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APPLICATION OF ON-LINE RESPIRATORY MEASUREMENT FOR WASTEWATER TREATMENT PLANTS CONTROL

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Abstract: In order to keep the WWTP performance under control and to make decisions of minimizing the potential influence of wastewater components on the stable and proper WWTP operation, the devices for on-line control of oxygen uptake rate were designed and manufactured. The devices were used for three aims:

- controlling the presence of harmful substances for microorganisms in raw wastewater (Toximeter),
- assessment of the real physiological condition of activated sludge in the aeration chamber (Activmeter),
- determining of the effects of activated sludge settling properties deterioration and its influence on the secondary clarifiers operation as well as microorganisms presence in treated wastewater (Sedimeter).

The results confirmed that the devices are helpful for the WWTP operators as an early warning system and enable optimal decisions making.

INTRODUCTION

The wastewater treatment plant (WWTP) performance depends on suitable process design, quality of installations and devices as well as the plant operation and its maintenance. The latter one requires the professional knowledge from the treatment plant workers combined with their wide experience. Even the most sophisticated instrumentation cannot replace the professional staff at the wastewater treatment plant; however, the appropriate measurements' application can make the control easier and can support the decision making.

The biological part of the wastewater treatment plant is the most vulnerable to different factors. Therefore, because of the fluctuation of raw wastewater composition and especially the presence of toxic substances, it is really substantial to detect these substances early in the influent to the treatment plant. It should allow finding the institution which is responsible for pollution by the samples' analysis right after receiving the sign about the toxic substances in raw wastewater. Moreover, some activities may be underta-

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ken which would diminish the negative influence of toxic substances on microorganisms involved in wastewater treatment.

Different methods can be applied for wastewater toxic effect assessment [1, 6]. In this field, respirometric measurements are widely used, especially oxygen uptake rate (OUR) by microorganisms [3]. In the past, these measurements were used for the chemical compounds toxicity assessment in experiments performed on the laboratory scale [7, 12]. Nowadays they are adapted to continuous control of toxic substances in raw wastewater [5, 10, 11]. Basing on this control treatment process can be operated [9].

Usefulness of the respirometric measurements for raw wastewater toxicity control has been proved and now the specialists' efforts are focused on the reliability of the devices for these measurements and the decrease of manufacturing costs. The reliability of the devices applied on the laboratory scale does not generate problems. However long-lasting and reliable performance of the devices on technical scale at the wastewater treatment plant is still adding to designers' and scientists' troubles. Therefore there is not a lot of information about long-term full-scale optimization of such a toxicity control [2, 4].

METHODS

In this research, two types of device – laboratory and technical, operating in the same way were used. In both devices main measurement was carried out in the reactor, where in the activated sludge samples, taken from the aeration chamber, the decrease of dissolved oxygen was registered. Based on this measurement oxygen uptake rate (OUR) was calculated and expressed in mg O_2/dm^3h. In the laboratory scale device, the reactor and the programmable logic controller (PLC) were separated but in the technical scale one both parts of the device were integrated in one. Designed and manufactured devices for WWTP on-line control base on oxygen uptake rate measurements and give three possibilities (Fig. 1):

- located at the inlet to WTTP they allow to warn of toxic substances in raw wastewater (Toximeter),

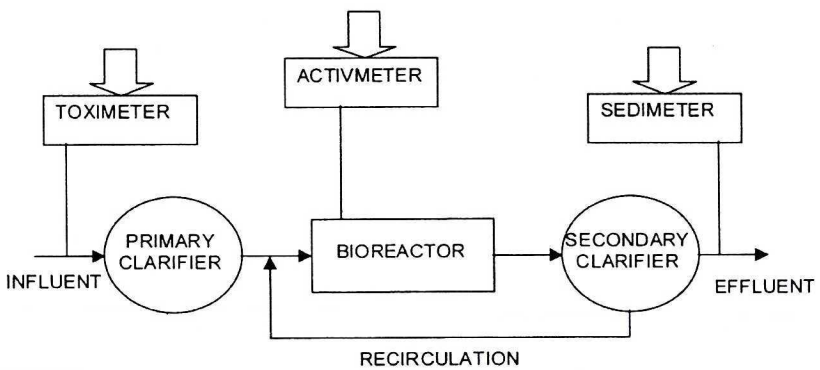

Fig. 1. Location of the devices for on-line WWTP performance control

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- located directly in aeration chamber they allow to follow very easily the activity of microorganisms and to optimize their work (Activmeter),
- located at the outlet of WWTP they allow to control secondary clarifiers performance by detection of the activity of microorganisms in treated wastewater (Sedimeter).

