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Role of carbon source and nutrient availability in sculpturing activated sludge flocs and optimizing bioreactor arrangement

Thesis book

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1. INTRODUCTION, AIMS AND SCOPE

In Hungary application of standardized values and rules of thumb are still in the common practice for designing wastewater treatment technologies, just like in most part of the world. However, standardization of inlet wastewater quality (e.g. using population equivalent, PE) and design process carried out without taking into consideration the unique characteristics of influent and local peculiarities of catchment areas, sewage networks and industrial discharge may lead to mis-designed and costly solutions and/or poor treated effluent quality.

Quality of influent wastewater, however, basically affects and determines the results of design and upgrading calculations. Accordingly, the main purpose of my Ph.D. thesis was to provide a thorough screening of Hungarian inlet wastewater quality and treatment technologies and to compare the results with international data in order to determine adaptability limits of technologies successfully applied in Western and North Europe and North America. Further research purpose was to highlight and trace latent failures of sampling wastewater and biomass and to provide novel methods and appropriate recommendations for more efficient and accurate applications.

The carbon source as well as nitrogen and phosphorus content of inlet wastewater and their ratios are crucial to the composition of activated sludge culture and efficiency of the treatment process.

Accordingly, the research included

- investigation of technological possibilities for overcoming inlet carbon deficiency, low BOD_5/NH_4N ratio and low S - low DO conditions in order to improve biological nitrogen removal and activated sludge settleability.
- development and successful application of novel methods for upgrading biological nitrogen removal and sculpturing activated sludge flocs at highly fluctuating inlet BOD_5/NH_4N ratios.
- verification of harmful effects and risks of dosing minimized supplementary nitrogen and phosphorus amounts on sludge settleability in case of extremely high inlet BOD_5/NH_4N ratio.

2. BACKGROUND

It is well-known that discharging nitrogen and phosphorus containing compounds (so-called *nutrients*, Grady et al., 1999) may lead to eutrophication of natural receiving water bodies, therefore the efficient removal of these pollutants is a leading issue in wastewater treatment. At the same time good activated sludge settleability is crucial for achieving appropriate treatment efficiency since on one hand poorly separable biomass may risk the majority of effluent limit values, and on the other hand activated sludge washed out due to inappropriate floc structure may cause deterioration of biodegradation processes through dilution of bioreactors.

Activated sludge floc structure is highly affected by several parameters (Wanner and Jobbágy, 2014), such as inlet wastewater quality (i.e. readily biodegradable organic carbon content, F/M ratio, C/N ratio), dissolved oxygen concentration, bioreactor arrangement and sludge age. Solids separation problems may occur in system being un-staged and/or receiving low concentration of biodegradable carbon source leading to

filament overgrowth under low S – low DO conditions or viscous bulking caused by overproduction of extracellular polysaccharides (Jenkins et al., 2004; Wanner and Jobbágy, 2014).

Inlet wastewater quality has a key importance for successful technological design and upgrading, however, determination of sampling points of campaigns, applied techniques of sampling (composite/grab/qualified grab samples), sample storage, sample preservation and preparation, homogenization of heterogeneous-phase samples carry several challenges and imply serious latent failures (Rieger et al., 2010). The influent quality determines basically the amount of carbon, nitrogen and phosphorus and their typical ratio available for biodegradation and metabolic processes of microorganisms. If data of wastewater quality are erroneous or inaccurate, the whole design of biodegradation process may fail.

In the international state of the art practice of technological design use of mathematical simulation for modelling biokinetics is common and crucial that requires several analytical and operational data. Without defining reliable and accurate input parameters calculations cannot be carried out successfully, both appropriate model selection and model fitting are impossible if the process lacks unique and characteristic high-quality data (Hauduc et al., 2013). However, in the common practice the quality of data is generally questionable and important background informations (e.g. conditions and methods of sampling, sample preparation, measuring methods) are not transparent or even not documented at all.

Appropriate biological nitrogen removal requires both efficient nitrification and denitrification. Nitrification needs high sludge age and oxygen availability while for denitrification exclusion of oxygen (anoxic conditions) and availability of sufficient readily biodegradable carbon source are crucial. Similarly to denitrifiers Phosphorus Accumulating Organisms (PAOs) are also heterotrophic, therefore they are competitors for readily biodegradable organic substrates in non-aerated basins (Barnard and Comeau, 2014).

