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# USE OF MEASUREMENTS OF ACTIVATED SLUDGE RESPIRATORY ACTIVITY FOR THE CONTROL OF THE COURSE OF BIOLOGICAL WASTEWATER TREATMENT PROCESSES

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Abstract

**The following paper describes the results of investigations in Rybnik-Orzepowice waste-water treatment plant as part of the targeted project No 6 ZR7 2008C/07051 entitled "The increase in biogene reduction through the optimisation of the biological waste-water treatment process in Rybnik-Orzepowice waste-water treatment plant". The investigations presented in this article were carried out in April and May 2010 (four measurement days), using a transportable Bioscope respirometer. The obtained results were compared with the read-outs from stationary oxygen probes. A comparative laboratory test was also carried out in order to determine the activated sludge respiratory activity and to verify the correctness of results received with the use of respirometer. The investigations constituted a part of studies conducted in the framework of the targeted project. They might be also regarded as an attempt to make use of the experience acquired before research in terms of real conditions for an exploitation of biological wastewater treatment plants.**

Streszczenie

**W niniejszym artykule opisano wyniki badań przeprowadzonych w oczyszczalni Rybnik-Orzepowice w ramach projektu celowego nr 6 ZR7 2008C/07051 pt. „Zwiększenie redukcji biogenów przez optymalizację procesu biologicznego oczyszczania ścieków w oczyszczalni ścieków Rybnik-Orzepowice". Opisywane w artykule badania wykonano w kwietniu i maju 2010 roku (cztery dni pomiarowe), wykorzystując do tego celu przenośny respirometr Bioscope. Otrzymane wyniki zestawiono z odczytami ze stacjonarnych sond tlenowych. Wykonano również porównawczy laboratoryjny test na wyznaczanie aktywności oddechowej osadu czynnego w celu sprawdzenia poprawności wyników otrzymywanych z wykorzystaniem respirometru. Badania te były częścią prac prowadzonych w ramach projektu celowego, a także próbą wykorzystania zdobytych doświadczeń badawczych, w warunkach rzeczywistych eksploatowania biologicznych oczyszczalni ścieków.**

Keywords: **Sludge; Dissolved oxygen; Respirometry; Oxygen uptake rate.**

## 1. INTRODUCTION

The biological wastewater treatment processes using the activated sludge are connected with the necessity of the sludge oxygenation. Providing air (aerators, aeration grids, etc.) is essential to remove ammonia from the influent wastewater. Ammonia is oxidized in the nitrification phase, with the participation of nitrifying bacteria such as *Nitrosomonas* (Kunicki-Goldfinger, 2008; Miksch 2010). The adequate concentration of dissolved oxygen (DO) should ensure the proper conduct of the process. The process of ammonia oxidation might be observed when laboratory tests, such as AUR – *ammonia uptake rate* and the OUR – *oxygen uptake rate* (Davies 2004; Zuojun 2000), are carried out. With this type of research, the conclusion regarding the optimal concentration of oxygen in the chambers of the activated sludge might be proposed: the processes will be carried out by the micro-organism efficiently and without disruptions.

Controlling of respiratory activity of the activated sludge and determination of OUR sludge value in the endogenous state, during the inflow of water and in the presence of toxic substances, can provide the wastewater treatment operators with the information on the work of the activated sludge under different conditions (Davies 2007, Gray 2004). Information regarding the physiological condition of the activated sludge system and respiratory activity is the basis for confirmation of the good state of sludge, which the proper conduct of biochemical process depends on. The biochemical processes that proceed in the cells of micro-organisms, are found in the biomass of the activated sludge. (Okutman 2010, Schlegel 2005). The determination of the critical oxygenic parameters, for the technological system using the activated sludge for a biological treatment plant, enables precise determination of the amount of dissolved oxygen that is necessary for the proper work of the biological section of the wastewater treatment. Because of the fact that each wastewater treatment plant has its own different working conditions; the information about the quantity of oxygen being supplied to the sediment will help to better understand the biochemical processes by the operators from wastewater treatment plants. The biochemical processes are those that proceed in the chambers of the activated sludge. (Gray 2004; Sadecka 2010).

