

GAINS OF SWEDISH-POLISH RESEARCH CO-OPERATION IN ENVIRONMENTAL ENGINEERING

S. M. Rybicki¹ and E. Plaza²

¹ Institute of Water supply and Environmental Engineering, Cracow University of Technology, 31-155 Krakow, Poland; e-mail: stan@venus.pk.edu.pl

² Department of Land and Water Resources Engineering, KTH 100 44 Stockholm, Sweden
e-mail: elap@kth.se

ABSTRACT

This paper describes co-operation between Royal University of Technology and growing group of Polish Universities as well as local communities and water utilities, which led to creation a specific net of knowledge in wastewater treatment processes. Twenty years of co-operation resulted in unique publication series focused on exchange of research results and dissemination of knowledge in environmental engineering.

INTRODUCTION

This paper shows not so visible but also important scientific input of the KTH to improve new standards and procedures regarding water treatment as a part of wider field of ambient water quality control. Financial support for this joint Polish-Swedish co-operation has been obtained from the Swedish Institute within the Visby Program. The join team was granted with this support or three consecutive periods of three years each.

Program History in Brief

A presentation of KTH staff's achievements in wastewater treatment with a special emphasis on a nitrogen removal which took place during 3rd International Conference "Advanced Wastewater Treatment" being held in Cracow in 1989, is recognized as the first institutional activity of bilateral co-operation was. It was followed by few personal visits of both KTH and CUT staff including four-month PhD research scholarship of CUT's researchers in Stockholm.

Development of projects' spectrum within each of three programs reflects change in local (Polish) needs as well as changes in general attitude towards solving ecological water-related problems.

Three consecutive projects were completed in almost 10 year project, these were:

- 1995 – 1998 Advanced Wastewater Treatment,
- 1998 – 2001 Product and Energy Recovery From Wastewater Sludge and Organic Wastes
- 2001 – 2004 Integration and Optimization of Sanitation Systems in Urban Areas.

Late 80s and beginning of 90s was a period of great socio-economic changes in Poland resulted in modern attitude towards high environmental standards. Conversions of Polish industry from obsolete, heavy type to modern – environmental oriented one require a great effort to be made. In relatively short period Polish professionals in this field had to significantly reduce pollution, including ambient water. So the first of three programs was performed between 1995 and 1998 with

a general topic Advanced wastewater treatment. This program was focused on dissemination of modern knowledge including exchange of students and researchers and joint performance of experiments. Its core part was transfer of Swedish advanced knowledge in wastewater treatment to Polish water utilities, professionals and university students. This was rather an aid than co-operation itself. However Polish feedback to the project was presentation of fresh experience in operation of modern treatment plants.

Following was the next project, named as Product and energy recovery from wastewater sludge and organic wastes, completed in 1998 – 2001. In early 90s a main aim of operation personnel was to fulfill the quality requirements of treated wastewater. When this was solved, next step was to make plants' operation more feasible and tariff more acceptable for customers. Their subjects covered broader area than previous one. As focused not only on specific technical problems of WWTP but implementing wider concept of sustainable development it showed possibilities of balanced handling of various group of municipal wastes. Its formal scope was chosen by the co-ordinators and meeting of participants in accordance to trends in global research and based on real needs of water utilities in entire Baltic Sea region.

Last project, being conducted in 2001-2003 period also followed general needs of communities and water utilities of break of 20th and 21st Centuries. It was called Integration and optimization of urban sanitation systems. Its title as well as scope of interests came from European and global trends in creation of research programs. It was more globally orientated. On the contrary to previous two projects, which were oriented towards solving contemporary problems this one is directed towards future development of urban sanitation systems. This caused greater input of theoretical studies (mathematical modelling, general concepts etc).

ACTIVITIES AND DEVELOPMENT OF THE PROGRAM ADVANCED WASTEWATER TREATMENT,

This program was established basing on knowledge transfer from Sweden to Poland mainly. Presentation of fresh experience and problems' solving by Polish professionals was second activity. Four areas of interest in research activities were established after analysis of needs and research possibilities, as follows:

1. Optimization of biological nutrient removal process for municipal wastewater with application of computer dynamic simulation.
2. Interactions between biological and chemical phosphorus removal from municipal wastewater in three stage treatment systems.
3. Sludge Volume Index (SVI) as the parameter used to monitor the integrated process for nutrient removal in multiphase activated sludge.
4. Activated sludge stabilization in SBR reactors.