Both efficient carbon and nutrient removal and good sludge separability are to be achieved in wastewater treatment. Accordingly, taking into consideration the quantities of available carbon, nitrogen and phosphorous sources is crucial for the proper selection and application of treatment technologies.

Barnard, J. and Comeau, Y. (2014) Phosphorus removal in activated sludge. Chapter 10 in Activated sludge – 100 years and counting, Eds. Jenkins, D. and Wanner, J., 2014 IWA Publishing, Glasgow, ISBN 9781780404936, 93-115.

Grady, C.P.L. Jr.., Daigger, G.T., Lim, H.C. (1999): Biological Wastewater Treatment. 2nd edition, Marcel Dekker, Inc., New York, Basel.

Hauduc, H., Rieger, L., Oehmen, A., van Loosdrecht, M.C.M., Comeau, Y., Héduit, A., Vanrollhegem, P.A., Gillot, S. (2013): Critical Review of Activated Sludge Modeling: State of Process Knowledge, Modeling Concepts, and Limitations. Biotechnology and Bioengineering, **110**(1), 24-46.

Jenkins, D., Richard, M.G., Daigger, G.T. (2004): Manual on the Causes and Control of Activated Sludge Bulking and Foaming. 3rd edition., CRC Press LLC, Boca Raton, Florida, US.

Rieger, L., Takács, I., Villez, K., Hansruedi, S., Lessard, P., Vanrolleghem, P.A.,

Comeau, Y. (2010): Data reconciliation for wastewater treatment plant simulation studies – planning for high-quality data and typical sources of errors. Water Environment Research, **85**, 426-433.

Wanner, J. and Jobbágy, A. (2014) Activated sludge solids separations. Chapter 10 in Activated sludge – 100 years and counting, Eds. Jenkins, D. and Wanner, J., 2014 IWA Publishing, Glasgow, ISBN 9781780404936, 171-193.

3. METHODOLOGY

The survey aimed to review the Hungarian wastewater treatment technologies and the spectrum of inlet wastewater quality. It was carried out by development and use of a detailed questionnaire which was sent to almost 80 Hungarian wastewater treatment plants. Evaluation was performed for 55 answers received about full-scale systems with hydraulic capacity in the wide range of 500 – 150 000 m^3/d but including mostly plants with capacity between 2 000 and 50 000 m^3/d. Results were compared to benchmark data of Western and North Europe and North America.

The research in the field of wastewater and biomass characterization applied both on-site sampling and measurements and laboratory experiments. Investigations for comparing analytical methods were carried out several times with 5-time repetition for each measurement, and the results were evaluated by advanced statistical methods (ANOVA, analysis of variance).

For representative determination of inlet wastewater quality and treatment efficiency of the full-scale systems investigated carefully designed sampling campaigns and on-site concentration profile measurements were carried out at least 3 times for each plant having also taken into consideration the local peculiarities of the treatment plants and their catchment areas. Supplementary analytical parameters were also determined for biodegradability based fractionation of total COD (chemical oxygen demand) in order to carry out ASM (Activated Sludge Model) based mathematical simulations by the use of diverse software (SSSP, BioWin, WEST). Laboratory analyses were implemented according to the valid standards. The limits and nuisances of full-scale technologies were evaluated by the use of operational data provided by the plant operator companies, and cost-effective upgrading solutions were proposed.

Comparative lab-scale continuous-flow experiments were carried out for several weeks both for investigating a combined activated sludge – biofilm system with marginal inlet carbon source availability, and for mimicking processes and consequences of minimized N and P dosing in case of treating nutrient deficient wastewater. For the appropriate implementation of the experimental results and for assuring the full-scale adaptability of findings, reference systems were simultaneously operated and the substrate concentration profiles of the experimental systems were carefully adjusted.

