Water management in the paper industry: Solving scaling problems and recovering recyclable materials by means of membrane processes

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Paper production requires large amounts of water. To produce 1 ton of paper, a paper machine needs several hundred m^3 of water. Skillful circuit design and re-use have brought the fresh water demand of an average paper production unit down to around 10 m^3 / t today. Water extraction and treatment play an important role in the economic efficiency of the paper industry. For this reason, Papiertechnische Stiftung (PTS) in Munich organized two seminars on the topic of water from 11 to 13 June 2012, under the headings "Membrane technology in the paper industry" and "Water circuits in paper production". The first one was carried out in cooperation with the Deutsche Gesellschaft für Membrantechnik DGMT e.V., supported and represented by Dr. Ines Bettermann (CUT Membrane Technology GmbH & Co.KG). With around 50 participants mainly from paper mills and plant construction companies, each of the two events attracted great interest. Lectures were presented by experts from the industry, universities and PTS.

Membrane technology in the paper industry: A success, despite critical conditions

Although membrane systems have become state of the art in many industries, they continue to be an exception in the paper sector. This may be due to the high volume flows or sometimes difficult water compositions involved, for example calcium concentrations of > 300 mg / L. The seminar, which has been organized for the fourth time in a row by PTS, nonetheless demonstrated that membrane systems can be used economically and successfully also in the paper industry. Widely known, but of constant interest, is the MBR technology (Ingulf Schroeter lecture, Hager + Elsässer GmbH), which is currently used in nine large-scale installations in European paper mills. The technique of coating pigment recovery from the wastewater of high-quality paper coating processes has been known for more than 20 years as well. The presentation of Ms Tuija Kuula (Metso Paper Inc.) showed that it can be used very economically with an ROI of <0.5 years. This was confirmed by a reference list of 40 full-scale plants worldwide. The applied ultrafiltration technology from Metso Paper Inc. is also suitable for the treatment of so-called white waters and thus the actual circuit water of a paper mill. Mr Thomas Boehme (Propapier PM2 GmbH) presented one of these systems, which has been operated very successfully and without technical problems in the mill for some time.

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Recovery of recyclable materials from wastewater

Applications, where membrane technology is not only used to treat water, but creates direct economic benefits for the operator by recovering another valuable material, were of particular interest. In this context, the seminar participants discussed ongoing developments of membrane techniques for the concentration of lignin and hemicelluloses. Dr. Frank Lipnizki (Alfa Laval - Business Centre Membranes A / S) presented an industrial plant for the extraction of hemicellulose from the wastewater of a pulp mill that will soon be put into operation. A variety of uses are conceivable for both lignin and hemicelluloses, e.g. to produce biopolymers or alternative fuels.

A presentation about anaerobic MBR technology met with great interest as well (lecture by Dr. Benjamin Simstich, PTS). In principle, the procedure is the same as in a conventional (aerobic) MBR, but membrane operation is linked to an anaer-

Fig. 1: Participants of the seminar "Membrane technology in the paper industry"

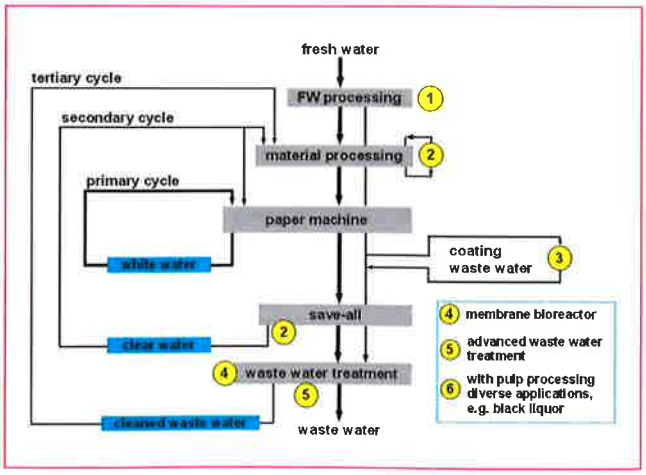

Fig. 2: State of the art: Application sites of membrane systems in the water circuits of paper mills (lecture by B. Simstich, PTS)

