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EFFECT OF THE ADDITION OF PRIMARY PREFERMENTED SLUDGE INTO BIOLOGICAL BIOREACTORS ON THE DENITRIFICATION AND PHOSPHORUS REMOVAL PROCESSES

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Abstract. The work presents the results obtained in the pilot installation BIODEN for denitrification and phosphorus removal from urban waste water additioned with prefermented primary sludge hydrolisate as a supplementary organic source. The pilot installation is equipped with vessels for primary sludge anaerobic fermentation, denitrification, phosphorus removal, primary and secondary settlers. Efficiencies of 80-90% for NO_3 reduction and 60-84% for total P removal were obtained. The average N-NO_3 removal rate was 0.076 mg N-NO_3/mg volatile suspended solids per day and average total P removal rate was 0.06 mg tot. P/mg volatile suspended solids per day. Our results were comparable with those obtained by Cuevas-Rodriguez and Pavan et al. in a laboratory installations fed with urban waste water supplemented with prefermented primary sludge.

Keywords: denitrification, phosphorus removal, prefermented primary sludge.

AIMS AND BACKGROUND

The results obtained in other countries show that primary sludge prefermenters integration into the urban treatment plants is feasible and provides good performances of nitrate and phosphorus removal processes[1].

Fundamental studies regarding the acidification of primary sludge were conducted by Eastman and Fergusson (1981) and Concalves (1984) in the Eureka framework. Practical applications of prefermented process precede the laboratory research.

Today, in the urban treatment plants (Barnard and Rabinowitz, 2000) four types of prefermenters are used. Prefermenter in function at Kelowna, Westbank and Bonnybrook plants contributes to enrichment of waste water in volatile fatty acids with 5-25 mg/l. These values are comparable to those reported by Oldham and Abraham (1984) for Penticton and Kalispell plants.

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Production of volatile fatty acids varies between 0.08 and 0.25 kg/kg volatile suspended sdids (v.s.s.) in single step prefermentes and attains 0.067 kg/kg v.s.s. in two steps prefermenters.

The laboratory experiments conducted by the authors cited in Refs 2-5 fundament primary sludge addition upon the nitrates and phosphorus advanced removal by increasing the C/N and C/P rations.

Our experiments were conducted in order to evaluate the performances of pilot installation BIODEN, designed on the basis of previously technological parameters elaborated[6,7].

EXPERIMENTAL

The BIODEN experimental installation (Fig. 1) was designed in order to intensify the denitrification and phosphorus removal processes, by addition in denitrification vessel (anoxic) and from here in anaerobic and aerobic vessels for phosphorus removal of the primary prefermented sludge hydrolisate. The main technological phases performed in pilot installation are:

- primary sludge prefermentation;
- denitrification;
- phosphorus removal (anaerobic and aerobic phases);
- secondary sedimentation.

The waste water stored in feeding vessel is conducted by pumping into anoxic denitrification vessel. In the same vessel prefermented sludge from primary lamellar settler flows gravitationally, and excedentar activated sludge by pump-

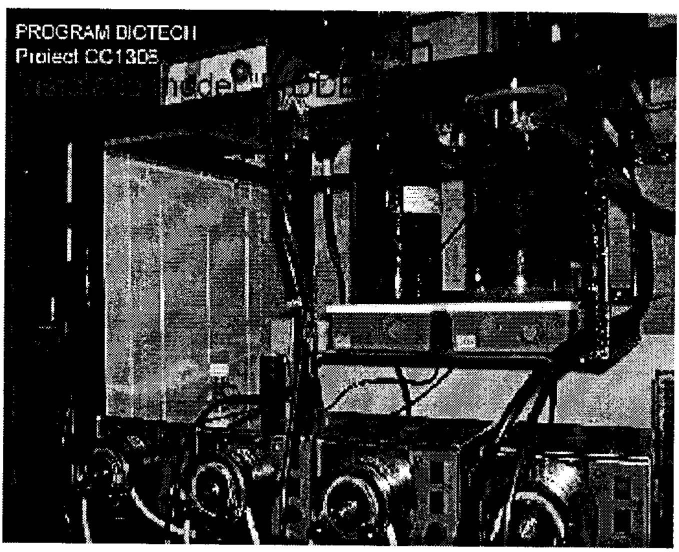

Fig. 1. BIODEN pilot installation (general view)

ing from secondary settler. The denitrification vessel is covered and its content is mixed with a magnetic stirrer. After denitrification, the waste water flows gravitationally in the anaerobic vessel which is covered and which content is mixed with a magnetic stirrer. From anaerobic vessel, waste water flows gravitationally in aerobic reactor. The phosphorus removal process was performed in the anaerobic and aerobic vessels. The air from compressor is uniformly distributed at the bottom of the aerobic vessel through a laser perforated membrane.

