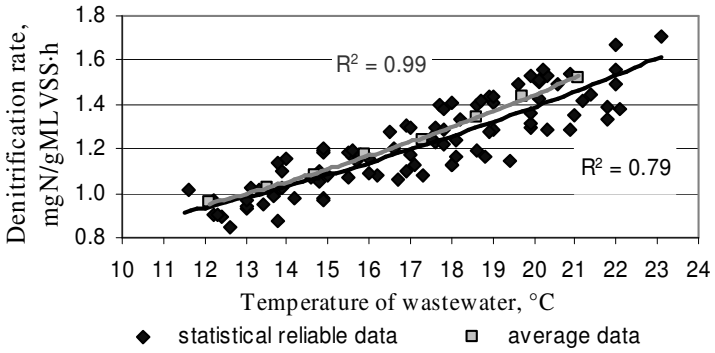

Fig 5.3. Relationship between the denitrification rate and the temperature of wastewater

After the full-scale experiments with 5 different regimes of aeration in the activated sludge reactor were carried out, it was stated the optimum durations of aeration for efficient biological nitrogen removal using SND technology (Fig 5.4).

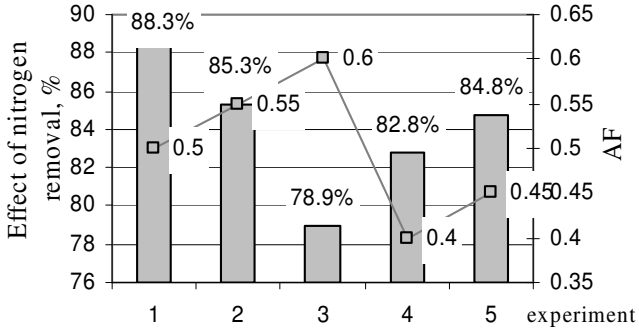

Fig 5.4. Efficiency of nitrogen removal when the activated sludge reactor worked in different regimes of aeration

The average efficiency of nitrogen removal was the highest (88.3 %), when the part of aeration fraction (AF) was equal 0.5. Meanwhile, when the AF was 0.45 and 0.55, the average efficiency of nitrogen removal decreased about 3 % (up to 85 %). A similar decrease of about 2 % (up to 83 %) was determined when the AF was equal 0.4. Although, when the AF was equal 0.6, the average efficiency of nitrogen removal decreased about 4 % (up to 78.9 %).

These results coincide with the results of research that are presented in literature and that were obtained when the investigations were carried out in laboratory-scale conditions and it confirms how important is to determine precisely the regime of aeration.

The nitrification rates during the five experiments fluctuated from 1.02 up to 2.3 mgN/(g MLVSS·h), the denitrification rates fluctuated from 1.0 up to 2.7 mgN/(g MLVSS·h). Meanwhile, the temperature of wastewater fluctuated between 16.5 ºC and 20.1 ºC.

The highest average value of nitrification rates (2.04 mgN/(g MLVSS·h)) was determined during the first experiment when the duration of aeration was 150 min and the lowest value (1.21 mgN/(g MLVSS·h)) was determined during the third experiment when the duration of aeration was 180 min.

The highest average value of denitrification rates (2.41 mgN/(g MLVSS·h)) was obtained during the first experiment also when the duration of reduced aeration was 150 min. The lowest average values of denitrification rates (1.22 and 1.44 mgN/(g MLVSS·h)) were determined during the fourth and fifth experiment when the duration of reduced aeration was 180 min. The correlation regression analysis of analysed parameters showed the relationship between the rates nitrification and denitrification and the regime of aeration.

6. Research of the impact of glycogen accumulating organisms (GAO) on the biological phosphorus removal

After it was turned out that the biological phosphorus removal gets significantly worse during a warm period of a year at the most largest wastewater treatment plants of Lithuanian cities and that the impact of nitrogen removal on the BPR differs during the warm and cold periods it could be stated that the BPR process interfere with the problem of the increase the population of glycogen accumulating organisms.

That is why in this chapter the periods were investigated when the efficiency of BPR decreases during warm period and there were determined means such as change of values of sludge age and BOD_7/TP in influent for restoration of the BPR efficiency.

It was determined a linear dependency between sludge age and the duration of acclimatization for the glycogen accumulating organisms upon which depends the efficiency of BPR (Fig 6.1).

