AquaFit4News Issue 5—Nov 2010

Coordinator's Column

In sustainable water use more things enter than the production of Water-fit-for-Use with an as low as possible environmental impact. By closing the water cycle other problems are involved, like the increase of biofouling and scaling and - by using other water sources than drinking water - the need for a better quality control increases. A number of these topics are also research topics in AquaFit4Use and in this newsletter three subjects are discussed. More insight in the formation of biofilms is important for setting up procedures for cleaning and disinfection. Going into more detail by monitoring specific micro-organism gives you the opportunity to develop new more dedicated biofilm inhibition strategies.

In paper industry, but also in other industries closing the watercycle is often limited by the building up of salts and other components causing deposits everywhere in the system, resulting in damage to process apparatuses and water treatment systems. Silica is one of the components causing big problems. The research of UCM described in this newsletter is a good start for solving this kind of problems.

At the renewed AquaFit4Use website in the coming period more examples of solutions for these type of problems will be published.

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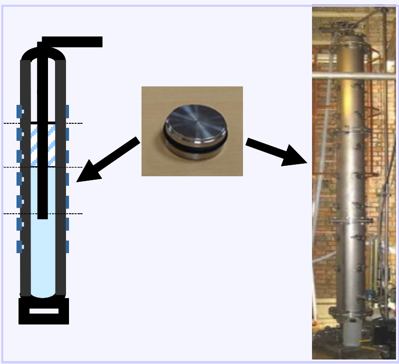
AquaFit4Use — Fouling monitoring and prevention

In an industrial context, the term fouling is coined to indicate deposition of undesired material on the surface of equipment. The formation of deposits or deposition layers is an ubiquitous phenomenon in those industrial sectors involving the handling of aqueous streams. Fouling can have inorganic (scaling) or organic nature (biofouling). The negative effects of fouling present a wide variety. Scaling, for instance, can lead to losses in the heat transfer capacity of heat exchangers or impede the correct filtration in separation or purification equipment; mature biofilms can detach from the surface where the develop and affect downstream equipment or the final product. This AquaFit4Use newsletter focuses on key activities of the project related to the prevention of scaling in RO membranes and to the characterization and monitoring of biofilms.

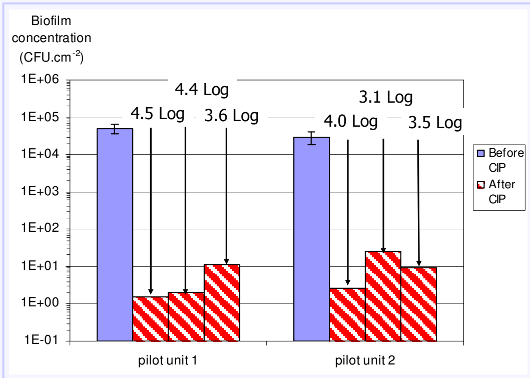
Tools for Biofilm detection

In industrial water processes, the presence of biofilm can promote several problems such as loss of process efficiency, scale formation and particulate deposition or microbial influenced corrosion. Therefore, the challenge in the industrial use of water is to control and reduce the development of biofilm on the surfaces of the equipment. Within this objective, specific methods and tools have been developed to take and analyse biofilm samples at different steps of water processes. Nestlé Waters have carried out pilot tests to evaluate biofilm formation in water processes and to evaluate the efficiency of cleaning and disinfection procedures on biofilm. Two different pilot units have been used: 1) part of stainless steel pipe with coupons that can be installed in parallel of existing water processes, 2) stainless steel column with coupons that simulates a well column.

The main results of the tests carried out with both pilot units show that biofilm formation occurs shortly after the start-up of the pilot units with significant increase during the first 2 to 3 weeks to achieve constant biofilm concentrations. The results of the pilot tests also show that the tested cleaning and disinfection procedures do not totally remove cultivable bacteria in biofilm (no total disinfection). The observed disinfection efficiency was comprised between 3 and >5 log reduction on cultivable bacteria in biofilm for the most efficient CIPs. These results confirm that CIP procedures with cleaning disinfection steps seem to be more efficient than disinfection step alone.



