ANAEROBIC TREATMENT OF MUNICIPAL SEWAGE IN THE PSYCHROPHILIC CONDITIONS

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ABSTRACT
Psychrophilic anaerobic process is an attractive option for sewage treated at moderate and low temperature. The article discusses possibilities of municipal sewage treatment in an upflow anaerobic filter (UAF), operated in the psychrophilic conditions. Investigations were carried out in laboratory scale and the temperature of the bioreactor varied between 17- 20ºC. The investigations comprised two series of tests. The values of hydraulic retention time (HRT) amounted to 30 and 48 h. The digestion feedstock comprised of sewage taken from a treatment plant (WWTP Bielsko-Biala, Komorowice), operated in a full scale. The treatment process of sewage with the application of The UAF reactor system has shown positive results in the laboratory scale of studies. The process ensured a high effluent quality - COD < 200 mgO$_2$/dm^3, however, degree of COD removal depended on the value of HRT used.

KEYWORDS
psychrophilic anaerobic digestion, domestic wastewater, UAF, organic pollutants,

INTRODUCTION

Anaerobic digestion is one of treatment methods applied for domestic and industrial wastewaters. The process has many advantages, including a low space requirement, much less waste sludge production, no need for aeration and most importantly, the production of biogas (50 – 80 % methane), as an useable fuel (Lettiga, 1995).

Despite the advantages of the anaerobic treatment, the effluent needs an aerobic post-treatment process for removal of remaining COD, nutrients and pathogens. The characteristic of anaerobic treatment process is presented in Table 1 (Gasparikova et al, 2005).

The post treatment system for the anaerobic effluent should be, like the anaerobic pre-treatment, a high-rate, low-cost and sustainable technology (Gasparikova et al, 2005). Various aerobic systems have been proposed for post-treatment, such as rotating biological contactors (Castillo et al., 1997), down-flow hanging sponge cubes (Machdar et al., 1997), and activated sludge process (Sperling et al., 2001).

Anaerobic digestion allows effective treatment of a variety of industrial wastewater categories: chemical and petrochemical (Macarie, 2000): domestic sewage (Elmitwalli et al., 2001); fruit and vegetable waste (Bouallagui et al., 2005), olive mill solid wastes (Rincon et al., 2006).

Table 1. Characteristic of anaerobic process

Parameter	Anaerobic process
Energy consumption	Low
Construction	Simple
Biomass production	Low
Nutrition demand	Low
Reaction speed	Low
Nutrient removal	Minimal
Starting period	Long

However, the majority of full-scale applications and research effort, until recently, has been concentrated on anaerobic digestion within the mesophilic (25–45 ℃) or thermophilic (45–65 ℃) of temperature ranges. Heating is required to maintain the appropriate mesophilic or thermophilic treatment temperature and therefore is energy intensive and costly. Anaerobic digestion of sewage sludge or waste waters with high concentration of organic matter results permit sufficient production of biogas for heating and marinating the required temperature. Anaerobic processes in low temperature (psychrophilic) and in addition for treatment of municipal sewage with relatively low concentrations of organic matter was so far understood as unrealistic. With the need of energy conservation and required greenhouse gases emission reduction, innovative solutions of sewage treatment are sought. The presented article presents investigation procuring possibilities of feasible low temperature anaerobic fermentation process using an upflow anaerobic filter. Many aspects have to been taken into account. First of all the sewage quality variation of the inflow in terms of pollutants concentration and temperature is an important factor to be considered. Solubility of gases increases in sewage with the decrease their temperature, leaving more methane into effluent than at higher temperatures. Moreover, the higher solubility of carbon dioxide may lower the pH (Lettiga et al., 2001).

Many industrial wastewaters, such as malting (Rebac et al.,1997), brewery (Kato et al., 1999, Connaughtonet al., 2006), food – processing (McHugh et al.,, 2006), pharmaceutical (Enright et al., 2005,2007), winery (Kalyuzhnyi et al., 2001), acidified (McKeown et al., 2009) wastewater are effectively treatmed in low temperature (in psychrophilic conditions). Here however, high organic matter was the advantage.

Nevertheless, the concept to use bioreactors such as various versions of the up-flow anaerobic sludge blanket (UASB) (Bodik et al. 2000, up-flow anaerobic filter (UAF) (Bodic et al. 2000), anaerobic sequencing bath reactor (AnBBR) (Bodik et al. 2000), internal circulation (IC), expanded granular sludge bed (EGSB) (McKown et al. 2009) and EGSB-anaerobic filter (EGSB-AF) bioreactors (Connaughtonet al., 2006), which in part facilitated the successful demonstration of psychrophilic anaerobic digestion (PAD) has inspired the presented investigations.