Although the rule of the devices' operation was the same in all three cases, they differed in the operation parameters in each case. In Toximeter activated sludge taken from the recycle of secondary clarifier was aerated and then mixed with the experimentally defined portion of raw wastewater. After aeration had finished the measurement of dissolved oxygen uptake was started. When directly proportional decrease of dissolved oxygen concentration was reached, the mean value of oxygen uptake rate was calculated by the PLC. This measurement cycle was repeated with the frequency chosen by WWTP operator. It could not be shorter than the mean measurement time (a few minutes), but the most frequently it was from 10 to 15 minutes. Toximeter was tested for a few years in three large WWTPs in Upper Silesia region. When the device was used for the control of real physiological condition of microorganisms in the aeration chamber (Activmeter) as well as for the evaluation of secondary clarifier's performance (Sedimeter) the OUR was measured directly in the samples withdrawn from the aeration chamber or the effluent of secondary clarifier. In the last case the measurement lasted much longer because of smaller oxygen uptake by not numerous microorganisms present in the effluent.

RESULTS AND DISCUSSION

Before the technical version was constructed, the device was applied in the laboratory scale experiments as Activmeter [8]. Influence of single doses of toxic substances on the activated sludge was controlled. The effects of substrate overloading directly aeration chamber were measured by use of this device as well. The results were achieved in the model, ideal conditions because no changeable technological parameters were established in the aeration chambers. However, the construction of the device for technical application was the terminal goal of the research. Presented results concern the data collected from the device testing period at the municipal WWTP in the city of the population over 100 000.

If toxic substances were not present in the raw wastewater, Toximeter performance reflected daily changes in substrate load entering the WWTP (Fig. 2). It is well visible that in the consecutive days OUR changed in a regular way. The uptake increased rapidly in the morning hours then reached stable values and after midnight was steadily decreasing to the lowest values of the very morning hours. It is remarkable that on the third day the temporary increases in the oxygen uptake were observed but they did not result in permanent changes in condition of the activated sludge.

The collapse of the daily rhythm of oxygen uptake changes is shown in Figure 3. After the typical run of the oxygen uptake on the first day, a sharp decrease of the uptake was noticed around 3 p.m. The question, whether toxic substance or substrate overloading was responsible for the break-down, can be answered by analyzing the further run of the oxygen uptake changes. After a temporary decrease, the oxygen uptake increased again to

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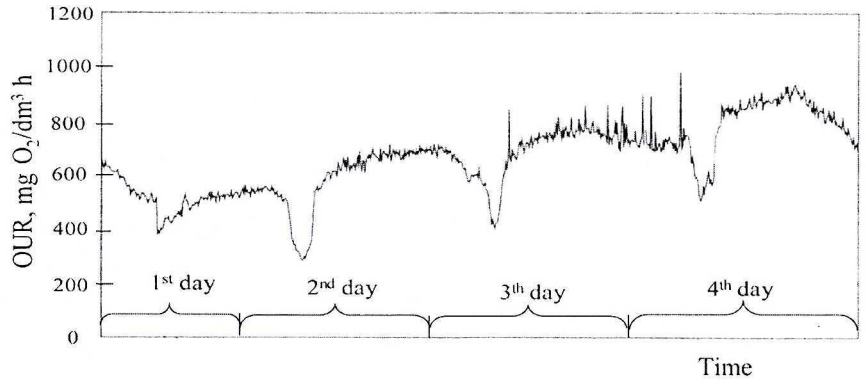