4. RESULTS

4.1. Results related to the research investigating the inlet quality, applied technology and most frequent operational nuisances of 55 Hungarian wastewater treatment plants

- Major part of the investigated plants had high inlet total COD and ammonium load compared to typical data for Western and North European and North American facilities.
- 26% of the investigated plants could be characterized by marginal availability of inlet biodegradable carbon source, whereas 16% suffered by severe carbon deficiency resulting in poor denitrification capacity and risk of exceeding effluent limit values.
- Inlet wastewater quality differed remarkably from site to site even in case of pure domestic wastewater treatment plants, thus design practice based on standardized domestic wastewater quality can be considered out of date and leads to mis-designed technologies.

4.2. Results highlighting and discovering the failures of wastewater and biomass characterization by sampling and analysis, elaboration of novel measuring methods

- Accurate sampling process needs higher level of attention and know-how than it is commonly applied in the practice, since failures potentially occurring during the sampling, sample storage, sample preparation and analysis processes may highly effect analytical data due to microbial activity.
- In measuring five-day biochemical oxygen demand (BOD_5) results of widely used electrochemical (MSZ EN 1899-1,2:2000; Standard Methods No. 5210B., with the use of membrane electrode) and manometric (MSZ E 21420-9:2004; Standard Methods No. 5210D.) methods give remarkable difference depending on the method applied at a significance level of 5% in case of characterizing inlet (pre-clarified) wastewater samples.
- BOD_5 values measured by manometric method proved to be higher by 23% in average for non-filtered pre-clarified wastewater samples and 15% in average for filtered pre-clarified samples. Mixing proved to be one of the main possible background causes: While sample is in a completely stirred reactor during the manometric measurement, electrochemical method does not apply mixing, thus suspended solids may settle down in the measuring glass slowing down the aerobic biodegradation processes.
- BOD_5 is a key parameter for biodegradability based COD fractionation, thus differences in BOD_5 concentration values coming from the measuring method cause remarkable changes in results of full-scale denitrification efficiency calculations. Depending on the BOD_5 value applied the apparent BOD_5/NH_4N (C/N) ratio (i.e. denitrification capacity) of the influent wastewater may remarkably be shifted. Accordingly, calculations for required anoxic volume, nitrate recirculation flow rate, aeration settings, blower capacity and supplementary carbon dosage strategy may fail.
- Besides activated sludge floc structure temperature, dilution, electron acceptor availability (i.e. nitrate and/or DO concentration) and the biochemical switch of the biomass between O_2 and NO_3^- consumption are important factors influencing the results of SVI (sludge volume index) measurement both individually and in

synergistic interactions. The measured SVI is unambiguously lower at lower temperature, with the use of dilution method, in case of pre-aeration of the sample and at lower nitrate concentration.

- Particular attention has to be paid for biomass sampling method preceding settling test in case of bioreactors operating with intermittent aeration. In summer period sample is recommended to be taken in the aeration phase, after at least 30 minutes of intensive aeration in order to ensure the full anoxic/aerobic switch of the biomass and to avoid bulking or floatation of sludge during the settling test.
- A novel method was developed and successfully applied for the early detection of activated sludge floc structure changes. Implementation of this new method is very simple since it deals with the simultaneous measurement and comparison of SVI (sludge volume index) and DSVI (diluted sludge volume index) values.
- Based on the results achieved, the risk of biological sludge floatation in gravity thickeners could be minimized by the intensive pre-aeration of excess sludge transferred from the secondary clarifiers.

4.3. Results related to the research aimed to overcome operational problems caused by inlet carbon source deficiency, leading to low BOD_5/NH_4N ratio and/or low S - low DO conditions

- Intermittent aeration may notably deteriorate denitrification efficiency, thus this technology requires higher inlet BOD_5/NH_4N ratio (ca. >8) for safe operation.
- In case of influent biodegradable carbon shortage repression of excess biological phosphorus removal may be necessary in order to ensure efficient denitrification since bioreactor arrangement favoring biological P removal can lead to insufficient efficiency both for nitrate and phosphorus elimination.
- Operation of low SRT (sludge retention time) activated sludge (AS) system combined with consequent fixed-film nitrification and denitrification can be successfully optimized through back-seeding by the nitrifiers contained in the backwash suspension and increasing nitrate recirculation from the fixed-film reactors into the non-aerated basins of AS stage. This practically no-cost invention could decrease amount of supplementary dosed carbon source remarkably.
- Application of float-seal on the surface of non-aerated AS reactors improved sludge settleability through exclusion of oxygen and suppressing the growth of micro-aerophilic filamentous organisms.