In general terms first project was focused on optimization of process technology of wastewater treatment in WWTPs based on multi-phase biological reactors. Wide application of this relatively modern plant in Poland was a great step forward in wastewater treatment (and in water quality control in general) but also created serious operational problems related with nutrient removal. During this period a new initiative of Joint Polish-Swedish Reports was developed. From this moment on, this is a main forum for presentation of activities related to co-operation. As great need for knowledge in enhance biological nutrient removal was still present, mid 90s state of art was prepared in form of a literature review Report 1 (1997) "Phosphorus removal from wastewater" analyzing over 100 papers related to phosphorus removal, has been used in both countries as a data source on process.

Advanced WWTPs commissioned in Poland since early 1990s were based on a Bardenpho and Bardenpho-related process for large and medium size communities. Sequencing batch reactors (SBR) were mostly adopted for small size plants however the City of Nowy Targ (pop served 50 000, p.e. 120 000) is one of biggest plant of this operation pattern in Europe. Dynamic implementation of new technologies in Poland caused some operational issues, especially biological enhanced phosphorus removal was difficult for managerial as well as operational staff. Typical problems as presented in Report 2 (1997) of that time in Polish utilities were:

- Hydraulic over dimensioning of plants;
- Lack of proper design data especially regarding nutrients, their loads and trends in changes;
- Little experience in enhanced nutrient removal

Use of Swedish experience was not only 'pure' process knowledge but also rat loat of operational and organizational abilities, presented to Polish scientists and professionals. Common Polish-Swedish research were focused on unit processes in nutrient removal. Peak point of this project was a 3-day Polish-Swedish seminar "Advanced wastewater treatment" held in Nowy Targ in October 1998 (Report No.3). it was attended by approx 140 participants from Sweden, Poland and Austria with balanced proportions between research, design, operation and municipal professionals. Bi-lingual proceedings of this seminar were recognized in Poland as one of mostly welcomed professional proceedings in the field. Despite two additional printing issues 400 copies, these proceedings are unavailable. Some of research results of this stage of cooperation created a backbone for next step of activity, it were:

- Operational issues:
 - Decrease of operational costs of treatment;
 - Sludge managements towards sludge minimization;
 - Implementation of sustainable development rule in wastewater sector, especially energy and product recovery;
- Research issues:
 - Nitrogen removal from nitrogen-rich streams;
 - Phosphorus recovery need.

One of results of "Advanced wastewater treatment " project was detailed recognition of need for more detailed scientific support for a process knowledge. Operation of complexed biological nutrient removal systems showed great need for knowledge on relationships between settlement characteristics and nutrient removal as well as basics of mathematical modelling of sludge settling. So following was a Report No4. "Factors influencing sludge settling parameters and solids flux in the activated sludge processes" was a detailed literature review, summarizing more than 200 contemporary papers on sludge settling. In the next project this review was used as a theoretical support both for teams working on increase of operational capacities of plant (e.g. phosphorus removal and recovery) but also by a group of researchers working on energy and product recovery from sludge. Great necessary for this paper was noted from designers, consultants and other professionals in wastewater treatment field.

Significant part of this project was an elaboration of process obstacles using the largest Sequencing Batch reactor (SBR) in Europe, located in Nowy Targ, as a base for field studies. To execute the program a consortium between the Cracow University of Technology, the City of Nowy Targ, Municipal Water and Sewage Works in Nowy Targ and KTH has been established. As the entire research was ended in 1999, the detailed result of this period's actions were summarized in Report No.6.

Practical application of process knowledge

The best benefit of any of research activities is its practical application. This sentence especially applies to technical sciences, so as it was mentioned previously, the co-operation being described in this paper included solution of practical problems related to wastewater treatment technologies. Both were caused by the same general problem i.e. lack of proper data regarding a raw wastewater quality, typical – to some extent – in those location where the new WWTP is being built ‘at the end of pipe’ i.e. where there was no proper wastewater quality control.