Repeating again ,the aim of the carried out investigations have be the assessment of possibilities of municipal sewage treatment in the bioreactor - upflow anaerobic filter (UAF), operated in the psychrophilic conditions in the temperature range 17- 20℃.

MATERIALS AND METHODS

The model of UAF, shown in fig.1, was constructed as the plastic tube with 12 litres volume filled in with propylene rings on which a film of microorganisms had grown. The feedstock digestion comprised of the municipal sewage taken from a treatment plant (WWTP Bielsko-Biala Komorowice), operated in a full scale. A continuous flow of the wastewater was directed to the bottom of reactor, which after passing through the reactor was discharged on its top. Two series of investigations have been carried out in laboratory scale. The temperature of sewage in the bioreactor varied between 17-20ºC. The investigations in each series were carried out with different retention time (HRT) - 30 and 48 h, respectively.

For the UAF reactors as the inoculums the anaerobic activated sludge from WWTP Bielsko – Biała Komorowice were used. The sludge was exposed in conditions of anaerobic digestion to temperature of 20 ºC during 50 days.

ANALYTICAL TECHNIQUES

The sewage samples of influent and effluent were measured for: pH, temperature, redox (oxidation-reduction) potential and chemical oxygen demand (COD). Samples for COD determination were analyzed in glass vials of Hach COD reactor Model 4000.
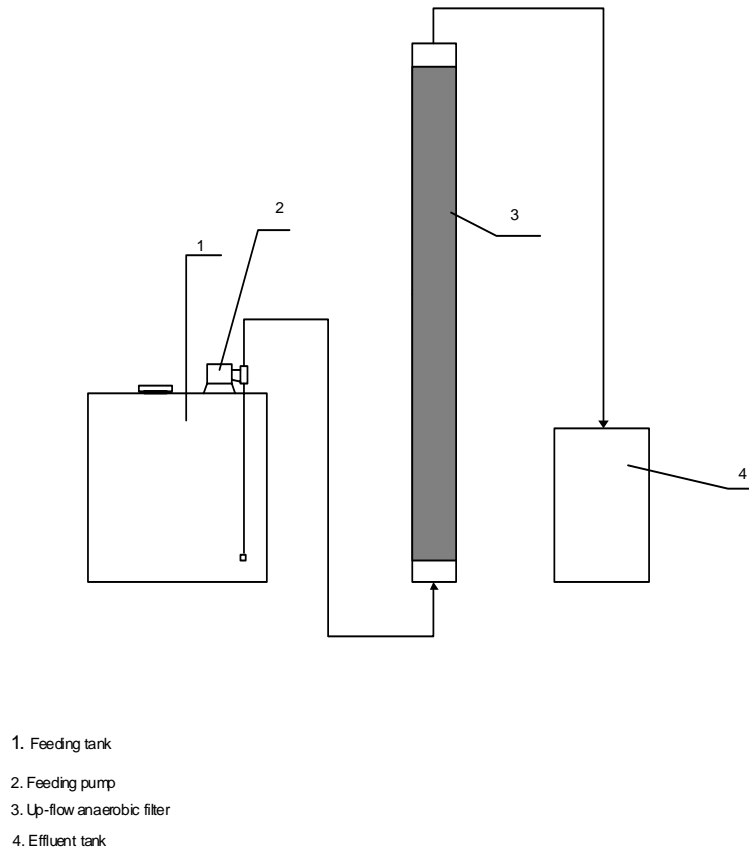

1. Feeding tank

2. Feeding pump

3. Up-flow anaerobic filter

4. Effluent tank

Figure 1. Schematic diagram of the laboratory UAF reactor system

RESULTS

Series 1

During the first series the hydraulic load on the level of 0.051 m^3/ m^2h and the hydraulic retention time of 30 hours have been applied. In the analyzed period of twenty days the COD concentration in influent was relatively low, but stable in the range of 168 to 375 mgO_2/dm^3. The effluent after anaerobic filter had COD in the range of 110 to 216 mgO_2/dm^3 (Fig 2).