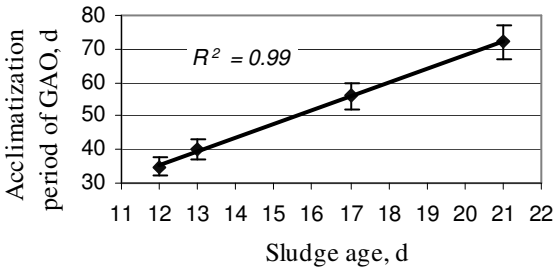

Fig 6.1. Relationship between the duration of acclimatization for the GAO and the sludge age

According to the results of research it was obtained the model of multiple linear regressions (6.1) that describes the change of phosphates in aeration zone, according to ratio of BOD_7/TP in influent, temperature of wastewater influent, sludge age and acclimatization period for the glycogen accumulating organisms:

$$lny = -7.4776 - 0.17228 \cdot x_1 + 0.4989 \cdot x_2 - 0.0358 \cdot x_3 + 0.0176 \cdot x_5 , \quad (6.1)$$

here y – the concentration of phosphates in the aeration zone, x_1 – ratio of BOD_7/TP in influent, x_2 – temperature of wastewater influent, x_3 – sludge age, x_4 – BOD_7 in influent, x_5 – period of acclimatization for the glycogen accumulating organisms.

According to standardised values of parameters it was obtained that the most important variable is the BOD_7/TP in influent for the prediction of values of phosphates. The value of standardised parameter β_1 is equal to 0.787. The second most important variable is temperature of wastewater (β_2 = 0.418). Sludge age (β_3 = 0.196) and period of acclimatisation for the glycogen accumulating organisms (β_5 = 0.257) are less important.

The statistical model is formed so that the obtained result would be presented as all the cases from 10000 of modelled cases when the concentration of phosphates exceeds 1 mg/l in the activated sludge reactor. Such concentration of phosphates shows that phosphorus removal is not enough to ensure the TP concentration of 1 mg/l in effluent.

The results of modelling showed that the phosphate concentration of over than 1 mg/l in the aeration zone mostly can occur after 60 days when temperature of wastewater reaches 20 °C and maintaining a short sludge age (10–15 days).

Maintaining a longer sludge age after acclimatization period of glycogen accumulating organisms higher than 1 mg/l concentration of phosphates can occur more often than maintaining a short sludge age. When a short sludge age is maintained (10 days), higher than 1 mg/l concentration of phosphates in the aeration zone will usually occur from 30 to 70 days, i.e. the frequency is from 99.6 % up to 13.9 % according to the ratio of BOD_7/TP in influent.

Later the frequency of cases of non-sufficient phosphorus removal declines. Meanwhile, maintaining a long sludge age (25 days) acclimatization period for the glycogen accumulating organism's gets longer and period of non-stable phosphorus removal begins only after 90 days.

At that time the possibility that the temperature of wastewater will be higher than 24 °C declines, this is why the cases of non-sufficient phosphorus removal can occur more seldom. Nevertheless, the frequency of cases of non-sufficient phosphorus removal is rather high from 90 to 120 days according to the ratio of BOD_7/TP in influent.

Micros-coping the samples of activated sludge there were found the bacteria in a form of tetrads. In literature they are characterised as the glycogen accumulating organisms and they are presented in a figure 6.2.

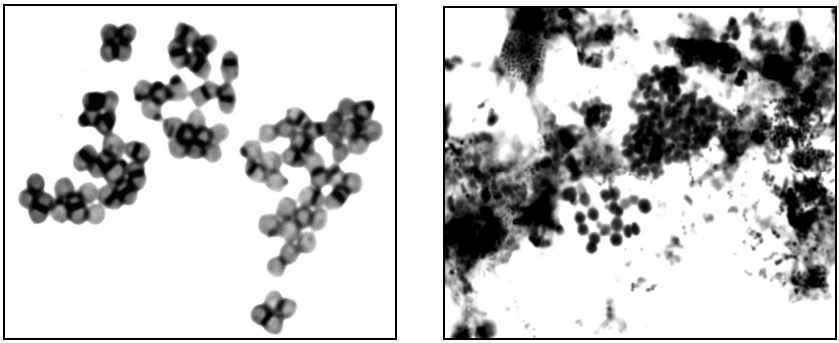

Fig 6.2. Pictures of the GAO bacteria conglomeration that were found at preparations of activated sludge during the non-sufficient periods of phosphorus removal

Micros-coping prepared preparations of sludge the abundance of GAO bacteria population was evaluated with scale numbers from 0 to 6. During the non-stable phosphorus removal period the abundance of GAO bacteria population at activated sludge was evaluated from 4 to 6. Meanwhile during the stable phosphorus removal period it was from 1 to 1.5.