4.4. Results of the research aimed to enhance biological nitrogen removal and improve activated sludge settleability in case of highly fluctuating inlet C/N ratio

- A novel method was developed and applied successfully based on on-site measurements and mathematical simulations for determining the inlet wastewater quality of a domestic treatment plant receiving high organic carbon containing discharge of a soft drink factory seasonally.
- Upgrading the full-scale system receiving the influent with highly fluctuating C/N ratio and having originally an un-staged, low DO technology was successfully carried out by the use of the developed new method. The former low DO system was reconfigured into staged anoxic compartments and intensively aerated basins in order to achieve efficient biological nitrogen removal and good sludge settleability in a long term.

4.5. Results of the research focused on risks of marginal supplementary N and P dosage in case of extremely high inlet C/N ratio (i.e. nutrient deficiency)

- Lab-scale experiments verified that in case of certain readily biodegradable carbon sources the biomass yield may be higher than the commonly used values. This experience is recommended to be taken into consideration in case of treating influents with extremely high C/N ratios coming from the food industry (e.g. wastewater of winery, diary, soft drink or beverage industry).
- The supplementary N and P dosing strategy based on widely used ratios of carbon source to nutrients aiming to minimize the chemical consumption proved to be inappropriate, this traditional technique may fail through underestimating the amounts of external nutrients required.
- Nutrient shortage occurring at moderate supplementary N and P dosing may cause serious activated sludge solids separation problems in case of winery wastewater treatment plants through deterioration of AS floc structure. Depending on the bioreactor arrangement the undesirable consequence can be either filamentous bulking and/or viscous bulking caused by excessive extracellular polysaccharide production.

5. NOVEL FINDINGS

1. It has been revealed that inlet wastewater in Hungary has typically high total COD and ammonium content. However, 26% of the 55 wastewater treatment plants investigated operate with marginal biodegradable carbon availability, moreover, 16% are suffering by severe carbon deficiency. It has been proven that even pure domestic inlet wastewater quality may remarkably differ from site to site, thus design practice based on population equivalent is not correct. (Paper I and VIII)
2. Novel recommendations have been addressed to the currently used standard measuring methods of Sludge Volume Index (SVI) and Biochemical Oxygen Demand (BOD) in order to ensure accuracy, reliability and comparability of the results. A novel comparative method based on simultaneous measurement of SVI and DSVI has been developed for early indication of activated sludge floc structure changes (Paper VI)
3. It has been revealed that intermittent aeration and low DO conditions may drastically deteriorate denitrification efficiency. In case of marginal carbon availability ($4<BOD_5/NH_4N<6$) staging of bioreactors (i.e. inserting anoxic selectors) would be a safer and more effective solution for high SRT activated sludge systems, while low SRT plants could be connected with a properly combined additional biofilm treatment step in order to meet effluent criteria. (Paper I and II)
4. Full-scale experiments proved that in case of inlet carbon shortage seal-covering of non-aerated basins improves activated sludge settleability through exclusion the growth of micro-aerophilic filaments prolifering under low DO conditions. (Paper V)
5. A novel combined methodology based on both on-site measurements and mathematical simulations has been developed for accurate inlet wastewater quality determination of a regional domestic wastewater treatment plant receiving high

organic load of soft drink industry seasonally. The new method is applicable for exploring hidden industrial discharge. (Paper VII)

6. Using the newly developed method, in case of highly fluctuating inlet C:N ratio the application of staged, non-aerated selectors proved to be more efficient both for enhancing biological nitrogen removal and improving sludge settleability than the commonly used low DO operation. (Paper VII)
7. Lab-scale experiments verified that in case of certain readily biodegradable substrates biomass yield may reach higher values (0.7 g biomass / g substrate COD) than the ones used commonly. Therefore, the N and P dosing strategy aiming minimal chemical consumption for the treatment of nutrient deficient wastewater may fail leading to nutrient deficiency, undesirable biomass structure and serious solids separation problems. Thus, the encouraging growth of GAOs is more efficient and safer than using traditional way external nutrient dosing (Paper III and IV)