A modern portable device for measuring the respiratory activity of the activated sludge can be used to acquaint oneself with the specifics of sediment work in wastewater treatment plants and to determine the optimal parameters for aeration.

This article describes the investigations of respiratory activity of the activated sludge that have been carried out with the use of a portable Bioscope respirometer. The determination of the critical oxygen point, that is the concentration of the oxygen in the chamber of the activated sludge, below which the activated sludge ceases to function properly, with the use of this device, can make a contribution to supporting of the decision-making processes concerning the oxygenation of the biological chambers. (Aspraya, Carvalho, Philp 2007; Sadecka 2010).

## 2. MATERIALS AND METHODS

The investigations of respiratory activity of the activated sludge were pursued in the mechanical-biological wastewater treatment plant in Rybnik-Orzepowice on 16$^{th}$ and 22$^{nd}$ April and 11$^{th}$ and 14$^{th}$ of May in 2010 in the chambers of the activated sludge during nitrification. Rybnik-Orzepowice wastewater treatment plant operates in BIO-DENIPHO system. The specificity of this system consists in the application of the sequential flow technology (BIODENIPHO) at the point of bio-filtration, with the preliminary anaerobic chamber and the phases sequence in reactors used for the biological removal of nitrogen and phosphorus. The exploitation of the chambers functions as an alternate pairwise work – if one of the chambers is aerated, in the other one the process of mixing will occur. In the air entrainment chamber, there are oxygenic conditions enabling nitrification. In the second one, there are the anaerobic conditions enabling denitrification. In order to steer the inflow and outflow of wastewater the following were applied: four ratio control bolts, four valves controlling the outflow valves. The sludge from the secondary settling tanks is delivered to the anaerobic chamber and to the reactors by the pumping plant station of recycled sludge.

A portable Bioscope respirometer was used in order to measure the respiratory activity of the activated sludge. That respirometer was bought within the framework of the project “Modernization of research facilities within the Innovative Economy Operational Programme Priority 2 Measure 2.1 No 08055923” by Water Protection Department – a department of the Central Mining Institute. However, this device is not widely used in wastewater treatment plants to determine the status of the activated sludge. It has been used in the targeted project No. 6 ZR7 2008C/07051 entitled “The increase in biogene reduction through the optimisation of the biological waste-water treatment process in Rybnik-Orzepowice waste-water treatment plant” implemented by the Consortium of Industrial-Science, this is Water Supply and Sewage Ltd. in Rybnik and the Water Protection Department of the Central Mining Institute. The measurements can be conducted in real conditions directly in industrial facilities. It is the Mobile Research Laboratory (MBL) from Department of Water Protection, which is fully equipped with Bioscope respirometer, that gives the possibility of carrying out such measurements. The portable Bioscope respirometer consists of a lockable measuring chamber with a mixer. A temperature sensor and an oxygen electrode – that constitute basic elements of the measuring equipment (Gray 2004) – are located in the chamber. The electrode, installed in the Bioscope device, is a polarographic Clark electrode, consisting of a platinum cathode, about 22 microns in diameter, and a silver anode (silver chloride) located in the buffered


**Figure 1.**
**The Bioscope measuring chamber and touch screen that is used to steer the device. It can provide an immediate analysis of obtained results**

electrolyte solution (potassium chloride). In a typical configuration, the cathode is covered with a polypropylene diaphram with a relatively low permeability, so that the electrode might be used in incompatible or minimally compatible solutions. These diaphragms are characterized by relatively slow response time. For rapid measurement of respiratory activity of enzyme preparations, a thin diaphragm FEP (tetrafluoroethylene/exafluoropropylene) was used. In order to achieve valid measurement, it is necessary to mix the medium rapidly.

The Bioscope respirometer is equipped with measurement location detection system. The locator is positioned on the back panel of the steering panel. The locator enables reading all the measurement data from a given place. This feature is useful for making the results compilation from one data point. The software installed on the device allows to determine the values of OUR and the critical oxygen point immediately after the measurement in the activated sludge chamber. (ASCh.)