According to the selected and introduced methodology for determination of concentration of glycogen that hasn't been applied before there has been determined the concentration of glycogen at activated sludge when the temperature seasonally declines from 18.9 °C to 15.8 °C (Fig 6.3).

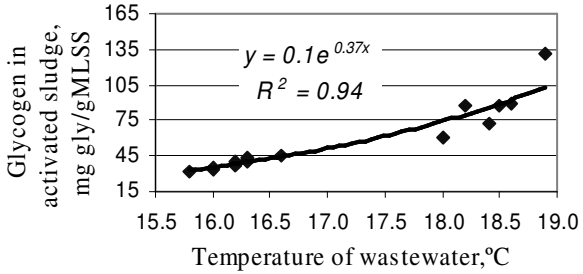

Fig 6.3. Relationship between concentration of glycogen at sludge and temperature of wastewater

The results of the investigations showed that the relationship of analysed parameters can be expressed by an exponential regression model.

General conclusions

1. It was determined that there are favourable conditions for the growth of glycogen accumulating organisms at wastewater treatment plants of Lithuania during the warm period of a year. Meanwhile, the concentration of total phosphorus in effluent increases at wastewater treatment plants of the largest Lithuanian cities.
2. It was determined that the concentration of total phosphorus in effluent exceed 1 mg/l during the warm period of a year, when the nitrification and denitrification process is incomplete. However, this tendency was not determined during the cold period of a year. The glycogen accumulating organisms could have been the reason for the difference of the obtained results. A small concentration of oxygen (0.5 mg/l – incomplete nitrification) encourages the growth of glycogen accumulating organisms.
3. It was determined that the denitrification rate increases according to an exponential regression model $q_{DN} = 0.5 \cdot e^{0.05 \cdot \tau}$ when temperature of wastewater increases from 11.5 to 23.1 ºC, applying simultaneous nitrification denitrification technology for nitrogen removal. The highest efficiency of nitrogen removal is obtained when the values of aeration and reduced aeration are equal to 150 min each. At that time these were determined the highest nitrification and denitrification rates.
4. It was determined that the efficiency of biological phosphorus removal decreases in summer time when temperature of wastewater reaches 20 ºC, but not at once, in a period after 3 to 4 sludge ages. During this period, that could be called the acclimatization period for the glycogen accumulating organisms, there forms the negative ratio of glycogen accumulating and polyphosphates accumulating organisms for the biological phosphorus removal. So this process is disturbed.
5. It was determined that the abundance of glycogen accumulating bacteria is typical for samples of the non-stable phosphorus removal period. Meanwhile, when the efficiency of biological phosphorus removal is high, only single glycogen accumulating organisms were recorded in the activated sludge.
6. The method of the determination of glycogen at activated sludge has been selected, applied and introduced using anthron reagent.
7. When the temperature of treated wastewater decreases, the concentration of glycogen in the activated sludge decreases according to the exponential model: $Gly = 0.1 \cdot e^{0.37 \cdot \tau}$ in diapason of temperature 15.8–18.9 °C. It shows that the population of glycogen accumulating bacteria decrease and better conditions are composed for the development of polyphosphates accumulating organisms, therefore the enough efficiency of phosphorus removal obtained.