Mixed liquor flows gravitationally into secondary settler, after denitrification and phosphorus removal. The treated effluent is collected in a vessel for treated waste water.

Primary sludge, stored and homogenised by magnetic stirring, is pumped in fermentation reactor. The pump is operating controlled by programmable logic controller (PLC).

Fermented sludge flows gravitationally in lamellar primary settler. The more dense part is recirculated in the fermentation reactor with a dosing pump, and clarified liquid flows gravitationally into denitrification reactor.

The BIODEN installation was seeded with a mixture of activated sludge adapted to sequential nitrification-denitrification processes and to phosphorus removal process. The total suspended solids concentration in the reactors was maintained at 3 g v.s.s./l. The BIODEN installation was fed with urban waste water withdrawn from Bucharest general collector Glina.

The prefermenter was fed with primary sludge, drown from the Pitesti treatment plant, diluted at 1:10 ratio with urban waste water.

BIODEN installation was monitored by daily influent and effluent analyses for indicators: pH, COD, BOD, NH_4^+, TKN, NO_2^-, NO_3^-, tot. P. The effluent analysed samples were 24 h composite samples.

RESULTS AND DISCUSSION

In order to emphasise BIODEN installation performances, working data (Tables 1 and 2) served as data base for estimating the efficiencies of denitrification and phosphorus removal processes (Table 3) and removal rates of N-NO_3^- and tot. P (Table 4). Feeding water of installation (Table 1) has a relative small organic load, varying between 125 and 20 mg O_2/l, values comparable with TKN values and lower than NO_3 concentration resulting from nitrification process. As consequence, feeding water did not assure the necessary organic load for denitrification process. Phosphorus content of feeding water, which is equal or lower than 2 mg/l, did not raise special treatment problems. The prefermented sludge hydrolysate (Table 2) brings into the denitrification and phosphorus removal vessels a significant contribution in organic load. As we showed in earlier works, in the primary settler of the Pitesti municipal treatment plant, there is not only

Table 1. Experimental results obtained in BIODEN pilot

Date	pH		COD (mgO_2/l)		BOD (mgO_2/l)		TKN (mg/l)		NO_3^- (mg/l)		Total P (mg/l)	
	infl.	effl.	infl.	effl.	infl.	effl.	infl.	effl.	infl.	effl.	infl.	effl.
27.01.	7.61	8.62	124.8	67.2	27.5	4.08	28.0	16.46	40.7	27.3	2.0	1.9
28.01.	7.61	8.99	124.8	85.5	27.5	5.02	28.0	18.56	40.7	26.6	2.0	1.3
29.01.	7.61	8.17	124.8	38.4	27.5	8.1	28.0	19.61	40.7	36.58	2.0	2.33
30.01.	7.61	7.99	124.8	14.4	27.5	3.4	28.0	26.6	40.7	33.28	2.0	1.0
3.02.	7.61	8.07	124.8	48	27.5	11.41	28.0	19.6	40.7	15.6	2.0	2.4
4.02.	7.61	7.91	124.8	76.8	27.5	15.71	28.0	10.8	40.7	16.2	2.0	1.11
10.02.	8.78	8.44	28.8	67.2	6.5	12.8	28.0	20.3	14.13	18.2	2.0	13
11.02.	8.78	8.17	28.8	76.8	6.5	14.8	28.0	17.51	14.13	33.25	2.0	1.6
12.02.	8.78	8.18	28.8	67.2	6.5	12.9	28.0	9.81	14.13	30.62	2.0	1.7
13.02.	8.78	8.89	28.8	72.0	6.5	14.5	28.0	9.1	14.13	27.34	2.0	1.66
17.02.	8.87	8.7	96	19.2	33.5	3.74	19.6	14.0	13.0	20.10	1.77	0.99
18.02.	8.87	8.13	96	19.2	33.5	4.33	19.6	9.1	13.0	28.3	1.77	1.00
19.02.	8.87	8.16	96	67.2	33.5	12.58	19.6	4.9	13.0	31.88	1.77	1.00

Table 2. Characteristics of feeding water (Glina general outflow) and denitrification vessel's feeding water (feeding water) supplemented with prefermented sludge hydrolisate)