6. APPLICABILITY IN PRACTICE

- Results summing up the data evaluated 55 Hungarian wastewater treatment plants can be considered as overall complex survey both for analyzing inlet wastewater quality and full-scale technologies applied. Findings can carry interest in tendering and design processes and unambiguously prove the unacceptability of using rules of thumb.
- Results and recommendations on BOD measurement methods can be used as useful aspects and advices for avoiding mis-designed technologies (e.g. non-aerated volume and/or aeration) due to questionable data from low quality database.
- The novel method based on comparative measurement of SVI and DSVI was successfully applied in full-scale following-up sludge floc structure changes (at the Budapest Central Wastewater Treatment Plant). Besides the original application results achieved for SVI measurement can also be useful for design and operation of biological sludge gravity thickeners. The undesirable floatation of biomass occurring frequently in gravity thickeners can be minimized by intensive pre-aeration of the biomass directly after the removal of excess biological sludge from the secondary clarifiers.
- The cost-effective seal-covering of non-aerated bioreactors has been applied in full-scale from 2013 (at North-Budapest Wastewater Treatment Plant) for achieving better biomass structure. The full-scale implementation of floatseal is now processing at other wastewater treatment plants as well.
- The novel methodology for accurate influent quality spectrum determination proved to be reliable and efficient for discovering properly the hidden industrial loads of Szob Wastewater Treatment Plant. In case of highly fluctuating inlet C/N ratio the method developed can be useful for tendering and upgrading process, especially for regional wastewater treatment plants with large catchment areas. Moreover, this method can be efficient for tracing latent industrial loads.
- In case of treating nutrient deficient wastewater, in order to achieve good performance, safely increased dosage of supplementary N and P sources can be applied instead of the estimated minimum quantity of chemicals, however, this may

need nitrification and denitrification which cause further additional costs. Regarding the uncertain consequences and high operational costs of chemical dosing, encouraging GAOs by appropriate, advanced biotechnology can rather be recommended.

7. PUBLICATIONS

Basic publications of the thesis

Peer reviewed scientific papers in English

I. Tardy, G.M., Bakos, V., Jobbágy, A. (2012): Conditions and technologies of biological wastewater treatment in Hungary, *Water Science and Technology*, **65**(9), pp. 1676-1683. IF: 1.102 (2012)

II. Bakos, V., Tardy, G., Palkó, Gy., Jobbágy, A (2013): Pilot-Scale verification of efficient nitrifier backseeding in a combined activated sludge – biofilm system, *Periodica Polytechnica Chemical Engineering*, **57**(1-2), 93-99. IF: 0.130 (2013)

III. Bakos, V., Kiss, B. and Jobbágy, A. (2016): Problems and causes of marginal nutrient availability in winery wastewater treatment, Acta Alimentaria, *közlésre elfogadva 2016.07.15-én* IF: 0.333 (2015)

IV. Kiss, B., Bakos, V., Liu, W.T., Jobbágy, A. (2011): Full-scale use of glycogen-accumulating organisms for excess biological carbon removal, Water Environment Research, 83(9), 855-864. IF: 0.883 (2011)

Presentations published in conference proceedings in English

V. Jobbágy, A., Weinpel, T., Bakos, V., Vánkos, Zs. (2015): Factors potentially converting non-aerated selectors into „low-S – low-DO basins", effects of seal-covering, *12th IWA Specialised Conference on Design, Operation and Economics of Large Wastewater Treatment Plants*, 6-9 September, 2015, Prague, Czech Republic. Proc. pp. 149-155.

VI. Bakos, V. and Deák, A. (2015): Wastewater sampling and analysis: bottlenecks in design and modelling practice, IWA 7th Eastern European Young Water Professionals Conference, Belgrade, Serbia, 17-19 September 2015, Proc. pp. 405-414.

VII. Bakos, V. and Jobbágy, A. (2016): Upgrading biological nitrogen removal and sculpturing activated sludge flocs in industrial wastewater treatment, *IWA 8th Eastern European Young Water Professionals Conference*, Gdansk, Poland, 12-14 May 2016, Book of full papers (Proc. pp.), 735-742.

Scientific paper in Hungarian

VIII. Jobbágy, A., Bakos, V. (2006): A szennyvízminőség szerepe a tisztítási technológia kiválasztásában, Hírcsatorna, 2006. május-június, pp. 5-14.

