BIOFOULING:

A Unique South African Solution to an Expensive Problem

In May this year, a major brewery in Port Elizabeth will be the first to test the abilities of a new biofilm monitoring and treatment system – one that looks set to save industrial water users hundreds of thousands of rands in production and running costs.

Professor Eugene Cloete with the full-scale laboratory model of the Rotoscope, which is being used at the University of Pretoria for ongoing studies and monitoring.

Developed at the University of Pretoria, the Rotoscope is a uniquely South African answer to a problem that costs global industry several billion Euros a year. The system is designed to monitor and treat the formation of unwanted biofilm – the accumulation of bacteria, proteins, algal material and fungi that causes the deterioration in the microbiological quality of treated water.

The corrosion and weathering caused by this biofilm can lead to considerable damage, ranging from contamination of pharmaceutical or microelectronic products, to reduced efficacy of heat exchangers, unexpected corrosion of stainless steel and premature destruction of mineral materials.

In a nutshell, the Rotoscope aims to provide an affordable on-line, real-time, non-destructive method to monitor biofilm. And at roughly a tenth of the price of similar high-end systems, it holds huge promise for local companies who want to improve the price and quality of their products. Once commercialised, it could also capture a substantial slice of the somewhat underserved overseas market.

According to local company BTC Products & Services, who have been licensed to manufacture and market the Rotoscope, there are only two other commercial units currently available. Both sell for around 40 000 Euros each, and are bought almost exclusively by large utility companies.

BTC owner, Hugh Mitchell, says that the first three Rotoscope prototypes will be installed at the brewery in Port Elizabeth by mid-May, and five to ten units will be under evaluation by June. The units will be used in the brewery's pasteuriser, and to measure biofilm formation in a pipeline carrying re-treated effluent.

"This 'test' phase will determine the robustness of the unit as well as the value and practicality of the data and information it generates," he explains.

"We have secured funding from the Department of Trade and Industry, as well as the support of three major organisations, for the commercialisation process. We hope to sell the first two commercial units to our technology transfer partners in the USA and in England."

The Rotoscope aims to provide an affordable on-line, real-time, non-destructive method to monitor biofilm – at roughly a tenth of the price of similar high-end systems.

This success follows more than two years of internally-funded development by Rotoscope inventors Professor Eugene Cloete (head of the Department of Microbiology and Plant Pathology at the University of Pretoria) and Professor Fanie van Vuuren (from the Department of Civil and Biosystems Engineering).

"I have been studying biofouling and biocorrosion for the past 10 years and one major challenge has always been monitoring the adhesion of bacteria to surfaces exposed to water and the adverse effects that go along with this," explains Prof Cloete.

"In 2002 I organised an international conference on biofouling monitoring to discuss the challenges and review what was on the market. This led to the publication of a book on biofilm monitoring, of which I was co-editor. What became clear was that there was no affordable on-line real time non-destructive method to monitor biofilms. My many contacts in the industrial water treatment industry, and their need to control biofouling, added to the challenge."

BIOFILM: A DIFFICULT CUSTOMER

So what is biofouling, and what makes it such a tricky – and widespread – problem?

Prof Cloete explains that when water-borne bacteria congregate in sufficient numbers they form a film on the surface of pipes, tanks and indeed any piece of equipment. This

BIOFOULING CONTROL – A SOPHISTICATED SCIENCE

Many bacteria are *planktonic* – they float around in water. Most microbiological work is done using these suspended cultures on water samples. The bulk of the bacteria that cause problems, however, are *sessile* – attached to a surface.

Once bacteria attach to a surface they go through a series of changes, the most obvious of which is the excretion of a slimy material, referred to as biofilm. Linked to this is the problem that when bacteria attach to a surface, a whole different set of genes are activated, making it a significantly different organism to deal with compared to the planktonic material suspended in the water.

Industrial process water or potable water is not a sterile system, so there is a level of biofilm in all systems that is inherently present without causing problems. Problems occur when the biofilm builds up ("biofouling"), creating dead biomass and therefore a nutrient source that leads to re-growth of organisms in the water.

Biofilm structures vary according to flow conditions in a water system, for example, a turbulent flow produces homogenous and slimy biofilms, which are harder to "inactivate" than biofilms produced by laminar flows.

Also, the effectiveness of a disinfectant or biocide depends on the age of the biofilm as well as its particular physical and chemical structure. To complicate things even further, the same type of bacteria can vary from site to site.

Biofilms do not conform to any mathematical model; they vary in thickness, density and composition from point to point, and in any given process water system. Treatments that work at site A might not work at site B, and therefore there is no standard level for the removal of biofilm.

Water flows from a slipstream of the main process water, into the Rotoscope through this pipe, before being channelled up to the rotating plastic wheel.