Date	Sample	pH	COD (mgO_2/l)	BOD (mgO_2/l)	TKN (mg/l)	NO_3^- (mg/l)	Total P (mg/l)
27.01.	installation feeding water	7.61	124.8	27.5	28.0	40.7	2.0
	denitrification vessel's feeding water	8.70	1574	208.4	123.3	141	5.4
	supplementary load bring by prefermented sludge	–	1449.2	180.9	95.3	100.3	3.4
10.02.	installation feeding water	8.78	28.8	6.5	28	14.13	2.0
	denitrification vessel's feeding water	8.72	576	720	17.5	191.3	6.0
	supplementary load bring by prefermented sludge	–	547.2	113.5	–	177.17	4.0
17.02.	installation feeding water	8.87	96	33.58	19.6	13.0	1.77
	denitrification vessel's feeding water	8.81	211.2	75.67	122.6	182.9	6.4
	supplementary load bring by prefermented sludge	–	115.2	42.09	103	169.9	4.63

Table 3. Denitrification and phosphorus removal efficiencies performed in BIODEN pilot

Date	Denitrification *			Phosphorus removal		
	influent (NO_3mg/l)	effluent (NO_3mg/l)	denitrification efficiencies (%)	influent total P_1 (mg/l)	effluent total P (mg/l)	phosphorus removal efficiencies (%)
27.01.	192	27.3	85.78	5.4	1.9	64.81
28.01.	182.7	26.6	85.44	5.4	1.3	75.92
29.01.	178.1	36.58	79.46	5.4	2.33	56.85
30.01.	202.9	33.28	83.59	5.4	1.0	80.48
3.02.	178.1	15.6	91.24	5.4	2.4	55.55
4.02.	217.1	16.2	92.5	5.4	1.11	79.44
10.02.	225.4	18.2	91.9	6.0	1.2	80.0
11.02.	237.7	33.25	86.01	6.0	1.3	78.33
12.02.	271.8	30.62	88.73	6.0	1.6	73.33
13.02.	274.9	27.34	90.05	6.0	1.7	71.66
17.02.	207.7	20.10	90.32	6.4	1.66	74.06
18.02.	229.3	28.3	87.65	6.4	1.0	84.3
19.02.	247.9	31.88	87.13	6.4	1.0	84.3

Table 4. N-NO_3 and total P removal rates performed in BIODEN pilot

Day	N-NO_3 removal rates (mg N-NO_3/mg v.s.s./day)	Total P removal rates (mg total P/mg v.s.s./day)
27.01.	0.065	0.0047
28.01.	0.062	0.0055
29.01.	0.056	0.0042
30.01.	0.067	0.0059
3.02.	0.064	0.0041
4.02.	0.079	0.0058
10.02.	0.082	0.0065
11.02.	0.081	0.0064
12.02.	0.095	0.0059
13.02.	0.098	0.0058
17.02.	0.074	0.0064
18.02.	0.079	0.0073
19.02.	0.086	0.0073
Average	0.076	0.0058

the primary sludge but as in the majority of the Romanian municipal treatment plants a mixture of primary and biological sludge. Because of this, prefermented sludge brings into denitrification and phosphorus removal reactors, a supplementary content of nitrogen and phosphorus compounds. The denitrification efficiencies varied between 80-90% (Table 3). Treated effluents have a remanent NO_3^- concentrations under 37.0 mg/l, concentration limit for sensitive areas imposed by NTPA 001/2002.

Phosphorus removal efficiencies varied between 55-84%. Treated effluents have remanent total phosphorus content under 2 mg/l, the limit for discharges in sensitive areas imposed by NTPA 001/2002.

N-NO_3 and total P removal rates (Table 4) were in average 0.076 mg N-NO_3/mg v.s.s./day, respectively 0.0058 mg tot. P/mg v.s.s./day. The maximum N-NO_3 removal rate was 0,095 mg N/NO_3/mg v.s.s./day and of total phosphorus – 0.0073 mg tot. P/mg v.s.s./day.

CONCLUSIONS

The work presents the results of an experiment conducted in pilot installation BIODEN. Pilot installation BIODEN was designed with vessels for primary sludge anaerobic digestion, denitrification (anoxic step) and phosphorus removal (anaerobic and aerobic steps). The experiment was conducted on a time period of 30 days.

By supplementation of Bucharest general outflow samples with hydrolisate of prefermented primary sludge, denitrification and phosphorus maximum removal efficiencies arise to 90%, respectively above 80%.

Average denitrification rate was 0.076 mg $N\text{-}NO_3$/mg v.s.s./day and average phosphorus removal rate was 0.0058 P/mg v.s.s./day.

The obtained data were in accordance with the data of Rodriquez et al.[3] and Pavan et al.[4]

Experimental results demonstrate that proposed technology is feasible and may be applied in the Romanian urban waste water treatment plants.

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