Other peer reviewed scientific paper in English related to the scope of the doctoral thesis

Jobbágy, A., Kiss, B., Bakos, V., Tardy, G. (2009): Activated sludge nuisances in a vegetable processing wastewater pretreatment plant, *Acta Alimentaria*, **38**, 393-404. IF: 0.505 (2009)

Platform presentations related to the scope of the doctoral thesis

Bakos V., Weinpel T., Vánkos Zs., Hári M. F., Nagy E., Makó M., Jobbágy A. (2016): Felszíni oxigén beoldódás kizárása úszó fedlappal nem levegőztetett eleveniszapos medencékből. Magyar Hidrológiai Társaság XXXIV. Országos Vándorgyűlése, Debrecen, 2016. július 6-8. (Csatornázás, szennyvízelvezetés és –tisztítás szekció)

Bakos V. (2016): Mintázás és mérés a szennyvíztisztításban: a technológia tervezés, modellezés és üzemeltetés rejtett hibái és kihívásai. III. Környezetvédelmi mérés és mintavétel aktuális kérdései c. konferencia, Környezetvédelmi Szolgáltatók és Gyártók Szövetsége, Budapest, 2016. május 24.

Bakos, V. (2016): Upgrading biological nitrogen removal and sculpturing activated sludge flocs in industrial wastewater treatment, *IWA 8th Eastern European Young Water Professionals Conference*, Gdansk, Poland, 12-14 May 2016, platform presentation.

Bakos, V. and Deák, A. (2015): Wastewater sampling and analysis: bottlenecks in design and modelling practice, IWA 7th Eastern European Young Water Professionals Conference, Belgrade, Serbia, 17-19 September 2015, platform presentation.

Bakos, V. (2015): Mintázás és mérés: a szennyvíztisztítási hatékonyság meghatározásának látens kihívásai. Magyar Szennyvíztechnikai Szövetség – IV. Junior szimpózium, Budapest, 2015. január 26., előadói díj: I. helyezés, MASZESZ Junior Díj

Tardy, G.M., Bakos, V., Jobbágy, A. (2011): Conditions and technologies of biological wastewater treatment in Hungary. The 11th IWA Specialised Conference on Design, Operation and Economics of Large Wastewater Treatment Plants, 4-8 September 2011, Budapest, Hungary. Proc. pp. 27-34. Presenter: Tardy Gábor Márk.

Bakos, V. (2010): Eleveniszapos tisztítás hatékonyság növelése a szennyvízminőség függvényében. Magyar Szennyvíztechnikai Szövetség – 1. Junior szimpózium, Budapest, 2010. március 25.

Jobbágy, A., Bakos, V., Miklósfalvi, G., Pécsi, K. (2008): Eleveniszapos tisztítás hatékonyság növelése a szennyvízminőség függvényében. IX. Országos MASZESZ Konferencia „Klímaváltozás és a szennyvíztechnika"; Lajosmizse, 2008. május 26-27. Presenter: Jobbágy Andrea.

Poster presentations related to the scope of the doctoral thesis

Bakos, V., Kiss, K., Patziger, M., Jobbágy, A. (2015): Hydraulic and biochemical profiles of primary settling, 12th IWA Specialized Conference on Design, Operation and Economics of Large Wastewater Treatment Plants, Prague, Czech Republic, 6-9 September 2015.

Bakos, V. (2015): Sampling and analysis: latent challenges of wastewater treatment

efficiency simulations, European Water Association (EWA) Spring Days 2015, Budapest Water Conference, Budapest, 2015. március 4-6.

Bakos, V., Kiss, B., Jobbágy, A. (2007): A tápanyaghiány hatása az eleveniszapos szennyvíztisztításban, IV. Szennyvízágazati Konferencia (MAVÍZ, FCsM Zrt.), Budapest, 2007. november 29-30.

Kiss, B., Bakos, V., Tardy, G.M., Jobbágy, A. (2007): A Dél-pesti Szennyvíztisztító Telep kombinált biológiai tisztító rendszerének optimalizálása, VIII. Országos MASZESZ Konferencia, Lajosmizse, 2007. május 21-22.

