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Enhancement of biological wastewater treatment by magnetic field exposure

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Abstract

In this work the results of investigation on the effect of magnetic field of induction 40 mT on organic compounds removal were presented. Moreover the transformation of nitrogen compounds and the oxygen uptake rate of nitrifying microorganism in activated sludge wastewater treatment process was determinated.

The experiments were performed at temperature 14 ± 1°C in two simultaneously operating laboratory activated sludge plant units. In one of the unit a pair of permanent magnets was installed on the pipe using to recycle of activated sludge from the secondary clarifier to the aeration vessel. The second was a control unit.

The data show that COD removal for unit where the activated sludge return was exposed to magnetic field was as higher as for control unit. However the analysis of nitrogen compounds transformations shows that elimination of organic nitrogen compounds was more effective for unit with magnets. The confirmation of more intensive nitrogen compounds transformations is also higher nitrification rate for unit where magnets were installed as compare with the unit without magnetic field application. The studies on oxygen uptake rate of activated sludge microorganisms show also that the nitrification process was more effective for unit with magnets.

Keywords: Magnetic field; Biodegradation; Activated sludge; Nitrification

1. Introduction

The new methods to intensification elimination of waste water pollution, which not required extension of existing plants or building very expensive bioreactors, are still searching. In recent years increasing attention has been directed to the possibility of improvement of waste water treatment by static magnetic field.

The scarce information is available on the effect of magnetic field (MF) on biodegradation process of wastewater organic substrates, especially transformations of nitrogen compounds. The strength of MF which should be use to

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improve biological process of wastewater treatment is real problem, which has not been solved. The range of MF induction noted by researchers is wide and varies from 7 to 490 mT [1–5].

Jung and Sofer [1] showed that application of MF at induction of 150 and 350 mT improved of phenol biodegradation by using immobilized activated sludge. Mentioned authors used unipolar south MF. Already, in the earlier studies Jung et al. [2] showed the positive effect of MF on phenol biodegradation but at induction of 490 mT. Yavuz and Çelebi [3] demonstrated that MF of 17.8 mT induction generated by direct current supplied solenoid supported glucose biodegradation with activated sludge action. Łebkowska [4] showed also that, static MF at induction in the range from 5 to 140 mT generated by electromagnet coils intensified of biodegradation process by activated sludge for majority of testing organic substrates. Rutkowska-Narożniak [5] observed that MF at induction of 7 mT generated by permanent magnets was a factor improving *p*-nitroaniline biodegradation by microorganisms inhabiting activated sludge. Further, she also observed that MF had a positive effect on nitrification process.

The aim of this work was determination of treatment efficiency of synthetic sewage similar to domestic sewage by periodic influence on recirculated activated sludge by 40 mT MF generated by permanent magnets.

2. Materials and methods

The activated sludge was collected from the Municipal Wastewater Treatment Plant located in Poland was used in this study. The synthetic, domestic-like sewage, called as raw sewage was composed of: peptone – 110 mg, bouillon – 110 mg, K_2HPO_4 – 28 mg, NaCl – 7 mg, $CaCl_2 \cdot 2H_2O$ – 4 mg, $MgSO_4 \cdot 7H_2O$ – 2 mg, CH_4N_2O – 20 mg, NH_4Cl – 20 mg, tap water – 1 dm^3 was treated.

The concentration of organic substrates in raw sewage was changed to obtain a required COD value. Also were changed the mineral substrates concentrations. The $CO(NH_2)_2$ and NH_4Cl concentration in raw sewage were constant.

The experiments were performed in two simultaneously operating laboratory systems. Each of the systems consisted of: 3.7 dm^3 aeration vessel, a secondary clarifier, dosing pumps for raw sewage and for recirculated activated sludge, an air pump and storage vessels for raw sewage (influent) and effluent. The total capacity of individual laboratory system was 5.8 dm^3. In the first system a pair of permanent magnets was installed on the pipe used to recirculation of activated sludge from the secondary clarifier to the aeration vessel. The installation method of permanent magnets caused, that MF influenced only on activated sludge return. The test system, where the activated sludge return was exposed to MF, was named as system M. The second system used as a control was noted — system C. The scheme of laboratory system considering the installation place of a pair of permanent magnets is given in Fig. 1. The permanent magnets were located provide that maximum MF induction of 40 mT along pipe axis used to recirculation of the activated sludge. Between magnets the glass pipe with diameter 5 mm was central located. Installation with magnets was scaling (with measurement accuracy ±5%) by using gaussmeter.