Recommendations

1. It is recommended to assure the conditions for denitrification and nitrification, to supervise the concentration of ammonium nitrogen in the aeration zone and nitrates at the anaerobic zone that can't exceed the concentration of 1 mg/l.
2. When it is used simultaneous nitrification denitrification technology for the removal of nitrogen, it is recommended to use the aeration regimen when the durations of aeration and decreased aeration are equal 150 min each because the highest efficiency of nitrogen removal is obtained.
3. When the temperature of wastewater is 20 ºC, it is recommended to maintain a short sludge age up to 10 days and ensure the relation of BOD_7/TP not lower than 35 at treated wastewater. If a longer sludge age is maintained it is necessary to ensure the relation of BOD_7/TP not lower than 40 at treated wastewater.
4. It is recommended to decrease sludge age up to 5 days if the efficiency of biological phosphorus removal decreases during the warm period of a year. It is enough for reduction of glycogen accumulating bacteria quantity into activated sludge.
5. It is recommended to supervise the concentration of glycogen applying the recommended methodic for determination of glycogen at the activated sludge. Due to this there could be noticed the regularities of the fluctuation of concentration of glycogen within a period of a year and it could be predicted the amount of glycogen accumulating organisms population in the system of the activated sludge.

List of published works on the topic of the dissertation

In the reviewed scientific periodical publications

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Giedrė Vabolienė was born in Utena, on 16 of Mach 1975. She acquired the Bachelor's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 1997 and Master's degree in Environmental Engineering at Vilnius Gediminas Technical University Faculty of Environmental Engineering in 1999; in 1999–2003 was working at Environmental Protection Department of Utena region; in 2003–2008 was working at UAB "Utenos vandenys" engineer – technologist; in 2004–2008 – PhD student of Vilnius Gediminas Technical University.

FOSFORO IR AZOTO BIOLOGINIO ŠALINIMO IŠ NUOTEKŲ TYRIMAI IR VERTINIMAS

Mokslo problemos aktualumas

Biogeninių medžiagų perteklius paviršinio vandens telkiniuose sukelia eutrofikaciją – masinį fitoplanktono vystimąsi ir aukštesniųjų vandens augalų augimą. Dėl to pablogėja organoleptinės vandens savybės, nyksta kai kurios žuvys, mažėja biologinė įvairovė. Vandens telkinių eutrofikacijos galima išvengti iš nuotekų šalinant azotą bei fosforą. Lietuvoje 2005 metais į paviršinio vandens telkinius išleista 192,2 mln. m^3 ūkio buities ir gamybinių nuotekų. Iš jų 56,7 mln. m^3 nuotekų išleista išvalytų nepakankamai iki leistinos taršos pagal BDS_7, bendrąjį azotą ir fosforą.

Šioms biogeninėms medžiagoms iš nuotekų šalinti pasaulyje plačiai naudojamos biologinės nuotekų valymo technologijos, panaudojant specialius veikliojo dumblo mikroorganizmus, gebančius sukaupti bei suskaidyti azoto ir fosforo junginius. Tačiau yra eilė nuolat kintančių veiksnių, darančių įtaką

biocheminiams procesams bei mikroorganizmų veiklai. Tai yra nuotekų sudėtis, aplinkos, technologiniai veiksniai. Daugelis veiksnių yra plačiai nagrinėti bei nustatyti jų kitimo dėsningumai. Nepaisant to, dažnai susiduriama su nepaaiškinama biologinio fosforo šalinimo (BFŠ) efektyvumo sumažėjimo problema.

Pastarąjį dešimtmetį Lietuvoje buvo intensyviai rekonstruojami miestų buitinių nuotekų valymo įrenginiai, įdiegiant azoto bei fosforo šalinimą. Po rekonstrukcijos ne visos technologijos pasiteisino ir dirba patikimai, ypač biologinės. Nepajėgiant užtikrinti reikiamo išvalymo laipsnio pagal bendrąjį fosforą biologiniu būdu, plačiai naudojamas cheminis būdas, kuris ženkliai padidina nuotekų išvalymo savikainą. Tuo tarpu, siekiant sumažinti eutrofikacijos problemą, keliami vis griežtesni reikalavimai azoto ir fosforo šalinimui. Todėl tikslinga ištirti visus veiksnius, trukdančius veiksmingai šalinti biogenines medžiagas iš nuotekų. Iki šiol Lietuvoje nebuvo nagrinėta kokią įtaką BFŠ turi valomų nuotekų temperatūra. BFŠ paprastai derinamas su azoto šalinimu. Pastarojo įtaka plačiau nagrinėta tik nitratų atžvilgiu.