The measurements can be carried out in selected places of the wastewater treatment plant. It is sufficient to dip the open measuring chamber in the desired position of the technological sequence, then close it and wait for the measurement to be carried out. The obtained results will appear on the screen (Fig. 1).

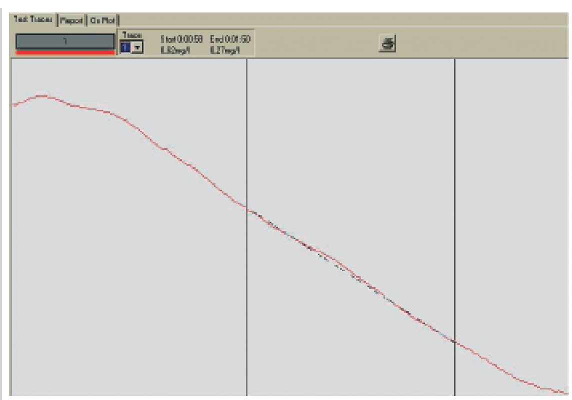

**Figure 2.**
**The graph from the AS Bioscope Analyses Programme. It illustrates the respiratory activity process that proceeds in the chamber of the activated sludge**

The device logs data in real time, data such as a temperature of sewer, the dissolved oxygen concentration in the sewer, degree of oxygen consumption by sediment. On the basis of them, the respiratory activity of the activated sludge might be determined indirectly after having carried out the measurement. The special software of respirometer provides for further analysis of results. All data will be saved in memory of device.

The use of the Bioscope respirometer will facilitate the profiling of wastewater treatment plan in terms of the sludge demand for oxygen, and the comparison of gathered results with any form. An exemplary graph is presented in the photo no 1. It was acquired on the basis of real measurement, and have been generated by the AS Bioscope Analyse – software programme. It enables to edit and process the data that have been gathered by means of the respirometer. In the graph there is a noticeable decrease in the amount of oxygen during the time when the measurement was carried out, which might be read as a high respiratory activity of the activated sludge. The programme allows selection of the area assigned to the analysis, as well as the start and the ending of measurement. The direction and gradient of the curve indicate rapid oxygen consumption of the activated sludge. The total consumption of oxygen dissolved in the sludge that is located in the measuring chamber of the repirometer is the condition of the designation of the critical oxygen point.

## 3. THE PROCESS OF RESEARCHES IN REAL CONDITIONS

The measurement of the respiratory activity of the activated sludge was performed directly in the activated sludge chambers (Fig. 3) during nitrification. The samples were taken every 5 minutes throughout the nitrification phase, exactly for 90 minutes. The sludge was taken to the respiratometer measuring chamber. Then in the second stage, the consumption of oxygen dissolved earlier by the micro-organisms of the activated sludge have been measured until attaining oxygen – free conditions.

**Figure 3.**
**The respiratory activity measurement of the activated sludge with the use of the respirometer directly in the chamber of the activated sludge**

## 4. THE MEASUREMENTS RESULTS OF RESPIRATORY ACTIVITY OF THE ACTIVATED SLUDGE IN REAL CONDITIONS

The graphs plotted on the basis of the field measurements the OUR, NOUR (normalized by dry sediment mass) relations, as well as the oxygen concentration in the chamber and the critical oxygen point results, are presented below. The measurements were carried out in April and May, 2010. The variations of the oxygen concentration in the chambers, obtained with the use of the respirometer, have been compared with the measurements of stationary oxygen probes (Endress + Hauser Liquisys S), installed on the chambers of the activated sludge. They were also related to the value of the critical oxygen point that was calculated using the AS Bioscope software. The differences between the oxygen concentration in chamber, and the results obtained from the measurements (values of critical oxygen point) are shown as both instantaneous values and average for values for the whole phase. The critical oxygen point was calculated for all these values. The tests were performed on different days and at different hours during the phase of nitrification in order to check the possibility of any relation between the obtained results and the hour in which the nitrification was conducted and whether the average value of critical oxygen point would be similar for different phases.