Fig. 3: Effectively staged: Views of membrane systems (lecture by A. Lüer, PANTREON GmbH)

Fig. 4: Pilot plant trials performed in the EU research project AquaFit4Use (lecture by B. Simstich, PTS)

obic reactor here. The advantage of the process is that it generates biogas with at the same time minimal energy demand and residue production. The technology is currently under development in several companies and several full-scale plants have already been implemented, though so far not (yet) in the paper industry.

Innovative applications

Mr Buurmann-Behne (Pall GmbH) presented a cost-effective alternative to traditional sand filters for freshwater treatment in paper mills: a dead-end ultrafiltration system with minimal flushing water volume. Other technological developments that proved to be of interest to the professional audience included a pretreatment process for water softening (PhD Marie-Pierre Denieul, Veolia Environnement Recherche & Innovation) as well as the ZELIX membrane system of PANTREON GmbH (lecture by Dr. Andreas Lüer, see Fig. 3) with practical examples of biomass ultrafiltration from anaerobic digestion.

Future workshop: Results of ongoing R & D activities

The development of a ceramic nanofiltration membrane having a separation limit of 200 D enables entirely new applications of membrane technology. The known advantages of ceramic materials, especially their high resistance, make it possible to use this membrane in highly demanding areas, e.g. processes with very hot partial streams (lecture by Dr. Hannes Richter, Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, Institutsteil Hermsdorf and Ms. Daniela Roemer, PTS).

The last three lectures of the seminar were devoted to other ongoing research and development projects. Organizer Dr. Simstich presented his research on the use of submerged MBR technology at 50° C. This unusual membrane use indeed poses a challenge to biology and materials, but opens up opportunities and possibilities that cannot be offered by conventional mesophilic MBR operation. Ms Daniela Roemer (PTS) presented the goals and first results of the EU research project "CapWa", which investigates the use of gas permeation membranes for water recovery from the moist exhaust air of paper machines. The event was concluded by the lecture of Mr Sebastian Tews (GKU Gesellschaft für kommunale Umwelttechnik mbH), who introduced a project about concentrate treatment conducted by the University of Stuttgart (Department of Sanitary Engineering, Water Quality and Waste Management).

Re-definition of aims for the use of membrane processes: Valuable materials instead of only H_2O

To sum up, three central statements can be made about the future of membrane technology in the paper industry:

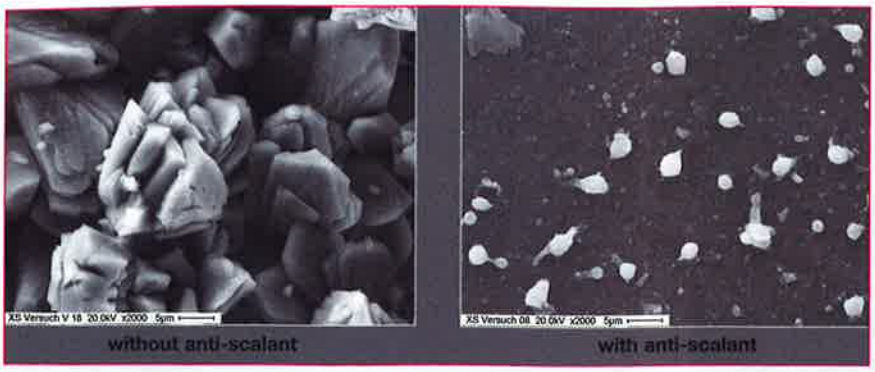

Fig. 5: Calcium carbonate deposits on a membrane: The effect of antiscalants is clearly visible in the SEM image (lecture by T. Richter, BK Giulini GmbH)

- Membrane processes used for water treatment only have certainly potential for further development; but on account of their lower economic efficiency they only have a chance in isolated cases today.
- The biggest opportunities for further developments and new installations are offered by membrane processes that recover recyclable materials in addition to water treatment. The following processes have proved to be particularly promising here: coating pigment recovery, the anaerobic MBR process and the extraction of lignin and hemicelluloses.
- Membrane processes for fresh water treatment offer advantages and will be developed further.