Darbo tikslas

Nustatyti ir ištirti veiksnius, trukdančius efektyviai šalinti fosforą ir azotą biologiniu būdu iš nuotekų Lietuvos klimato sąlygomis. Pateikti pasiūlymus kaip, keičiant technologinius parametrus, išvengti arba sumažinti šių veiksnių įtaką.

Darbo uždaviniai

1. Atlikti Lietuvos didžiųjų miestų nuotekų valyklų darbo analizę, įvertinant fosforo šalinimą iš nuotekų. Nustatyti valomų nuotekų temperatūros kitimo ir fosforo šalinimo dėsningumus.
2. Atlikti azoto šalinimo poveikio biologiniam fosforo šalinimui eksperimentinius tyrimus šiltuoju ir šaltuoju metų laikotarpiu. Nustatyti optimalias aeracijos ir sumažintos aeracijos trukmes efektyviam azoto šalinimui užtikrinti, įvertinant nitrifikacijos ir denitrifikacijos greičius.
3. Ištirti laikotarpius, kai fosforo šalinimo efektyvumas smarkiai sumažėja. Atliekant eksperimentus gamybinėmis sąlygomis, nustatyti priemones fosforo šalinimo efektyvumui atstatyti.
4. Atlikti statistinį modeliavimą, siekiant kompleksiškai įvertinti veiksnių, tokių kaip BDS_7/P_b santykio valomose nuotekose, valomų nuotekų temperatūros, dumblo amžiaus, valomų nuotekų užterštumo pagal BDS_7 bei glikogeną kaupiančių bakterijų aklimatizacinio laikotarpio, įtaką biologiniam fosforo šalinimui.

5. Atlikti glikogeną kaupiančių bakterijų mikroskopinę analizę. Parinkti glikogeno nustatymo metodiką, tinkančią veikliojo dumblo tyrimui. Nustatyti glikogeno koncentracijos veikliajame dumble kitimo, keičiantis valomų nuotekų temperatūrai, dėsningumus.
6. Remiantis tyrimų rezultatais bei jų analize, pateikti rekomendacijas veiksmingam fosforo ir azoto šalinimui iš nuotekų užtikrinti.

Mokslinis naujumas

Nustatytos biologinio fosforo šalinimo efektyvumo sumažėjimo šiltuoju metų laikotarpiu Lietuvos klimato sąlygomis priežastys. Nustatytos priemonės, tokios kaip dumblo amžiaus ir BDS_7/P_b santykio valomose nuotekose kitimas, biologinio fosforo šalinimo efektyvumo atstatymui šiltuoju metų laiku. Veikliojo dumblo tyrimams parinkta, pritaikyta ir įdiegta glikogeno nustatymo metodika.

Tyrimų metodika

Pagrindinis darbo tyrimų metodas – eksperimentiniai tyrimai, atliekami gamybinėmis sąlygomis. Taip pat panaudoti analitiniai bei matematinės statistikos analizės metodai. Taikyti veikliojo dumblo mikroskopavimo bei glikogeno nustatymo dumble metodai. Naudojant pažingsninės regresijos analizės metodą, parinktas modelis, kompleksiškai aprašantis veiksnių įtaką biologiniam fosforo šalinimui ir atliktas statistinis modeliavimas.

Praktinė vertė

Atsakyta į daugelyje Lietuvos miestų nuotekų valyklų kylantį klausimą dėl biologinio fosforo šalinimo šiltuoju metų laiku sutrikimo. Remiantis tyrimų, atliktų, gamybinėmis sąlygomis, rezultatais pateiktos rekomendacijos veiksmingam fosforo ir azoto biologiniam šalinimui iš nuotekų užtikrinti. Darbo rezultatai gali būti naudojami projektuojant naujus, rekonstruojant, o ypač eksploatuojant esamus fosforo ir azoto biologinio šalinimo įrenginius.

Ginamieji teiginiai

1. Biologinis fosforo šalinimas šiltuoju metų laikotarpiu Lietuvoje gali sutrikti dėl glikogeną kaupiančių bakterijų veiklos.
2. Azoto šalinimo įtaka fosforo šalinimui išryškėja tik šiltuoju metų laiku dėl glikogeną kaupiančių bakterijų veiklos.
3. Azoto šalinimui taikant simultaninės nitrifikacijos denitrifikacijos technologiją, didžiausias azoto šalinimo efektyvumo pasiekiamas, kai aeracijos ir sumažintos aeracijos trukmės lygios po 150 min.