Report No6. covered activities on sludge handling at Nowy Targ wastewater treatment plant. It was mainly caused by problem with unexpected tannery wastes being discharged into municipal sewage. That excluded sludge from deposition and forced the City to transport entire sludge to specialised industrial landfill creating serious economical problem for customers related to tariff increase. As this problem could not been solved by the local community, research effort were made to present feasible procedure for countermeasure. Research efforts were supported by four MSc thesis completed by KTH’s students. Final results were published as a bound report (described later in this text). It contains consecutive activities in following order:

- Recognition tests with emphasis on heavy metals;
- Field and laboratory tests on impact of chromium on sludge characteristics.
- Odour reduction field tests
- Recognition of technically feasible sludge handling options for this very case;
- Analyses on chromium recovery possibilities, as a tool for improving sludge properties;
- Technical and economical analyses of landfilling versus incineration options;

The City adopted final results and sludge incineration plant was constructed and is being operated until now.

PRODUCT AND ENERGY RECOVERY FROM WASTEWATER SLUDGE AND ORGANIC WASTES,

Second of consecutive projects was executed in years 1998 – 2001. Its subject was chosen by the co-ordinators and meeting of participants in accordance with trends in global research and based on real needs of water utilities. On the contrary to the previous one, this project was devoted to broaden problem of implementation a general rule of a sustainable development in a field of wastewater treatment. It created an overall structure of activities as directed towards more general problems, dedicated to environmental issues in municipal or community scale. Also organizational scope of the project was changed. As in 1995-1998 period most part of work was a knowledge transfer from Sweden to Poland, during the second project more emphasis was put on real co-operation built on balanced research roles. Based on this general idea, a new project was established then approved by the Swedish Institute for years 1998-2001 entitled Product and energy recovery from wastewater sludge and organic wastes.

The main objective of the project was to thoroughly evaluate specific technical processes that were able to be applied for energy and product recovery from sludge and solid waste. Possibilities to common treatment of wastewater and municipal solid wastes were also examined. Both wastewater and organic waste are a vary complex mixture, which apart from harmful substances contain also some valuable components as nutrients and energy intensive products. So the aim was to find a way of utilizing wastewater and solid wastes according to a sustainable approach focusing on two important goals:

- Recycle of valuable compounds back to the environment
- Utilization or separation of hazardous trace substances

The idea of the project was to create a support for supply local governments and communities with tools in a decision making process when they have to consider indicators of sustainability. The project was organizationally divided into several subprojects:

- Influence of sludge characteristics on sludge treatment process efficiency
- Application of biomass methanogenic activity to predict the biogas production during the fermentation process
- Product recovery by use of sludge fractionation
- Improvement of sewage sludge processing and utilization through application of quantitative methods
- Identification and evaluation of the presently used sludge disposal technology in Southern Poland
- Evaluation of present sludge disposal in the Stockholm region
- Optimization of regional sludge treatment and solid waste disposal using the criteria of sustainable development
- Heat management at wastewater treatment plants
- Modeling of the optimum energy balance of wastewater treatment plant including wastewater treatment processes and sludge handling operations
- VFA balance in wastewater treatment plants: conditions for optimal VFA generation from primary sludge and its utilization.
- Decrease of an energy consumption via development of new less energy consuming technologies of a supernatant treatment.

This project had not contained an element of solving of specific operational problems and was more research orientated. Visible signs of this were no need for literature reviews and more seminars being organized. At almost beginning of entire project a seminar was organized in Stockholm to present views on important issues related to the main topic. Main discussion showed following starting point (Report No 5):

- Polish WWTPs stabilized (in 1999) almost all of sludge i.e. 92,7% dry mass, with over 60% with the use of anaerobic digestion but over 70% of plants applied natural drying method, creating final product in difficult to apply form;
- First 5 years of operation of Polish WWTPs showed significant costs of sludge handling and problems with its final use, there was visible interest of water utilities on increase energy recovery from a biogas;
- Polish state issued at that time first formal quality requirements for land disposal, including agriculture use which at that time was recognized as a most welcomed final use of sludge, but only 3% of total dry mass was used.
- At the same time Sweden applied 12 times higher ratio of sludge in agriculture, gaining valuable experience about real terms of this kind of application, including tests on harmful substances' impact; on the other hand serious problems related with farmers' obstacles were presented to public.
- KTH made first steps towards phosphorus recovery from wastewater sludge; parallel investigation on biological nutrient removal were conducted
- CUT (Krakow) implemented long term tests on fate of constituents of the wastewater sludge with a respect to increase energy and product recovery
- Common studies were made on possibilities of optimisation of common wastewater sludge and solid municipal waste handling.

- Some theoretical works concerning solid waste handling even if focused on specific local problems (Stockholm and Cracow regions respectively), reflected in general terms the global issues and could be easily apply in the whole region of the Baltic Sea.