Inside this section of pipe is a series of removable glass slides. Biofilm forms on these slides as well as the plastic wheel, and while the wheel provides for real time monitoring, the slides give the user the option of sending samples away for more in-depth analysis and testing, if required.

At the centre of the Rotoscope is a rotating plastic wheel that is half submerged in the main process water. Biofilm forms on the disc and is measured by green and/or infrared light that is projected onto the back of the disc (which is covered). The front of the disc is clear, which means the system could also be used to visually monitor algal growth, where relevant.

A digital measuring unit is linked to the red/green light box on the back of the plastic wheel. This unit measures the refraction of the light, which changes as biofilm forms on the wheel's white surface. When a pre-determined threshold is reached, the unit send a signal to the chemical dosing unit and a slug dose is released into the main water tank of the system.

ABOUT BTC PRODUCTS & SERVICES

BTC Products & Services is a local disinfectant specialist focussing on stabilised chlorine dioxide and its applications, primarily in the food safety, agricultural and water treatment industries.

Services include trouble shooting in terms of disinfection and sanitising; microbial sampling of water, produce, swabs and air samples; ethylene measurement; and the design, development and installation of dosing and monitoring equipment.

The company's chlorine dioxide generators make BTC a logical partner in the Rotoscope commercialisation, in that they make the on-site generation and delivery of chlorine dioxide possible.

"biofilm" is a living organism which consists of mainly water, bacteria, suspended solids, corrosion products, algae, yeasts /molds, protozoa and molluscs.

Biofilm is typically found wherever liquid and a solid surface interface, such as in heat exchangers, cooling towers, municipal water storage and the food and beverage industry. To prevent contamination of water and related products, biofilm development must be monitored and treated continuously by taking water samples and measuring plate counts to determine the level of microbiological contamination. "Even the most efficient organisation work on the principle that if

these samples are clear then the whole production will be clear from microbiological contamination," says Prof Cloete.

This is extremely costly, which means most companies are restricted to intermittent testing and treatment.

"However, this film has been found even in water that has been tested and shown to have very low microbiological counts when water samples are plated out. Therefore product loss still occurs as a result of microbiological contamination, even though quality control samples show little evidence thereof."

BTC's Hugh Mitchell adds that currently, biofilm management is based on decisions made from the results obtained from bulk water samples – even though research shows there is little correlation between planktonic bacteria (floating in water) and sessile (attached to surface) bacteria of the same type.

"Any strategy that incorporates antifouling technologies will therefore be more cost-effective if the extent of the biofilm can be monitored online and in real time, without destroying the biomass formation," he says.

Most monitoring techniques rely on the removal of biomass from the system in the form of coupons that have been exposed to the fluid for a given period. These samples are then sent away and analysed, which is time-consuming and require skilled personnel.

"Usually biofilm is only detected after it has already caused economic losses," says Mitchell. "Current treatment techniques are also problematic, as many are based on the assumption that if one kills the organisms in the bulk water, one will prevent the formation of biofilm. However, biofilms are resistant to many non-oxidising biocides and re-growth of biofilm is inevitable. This often leads to significant overuse of poorly selected disinfectants or biocides, which raises costs and creates environmental concerns."

THE CHEMICAL DOSING QUANDARY: SLUG VS. CONTINUOUS

Continuous low-level chemical dosing is often used in the removal or detachment of biofilms. However, slug dosing – which is part of the Rotoscope system – has been demonstrated to be significantly superior. "In many cases, the level of detachment changes by factors of 10 to 100 times for slug dosing compared to continuous dosing," says Mitchell. "Slug dosing is also more cost-effective."

> "It is a proactive system, in that biofilm forms in the Rotoscope before it forms on mild or stainless steel. This means that appropriate dosages of biocide can be released before biofilm becomes a serious problem."

HOW IT WORKS

Besides real-time, online monitoring of biofilm, the Rotoscope automatically releases a dose of biocide used to disperse the biofilm, whenever a threshold level is reached.

The device has a rotating plastic wheel that is half submerged in water flowing from a slipstream of the main process water. Biofilm forms on the disc and is measured by green and/or infrared light reflecting off the white surface. The frequency of measurement can be varied, from every five minutes to every 120 minutes and/or be continuous.

"It is a proactive system, in that biofilm forms in the Rotoscope before it forms on mild or stainless steel," explains Prof Cloete. "This means that appropriate dosages of biocide can be released before biofilm becomes a serious problem in any system."

Simply put, the Rotoscope is immediate, effective, non-destructive, continuous and affordable.

The technology has been patented in South Africa, with international patents pending. Each unit is expected to sell for between R35 000 and R50 000, and the most significant applications are expected to be in industrial water systems like paper mills, cooling towers, brewery pasteurisers, water utilities, water distribution pipelines and heat exchangers.

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