***Results of the research conducted on 16/04/2010 are presented in Fig. 4, 5 ,6.***

Duration of the measurement – approx. 1.5 h

Dry sediment mass in the chamber of the activated sludge – 3.8 g/dm$^3$

Temperature in the chamber of the activated sludge – 12.8°C / 55.04 F

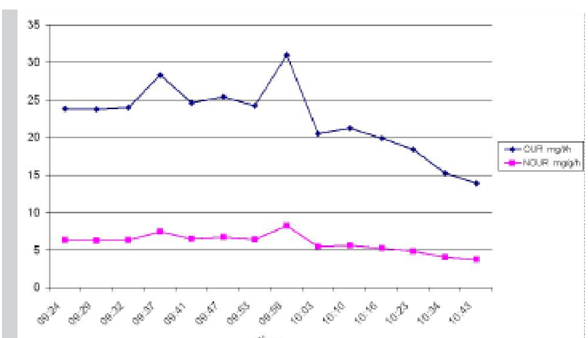


**Figure 4.**
**Oxygen uptake rate (OUR) and the rate of oxygen uptake per unit were converted with an allowance made for the concentration of the activated sludge (NOUR). (The measurement was carried out in the nitrification phase)**

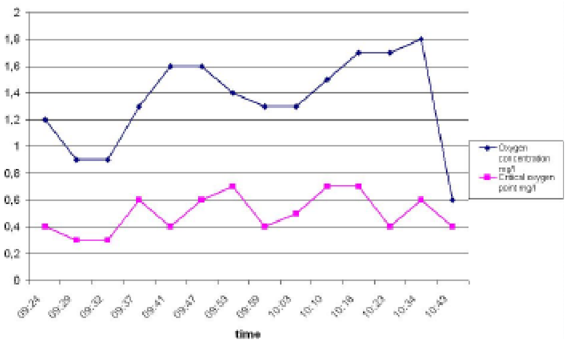


**Figure 5.**
**The concentration of oxygen in the chamber of the activated sludge compared with the critical oxygen point (the measurement was carried out in the nitrification phase)**

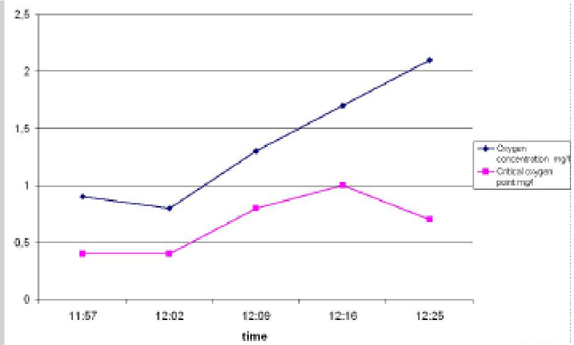


**Figure 8.**
**The concentration of oxygen in the chamber of the activated sludge compared with the critical oxygen point (the measurement carried out in the nitrification phase)**