Against this background, it was decided to organize the seminar again in 2014, focusing on the "Recovery of recyclable materials from wastewaters of the pulp and paper industry ".

Scaling problems in the water circuits of paper production

The seminar "Water circuits in paper production", which has been held by PTS every two years for many decades, had an entirely different focus this year: Scaling problems, focusing especially on the causes and possible avoidance strategies. The use of $CaCO_3$ as filler and coating pigment is standard practice in papermaking. Recovered paper, the main raw material used for papermaking today, introduces large amounts of calcium in the mill water circuit. In recent decades, it has become increasingly evident that closed loop recycling management and the multiple recycling of papermaking fibers tend to raise the calcium concentrations in the circulation waters of paper mills (lecture by Georg Hirsch, TU Darmstadt, PMV).

There are basically three options to prevent lime deposits: avoiding the introduction of calcium, targeted precipitation and removal of calcium, or avoiding the dissolution of $CaCO_3$ from recovered paper to retain most of it on the fibers and remove it from the circuit with the new paper product. Based on the carbonate balance, pH is the central parameter here. The fact that microbial activity has a major influence on the pH of complex water circuits as well was highlighted by two presentations on biocide use given by Ms Elke Tiedtke (Kolb Distribution Ltd.) and Mr Roland Fliegen (Ashland Industries Deutschland GmbH). The relationships between pH and anaerobic microbial activity as causes of odor problems and scaling as well as an optimized water circuit design were explained by Mr Holger Jung (PTS) (see. Fig. 6). His presentation was based on the experience and data gained by consultancy and research projects on water circuit optimization, a service PTS has been providing to its customers from the paper industry for many years. Together with the project partners from industry, PTS regularly develops customized solution concepts to reduce odor or scaling problems.

The lectures by Mr Bernd Mueller (Siemens AG) and Mr Frank Wiemeyer (KOWITEC Ingenieurgesellschaft für Wassertechnik mbH) introduced various technological possibilities for the specific elimination of calcium carbonate from water. Dr. Torsten Richter (BK Giulini GmbH) showed in his presentation that lime deposits can also be prevented with the help of chemical additives (see Fig. 5).

To sum up: Even though scaling problems have been an issue in the paper industry for decades, they continue to be high on the agenda to date. In particular the trend towards increasingly closed water circuits and the higher calcium contents of recovered paper contribute to this development.

Well informed with continuing education offers of PTS

All seminar proceedings (only in German) can be purchased from PTS. Most of the presentations can also be found in other publications or documents. Feel free to contact the authors of this article for further details. PTS organizes several other seminars and symposia on the subjects of environmental and process engineering in the paper industry. Please visit our website www.ptspaper.com for further details.