The anaerobic process of sewage treatment was accompanied by effective removal of organic matter. The efficiency of COD removal was on average 45%.
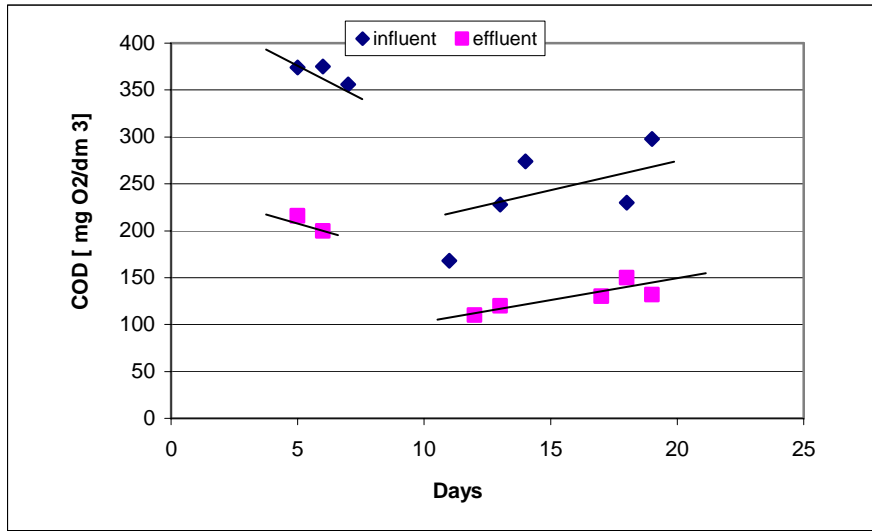

Figure 2. COD concentrations in the influent and effluent of the up-flow anaerobic filter (series 1)

Series 2

In the second series the hydraulic load was 0.032 m^3/m^2h, thus the hydraulic retention time increased to 48 hours. The concentrations of COD in the influent to the anaerobic filter was variable in the range of 91 to 410 mgO_2/dm^3. The COD contents in the effluent ranged from 61 to 180 mgO_2/dm^3 (Fig.3). The efficiency of COD removal for individual samples varied in the range of 26 to 70 %. The average was 48%.
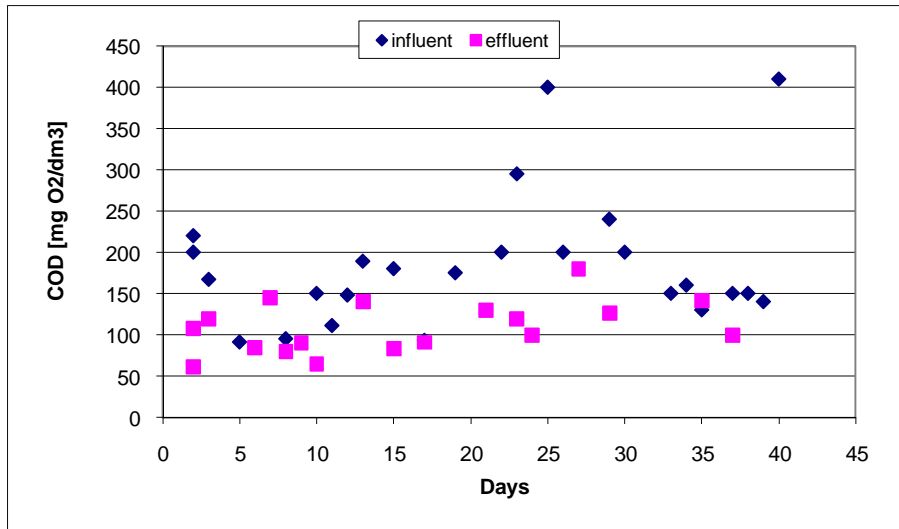
Figure 3. COD concentrations in the influent and effluent of up-flow anaerobic filter (series 2)

It was found that pH was of great significance in the anaerobic process of organic matter reduction. For first series the pH of the inflow was in between 6.9 to 7.2. For the second series pH has varied from 6.7 – 7.3. Practically the pH values of the influent were in both series in the same range. During the anaerobic treatment process the pH of the effluent has decreased in comparison with pH influent and were measured from 6.6 to 7.0 for first series and from 6.6 to 6.9 for second series. Similarly, these values of pH in the effluent were the same.

