INTERGRATED WATERMANAGEMENT IN THE WOOD MANUFATURING INDUSTRY

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ABSTRACT

Industrial wastewater management is still neglected in a dominating part of the companies in Sweden and it is not considered as a threat to health of man and environment. The Environmental Science & Engineering Research Group (ESERG) at LNU has under financial support of KK-foundation and large/medium-size companies in Southern Sweden been studied. Even though the problem has been studied for half a century there is knowledge missing and the stormwater is still a growing problem. Every time rain falls, it washes off oils, microorganisms, litter, sediments, fertilizers, and foreign chemicals from streets, parking lots, lawns, dumpster pads, metal roofs as well from landfill, industrial and harbour sites. Industrial facilities with large impervious surfaces for different types of handling of materials are generating stormwater effluents of different qualities which vary during different time periods and same stands for process water generated of a variety of volumes and often of high pollutant concentrations. In some catchment areas, industrial and small business activities can release a significant portion of some pollutants that ends up directly into receiving waters but also at the municipal wastewater treatment plant. Small businesses and enterprises do not pay attention to routine operations and neither have they had the economic resources to implement preventive measures, treatment facilities or to employ expertise on their particular environmental issues. The project "*Development of an Integrated Approach for Industrial Wastewater and Stormwater Management in the Wood-Industry Sector"* has generated new knowledge about industrial waste water treatment that will be presented at the Linnaeus Eco-tech 10 international conference.

Keywords: Integrated industrial wastewater management, wood industry, stormwater, landfill leachate, organic pollutants

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INTRODUCTION

In urban areas surface runoff from industrial can give serious quantitative and qualitative problems. Industrial and small business activities can release a significant portion of pollutants that ends up directly into receiving waters but also at the municipal wastewater treatment plant if combined sewer system is used. The stormwater and discharge of diluted process water might during shorter and longer periods (some hours up to days) in particular during the summer and the early autumn dominate the river flow from both quantitative and qualitative point of view. Small businesses and enterprises do not pay attention to routine operations, neither have they had the economic resources to implement preventive measures, treatment facilities or to employ expertise on their particular environmental issues. Some industrial for instant in the wood manufacturing industry activities generate low volumes (e.g.: 2.0 m^3 of cleaning wastewater for 100 000 m^2 of laminate wood floor weekly) of highly contaminated wastewater streams containing adhesive chemicals (e.g.: urea formaldehyde and phenol formaldehyde resins), ammonium sulphate, wood filler, lacquer and detergents, among others. Very high COD values (from 3 200 to 32 000 mg L^{-1}or higher) of recalcitrant organic compounds makes difficult to treat biologically this wastewaters in conventional centralized treatment plants. Dilution to 50 times or more with drinking water has been a common practice carried out by the industries in Europe before discharging into the sewage system.

By this knowledge a large co-production project named "*Development of an Integrated Approach for Industrial Wastewater and Stormwater Management in the Wood-Industry Sector"* was implemented by the *Environmental Science & Engineering Research Group* ESERG at LNU under financial support of KK-foundation and large/medium-size companies in Southern Sweden, including: one wood-laminate floor manufacturer AB Gustaf Kährs, two chemical suppliers AkzoNobel AB and Becker Acroma AB and one energy producer Kalmar Energi - which makes use of wood residues from Kährs to generate energy. During 2010, Anlager Svenska AB (that produces water treatment equipment) joined the project. The project with the wood industry is a good example of how research can be connected to education. Thanks to the financial resources available, this was the first time it was possible to have many post-graduate students in the same research project. Within the project theses on different academic levels are under production under the project's umbrella and includes: 1 post doc, 4 PhD students from LNU, 2 MSc students from the *Ecole du Genie de l'Eau et de l' Environnement de Strasbourg* ENGEES (*the School of Management of Water in Strasbourg* in France and 3 BSc students from LNU have been involved in the project. 18 students from the Industrial Ecology course developed assignments at companies involved in the project. The Kährs Environmental Ambassador Bruce Uhler and the environmental manager Åke Erlandsson has been teaching in the course and act as co-supervisors in the assignments developed at Kährs.