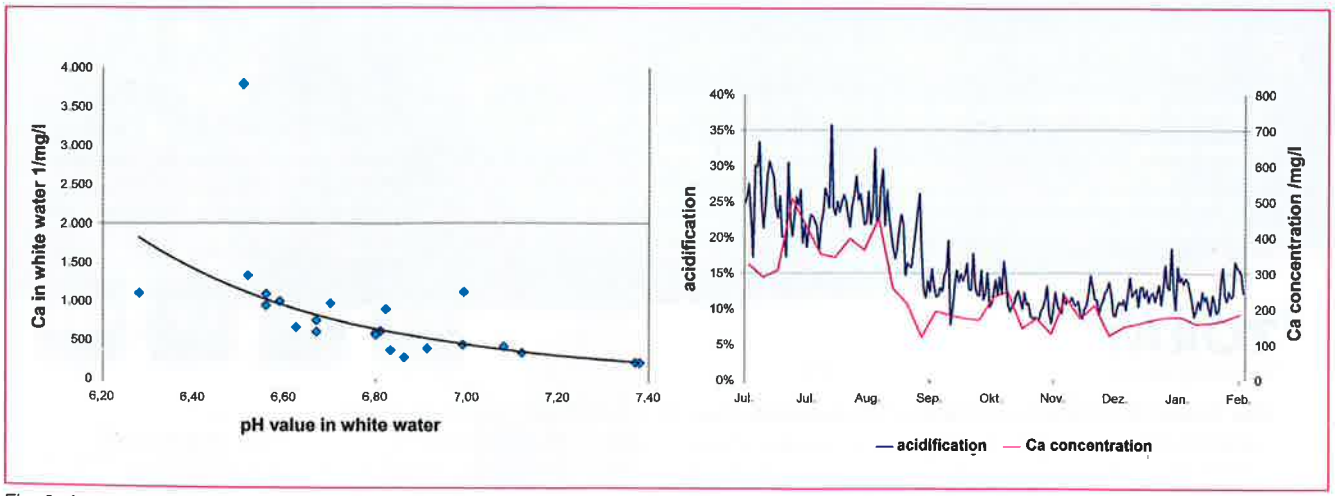

Fig. 6: An optimized water loop makes it possible to reduce anaerobic microbial processes as well as the formation of organic acids. This raises the pH and reduces the dissolution of calcium carbonate, causing its concentration in the water circuit to decrease (lecture by H. Jung, PTS)

Europe must use water more efficiently

A report by the European Environment Agency (EEA) published in March 2012 showed that Europe must redouble its efforts to use water more efficiently, or otherwise this could have negative consequences for the economy.

Water resources are scarce in many parts of Europe and the situation continues to intensify. Agriculture, energy, industry, the public water supply and ecosystems are all important, and they compete with each other for the scarce water resources.

In addition, climate change makes the future water supply less predictable.

In its report "Measures for the efficient use of water resources in Europe" / 1 /, the European Environment Agency (EEA) advocated an integrated water management system, where firstly, the existing legislation should be applied more efficiently.

Water scarcity has led to serious consequences for all economies that are dependent on agriculture and industry, and in parts of Europe has led several times already to restrictions in the supply of drinking water. Moreover, there are indirect effects on the economy. Reduced river flows, lower water levels and groundwater levels, as well as dwindling wetlands, all have a destructive impact on natural ecosystems, and can thus have a negative impact on economic productivity.

In some parts of Europe, the competition for water resources is becoming increasingly aggravated. On average in the EU, agriculture uses a quarter of the water from the natural environment, and in southern Europe, it can be even up to 80%. Moreover, a fifth of the available water is used for the public water supply - and about a quarter of this solely for toilet flushing. Also hydroelectric power plants change the natural structure and the flow of rivers and lakes, which in turn affects the ecosystems.

Efficiency improvements in agriculture would be easy to achieve, because a lot of water is being used inefficiently for the irrigation of crops. Some estimates suggest that about a quarter of the water that is currently being used for irrigation in Europe can easily be saved by replacing the hoses or pipes being used. The public water supply could also be made more efficient. In some EU Member States, as much as 50% of the drinking water is lost.

The report says that inefficient water use leads to higher energy consumption, which involves additional financial and environmental costs. Usually, about 0.6 kWh/m3 is needed for the transportation and processing of freshwater for drinking water. In addition, 4 MJ/m³ is used for the desalination of sea water. Several EU countries use desalination processes, especially Spain, which is one of the largest users of desalination technologies in the world.

It is also specified in the report that authorities should set clear and sustainable environmental targets for water use. These targets would be different according to the resources available in each case, but should be designed so that the natural environment has sufficient water for its requirements. It requires a kind of "decoupling", so that an increase in economic