Schematic diagram and picture of the "well column"



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participating partners

First successful application of developed specific gene probes for monitoring early biofilm forming bacteria in paper mill samples

Water samples originating from the same sampling points along the water process flow of paper mill SAPPI Maastricht were sampled during different years (autumn 2008 and 2009). They were directly analysed with a set of gene probes specific for the main bacteria groups by Vermicon. In environmental samples this set of gene probes normally covers more than 95% of all bacteria. The cultivation-independent bacteria population profiles were established and compared. Different sample types showed different population profiles but each sample compared to the corresponding sample from the other year showed similar bacteria population patterns. In Fig. 1 results on a selection of sampling points is shown. The relative shares of the analysed bacteria groups are indicated by different colours (see legend of Fig. 1). Using this approach most interesting population profiles regarding present diversity were retrieved for samples from production process (clear water after filtration at PM6). These samples were dominated by bacteria of the *Betaproteobacteria* and *Cytophaga-Flexibacter subphylum*. Both groups together represented more than 90% of all viable bacteria cells within these samples. All other analysed bacterial groups were underrepresented in these samples. More specific analysis with newly developed gene probes revealed that most bacteria of these two groups were related to *Tepidimonas arfidensis* (*Betaproteobacteria*) and *Cloacibacterium* spp. (*Cytophaga-Flexibacter subphylum*), respectively. The results obtained are consistent with results of an earlier EU-project ("ODOUR CONTROL") and confirm the findings of recent studies considering these two bacterial groups together with *Rhodobacter* species (*Alphaproteobacteria*) as the early biofilm forming bacteria in paper mills with neutral to alkaline pH process conditions (Tiirola et al., 2009). Our current findings within AquaFIT4Use project support these studies by the detection of at least two (*Tepidimonas*, *Cloacibacterium*) of the three bacterial groups in large quantities directly within samples of two different paper mills with neutral to alkaline process conditions. *Rhodobacter* was not detected in the analysed samples. Moreover, using specific probes the absence of *Deinococcus geothermalis* and *Meiothermus* was analysed. Both bacteria are supposed to be relevant as early biofilm forming bacteria in paper mills with acidic conditions. The findings of Vermicon strongly support the theory that biofilm formation in paper mills is pH-dependent. Ongoing analysis with the developed specific gene probes in paper mill samples will deliver valuable insights and will help to elucidate the process of biofilm formation and succession in situ. Whereas *Tepidimonas arfidensis* and *Cloacibacterium* seem to have a high potential to act as biofilm indicator organisms in paper mills with neutral to alkaline process conditions, the role of *Rhodobacter* is currently under investigation. Possible effects of strategies for inhibiting biofilm formation by these organisms can easily be monitored by application of the new specific gene probes. If the relevance of the bacteria can be confirmed in further studies first easy-to-use testkits targeting *Tepidimonas arfidensis* and *Cloacibacterium* spp. for monitoring biofilm formation and success of biofilm inhibition strategies in paper mills will be developed for general use.