Growing concern about discharge of stormwater and industrial wastewater into water bodies, thereby affecting fragile aquatic ecosystems has lead to intensive research and development of treatment techniques during the last decades. Therefore, for those industrial sectors that have water as an important input to their production processes, which also generate large amounts of wastewater, on-site treatment technologies have been made available. However, there are a large number of industries that produces highly polluted wastewater, which due to the nature of their activities, are small-medium size industries (e.g.: olive oil mill in Mediterranean countries) therefore generating small volumes of wastewater. There are also those so called "dry-process industries", such as the wood floor and wood-based furniture producers that have no water requirement for their industrial production processes. Wastewater streams in

the wood-furniture and floor industries are generated during floor washing and machinery cleaning after different processes, such as wood sizing, gluing, filling and surface coating. The research group at Linnaeus University are targeting expanded research and teaching cooperation of Triple Helix type in the Baltic Sea Region and other parts of EU community.

THE LAW AND ENVIRONMETAL REPORTING

In Sweden there exist 15 national environmental objectives that were established by the Swedish Government in 1999 which should be considered when working with industrial wastewater and stormwater management. Among them are those related to toxin free environment and eutrophication as well as that on keeping lakes and rivers alive and groundwater of good quality. Regional it is the 21 County Administrative Boards working with the stormwater issues but each municipality have also their local environmental goals. Stormwater shall be considered as a type of wastewater and its generation should be considered as an environmental hazardous activity and should be handled as such and it is regulated in what in Sweden is called Miljöbalken (MB). The industrial waters must be treated if it can't be discharged without risk for environmental nuisance for estimation of the risk the pollutants in the water and the sensitivity of the reviewing water. Permission are needed according to MB and environmental consequence description (MKB) should be made and the MKB must show that no direct or indirect effects are caused on human health, animal, vegetation, soil water and air by the planed activity or measures planned.
The Swedish VA-law regulated general water and wastewater facilities (SFS 1970:244). Others the ABVA which includes general requirements for the use of the municipal water and wastewater facilities which also include rules about stormwater handling. The plan and construction law (Plan och bygglagen, PBL, SFS 1987:10) and the Registration of property law (Fastighetsbildningdlagen (SFS 1970:988)) is also dealing with stormwater as well as Jordabalken (SFS 1970:994) that dealing with risk of effects on surrounding ground or property. The Swedish Transport Administration has worked a lot with vegetative pond systems and is consider one big stormwater actor in Sweden. Also the Swedish Road law (Väglagen SFS 1971:948) includes stormwater.

The industry need to make a storm water quality assessment to include in their annual environmental report. Quality data must be gathered based on the knowledge that the water quality varies in time and space and pollutant loads vary at different points. There is a need for an effluent description, setting consents, mass balance calculations and stormwater modeling. Important pollutants in urban runoff are: sediment/habitat alteration, oxygen-demanding substances (organic matter), nutrients (phosphorous, nitrogen), toxic substances (heavy metals, oil and grease), bacteria, floatables, multiple impacts of several of these pollutants acting in concert.

OBJECTIVES OF THE PROJECT

In order to comply with the global sustainability policy towards zero discharge, and to contribute to the development of onsite feasible treatment options this research project aims to:

- Build-up deeper knowledge about coupled treatment processes, improving the efficiency of low-cost sorbent treatments (sawdust, fly-ash, activated carbon);

- Select and implement advanced oxidative processes (AOPs) as pre- or post-treatment steps coupled to the low-cost options, in order to achieve high removal of COD-TOC using as little chemicals as possible to meet the stringent EU discharge requirements;
- Establish a set of eco-toxicity tests including one producer (photosynthetic algae), one consumer (crustaceans) and one decomposer (bacteria);
- Design and test different combined/coupled treatment systems, focusing not only on pollutants removal but also on the elimination of toxic effects;
- Perform cost analysis for different coupled treatment systems with focus on product development and patent implementation;
- Investigate the possibility of integrating wastewater treatment steps through a functional landscape to polish/treat the remaining pollution, using ecological engineering principles.

PROJECT ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES

There were initially seven organizations participating the project that can be classified basically in 3 categories: (1) R&D and education (University of Kalmar); (2) Wood-based industry (floor, furniture and energy from wood) that generates wastewater streams from cleaning and stormwater runoff processes (AB Gustaf Kähr, Swedwood International, Kalmar Energi); (3) Suppliers of chemicals for the wood-based industry, which are released in the wastewater (Becker Acroma and Casco Adhesives AB). Because of communication problems with Swedwood International they were exchanged with Anlager Svenska AB after the first half of the project time. In Figure 1 the initial project organizational structure with the five organizational components is shown.