Fig. 2. A typical curve of the OUR

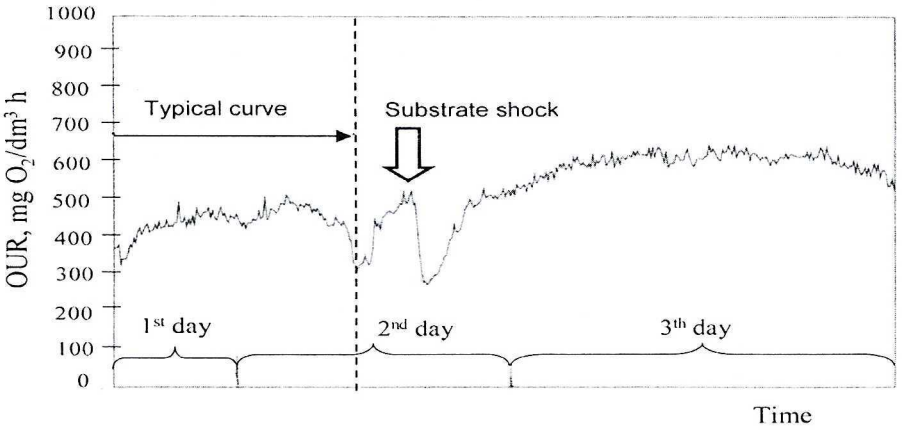

Fig. 3. Disturbance of typical OUR by substrate shock or toxic substance

the previous values but its further changes were not typical. The uptake did not diminish after midnight. Microorganisms present augmented activity resulted from the presence of higher amounts of substrate in coming wastewater.

Therefore, none of the toxic substance was a reason of the microorganisms' activity collapse but of a sudden increase of substrate in the raw wastewater (loading shock). In the described case the changes in the oxygen uptake informed about substrate loading fluctuation in the influent and they did not decrease wastewater treatment effects. However, in the second case the oxygen uptake changes were similar, first the decrease and then the increase of uptake to previous values was noticed, but the nitrogen compounds removal was disturbed. Generally, ammonia and nitrate nitrogen in the treated wastewater did not exceed values of 3 and 6 mg N/dm^3 respectively. However, when the oxygen uptake decreased, the increase of ammonia nitrogen to value of 14 mg/dm^3 was observed at the unchanged concentration of nitrate nitrogen (5.8 mg/dm^3). The next day ammonia nitrogen concentration went down even to the lower value than the previous one but

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nitrates concentration went up to 8.6–10.8 mg N/dm^3. In both cases the oxygen uptake rate measurements gave information about the untypical raw wastewater composition, which could affect microorganisms' activity and in the same way influence the WWTP's performance.

Therefore, the measures could be taken in order to protect the WWTP against disturbances in the plant operation; for instance raw wastewater could be directed to one aeration chamber whereas the remaining chambers would be protected. It should be taken into consideration that Toximeter information about the disturbances was overestimated. The measurements reflected influence of high doses of substrate. In practice, such high doses are not observed because of dissolution of raw wastewater in the aeration chambers. Therefore, for each WWTP, basing on the measurements of the oxygen uptake rate, the typical rhythm and fluctuation of the uptake values should be estimated along with undesired and dangerous deviations from the typical state. If such high concentrations responsible for the microorganisms activity changes appear, the oxygen uptake measurements in aeration chamber by use of Activmeter will inform about it.

Toximeter placed at the WWTP has an extra advantage. It informs about improper raw wastewater's composition and additionally gives the sign for withdrawal and the protection of raw wastewater samples in order to detect the institution responsible for pollution. Withdrawn samples' analysis could show what kind of substance appeared in wastewater and who was responsible for its presence in the sewage. It is particularly essential at the WWTPs where the automatic autosamplers are not installed. This situation is observed very often at the Polish WWTPs. Psychological aspect of Toximeters' application at the WWTPs should be also taken into account and information about its installation should be disseminated by the local mass media. It prevents the potential "poisoners" from bringing the improper wastewater in the sewage system. Until now, in Poland the majority of the disturbances in the WWTPs operation resulted from the toxic substances' disposal into the sewage systems during week-ends, when the analytical laboratories at WWTPs do not work. The knowledge about the raw wastewater's composition continuous control by Toximeter considerably restrains the activity of "poisoners".

The proper WWTP operation is disturbed very often by of affected structure of the activated sludge flocks. Bulking sludge or too strong dispersion of flocks can be responsible for this phenomenon. Both these reasons result in non-effective work of secondary clarifiers and the presence of microorganisms in the treated wastewater. This disturbed clarifiers operation can be also detected by the measurements of the oxygen uptake rate.