Other co-authored scientific papers in English in the field of wastewater treatment, not directly related to the scope of the doctoral thesis

Weinpel, T., Bakos, V., Jobbágy, A. (2013): Effects of increased influent nitrogen load on a part-time aerated activated sludge system, Water Practice and Technology, **8**(1), 18-26.

Hosseini, A., M., Tungler, A., Bakos, V. (2011): Wet oxidation properties of process waste waters of fine chemical and pharmaceutical origin, Reaction Kinetics, Mechanisms and Catalysis, **103**(2), pp. 251-260. IF: 1.104 (2011)

Hosseini, A., M., Bakos, V., Jobbágy, A., Tardy, G., Mizsey, P., Makó, M., Tungler, A. (2011): Co-treatment and utilisation of liquid pharmaceutical wastes. Periodica Polytechnica Chemical Engineering, **55**(1), pp. 3-10. IF: 0.262 (2011)

Other co-authored papers in Hungarian in the field of wastewater treatment, not directly related to the scope of the doctoral thesis

Kassai, Zs., Kiss, K., Muhi, A., Bakos, V. (2014): Az idei IFAT fiatal szemmel: a YWPP magyar résztvevőinek beszámolója, Hírcsatorna, 2014. július-augusztus, pp. 12-21.

Bakos, V. és Jobbágy, A. (2016): Magyar sikerek az IWA kelet-európai fiatal szakemberek számára nyolcadik alkalommal megrendezett konferenciáján, Hírcsatorna, 2016/3., pp. 39-43.

Other co-authored platform presentations in English in the field of wastewater treatment, not directly related to the scope of the doctoral thesis

Weinpel, T., Bakos, V. and Jobbágy, A. (2016): Utilization of diary wastewater as carbon source in a domestic activated sludge plant, IWA 8th Eastern European Young Water Professionals Conference, Gdansk, Poland, 12-14 May 2016, Book of full papers (Proc. pp.), 780-787. Presenter: Weinpel Tamás.

Wisniewski, C., Chrystelle, M-B., Bakos, V., Delalonde, M., Delarbre, J-L. (2015): Impact of tributyltin (TBT) on the bacterial activity in suspended-growth biological wastewater treatment systems (conventional activated sludge and membrane bioreactor), 10th European Congress of Chemical Engineering, 27th Sept. – 1st Oct., 2015, Nice, France (platform presentation) Presenter: Christelle Wisniewski.

Weinpel, T. and Bakos, V. (2012): Effects of increased influent nitrogen load on a part-time aerated activated sludge system, 6th IWA International Conference for Young Water Professionals, 10-13 July 2012, Budapest, Hungary. (Proc. CD, ID: IWA-9841).

Presenter: Weinpel Tamás.

Tardy, G.M., Bakos, V., Jobbágy, A. (2011): Conditions and technologies of biological wastewater treatment in Hungary. The 11th IWA Specialised Conference on Design, Operation and Economics of Large Wastewater Treatment Plants, 4-8 September 2011, Budapest, Hungary. Proc. pp. 27-34. Presenter: Tardy Gábor Márk.

Kiss, B., Bakos, V., Szabó, A., Jobbágy, A. (2007): Comparative experimental studies for upgrading the Northpest Wastewater Treatment Plant, 10th IWA Specialised Conference – Design, Operation and Economics of Large Wastewater Treatment Plants, Vienna (Austria), 9-13. September 2007. (2nd Prize awarded poster, oral presentation) Proc. posters pp 177-180. Presenter: Kiss Bernadett.

Other co-authored platform presentations in Hungarian in the field of wastewater treatment, not directly related to the scope of the doctoral thesis

Kiss, K., Patziger, M., Bakos, V., Jobbágy, A. (2014): Könnyen és nehezen biodegradálható szervesanyagok eloszlásvizsgálata előülepítő medencékben és ülepedési kísérleteknél, XXXII. Országos Vándorgyűlés, Magyar Hidrológiai Társaság, Szeged, 2014. július 2-4., Csatornázás, szennyvízelvezetés és –tisztítás szekció, Konferencia kiadvány (CD), ISBN 978-963-8172-32-7. (Előadás nélkül csak a kiadványban jelent meg.)