Next year annual seminar was held in Krakow, focused on sludge and waste processing and final handling. Investigation showed that processed (stabilized and dewatered) sludge is still a great ecological issue for community until final application is found. Utilities' experience proved that even if a sludge quality fulfils required standards (heavy metals, pathogens) their use can be abandoned by communities due to professional group lobbying (e.g. farmers). A dual role of municipal waste in general i.e. by-products of cities with significant potential for material recovery was analysed by teams (Report No. 7). Team activities of that period can be divided into two groups:

- Studies on strategic issues in sustainability in municipal waste and sludge handling, including:
 - Elements of regional and national management,
 - Activities towards energy savings etc.;
 - Discussion of recognized methods of phosphorus recovery, based on Swedish experience.
- Research activities to solve core problems of strategic areas mentioned such as:
 - Model of regional transportation of wastes was proposed and calibrated for Krakow region;
 - Methanogenic activity dynamic laboratory tests was applied , showing new possibilities of estimation of adverse impact of some sludge components on a biogas production, these specific tests were calibrated then successfully applied to estimate impact of trivalent chromium on a biogas production and composition
 - Laboratory tests of simplified phosphorus recovery showed a starting point for Polish tests in this field.

Best full-scale example of implementation of the project was a co-operation with the Nowy Sacz community (pop. 100 000) in conversion of a sludge stabilization in as existing modern WWTP into high effective biogas recovery system together combined heat and power production unit.

Advanced studies on factors affecting plants performance related to minimize use of energy and chemicals were developed in a form of following Report No.8, entitled "Intensification of biological nitrogen removal in a two-phase activated sludge process with pre-denitrification". This was work concerning possibility of intensifying two phase activated sludge process by addition of external carbon sources in parallel with seeding of nitrification bacteria. Significant part of the investigation was optimisation of kind, dose and application of an external carbon source to in accordance with general sustainability rule. The author of this report defended it as a PhD thesis at the Kraków University of Technology. Further application of its result may be done in full-scale operation of WWTPs, being a background for the evaluation of a pre-denitrification plants' operation and showing a role of an external carbon addition as well as seeding a nitrifying bacteria. Final results of this stage of co-operation were as planned on both applied and research fields, these were summarised in Report No 9, as follows:

- Practical results were:
 - Tests on new method of supernatant stream (N-rich) treatment based on a deammonification process, leading to significant decrease in external carbon sources use at WWTPs; that showed that it is possible to convert approx 40% of Ammonia N from supernatant through less energy consuming pathway;
 - Tests, thermodynamic calculations and initial design calculations for retrofitting existing WWTP for combined heat and power production from a biogas; (this resulted in full-scale practical application); These works showed that change of sludge

- stabilization from anaerobic digestion of primary sludge and aerobic stabilization of the WAS leads to higher biogas recovery and decrease of wet mass of processed sludge
- Presentation and calibration of procedures for use of methanogenic activity test for digestion chamber operation especially in presence of inhibitory substances; (applied several times in practical dimensioning of digestion chambers); That showed that small amounts of inhibitory substances can be adopted in a process of a mezophilic digestion, however the stabilized sludge quality may not be good enough for agriculture use;
 - Procedures to dimension and apply pre-fermenters for intensification of biological nutrient removal in multi-stage biological reactors, with an application of mathematical modelling;
 - Promising results of application of alum-rich sludge from water treatment to improve dewatering characteristics of a wastewater sludge;
 - Research results were also significant:
 - Initial results of phosphorus removal showing that in phosphorus recovery process use of acid addition is more reliable than use of bases due to better release characteristics;
 - Tests on sludge rheology showing how to estimate dewatering properties of sludge based on a rheology tests.

Practical application of process knowledge 2

Best full-scale example of implementation of the project was a co-operation with the Nowy Sacz community (pop. 100 000) in conversion of sludge stabilization in as existing modern WWTP into high effective biogas recovery system together combined heat and power production unit. In this case some concepts developed during KTH-CUT co-operation were applied. Best examples are:

- Methanogenic activity tests proved that an overall composition of mixed raw and WAS sludges can be used for a biogas production in upgraded digestion chambers;
- Respirometric tests combined with proposed procedure were applied to estimate proper SRT in new chamber , taking into account energetic needs for chambers' heating;
- These results above were used to make heat recovery calculations, these were based on steady state modelling and led to final decision by water utility to upgrade the sludge processing train, entire investment worth 1,2 mil EURO, was started in March 2004, commissioning is supposed on Mid 2005.