The measured oxygen uptake is much lower than that in the aeration chambers but sufficient to be registered. This case is shown in the Figure 4. It is visible that within two dates (the 22nd of May and the 4th of June) microorganisms were present in the effluent. While it is true that suspended solids in treated wastewater can be measured by means of other methods e.g. as a turbidity, the measurements of the oxygen uptake can show whether it is an active biomass or only inert suspended solids. This information is essential in the case of the nitrifiers, which are freely swimming bacteria, easily washed out from the WWTP, and this way they increase troubles with nitrification.

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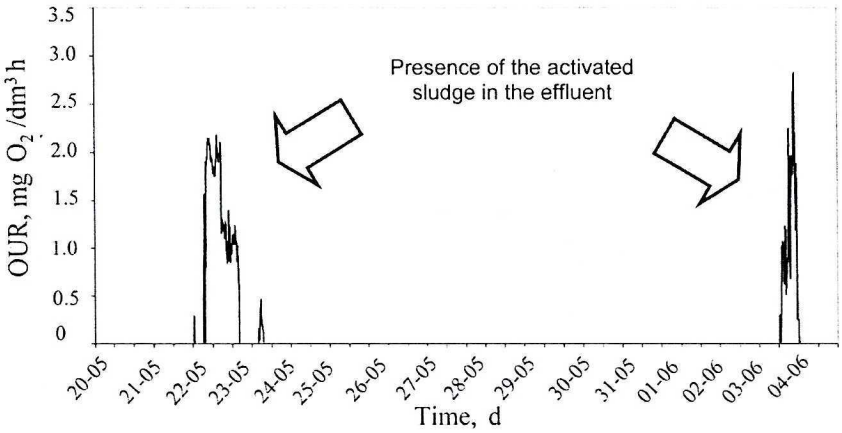

Fig. 4. Results obtained during measurement by Sedimeter

CONCLUSIONS

The device for the oxygen uptake rate measurements allows to:

- control the presence of harmful substances for microorganisms in raw wastewater,
- assess the real physiological condition of activated sludge in the aeration chamber,
- determine the effects of activated sludge settling properties deterioration and its influence on the secondary clarifiers operation as well as microorganisms presence in treated wastewater.

These three applications of the device for the oxygen uptake rate measurements allow to keep the WWTP performance under control and to make decisions minimizing the potential influence of wastewater components on the stable and proper WWTP operation.

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WYKORZYSTANIE CIĄGŁYCH POMIARÓW ZUŻYCIA TLENU DO KONTROLI PRACY OCZYSZCZALNI ŚCIEKÓW

Efekt oczyszczania ścieków zależy od właściwego zaprojektowania, wykonania i eksploatacji oczyszczalni. Ze względu na zmienność składu ścieków surowych, a w tym obecność związków toksycznych, bardzo istotne dla stabilnej pracy oczyszczalni jest wcześniejsze wykrywanie obecności tych składników w dopływających ściekach. Powinno to pozwolić na ustalenie ewentualnego sprawcy zagrożenia przez pobór próbek do analizy z chwilą pojawienia się sygnału o obecności związków toksycznych dopływających w ściekach, jak również na podjęcie zabiegów niwelujących ich wpływ na biologiczny stopień oczyszczalni ścieków. Do oceny toksycznego efektu składu ścieków wykorzystać można bardzo różne metody. Zaprojektowany uniwersalny aparat do ciągłego oznaczania aktywności mikroorganizmów umożliwia stały i skuteczny nadzór nad oczyszczaniem ścieków. Zasada działania aparatu polega na pomiarze tzw. aktywności metabolicznej drobnoustrojów, której miarą jest szybkość zużywania tlenu na ich procesy życiowe. Aparat ten spełniać może trzy odmienne role:

- umiejscowiony bezpośrednio w bioreaktorze, w którym zachodzą procesy oczyszczania informować będzie o aktualnej „kondycji" drobnoustrojów i jej wahaniach (aktywometr);
- umiejscowiony na kanale dopływowym ścieków surowych może informować o zawartych w nich sub-