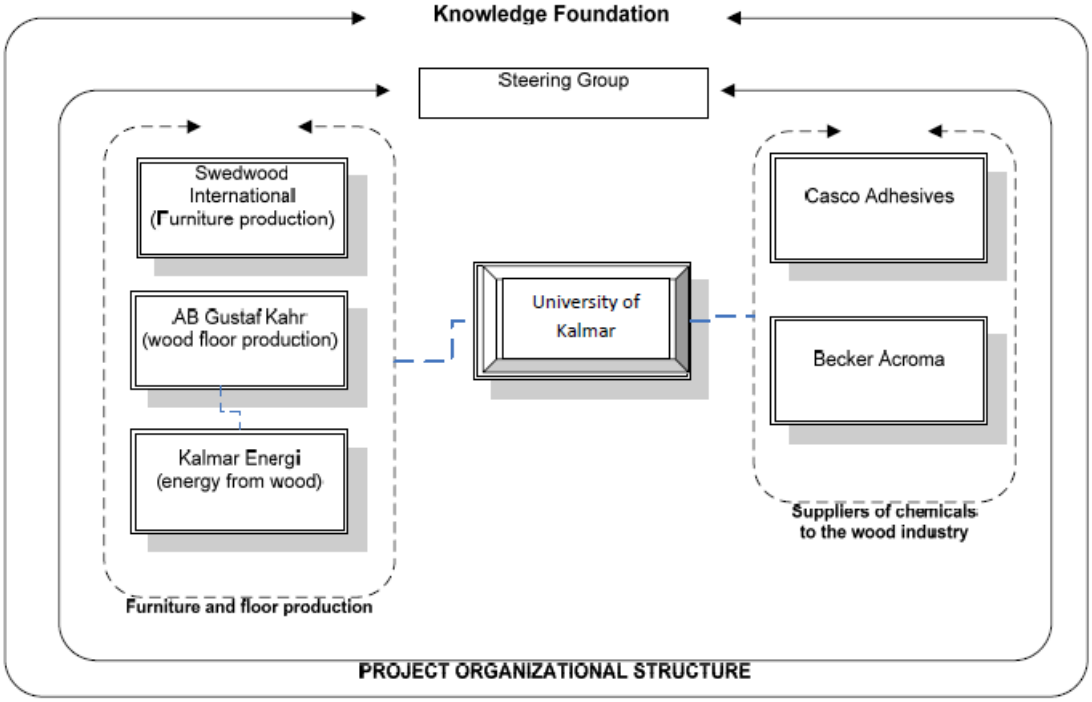

Figure 1. Project initial organizational structure including all participants according to their profiles (University of Kalmar is today a part of Linnaeus University)

THE STEERING GROUP

The Steering Group has a very important role in the project and then in particular if management and communication problem occur. It has the following composition: One Professor in Environmental Engineering; One Professor in Analytical Chemistry; A Researcher in Waste and water management; A Research & Development Manager from a waste management company; A Research & Development Manager from the wood industry sector; 2 Professors in Ecotechnology and one Professor in Environmental Engineering & Recycling.

The project Steering Group has the following responsibilities: a) to advise and review the project planning and activities, identifying eventual constraints or problems , proposing solutions; b) to ensure the widest applicability of the results of the project; c) in conjunction with the Project coordinator, to advise any changes to the project to reflect changes in circumstances during 3-year period; e) to ensure effective collaboration within the project team and with other research groups; f) to evaluate the practical and scientific merits of the proposed activities and results, advising the project team to promote changes in order to improve them, when it is the case.

