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TECHNICAL BRIEF

INDUSTRIAL WATER QUALITY

Developing an effective microbiological support service to underpin effective water management in the pulp and paper industry.

Microorganisms in Paper Mill Water Systems

Water-related challenges in the pulp and paper industry

Owing to the shortage of water, paper mills in South Africa are under pressure to use less water than their counterparts in Europe and North America. Integrated water management plans for paper mills include strategies to reduce water consumption, such as through water reuse that is affected by closure of water circuits.

Closure, however, results directly and indirectly in an increase in microorganism populations. Microbial biofilms frequently result in the production of odours, paper breakages, spotting, holes and discolouration of paper, resulting in a loss in paper quality. Microbial biofilms also play a significant role in microbiologically-induced corrosion. Microbial problems consequently result in poor operational control, lower production rates and higher maintenance costs of a paper mill.

The microbiological dimension

The current industry practice in monitoring microbial populations is to enumerate one or two guilds of microorganisms (i.e., groups of different microorganisms that respond similarly to their environment) at a limited number of points in the water circuit. Specific organisms are only identified in exceptional circumstances.

Through comprehensive characterisation and identification of microbial populations, however, it would become possible to improve control of microbial growth and extend the limits of water-system closure. Microbiological data could also assist in preventing biofilm formation, reducing corrosion, minimising health risks and improving efficiency of water treatment processes.

The microorganism-associated problems that frequently occur in paper mills depend primarily on the degree of closure of the water system. Upon closure, the temperature of the water system is generally elevated and nutrient concentrations increase. As more recycling of process water takes place, nutrient content and levels of degradable carbon rise,

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further contributing to problems of biofilm formation and microbially-induced corrosion. Microbiological control is, therefore, an important factor in reducing water consumption, health risks and maintenance costs, as well as increasing production.

The identification of microorganisms and characterisation of microbial populations is important for the design of effective microbial control programmes. Knowledge of the different microorganisms present in water systems and the interactions within microbial populations would assist in the selection of the most suitable biocides and dosage levels to minimise microbial build-up.

Identification of microorganisms is also important in managing system disturbances, such as acidification of stock tanks, with their associated health hazards. A microbial database that includes population, environmental and habitat characteristics could help to improve management of these water systems, resulting in reduced water consumption, production costs and health risks, and also help to improve effluent quality through efficient microbial control.

Microbiological support for the paper industry

A project was undertaken with the aim of developing an effective microbiological support service to underpin effective water management in the pulp and paper industry. The first objective was to compile a database of microorganisms and population characteristics in relation to physical properties of water systems. Further objectives were to establish a facility for routine identification of microorganisms encountered in water systems and to train technical staff and students in providing appropriate microbiological support to the industry.

As a first step, international literature was surveyed to guide investigations into issues relating to the paper mill water system environment, the influence of environmental parameters on microbial populations, the influences of corrosive biofilms in paper mill water systems as well as reduction of such influences, and the use of traditional as well as emerging techniques to quantify microorganisms in environmental samples and to assess biocide programmes.

Over a period of three years, the water systems of 15 paper machines at seven mills were surveyed on two occasions each, to study the microbial populations, process and environmental parameters (including temperature, pH, total dissolved solids, oxidation-reduction potential (ORP), dissolved oxygen, chemical oxygen demand, total nitrogen and total phosphorus) prevalent during the winter and summer. Eight sampling points per paper machine were selected on the grounds of accessibility and their previous use as customary sampling points.

Research findings and products

Analyses of data confirmed that the build-up of temperatures associated with water system closure could lead to increased microbial numbers. Microbial control must, therefore, be considered when planning modifications to mills.

The increase, as expected, in chemical oxygen demand, nitrogen and phosphorus resulting from recirculation, could further increase microbial loads. The significant inverse relationship observed between microbial counts and ORP, has provided a technique for rapid assessment of microbial levels. Since ORP is further influenced by oxidising biocides, it also serves to indicate the levels of active biocide.

Like ORP, most of the other environmental variables monitored had an influence on the microbial growth and diversity parameters. Nevertheless, the optimal combination of variables to use in a relationship or model that would explain the greatest part of the variation in microbial numbers has yet to be established.

Enterobacterial Repetitive Intergenic Consensus – Polymerase Chain Reaction (ERIC-PCR) was used successfully as a typing technique to distinguish between the prevalent bacterial isolates from paper machines. Furthermore, sequencing of the 16S rDNA gene made it possible to identify many of the isolates.

The most prevalent bacteria were identified as members of the genus ***Acinetobacter*** and these strains were also the most widely distributed. The prevalent isolates from all surveys were characterised using Biolog® substrate-utilisation profiles and Restriction Fragment Length Polymorphisms (RFLPs).

The data were used to develop a computer database supported by a software key that could be widely distributed at relatively little expense. It is easy to install and can be operated intuitively.

The database is unique in terms of its focus on bacteria from paper mill environments. Although it currently contains data on a limited number of strains, these strains represent more than 90% of the bacteria from the culturable populations in the surveyed environments.

The database user can identify unknown isolates by entering either Biolog or RFLP data; a data match returns morphological and cultural characteristics of the reference isolate, as well as information on the environment where it was collected. The database is set up in such a way that users could easily add information from their own studies.

Conclusion

- A database of prevalent microorganisms supported by a key, using either a molecular fingerprint or physiological profile, has been developed. The database includes information on the habitat characteristics, distribution and possible impact of each strain.
- Significant effects of different environmental attributes in water systems on microbial numbers have been determined, with results that are potentially useful for enhancing effectiveness of water management in paper mills.
- A facility for routine identification of microorganisms from industrial water systems was established and used throughout the investigations. The resulting reference cultures and database software have been transferred to Buckman Laboratories and the Department of Food Science (University of Stellenbosch) where they will be available to further the objective of providing an appropriate microbiological support facility for the benefit of the pulp and paper industry.
- Researchers and students trained during the course of the investigations could similarly provide a valuable microbiological service to the industry.
- The database and key software developed with the paper industry in mind could also benefit other industries that require tools for bacterial identification and control.

Further reading:
Characterisation of Planktonic Microbial Populations in Paper Mill Water Systems (**Report No: 1459/1/07**)
To obtain this report contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565 or E-mail: orders@wrc.org.za; Web: www.wrc.org.za