INTEGRATION AND OPTIMISATION OF SANITATION SYSTEMS IN URBAN AREAS.

Last project, being conducted in 2001-2003 period also followed general needs of communities and water utilities of break of 20th and 21st Centuries. It was named Integration and optimization of urban sanitation systems. On the contrary to previous two projects, which were oriented towards solving contemporary problems this one is directed towards future development of urban sanitation systems. This caused greater input of theoretical studies (mathematical modelling, general concepts etc). The topic of this project included performing cost-benefit analysis, definition of new approaches to sanitation system integration, evaluation of the existing techniques for material and energy recovery, and developing the theoretical basis for optimisation of sanitation systems (Report No.10) Much attention was put to technical and management issues related to phosphorus recovery from sewage sludge and solid waste and its reuse (Report No.11).

Due to growing number of participants, the cooperatively researched the problems grouped into the three main research areas:

1. Phosphorus recovery from sewage sludge and solid wastes:
 - Research showed that use of organic acids from solid waste for improvement of biological phosphorus removal in wastewater treatment plants may be a profitable way of a material recovery
 - Some tests were done on complementary phosphorus recovery from iron-rich sludge with the use of hydrogen sulphide generated in biological reactions
 - Energy demand and energy recovery in sludge and solid waste handling systems with phosphorus recovery, this is mostly focused on new aspect of pre-fermenter operation i.e. impact on VFA generation of pre-fermenters on a biogas volume and compositions, initial tests showed that adverse effect can be expected;
 - Studies on deammonification and its kinetics to optimize this process and to prove its efficiency in full scale installation; proposed process control with the use of conductivity meters for on-line control of process is one of greatest achievements of the project
 - Modelling of wastewater treatment systems with biological phosphorus removal, including both application of commercial platforms like GPS-X and tailor-made programs for unit processes modeling.
2. Toxic substances and product recovery:
 - Model system of solid waste handling for minimization of risk associated with toxic wastes, procedures are being developed
 - Risk minimization in sewage sludge disposal and utilization, based on dynamic laboratory respirometric tests.
3. Effects of regional approach to integrated sewage sludge and solid waste handling:
 - Modelling of integrated solid waste and sewage sludge disposal systems.;
 - Impact of specific wastewater like storm water on general efficiency of the plant;
 - Experiences with specialized treatment of wastewater potentially harmful for an environment (e.g. fishery, landfilling).

Participants

Number of participants was growing as programs evolved, but co-ordinators have remained the same. Institutional participants of the first Project “Advanced wastewater treatment” were:

- Royal Institute of Technology, Division of water resources Engineering
- Cracow University of Technology, Institute of Water Supply and Environmental Protection
- City of Nowy Targ as an owner of local water utilities (for this project only)

Broadening of the field of research in second program “Product and energy recovery from wastewater sludge and organic wastes “ resulted in wider group of participants. New academic member was:

- Cracow University of Technology, Institute of Heat Engineering and Air Protection

Visible is an increase of a number of participants in third program. Relatively widest scientific scope resulted in new members- three Polish universities:

- Academy of Techniques and Arts of Bielsko-Biala Institute of Engineering and Environmental Protection
- Technical University of Gdansk; Center for Environmental Studies
- Silesian University of Technology; Environmental Biotechnology Department

These numbers does reflects only participating person responsible for certain sectors of each of projects. But it does not cover M.SC students, WWTPs’ staff, auxiliary personnel involve in field tests or authors of papers delivered in seminars.

OUTPUTS AND ACHIEVEMENTS OF THE PROGRAM

Joint Polish Swedish Reports

An unique and more 'visible' output of the entire project is a publication series named "Joint Polish-Swedish Reports", published in English. These publications but Report No 8 (edited Dr J. Trela) have been edited by Bengt Hultman, Elzbieta Plaza and Erik Levlin, Reports No 3 and No 9 were co-edited by J. Kurbiel. Eleven of them were printed between 1997 and 2004 and two more issues are printed 2006.