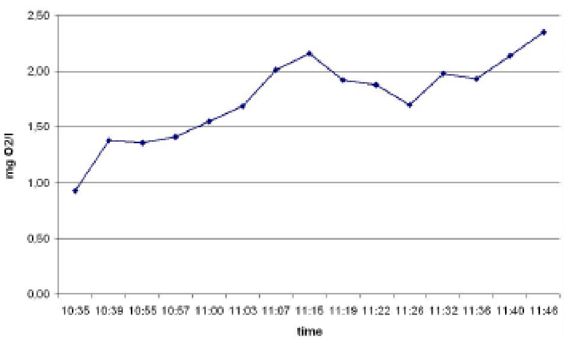


**Figure 6.**
**Measurement results from the stationary oxygen probe installed in the chamber of the activated sludge**

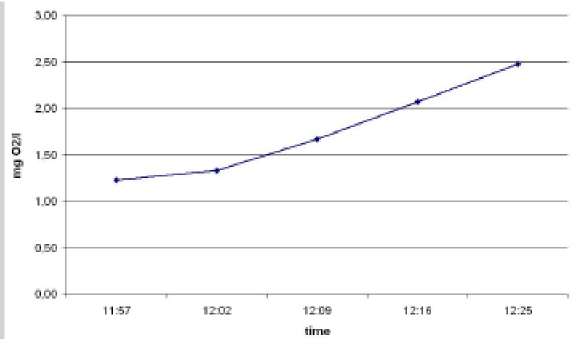


**Figure 9.**
**Measurement results from the stationary oxygen probe installed in the chamber of the activated sludge**

***Results of the research conducted on 22/04/2010 are presented in Fig. 7, 8, 9.***

Duration of the measurement – approx. 30 minutes

Dry sediment mass in the chamber of the activated sludge – 3.5 g/dm$^3$

Temperature in a chamber of activated sludge – 12.9°C / 55.22 F

***Results of researches conducted on 11/05/2010 are presented in Fig. 10, 11, 12.***

Duration of measurement – approx. 1.5 h

Dry sediment mass in a chamber of activated sludge – 3.8 g/dm$^3$

Temperature in the chamber of the activated sludge – 14.9°C / 58.82 F

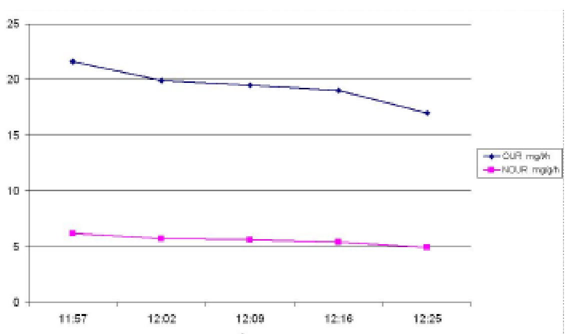


**Figure 7.**
**Oxygen uptake rate (OUR) and rate of oxygen uptake per unit were converted with allowance made for the concentration of the activated sludge (NOUR) (the measurement carried out in the nitrification phase)**

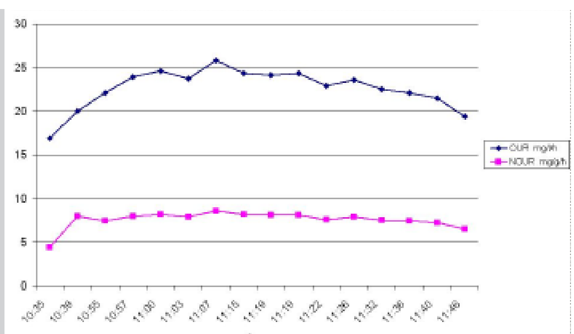


**Figure 10.**
**Oxygen uptake rate (OUR) and rate of oxygen uptake per unit were converted with an allowance made for the concentration of the activated sludge (NOUR) (the measurement carried out in the nitrification phase)**

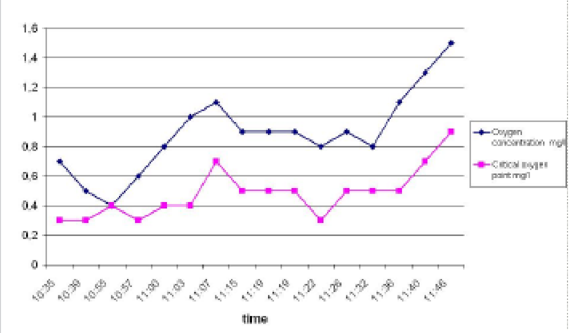


**Figure 11.**
**The concentration of oxygen in the chamber of the activated sludge compared with the critical oxygen point (the measurement carried out in the nitrification phase)**