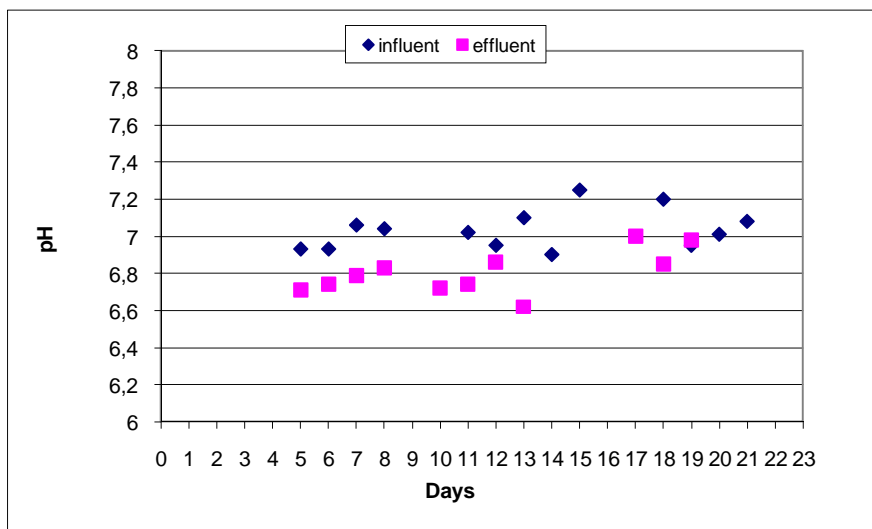The changes of pH in influent and effluent are shown in Fig. 4 and 5.

Figure 4. pH in the influent and effluent of up-flow anaerobic filter (series 1)
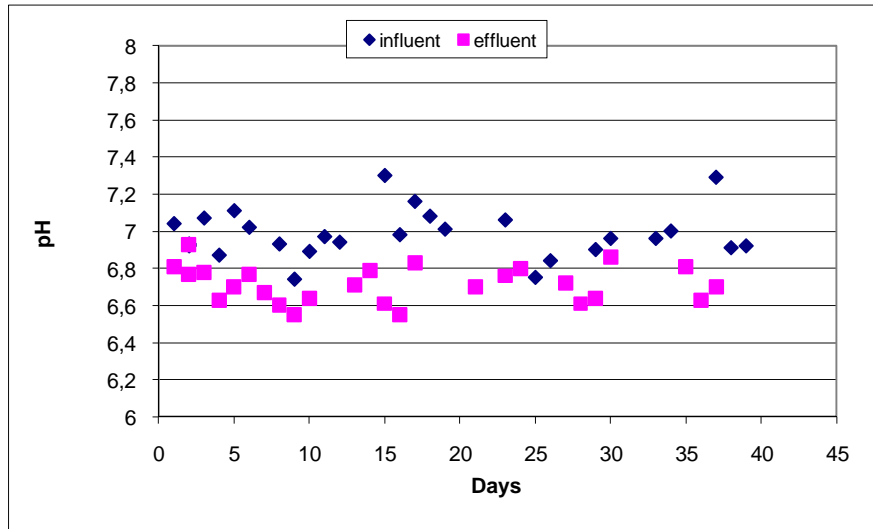
Figure 5. pH in the influent and effluent of up-flow anaerobic filter (series 2)

SUMMARY

For the purpose of finding economically and technologically suitable WWTP (wastewater treatment plant), our investigations are also aimed at the use of anaerobic reactors for pre-treatment and/or treatment municipal wastewater. This technology was used quite often in recent years, especially in regions with warmer climate. In Central and Eastern European countries, according to geographical location, temperature of municipal wastewater varied between 5 and 25°C. Temperature below 10 °C can slow down the anaerobic processes of the wastewater treatment, however such extreme temperatures usually last only for a couple of days or weeks.

It is obvious, that the observed removal efficiency of COD is at relatively low level. The cause of the such efficiency was unfavorable composition of the wastewater – the municipal sewage directly taken from WWTP Bielsko-Biała Komorowice contained a low concentration of organic pollutants.

Reduction of organic pollution by 45 % - 48% could be achieved with the application of discussed anaerobic process. At such temperatures, organic substances as the chemical oxygen demand (COD) are removed in limited degree and a long hydraulic retention time is needed for one-step of treatment system to provide sufficient hydrolysis of particulate organics.

Probably, a two-steps treatment system consisted of upflow anaerobic filter (UAF) combined with an aerobic treatment process will successful treat sewage at temperature lower than 20 °C in order to obtain the required efficiency of COD removal.

REFERENCES

Bidik I., Herdowa B., Drtil M. (2000) Anaerobic treatment of the municipal wastewater under psychrophilic conditions. *Bioprocess Engineering* 22.

