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Pulse-Chlorination®, the Best Available Technique in Macrofouling Mitigation Using Chlorine

ABSTRACT

In 1998, KEMA developed a new chlorination method called Pulse-Chlorination®. It enables optimal antifouling treatment with a minimum use of chlorine. This technology is based on the principle that in general mussels and clams have a recovery period after exposure to chlorination before opening fully and restarting filtration. The method takes advantage of this recovery time by using short successive periods of chlorination, alternating with periods without chlorine. The tests undertaken between 1998 and 2001 resulted in chlorine savings up to 50% on a yearly basis, compared to regimes applied in earlier years. Results on site after one year with Pulse-Chlorination® show improved control of macrofouling and a better overall performance of the cooling water system. This in turn allows longer intervals between planned outages, thus spreading the running costs over three years rather than two years. There are additional advantages for power plants that use electrochlorination plants to produce hypochlorite. As the Pulse-Chlorination® reduces the hypochlorite dosage up to 50%, only part of the installed equipment is used at any one time allowing maintenance of the unused electrochlorination plants. Because less hypochlorite is dosed, there is a reduction in chlorination byproducts discharged and thus less environmental impact.

INTRODUCTION

The majority of the Dutch (power) industry uses chlorination for antifouling treatment in their cooling water systems. This is due to proven efficacy, wide experience, moderate costs, opportunities to optimize the chlorination procedure, and to the fact that low-level chlorination has not proven to have a major ecological impact [2–7].

The Dutch power industry asked KEMA to study alternative methods of chlorination with the aim of reducing the total quantity of hypochlorite used without loss of effective fouling control. Any new system should be applicable in as wide a range of industrial plants as possible. The method described here is called Pulse-Chlorination® and has been declared as a BAT (Best Available Technique) under the terms of the EU Integrated Pollution Prevention and Control (IPPC) reference document for macrofouling mitigation in once-through cooling water systems using chlorine [1].

In the Netherlands, the majority of the macrofouling problems in industrial cooling water systems are caused by three mussel species: the marine mussel Mytilus edulis, the brackish water mussel Mytilopsis leucophaeata, and the fresh water mussel Dreissena polymorpha, known as the Zebra mussel.

Pulse-Chlorination® is based on the principle that in general mussels and clams have a recovery period after exposure to a chlorination period before they open fully and restart filtration for oxygen and food uptake. Pulse-Chlorination® takes advantage of this recovery time by using short successive periods of chlorination, alternating with periods without chlorine. During continuous chlorination the mussels close and switch from aerobic to anaerobic metabolism and can live on their own reserves for up to 10 weeks. By applying Pulse-Chlorination® the mussels continuously have to switch their metabolism from aerobic to anaerobic, leading to physiological exhaustion. This results in a more rapid antifouling compared to the conventional continuous chlorination. To exactly determine the behavior of the mussel, i.e., the recovery period, the valve movements are monitored in a special device, the MusselMonitor®.

MATERIALS AND METHODS

Mobile laboratory

All tests are carried out in the KEMA mobile laboratory on location; see Figure 1. This laboratory is a rebuilt 20-ft sea container consisting of a "wet" laboratory part and a "dry" part for the electronic equipment. The temperature in the laboratory is regulated with air-conditioning. In the laboratory the cooling water system conditions, which are unique for each plant location, are simulated so that the results are directly applicable to the station. The tested cooling water system conditions, which differ for each of the plant sites and which are crucial for the desired regimes, are ambient water composition, residence time of the cooling water (pumps to condensers) and water velocity. If possible, the organisms used as biosensors for the MusselMonitor®, are collected near the test location. For the chlorination experiments, sodium hypochlorite is used from that plant site. Water is usually obtained near the cooling water intake. In the laboratory, the water is collected in a 1 m^3 buffer tank with a water flow of about 500 L min^{-1}. Due to the high water flow no sediment precipitation occurs in the buffer tank. With submersible pumps, the water is directed from the buffer tank through a hard PVC tubing system to the test tanks. In this system, the water flow is regulated and measured on-line with a Magno flow meter. For a Pulse-Chlorination® test usually three test units (tanks) are used (Figure 1, right):

- In Unit 1, the natural (= control) valve movement of the mussels is monitored with the MusselMonitor® without chlorination.
- In Unit 2, chlorination takes place. The reaction of the mussels is monitored with a MusselMonitor®. The free oxidant (FO) and/or total residual oxidant (TRO) concentration is measured with a continuous colorimetric measurement using DPD reagent (HACH CL-17). The results gained with Unit 2 are compared with the control Unit 1. If mussels in Unit 1 show abnormal behavior, results of that period from Unit 2 are skipped out for data analyses.
- In Unit 3, continuous on-line measurements are made of the following water parameters: temperature, turbidity, dissolved oxygen, pH, and salinity.

On each visiting day, the FO or TRO concentration is measured with a single spot colorimetric measurement using DPD reagent (HACH DR/2000) and is used for checking the concentrations measured with the HACH CL-17; if necessary, the HACH CL-17 is calibrated. All recorded data from Mus-