4. Biologinio fosforo šalinimo efektyvumo sumažėjimą dėl glikogeną kaupiančių bakterijų veiklos, galima atstatyti, sumažinus dumblo amžių iki 5 parų.
5. Kai veikliojo dumblo sistemoje dominuoja glikogeną kaupiančioms bakterijoms, valomų nuotekų BDS_7/P_b santykis turi būti ne mažesnis nei 35.
6. Glikogeno nustatymo veikliajame dumble metodikos taikymas.

Darbo apimtis

Disertaciją sudaro septyni skyriai, iš kurių pirmasis yra įvadas, o paskutinysis – rezultatų apibendrinimas. Darbo apimtis yra 125 puslapiai. Tekste panaudotos 34 numeruotos formulės, 65 paveikslai ir 33 lentelės. Rašant disertaciją buvo panaudoti 181 literatūros šaltiniai.

Pirmajame skyriuje nagrinėjamas problemos aktualumas, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autorės pranešimai ir publikacijos, disertacijos struktūra. Antrajame skyriuje apžvelgiama biogeninių medžiagų šalinimo iš nuotekų reikšmė, principai, technologijos. Aptariami veiksniai, turintys įtakos biologiniam fosforo ir azoto šalinimui. Didžiausias dėmesys skiriamas temperatūros įtakai biologiniam fosforo šalinimui. Trečiajame skyriuje aprašomi metodai, naudoti biologinio fosforo ir azoto šalinimo įrenginių darbo analizei ir tyrimams. Ketvirtajame skyriuje pateikiama penkių Lietuvos miestų nuotekų valyklų duomenų analizė. Nustatyti valomų nuotekų temperatūros kitimo dėsningumai. Vertintas fosforo šalinimo priklausomumas nuo valomų nuotekų temperatūros bei nuotekų sudėties. Penktajame skyriuje nagrinėta azoto šalinimo įtaka fosforo šalinimui. Palyginta aeracijos įtaka fosfatų išsiskirimui į nuotekas šiltuoju ir šaltuoju metų laiku. Nustatyta denitrifikacijos greičio priklausomybė nuo nuotekų temperatūros. Nustatytos optimalios aeracijos trukmės efektyviam biologiniam azoto šalinimui, naudojant simultaninės nitrifikacijos denitrifikacijos (SND) technologiją. Šeštajame skyriuje ištirti laikotarpiai, kai fosforo šalinimo efektyvumas smarkiai sumažėja šiltuoju metu bei nustatytos priemonės kaip su šia problema kovoti arba jos išvengti. Kompleksiškai įvertinta veiksnių įtaka biologiniam fosforo šalinimui, atliekant statistinį modeliavimą.

Rezultatų aprobavimas

Disertacijos tema perskaityti 9 pranešimai Lietuvos bei kitų šalių konferencijose, paskelbta 14 straipsnių: trys – mokslo žurnaluose, įtrauktuose į Thomson ISI Master Journal List sąrašą, vienas – konferencijų medžiagoje, referuotoje Thomson ISI Proceedings duomenų bazėje, du – žurnale, cituojamame *Inspec* duomenų bazėje, vienas – recenzuojamoje tarptautinės konferencijos medžiagoje, penki – kitų konferencijų medžiagose, du – kituose leidiniuose.