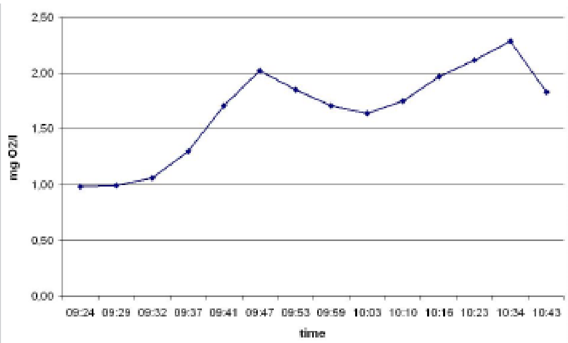


**Figure 12.**
**Measurement results from the stationary oxygen probe installed in the chamber of the activated sludge**

***Results of the research conducted on 14/05/2010 are presented in Fig. 12, 13.***

Duration of the measurement – approx. 1 h 30 minutes

Dry sediment mass in the chamber of the activated sludge – 3.5 g/dm$^3$

Temperature in the chamber of the activated sludge – 14.7°C / 58.46 F

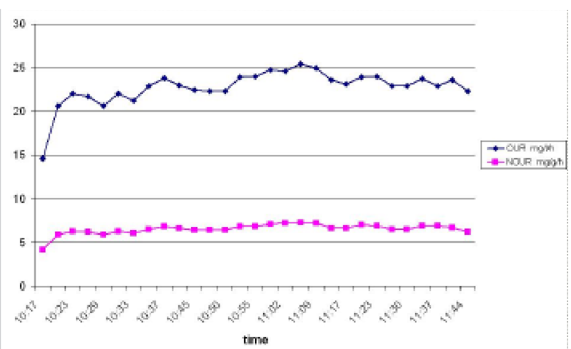


**Figure 13.**
**Oxygen uptake rate (OUR) and rate of oxygen uptake per unit were converted with an allowance made for the concentration of the activated sludge (NOUR) (the measurement carried out in the nitrification phase)**

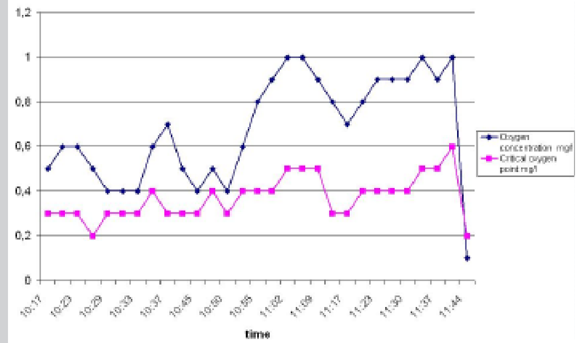


**Figure 14.**
**The concentration of oxygen in the chamber of the activated sludge compared with the critical oxygen point (the measurement carried out in the nitrification phase)**

The summary results of the measurements obtained directly from the respirometer and the oxygen probe are shown in Table 1.

**Table 1.**
**The average values of oxygen concentration [mg $O_2$/dm$^3$] in the chambers of the activated sludge and average critical oxygen point**

| Date | Critical oxygen point | The measurement of oxygen concentration | |
|---|---|---|---|
| | | with the use of the Bioscope respirometer | with the use of the Endress probe |
| 16.04.2010 | 0.5 | 1.34 | 1.66 |
| 22.04.2010 | 0.66 | 1.36 | 1.76 |
| 11.05.2010 | 0.48 | 0.90 | 1.76 |
| 14.05.2010 | 0.37 | 0.70 | n. o. |

## 5. THE MEASUREMENTS OF LABORATORY RESULTS

The comparative speed tests of the oxygen uptake by the activated sludge were conducted with the purpose of confirming the effectiveness of the respirometer. The classical laboratory method, known as the OUR test, was used in order to perform the investigations. The activated sludge had been aerated for approximately 2-3 hours in order to eliminate all easily degradable medium for bacteria. The aerated sludge was poured into a glass bottle placed on a magnetic stirrer. Then raw sewage was addes from primary settling tank in order to ensure the surplus of COD, about 150-200 mg/dm$^3$. Then the measurements of the oxygen concentration with the use of the oxygen probe was performed. The results were read every 10 seconds for approx. 10 minutes or until having reached oxygen concentration below 0.4 mg/dm$^3$. The obtained results were as follows: 36 mg$O_2$/dm$^3$/h for OUR, 9.6 mg$O_2$/g s.m./h for NOUR and are concurrent with the tests results carried out using the Bioscope respirometer.