For raw sewage and effluent from aeration vessel COD, total Kjeldahl, ammonia [6], nitrite and nitrate nitrogen [7] were determined. For activated sludge suspended solids and dissolved oxygen concentration were determined [6]. The biodegradation process was controlled on the base of the oxygen uptake rate measurements for nitrifying microorganisms [8].

The research carried out in temperature in the range from 13 to 15°C during 20 days. The process was led keeping beneficial sludge age for nitrification process in the range from 15 d to 10 d. The dissolved oxygen concentration in the aeration vessel was kept above 2 mg O_2/dm^3. The other process parameters and pollution

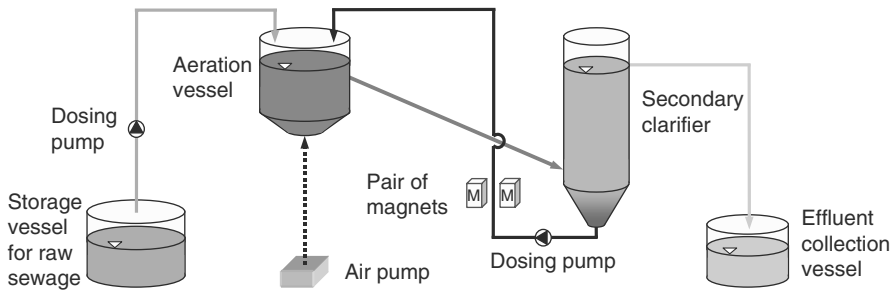

Fig. 1. The scheme of laboratory system with the location of permanent magnets pair installed on the pipe for recirculation of activated sludge.

Table 1
The process parameters of wastewater treatment and contaminations concentration of raw sewage

Parameters		Contaminations concentration	
Aeration period, h	5	COD, mg/dm^3	223 ÷ 536
		Organic nitrogen, mg N_{org}/dm^3	22.4 ÷ 53.8
Sludge age, d	13 ÷ 12	Kjeldahl nitrogen, mg N_{Kj}/dm^3	37.3 ÷ 67.9
		Ammonia nitrogen, mg N-NH_4^+/dm^3	10.2 ÷ 25.5
Activated sludge loading, g COD/gMLSS d	0.43 ÷ 0.78	Nitrite nitrogen, mg N-NO_2^-/dm^3	0.86 ÷ 3.15
		Nitrate nitrogen, mg N-NO_3^-/dm^3	1.86 ÷ 7.4

concentration in the raw sewage is shown in Table 1.

3. Results and discussion

The activated sludge periodical exposure to the MF did not cause intensification of organic pollution removal. The tests showed that COD elimination was high in the system in which the activated sludge was periodically exposed to MF as well as in the control system (kept in the range from 78 to 88%) — Table 2. The works of other authors using MF strength in the wide range from 5 to 460 mT show that MF is an intensifying factor for organic substrate degradation. However, these studies focused on the biodegradation of industrial wastewater [1,2,4,5].

The analysis of nitrogen compounds transformations shows that elimination of organic

Table 2
The COD removal efficiency

System	Unit	Measuring days																
		1	2	3	4	5	7	8	9	10	11	13	14	15	16	18	19	20
M	%	78	82	81	82	83	79	82	82	84	86	85	86	84	85	87	86	87
C		80	82	82	83	81	81	84	84	86	84	85	84	88	84	87	85	88

Table 3
Changes in the removal of nitrogen compounds in the sewage treatment process

Parameter	System	Unit	Measuring days																
			1	2	3	4	5	7	8	9	10	11	13	14	15	16	18	19	20
Organic nitrogen	M	%	96	97	97	96	96	96	97	96	93	93	95	92	94	95	92	93	91
	C		90	92	90	87	86	93	90	90	85	83	88	85	77	79	83	82	87
Kjeldahl nitrogen	M		92	93	90	94	90	84	86	85	80	81	79	79	70	76	72	73	73
	C		84	81	81	78	78	76	75	75	71	67	68	65	57	60	60	62	66

and Kjeldahl nitrogen was more effective in system with magnets. The elimination of Kjeldahl nitrogen for system M was higher from 7 to 16% compared with control test and kept in the range from 91 to 97%, and for system C from 82 to 96%, respectively (Table 3).