Bendrosios išvados

1. Nustatyta, kad šiltuoju metų laikotarpiu Lietuvoje nuotekų valyklose susidaro palankios sąlygos glikogeną kaupiantiems organizmams augti. Tuo metu Lietuvos didžiųjų miestų nuotekų valyklose padidėja bendrojo fosforo koncentracija valytose nuotekose.
2. Atlikus tyrimus gauta, kad nepilnai įvykus nitrifikacijos arba denitrifikacijos procesams šiltuoju metų laiku, bendrojo fosforo koncentracija valytose nuotekose viršijo 1 mg/l. Tačiau šaltuoju metų laiku ši tendencija nenustatyta. Tokį rezultatų skirtumą galima paaiškinti glikogeną kaupiančių bakterijų įtaka, nes maža deguonies koncentracija (0,5 mg/l) t. y. dalinė nitrifikacija skatina jų augimą.
3. Nustatyta, kad azoto šalinimui taikant simultaninės nitrifikacijos denitrifikacijos technologiją, didėjant nuotekų temperatūrai nuo 11,5 iki 23,1 ºC, denitrifikacijos greitis didėja pagal eksponentinį regresijos modelį: $q_{DN} = 0{,}5 \cdot e^{0{,}05 \cdot \tau}$. Didžiausias azoto šalinimo efektyvumas pasiektas, kai aeracijos ir sumažintos aeracijos trukmės buvo lygios po 150 min. Tuo metu nustatyti didžiausi nitrifikacijos ir denitrifikacijos greičiai.
4. Nustatyta, kad biologinio fosforo šalinimo efektyvumas sumažėja vasarą, kai valomų nuotekų temperatūra pasiekia 20 ºC, tačiau ne iškart, o praėjus nuo 3 iki 4 dumblo amžių. Per šį laikotarpį, kurį galima vadinti glikogeną kaupiančių organizmų aklimatizaciniu laikotarpiu, susidaro neigiamas biologiniam fosforo šalinimui glikogeną kaupiančių ir polifosfatus kaupiančių organizmų santykis veikliajame dumble, todėl sutrinka biologinio fosforo šalinimo procesas.
5. Nustatyta, kad glikogeną kaupiančių bakterijų gausa būdinga nestabilaus fosforo šalinimo laikotarpio dumblo mėginiams. Tuo tarpu, kai fosforo šalinimo efektyvumas aukštas, užfiksuotos tik pavienės glikogeną kaupiančios bakterijos veikliajame dumble.
6. Veikliojo dumblo tyrimams parinkta, pritaikyta bei įdiegta glikogeno nustatymo metodika, kurioje pasiūlyta naudoti antrono reagentą.
7. Nustatyta, kad mažėjant valomų nuotekų temperatūrai, glikogeno koncentracija dumble mažėja pagal eksponentinį modelį: $Gly = 0{,}1e^{0{,}37 \cdot \tau}$, mažėjant valomų nuotekų temperatūrai nuo 18,9 iki 15,8 °C. Tai rodo, kad glikogeną kaupiančių bakterijų populiacija sumažėja. Tokiu būdu, susidarius geresnėms sąlygoms polifosfatus kaupiantiems organizmams vystytis, pasiekiamas pakankamas fosforo šalinimo efektyvumas.

Rekomendacijos

1. Rekomenduojama užtikrinti sąlygas pilnai nitrifikacijai ir denitrifikacijai įvykti, t. y. amonio azoto koncentracija aeracinėje zonoje bei nitratų koncentracija anaerobinėje zonoje neturi viršyti 1 mg/l.

2. Azoto šalinimui taikant simultaninės nitrifikacijos denitrifikacijos technologiją, rekomenduojama naudoti aeracijos režimą, kai aeracijos ir sumažintos aeracijos trukmės lygios po 150 min., kadangi tyrimų metu, naudojant šį režimą, buvo pasiektas didžiausias azoto šalinimo efektyvumas.
3. Kai valomų nuotekų temperatūra pasiekia 20 ºC, rekomenduojama palaikyti dumblo amžių iki 10 parų bei užtikrinti ne mažesnį kaip 35 valomų nuotekų BDS_7/P_b santykį. Jei palaikomas ilgesnis dumblo amžius, būtina užtikrinti ne mažesnį kaip 40 valomų nuotekų BDS_7/P_b santykį.
4. Sumažėjus fosforo šalinimo efektyvumui šiltuoju metų laiku, rekomenduojama sumažinti dumblo amžių iki 5 parų, taip pakankamai sumažinant glikogeną kaupiančių bakterijų kiekį veikliajame dumble.
5. Rekomenduojama, taikant pasiūlytą glikogeno nustatymo veikliajame dumble metodiką, sekti glikogeno koncentraciją, kas leistų pastebėti glikogeno koncentracijos kitimo metų laikotarpyje dėsningumus bei prognozuoti glikogeną kaupiančių organizmų populiacijos dydį veikliojo dumblo sistemoje.

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RESEARCH AND EVALUATION OF THE BIOLOGICAL PHOSPHORUS AND NITROGEN REMOVAL FROM WASTEWATER

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