The main aim of these papers was to present research activities and result of common work to Swedish and Polish professionals and in general term to disseminate gains of the program among other research centres. Each of reports was printed in 200-300 copies and most of them are out of stock now. Detailed list of proceedings has been presented in references. There are papers of various scope as follows:

- Project: Advanced Wastewater Treatment,
 - Report no. 1, (1997) Phosphorus removal from wastewater: A Literature Review,
 - Report no. 2, (1997) Proceedings of a Polish-Swedish seminar,
 - Report no. 3, (1998) Proceedings of a Polish-Swedish seminar, Nowy Targ,
 - Report no. 4, (1998) Factors influencing sludge settling parameters and solids flux in the activated sludge process. A Literature Review,
 - Report no. 6, (1999) Sludge handling at Nowy Targ Wastewater Treatment Plant, Poland - Evaluation and recommendations for improvements Advanced Wastewater Treatment,
- Project: Product and Energy Recovery From Wastewater Sludge and Organic Wastes
 - Report no. 5, (1999) Proceedings of a Polish-Swedish seminar,
 - Report no. 7, (2000) Proceedings of a Polish-Swedish seminar,
 - Report no. 8, (2000) Intensification of biological nitrogen removal in a two-phase activated sludge process with pre-dentrification, Jozse Trela PhD
 - Report no. 9, (2001) Proceedings of a Polish-Swedish seminar, Nowy Targ - Zakopane,
- Project: Integration and Optimization of Sanitation Systems in Urban Areas.
 - Report no. 10, (2003) Proceedings of a Polish-Swedish seminar, Gdansk,
 - Report no. 11, (2004) Proceedings of a Polish-Swedish seminar, Wisla
 - Report no. 12, (2006) Proceedings of Polish-Swedish seminar, Stockholm
 - Report no. 13, (2006) Proceedings of Polish-Swedish seminar Cracow (this report)

Knowledge dissemination - Seminars

Seminars of two kinds were organized as a dissemination part of the program. At the beginning and during a conduction of each of projects internal seminars were organized, with limited access of participant from an outside of the program. It was because these seminars despite presentation of research and study result were devoted to organizational matters. These 2-3 meetings were attended by approx. 30-40 each and usually their program was two days of discussion and one day field trip to some interesting treatment/handling enterprise. People met both in Sweden in Poland and the progress in number of authors as well as number of papers is significant as follows:

- Polish-Swedish seminar, KTH, Stockholm, May 30, 1997. Advanced Wastewater Treatment; 6 papers, 6 authors
- Polish-Swedish seminar, KTH, Stockholm, August 24, 1999. Sustainable Municipal Sludge And Solid Waste Handling, 10 papers, 13 authors
- Polish-Swedish seminar, Cracow, May 29, 2000. Sustainable Municipal Sludge And Solid Waste Handling, 10 papers, 18 authors

- Polish-Swedish seminar, Gdansk, 23-25 March 2003. Integration and optimisation of urban sanitation systems, 14 papers, 26 authors.
- Polish-Swedish seminar, Wisla October 25-28, 2003. Integration and optimisation of urban sanitation systems, 17 papers, 30 authors.
- Polish-Swedish seminar, Stockholm June 6-8, 2004. Integration and optimisation of urban sanitation systems.

Second group of seminars are meetings being open for public, organized at the end of each project. Tradition is that there are organized in Poland, as main part of them is dissemination of Swedish professional knowledge and Swedish achievements into Poland. Location of seminars is related to support from Ministry of Environment of the Republic of Poland and communities involved in the program. There were two of them and the third one is planned to be in Krakow in spring 2005. These seminars are bi-lingual (with direct translation), English language proceedings of these seminars are incorporated into “Joint Polish Swedish Report Series”, Polish versions of papers are published as a conference proceedings by co-organizer. 140-150 participants, mostly wastewater professionals from Central and Southern Poland, attended first two seminars, i.e.:

International seminar, Nowy Targ, October 1-2, 1998. Advanced Wastewater Treatment,
Polish-Swedish seminar, Nowy Targ - Zakopane, October 24-26, 2001. Wastewater, Sludge
and Solid Waste Management,

Other achievements

Despite knowledge dissemination and Joint Papers publication some other gains were obtained during this program. These are typical academic outputs:

- Research results were applied in three PhD dissertation being defended and one to be defended;
- Six MSc thesis of KTH’s graduates were done based on research completed as a part of program and these students completed their experimental part during their stay to Poland;
- Ten MSc thesis at the CUT were prepared within the program;
- Nine peer reviewed publications was published by members of Program’s team, applying results of research in the Program
- Eleven papers published on international conferences (other than Polish Swedish Seminars) were completed as a part of the program.