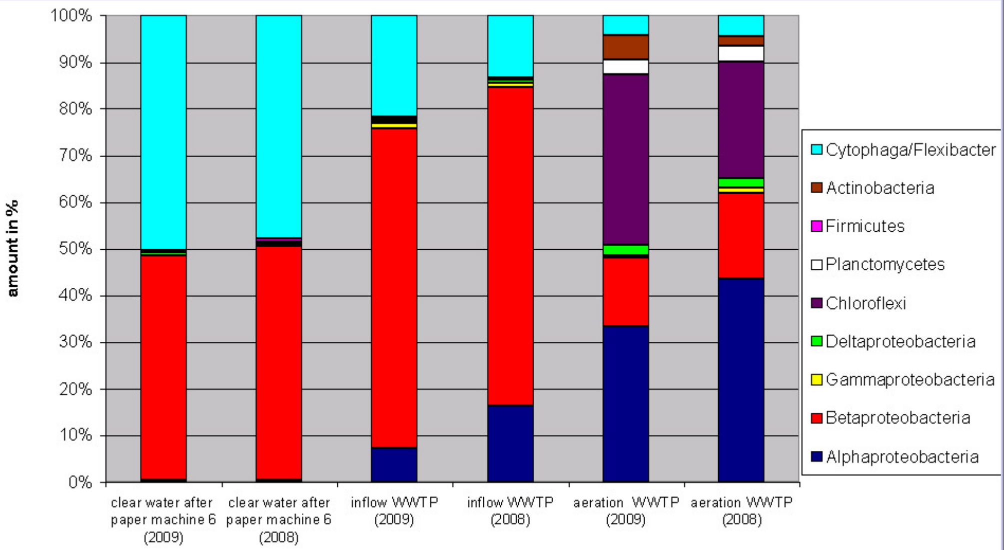

Figure 1. *Comparison of bacteria population profiles obtained by VIT-Profiling analysis on three different sampling points in paper mill SAPPI (clear water after filtration at paper machine 6 (PM6), inflow wastewater treatment plant (WWTP), aeration tank WWTP). Samples were taken in September 2008 and September 2009 and results compared.*

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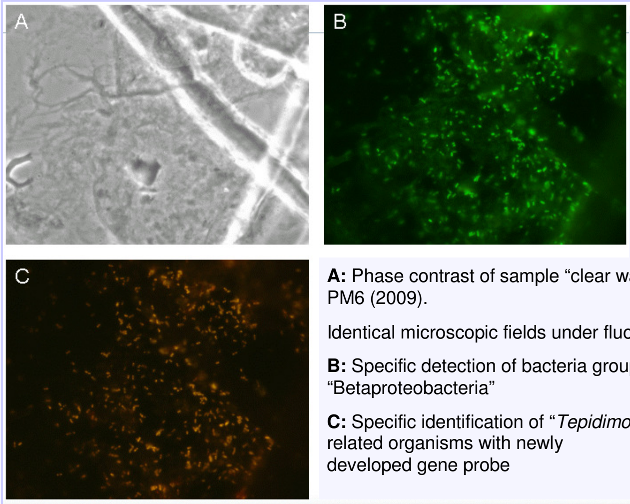


A: Phase contrast of sample "clear water after filtration at PM6 (2009).

Identical microscopic fields under fluorescence:

B: Specific detection of bacteria group "Betaproteobacteria"

C: Specific identification of "*Tepidimonas arfidensis*"-related organisms with newly developed gene probe

Figure 2. *Specific identification of bacteria related to Tepidimonas arfidensis in sample "clear water after filtration at PM6 (2009) using gene probes. Magnification: 1000x.*

Forthcoming Events

IWA Water and Energy conference 2010

10-12 November 2010, Amsterdam, The Netherlands

IWA Water and Energy Workshop - Balancing Water Quality and Energy: A Model-Based Approach

12 November 2010, Amsterdam, The Netherlands

Water Reuse and Desalination: Water Scarcity Solutions for the 21st Century

15-17 November 2010, Sydney, Australia

The Water and Business Conference 2010 "Measure and interpret your water footprint:

How to make water reduction pay"

8th December 2010, London, United Kingdom

Microbes in Wastewater & Waste Treatment, Bioremediation and Energy Production (IWA).

24 to 27 January 2011, Goa, India

WEX 2011 - Water & Energy Exchange

15-17 February 2011, Lisbon, Portugal

Water Innovation, Technology and Sustainability (WITS).