Bakos, V. (2014): Nagy szervesanyag tartalmú hulladékok ártalmatlanítása hasznosítással. Magyar Szennyvíztechnikai Szövetség – III. Junior szimpózium, Budapest, 2014. február 6., előadói díj: IV. helyezés

Deák, A., Szentgyörgyi, P. és Bakos, V. (2012): A mintavétel, az online mérések és a laboratóriumi analízis egymásra épülő rendszere a Budapesti Központi Szennyvíztisztító Telepen, I. Környezetvédelmi mérés és mintavétel aktuális kérdései c. konferencia, Környezetvédelmi Szolgáltatók és Gyártók Szövetsége, Budapest, 2012. május 22. Presenter: Deák Attila.

Jobbágy, A., Bakos, V., Tardy, G. (2010): Tipikus problémák kis szennyvíztisztító telepeken. XI. Országos MASZESZ Konferencia, Lajosmizse, 2010. május 11-12. Presenter: Jobbágy Andrea.

Bakos, V. (2009): Kommunális és ipari szennyvizek biológiai nitrogén eltávolítása eleveniszapos és biofilm rendszerekben. Oláh György Doktori Iskola, VI. Doktoráns Konferencia; Budapest, 2009. február 4.

Jobbágy, A., Bakos, V. (2008): Eleveniszapos tisztítás hatékonyság növelése a szennyvízminőség függvényében. V. Szennyvízágazati Konferencia – A csatornázástól a környezetgazdálkodásig (MAVÍZ, FCsM Zrt.); Budapest, 2008. november 27-28. Presenter: Jobbágy Andrea.

Jobbágy, A., Bakos, V., Miklósfalvi, G., Pécsi, K. (2008): Eleveniszapos tisztítás hatékonyság növelése a szennyvízminőség függvényében. IX. Országos MASZESZ Konferencia „Klímaváltozás és a szennyvíztechnika”; Lajosmizse, 2008. május 26-27. Presenter: Jobbágy Andrea.

Bakos, V. (2007): Az Észak-budapesti Szennyvíztisztító Telep költségkímélő hatékonyságnövelésének kidolgozása folytonos üzemű, helyszíni modellkísérletben. XXVIII. Országos Tudományos Diákköri Konferencia, Kémiai és Vegyipari Szekció; Szeged, 2007. április 2-4.

Bakos, V. (2007): Vegyipari szennyvíz biológiai nitrogén-eltávolítása eleveniszapos-biofilm rendszerben, Oláh György Doktori Iskola - IV. Doktoráns Konferencia; Budapest, 2007. február 7.

Other poster presentations in the field of wastewater treatment, not directly related to the scope of the doctoral thesis

Tardy G.M., Bakos V., Wisniewski C., Tungler A., Jobbágy A. (2015): Biological elimination of high organic content liquid wastes through utilization in suspended growth wastewater treatment systems, 10th European Congress of Chemical Engineering, 27th Sept. – 1st Oct., 2015, Nice, France.

Bakos, V., Jobbágy, A. (2008): Eleveniszapos szennyvíztisztító rendszer költségkímélő hatékonyságnövelése intenzifikált előülepítéssel, Oláh György Doktori Iskola, V. Doktoráns Konferencia; Budapest, 2008. február 8.

Kiss, B., Bakos, V., Szabó, A., Jobbágy, A. (2007): Comparative experimental studies for upgrading the Northpest Wastewater Treatment Plant, 10th IWA Specialised Conference – Design, Operation and Economics of Large Wastewater Treatment Plants, Vienna (Austria), 9-13. September 2007. Proceedings. (2nd Prize awarded and oral presentation by B. Kiss), Proc. posters pp 177-180.

Bakos, V., Jobbágy, A. (2007): Az eleveniszapos nitrogén-eltávolítás hatékonyság növelése kötöttágyas reaktorok alkalmazásával, VIII. Országos MASZESZ Konferencia, Lajosmizse, 2007. május 21-22.

Bakos, V., Jobbágy, A. (2006): Vegyipari szennyvíz biológiai nitrogén-eltávolítása eleveniszapos-biofilm rendszerben, III. Szennyvízágazati Konferencia (MAVÍZ, FCsM Zrt.) – A ma tudománya a holnap gyakorlata, Budapest, 2006. november 30. – december 1.