The Steering Group direct the project consisting of members from the different companies, PhD students and senior researchers from Linnaeus University. In order to be sustainable, the participation required from each organization in the project is based on the organization's aims and concerns, so a good level of participation is guaranteed during the project period. The members of the project team representing the organizations in the project are all involved with the institutional targets: they are researchers in the subject, environmental coordinators or managers in the company, advisors for environmental programs, etc. The main responsible for the project execution has been the Linnaeus University including project members, particularly the coordinators. A dominating part of the activities, mainly experiments in pilot scale, have carried out at the industry sites, at Kährs and at Kalmar Energi sites in Nybro. This means that the environmental managers and coordinators in these companies, as well as the technical staff associated to the maintenance and cleaning of equipment, machineries and floors, have been actively involved in different stages of the project execution, but mostly during the on-site pilot tests that are operated by the local staff with supervision of the research team.

COMMUNICATION PLAN

For a successful project there is a need for are well prepared communication plan based on (i) a well-established collaboration among the members of the project team, the steering group; KK Foundation; (ii) well-defined target groups and well-defined strategy to reach these groups. Six target groups were identified, as following: Target Group 1: Project team (research team, companies project supervisors) and Steering group; Target Group 2: Companies in the project, particularly their operational staffs with activities associated to wastewater generation and handling; Target Group 3: Other companies in the same branch or branches that can obtain benefit; Target Group 4: Research and high education institutions; Target Group 5: Environmental agencies, governmental authorities that will be informed about the new management strategies proposed for the studied wastewater streams; Target Group 6: Public, NGOs, etc

The collaboration among the project team members and the institutions represented in the project are such that the skills and specific knowledge of each component are used to reach specifics target groups.

SOME RESULTS OF THE PROJECT

With the purpose of minimizing the negative impacts of wood-based industries on the environment and municipal sewage treatment plants in a cost-effective way, the research has focused on the treatment of cleaning/washing wastewater using low-cost nature-based strategies to remove organics and metals such as: (a) sedimentation followed by biological treatment including microbiological anaerobic, aerobic-anoxic reactors (Kaczala et al., 2010); (b) sedimentation followed by adsorption/filtering processes using dead biomass such as untreated sawdust (Kaczala et al., 2009); (c) sorption mechanisms with treated and untreated fly-ash (Lahoaprapanon et al., 2010); (d) sorption/filtration with coal and wood activated carbons (Lahoaprapanon et al, 2010); (e) electrocoagulation and; (f) flocculation using wood fly ash as CaO supplier. Regarding the stormwater generated at log yards by the same wood sector, to improve the knowledge available about pollutants release and transport, as well as the potential impacts, stormwater hydrological-chemical characterization (1 manuscript under preparation) followed by toxicity studies to aquatic organisms (Kaczala et al, 2010) and treatment at pilot constructed wetlands (experiment in the stage of data collection) have also been carried out. The project has also started an investigation about possibilities for integrating stormwater and treated wastewater effluents through a functional landscape to polish the remaining pollution with ecological engineering principles. Besides 6 papers in scientific peer-reviewed journals: Kaczala et al, 2009; Kaczala et al, 2010; Lahoaprapanon et al, 2010, Kaczala et al, 2010; Lahoaprapanon et al, 2010; Svensson et al, 2010 and Kaczala et al, 2010 (under preparation), the project has produced 5 papers to international conferences (the most recent conference paper got the Best Poster Paper Award at the 5th International Conference on Environmental Science and Technology ICEST-2010, Houston-Texas, 12-16 July, 2010, American Academy of Science-AAS) and later Henric Svensson the scholarship of Sparbanksstiftelsen Kronan for the best MSc thesis in the area. Based on the experience and the results obtained so far, it was concluded that low-cost alternative treatment options such as sorption onto dead biomass (e.g. sawdust, activated carbon) have from excellent to good performance regarding removal of different toxic metals from the cleaning/washing wastewater (Kaczala et al, 2009), average performance to remove COD (Lahoaprapanon et al, 2010a), meanwhile anaerobic-intermittent aerobic biological treatment had excellent performance to remove specific organic pollutants such as formaldehyde and low-to-average performance regarding removal of COD and nitrification (Kaczala et al, 2010). Stormwater from log yards as well as the cleaning/washing wastewater posed toxic effects on the freshwater microalgae (Kaczala et al, 2010). These results suggest that the development of combined treatment approaches, such as biological treatment and/or sorption/filtration coupled with selected advanced oxidative processes (AOPs) could lead to still low-cost treatment solutions, at the same time, meeting the stringent level required for discharge into recipient waters and certainly to discharge into municipal sewerage systems.

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