In every measuring day the organic nitrogen lower than from 1.5 to 4 times in system M in relation to system C was noted (Fig. 2). Confirmation of more intensive nitrogen compounds transformations for system where magnets were installed is also higher nitrification rate expressed as a sum of nitrite and nitrate nitrogen amounts produced in the biodegradation process in relation to retention time. Changes of the nitrification rate calculated in this way related to sludge load are shown in Fig. 3. The studies on oxygen uptake rate of activated sludge microorganisms show also that the nitrification process was more effective for system M. In every measuring day the oxygen uptake rate of second nitrification phase was higher from 1.6 to 2.1 times for system where the activated sludge was exposed to MF compared to system C (Fig. 4).

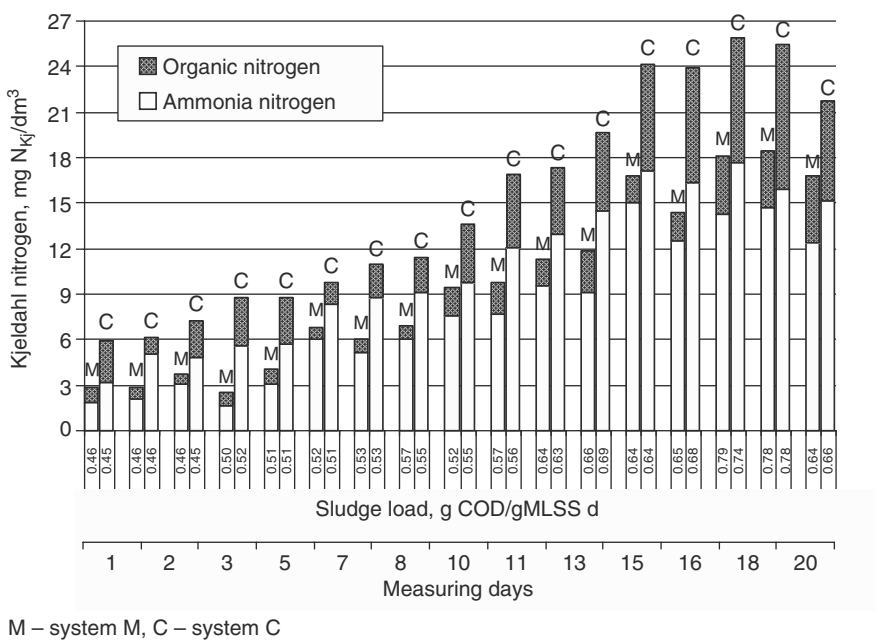

Fig. 2. Changes of the Kjeldahl nitrogen concentration in relation to activated sludge load in measuring days.