LIST OF REFERENCES/OUTPUTS

Joint Polish Swedish Reports

Report no. 1, Stanislaw Rybicki (1997) Phosphorus removal from wastewater: A Literature Review, Advanced Wastewater Treatment, E. Plaza, E. Levlin, B. Hultman (Editors) TRITA-AMI REPORT 3042, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3042-SE, ISBN 91-7170-247-4

Report no. 2, Proceedings of a Polish-Swedish seminar, KTH, Stockholm, May 30, 1997. Advanced Wastewater Treatment, E. Plaza, E. Levlin, B. Hultman (Editors) TRITA-AMI REPORT 3045, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3045-SE,

Report no. 3, Proceedings of a Polish-Swedish seminar, Nowy Targ, October 1-2, 1998. Advanced Wastewater Treatment, B. Hultman, J. Kurbiel (Editors) TRITA-AMI REPORT 3048, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3048-SE, ISBN 91-7170-324-1, 1998.

Report no. 4, Stypka A. (1998) Factors influencing sludge settling parameters and solids flux in the activated sludge process. A Literature Review, Advanced Wastewater Treatment, E. Plaza, E. Levlin, B. Hultman, (Editors) TRITA-AMI REPORT 3058, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3058-SE, ISBN: 91-7170-363-2, 1998.

Report no. 5, Proceedings of a Polish-Swedish seminar, KTH, August 24, 1999. Sustainable Municipal Sludge And Solid Waste Handling, E. Plaza, E. Levlin, B. Hultman, (Editors), TRITA-AMI REPORT 3063, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3063-SE, ISBN 91-7170-439-6, 1999

Report no. 6, Bengt Hultman, Erik Levlin, Elzbieta Plaza and Józef Trela (1999) Sludge handling at Nowy Targ Wastewater Treatment Plant, Poland - Evaluation and recommendations for improvements Advanced Wastewater Treatment, TRITA-AMI REPORT 3064, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3064-SE, ISBN 91-7170-444-2, 1999.

Report no. 7, Proceedings of a Polish-Swedish seminar, Cracow, May 29, 2000. Sustainable Municipal Sludge And Solid Waste Handling, E. Plaza, E. Levlin, B. Hultman, (Editors), TRITA-AMI REPORT 3073, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3073-SE, ISBN 91-7170-584-8. 2000

Report no. 8 Józef Trela (2000) Intensification of biological nitrogen removal in a two-phase activated sludge process with pre-dentrification, TRITA-AMI REPORT 3081, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3081-SE, ISBN 91-7283-020-4. 2000

Report no. 9, Proceedings of a Polish-Swedish seminar, Nowy Targ - Zakopane, October 24-26, 2001. Wastewater, Sludge and Solid Waste Management, M. Hopkowicz, B. Hultman, J. Kurbiel, E. Plaza (Editors), TRITA-AMI REPORT 3088, ISSN 1400-1306, ISRN KTH/AMI/REPORT 3088-SE, ISBN 91-7283-190-1. 2001

Report no. 10, Proceedings of a Polish-Swedish seminar, Gdansk, 23-25 March 2003. Integration and optimisation of urban sanitation systems. E. Plaza, E. Levlin, B. Hultman, (Editors), TRITA-LWR.REPORT 3004, ISSN 1650-8610, ISRN KTH/LWR/REPORT 3004-SE, ISBN 91-7283-471-4. 2003

Report no. 11, Proceedings of a Polish-Swedish seminar, Wisla October 25-28, 2003. Integration and optimisation of urban sanitation systems. E. Plaza, E. Levlin, B. Hultman, (Editors), TRITA-LWR.REPORT 3007, ISSN 1650-8610, ISRN KTH/LWR/REPORT 3007-SE, ISBN 91-7283-664-4. 2004

Report no. 12, Proceedings of Polish-Swedish seminar, Stockholm June 6-8, 2004. Integration and optimisation of urban sanitation systems. E. Plaza, E. Levlin, B. Hultman, (Editors), in edition

Report no. 13, Proceedings of Polish-Swedish seminar, Cracow March 17-18, 2005. Integration and optimisation of urban sanitation systems. E. Plaza, E. Levlin, B. Hultman, (Editors), in edition

Web site of the Project

<http://www.lwr.kth.se/Forskningsprojekt/Polishproject/>

Peer reviewed papers related to the Program

Kabacinski, M., Hultman, B., Plaza, E. and Trela, J. Strategies for improvement of sludge quality and process performance of SBR plant treating municipal and tannery wastewater. Wat. Sci. Tech. Vol 38, No. 4-5, pp. 69-77, 1998.