Bouallagui, H., Touhami, Y., Cheikh, B., Hamdi, M., (2005). Bioreactor performance in anaerobic digestion of fruit and vegetable wastes. *Process Biochem.* 40, 989–995.

Castillo A., Cecchi F., Mata-Alvarez J.(1997) A combined anaerobic-aerobic system to treat domestic sewage. *Water Research* **31** (12), 3057.

Connaughton, S., Collins, G., O'Flaherty, V., (2006a). Psychrophilic and mesophilic anaerobic digestion of brewery effluent: a comparative study. *Water Research* 40 (13), 2503–2510.

Elmitwalli, T.A., Soellner, J., de Keizer, A., Bruning, H., Zeeman, G., Lettinga, G., (2001). Biodegradability and change of physical characteristic of particles during anaerobic digestion of domestic sewage. *Water Research*. 35, 1311–1317.

Enright, A.-M., McHugh, S., Collins, G., O'Flaherty, V., (2005). Low temperature anaerobic biological treatment of solvent containing pharmaceutical wastewater. *Water Research* 39 (19), 4587–4596.

Enright, A.-M., Collins, G., O'Flaherty, V., (2007a). Low-temperature anaerobic biological treatment of toluene-containing wastewater. *Water Research* 41 (7), 1465–1472

Gasparikowa E., Kapusta S., Bodik I., Derco J., Kratochvil K., (2005). Evaluation of anaerobic-aerobic wastewater treatment plant operations,. *Polish Journal of Environmental Studies* Vol. 14, No.1

Kalyuzhnyi, S.V., Gladchenko, M.A., Sklyar, V.I., Kizimenko, Y.S., Shcherbakov, S.S., (2001). Psychrophilic one- and two-step systems for pre-treatment of winery waste water. *Water Science Technology* 44 (4), 23–31.

Kato, M., Rebac, S., Lettinga, G., (1999). Anaerobic treatment of low-strength brewery wastewater in expanded granular sludge bed reactor. *Applied Biochemistry and Biotechnology* 76, 15–32.,

Kim Y., Mikawa K., Saito T., Tanaka K., Emori H. (1997) Development of novel anaerobic/aerobic filter process for nitrogen removal using immobilized nitrifiers pellets. *Water Science Technology* **36** (12), 151

Lettinga, G., (1995). Anaerobic digestion and wastewater treatment systems. *Antonie van Leeuwenhoek* 67, 3–28.

Lettinga, G., Rebac, S., Zeeman, G., (2001). Challenge of psychrophilic anaerobic wastewater treatment. *Trends in Biotechnol.* 19 (9), 363–370.

Macarie, H., (2000). Overview of the application of anaerobic treatment to chemical and petrochemical wastewaters. *Water Science Technology*. 42 (5–6), 201–214.

Machdar I. Harada H., Ohashi A., Sekiguchi Y., Okui H., Ueki K. (1997) A novel and cost-effective sewagetreatment system consisting of UASB pre-treatment andpost-treatment units for developing countries. *Water Science Technology*.**36** (12), 189,

McHugh, S., Collins, G., O'Flaherty, V., (2006). Long-term, high-rate anaerobic biological treatment of whey wastewaters at psychrophilic temperatures. *Bioresource Technology* 97 (14),1669–1678.

McKeown R.M., Scully C., Mahony T., Collins G, O'Flahery V. (2009). Long term (1243 days), low temperature (4- 15 ºC), anaerobic biotreatment of acidified wastewaters: Bioprocess performance and physiological characteristics. *Water Research* 43, 1611-1620

Rebac, S., van Lier, J.B., Janssen, M.G.J., Dekkers, F., Swinkels, K.T.M., Lettinga, G.(1997). High-rate anaerobic treatment of malting waste water in a pilot-scale EGSB system under psychrophilic conditions. *Journal of Chemical Technology and Biotechnology* 68 (2), 135–146.

Rincon, B., Raposo, F., Borja, R., Gonzalez, J.M., Portillo, M.C., Saiz- Jimenez, C. (2006). Performance and microbial communities of a continuous stirred tank anaerobic reactor treating two phase olive mill solid wastes at low organic loading rates. *J. Biotechnol.* 121 (4), 534–543.

Sperling M.V., Freire V.H., CHernicharo C.A.L. (2001)Performance evaluation of a UASB -activated sludge systemtreating municipal wastewater. *Water Science Technology* **43** (11), 323,