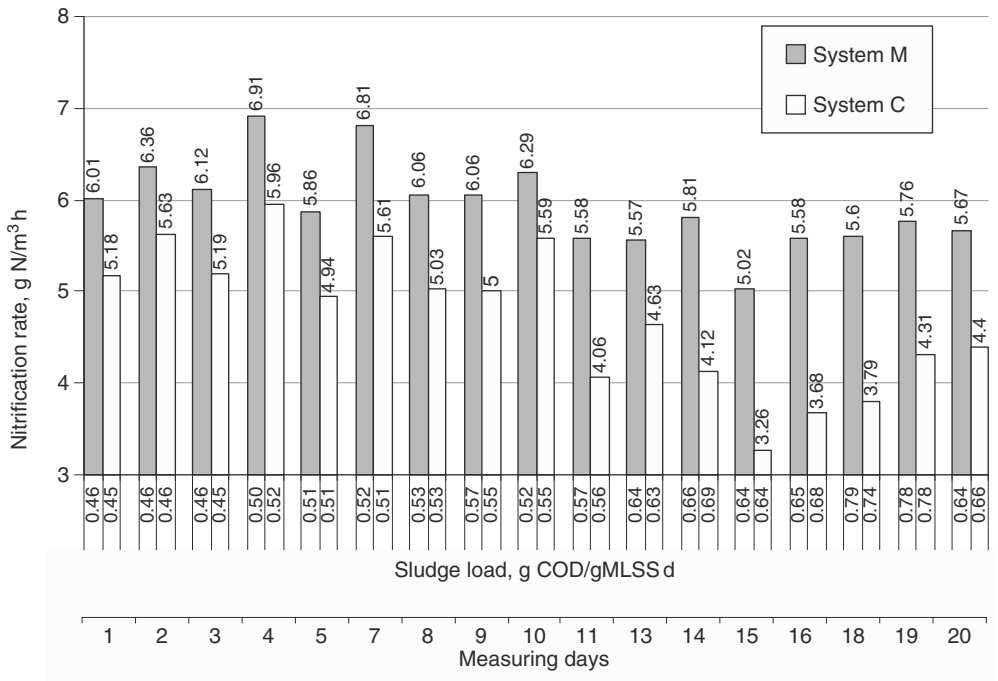

Fig. 3. The nitrification rate in relation to the activated sludge load during the measuring days in the sewage treatment process.

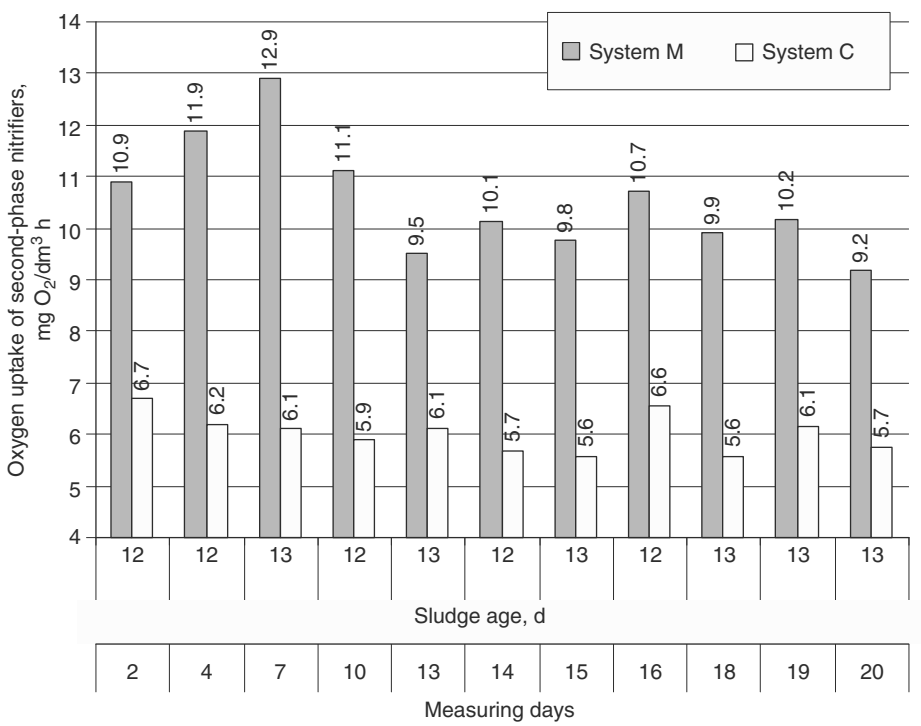

Fig. 4. The oxygen uptake of second-phase nitrifiers in relation to the sludge age during the measuring days.

Rutkowska-Narożniak demonstrated also that nitrification processes were more intensive for system where MF was applied but at induction of 7 mT. Author observed 10 times increase of nitrates formation for exposed test compared to the control test [5]. However, it is important that activated sludge microorganisms were treated with magnetostatic installation of continuous exposure which was installed directly on the aeration vessel. In contrast to investigation of Rutkowska-Narożniak [5] in our tests the activated sludge microorganisms were treated during the transport by recirculating pipe, so it was a periodical action.

4. Conclusions

- The periodical exposure to MF of 40 mT induction by using permanent magnets not affected on COD removal from sewage of composition similar to domestic.
- The nitrogen compounds transformations were more effective for system where activated sludge was periodically exposed to MF of 40 mT induction compared with the control system.
- The periodical exposure of activated sludge to MF of 40 mT induction intensified the oxygen uptake rate of second-phase nitrifiers.

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