Banas J., Plaza E., Styka, W. and Trela J. SBR technology used for advanced combined municipal and tannery wastewater treatment at high receiving water standards. Wat. Sci. Tech. Vol 40, No. 4-5, pp 451-458, 1999.

Banas J., Plaza E., Styka, W. and Trela J. SBR technology used for advanced combined municipal and tannery wastewater treatment at high receiving water standards. *Wat. Sci. Tech.* Vol 40, No. 4-5, pp 451-458, 1999.

Plaza E., Trela J. and Hultman B. Impact of seeding with nitrifying bacteria on nitrification process efficiency. *Wat. Sci. Tech.* Vol 43, No. 1, pp. 155-163, 2000

Mikosz J., Plaza E. and Kurbiel J. Use of computer simulations for cycle length adjustment in sequencing batch reactor. *Wat. Sci. Tech.* Vol 43, No. 3, pp. 61-68, 2001.

Levlin E., Löwén M., Stark K. and Hultman B. Effects of phosphorus recovery requirements on Swedish sludge management. *Water Science & Technology.* Vol 46, No. 4-5, pp. 435-440, 2002.

Stypka, T., Plaza, E., Stypka, A., Trela, J. and Hultman, B. Regional planning and product recovery as tools for sustainable sludge management. *Water Science & Technology.* Volume 46, Number 4-5, pp. 389-396, 2002.

International conference presentations other than Joint Polish Swedish Reports

Banas, J., Plaza, E., Styka, W. and Trela, J. SBR technology used for advanced combined municipal and tannery wastewater treatment at high receiving water standards. *Proceedings of the 2nd International Conference on Advanced Wastewater Treatment, Recycling and Reuse, Milan, Italy*, pp.649-656, 1998.

Kabacinski, M., Hultman, B., Plaza, E. and Trela, J. Strategies for improvement of sludge quality and process performance of SBR plant treating municipal and tannery wastewater. *Proceedings of the IAWQ 19th Biennial International Conference, Vancouver, Canada, June 21-26, Book 5*, pp 65-72, 1998.

Trela, J., Plaza, E., Mikosz, J. and Hultman, B. Addition of organic material for denitrification improvement. *Proceedings of the 2nd International Conference on "Advanced wastewater treatment, Recycling and reuse"*, Milan, Italy, pp 295-302, 1998.

Mikosz J., Plaza E. and Kurbiel J. Use of computer simulations for cycle length adjustment in sequencing batch reactor. *2nd International Symposium on Sequencing Batch Reactor Technology*, 10-12 July Narbonne 2000

Plaza E. Trela J., Hultman B., Levlin E. and Kabacinski M. Sludge handling in relation to operation of SBR plant in Nowy Targ. *2nd International Symposium on Sequencing Batch Reactor Technology*, 10-12 July Narbonne 2000. (poster)

Plaza, E., Trela, J. and Hultman, B. Treatment of ammonium rich waste streams with low content of organic matter. *Proceedings of the 3:d World Water Congress of IWA, Melbourne, Australia 7-12 april 2002.*

Stark, K. Phosphorus recovery from sewage sludge by thermal treatment and use of acids and bases. IWA-publishing; *Chemical Water and Wastewater Treatment VII*, H H. Hahn, E. Hoffmann and H Ödegaard (Eds.) *Proceedings of the 10th Gothenburg Symposium 2002*, 17-19 June 2002. pp. 331-338, 2002.

Stark, K., Hultman, B., Levlin, E., Löwén, M. and Mossakowska, A. Calculation of chemical needs in combined phosphorus removal and recovery at Henriksdal WWTP, Sweden. *3:d World Water Congress of IWA, Melbourne, Australia 7-12 april 2002.*

Stark, K., Hultman, B. and Levlin, E. New system technology for combined phosphorus removal and recovery. *3:d World Water Congress of IWA Melbourne, Australia 7-12 april 2002.*

Stark K. and Hultman B. (2003) Phosphorus recovery by one- or two-step technology with use of acids and bases. *Proceedings of IWA specialist conference Biosolids 2003 Wastewater sludge as a resource, Trondheim, Norway, 23-25 juni 2003*, pp. 281-288, 2003.