## 6. THE RESULTS FROM PERFORMED INVESTIGATIONS

After the analysis of the graphs plotted on the basis of the investigations results, it was found that there are differences between the critical amount of oxygen and the actual oxygenation of the chambers. Also the relation between the changes in the oxygenation at the chamber and the respiratory activity of the activated sludge and the critical concentration of oxygen was noticeable. One might assume that conducting the investigations at one particular spot for a long time, regardless of the season, summer or winter, will enable determination of optimal concentration of oxygen necessary to nitrification. These data concern the critical oxygen point and the actual oxygenation of the chambers. In case when the value of critical oxygen point is higher than the concentration of the oxygen in the chambers, the increase in the amount of the provided air is necessary. The critical oxygen point designated using the Bioscope respirometer, amounts from 0.4 to 0.7 mg $O_2$/dm$^3$, with the initial concentration of about 1.2 mg $O_2$/dm$^3$ registered by the oxygen probe installed in the device. This parameter ranged depending on the hours of the preformed measurement and the duration of the phase. Low value of the critical oxygen point indicates low oxygen demand of the activated sludge used in the chambers of the biological wastewater treatment plant in Rybnik-Orzepowice. According to literature data, an average oxygen demand of the activated sludge amounts to 2 mg $O_2$/dm$^3$. In order to provide the optimal conditions for the nitrification process, it is necessary to check if nitrification will progress properly with the oxygen concentration of about 1 mg $O_2$/dm$^3$. The amount of the dissolved oxygen should be tested in real conditions, and simultaneously the speed of the nitrification process should be determined on the basis of the online measurements from the ammonia nitrogen probes.

A reduction in oxygenation from 2 to 1 mg $O_2$/dm$^3$ will cause a decrease in the object operating cost by the expenses decrease for electric energy (Sadecka, 2010).

## ACKNOWLEDGEMENT

The following article was drew up within a framework of the targeted project No 6 ZR7 2008C/07051 entitled "The increase in biogene reduction through the optimisation of the biological waste-water treatment process in Rybnik-Orzepowice waste-water treatment plant".

## REFERENCES

[1] *Aspraya T.J., Carvalhoa D.J.C., Philp J.C.*; Application of soil slurry respirometry to optimise and subsequently monitor ex situ bioremediation of hydrocarbon-contaminated soils. International Biodeterioration & Biodegradation, No 60, 2007; p.279-284

[2] *Davies P.S.*; The Biological Basis of Wastewater Treatment. Strathkelvin Instruments Ltd., 2004

[3] *Gray N.F.*; Biology of Wastewater Treatment. Imperial College Press, Scotland, 2004

[4] *Kunicki-Goldfinger W.J.H.*; Życie bakterii (Life of bacteries). Warszawa, Wydaw. Naukowe PWN, 2008 (in Polish)

[5] *Miksch K., Sikora J., Surmacz-Górska J.*; Kilka mitów i prawd o nitryfikacji (Several myths and truth about nitryfication). Forum Eksploatatora, No 3, 2010 (in Polish); p.112-115

[6] *Okutman Tas D.*; Respirometric assessment of aerobic sludge stabilization. Bioresource Technology, No 101, 2010; p.2592-2599

[7] *Schlegel H.G.*; Mikrobiologia ogólna (General microbiology). Warszawa, Wydaw. Naukowe PWN, 2005 (in Polish)

[8] *Zuojun N., Gilles P.M., Spanjers H.*; Identification and quantification of nitrogen Nutrient deficiency in the activated sludge, process using respirometry. Wat. Res., Vol.34, No 13, 2000; p.3345-3354

[9] *Sadecka Z.*; Podstawy biologicznego oczyszczania ścieków (Foundations of biological sewage treatment). Warszawa, Wydaw. Seidel-Przywecki Sp. z o.o., 2010 (in Polish)