17 to 19 March 2011, Sao Paulo, Brazil (Accepting abstracts until 20/12/2010)

15th International Water Technology Conference

31 March 2011 to 2 April 2011, Alexandria, Egypt

FILTECH 2011

22-24 March 2011, Wiesbaden, Germany

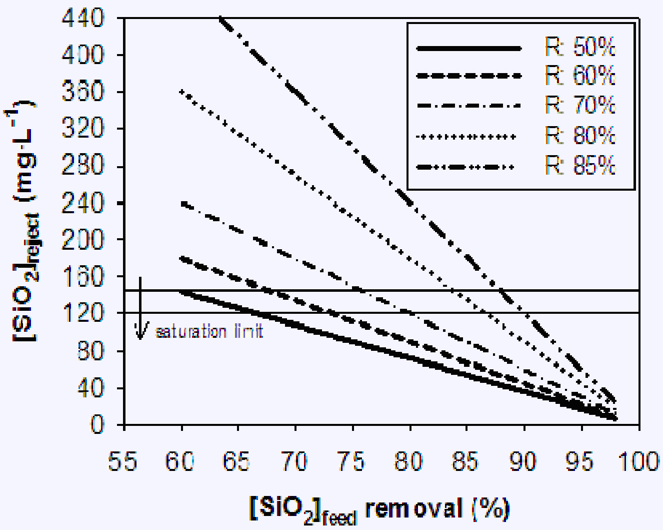
Water and Industry 2011, IWA Specialist Conference Chemical Industries

1-4 May 2011, Valladolid, Spain (Accepting contributions until 15/11/2010)

Silica removal from paper mill effluent employing flocculation-coagulation prior to reverse osmosis

Silica is present in paper mill effluents in a significant concentration. Silica mainly comes from the sodium silicate (Na_2SiO_3) added during the deinking process. Na_2SiO_3 is required in the process to perform several functions: (1) it stabilizes hydrogen peroxide used to bleach pulp in the pulper; (2) it has buffering and saponification properties; (3) it assists ink particles dispersion and influences their size; (4) it appears to act as an ink collector, and it reduces fibre losses and suppresses the flotation of fillers. Replacement Silica by other products is rather difficult, due to these different functions. One of the research lines addressed in the AquaFit4Use project comprised testing a pilot technology train aimed to enable the reuse of the HOLMEN Paper Madrid factory effluent as fresh water. The train integrated a biological treatment, a membrane bioreactor and a reverse osmosis. The relatively high concentration of silica in the effluent reaches much higher values in the retentate side of the reverse osmosis (RO) membrane, what makes it precipitate and form a layer on the membrane surface that obtrudes the pores and limits the RO recovery (see picture). In order to have a cost effective RO, the recovery should be above 80%. Silica solubility ranges from 120 to 150 mg·L^{-1} (25ºC, pH<8.0-8.5). Considering these conditions, the UCM group calculated theoretically that more than 90% of silica should be removed from the water feeding the RO to avoid scaling, whenever working at a recovery higher than 80% (see graph). One possible alternative to prevent silica precipitation is to limit its solubility through the increase of pH, although in the case concerned it would lead to carbonate scaling. The research team of UCM focuses therefore on coagulation as a previous stage to the RO to remove silica. The coagulation mechanisms induced by six inorganic coagulants was studied in real time at different pH levels. 100% removal of silica was obtained although at non economical conditions for industrial application. A reduction of over 50% was achieved without pH regulation, what is still not reaching the 90% reduction required for a feasible RO. Although promising, the results indicate that further studies are required to improve silica removal. The researchers from UCM points out that the key to achieve a better removal may lay on finding the adequate coagulants/flocculants and pH conditions.

Microphotography of the RO membrane



SiO2 concentration for different percentajes of removal and recovery rates.

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AquaFit4use—Water in industry, Fit-for-use, Sustainable Water Use in Chemical, Paper, Textile and Food Industry

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SEVENTH FRAMEWORK PROGRAMME