Biological monitoring of industrial effluent: better monitoring of water quality

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Discharges of treated industrial waste water can sometimes threaten the quality of the receiving surface water. Online monitoring with biological measuring systems (bio-monitoring) can help in the early detection of changes in effluent quality that may lead to increased toxicity load on the receiving surface water. Research by the Centre of Expertise Water Technology (CEW) and WLN has shown that the selection and implementation of online bio-monitors for the purpose of water quality control requires bespoke solutions. This article discusses the practical applicability of biological monitoring systems to the effluent of the Sitech Integrated Wastewater Treatment Plant (IWWTP) in Geleen, the Netherlands.

Sitech Services B.V. in Geleen treats waste water in the Integrated Wastewater Treatment Plant (IWWTP) serving a large number of factories on the Chemelot industrial park. The effluent from the installation is discharged into the Meuse via a tributary of the Ur. It is known that a fluctuating waste load on the IWWTP, e.g. as a result of malfunctions and maintenance stops (start-up or shut-down of factories), can have an effect on the biological treatment capacity, and thus on the quality of the effluent.
Effluent quality assurance can be improved by implementing an Early Warning System (EWS). As part of this EWS, Sitech intends to implement online bio-monitoring on the effluent of the IWWTP. The bio-monitoring is aimed at the early detection of changes in effluent composition that may cause significantly higher toxicity levels in the receiving surface water.

The following criteria were used in the selection of the bio-monitor(s):

- Sensitivity: for the IWWTP effluent, in terms of sensitivity, the system is at least comparable to other types of surface water bio-monitors used in the Netherlands.
- Reliability: the system does not give false negative or false positive alarms.
- Speed: the system does not lose any time in sample flow pre-processing.
- Simplicity: the system is easy to maintain and operate by Sitech's IWWTP operators.
- Robustness: the system works at least 95% of the time, regardless of conditions.
- Supplier continuity: the system is supplied by a reliable party, which is expected to still be able to provide support in five years.

A limited number of online bio-monitors are currently available on the market. Different test organisms and measuring principles are applied, such as photosynthesis inhibition (algae), reduction of bioluminescence (bacteria), abnormal swimming behaviour (water fleas, fish, Amphipoda) and respiration reduction (bacteria). After an expert assessment, a system based on a change in the swimming behaviour of the Amphipoda seemed to offer a better perspective, in particular because of the relative simplicity of the system.
Since there is little information in the literature about the sensitivity of the Amphipoda to contaminants relevant to Sitech, this sensitivity was investigated on a laboratory scale and compared to the water flea by means of EC50 measurements (EC50 is the concentration at which 50% of the test population exhibits deviant behaviour, in this case inactivation, or ceasing to move). This showed that the sensitivity of the Amphipoda to acute toxicity, caused by components relevant to the Sitech situation, is in the same order of magnitude as that of water fleas. However, based on the observed movement behaviour of the Amphipoda, it was concluded that the risk of false positive alarms in this application is relatively high. That is why we switched to exploring a different system: the Mosselmonitor®.

Mosselmonitor®

The principle of Mosselmonitor® is based on the detection of abnormal patterns in the opening and closing of mussel shells. Mussels close their shells when water quality is poor or abnormal. In the Mosselmonitor® the distance between the shells of eight mussels is measured every minute by means of induction. In the summer of 2018, the monitor was subjected to a range-finding study in the Water Application Centre (WAC) in Leeuwarden. It appeared that mussels are sensitive to disturbances in the water quality of the IWWTP effluent by the addition of small amounts of influent (1–2 % on a volume basis). However, there were still uncertainties about successful implementation in practice, in particular with regard to (a) the long-term behaviour of the mussels in the event of IWWTP effluent (will the mussels remain vital for a long period of time) and (b) adequate alarm settings. It was therefore decided to carry out on-site endurance testing to assess and demonstrate the applicability of the Mosselmonitor® in situ.

Endurance tests

Endurance tests were carried out in the spring and summer of 2019 and showed that the monitor functions in a stable way on the IWWTP effluent in situ. The mussels remain vital under normal conditions for periods of at least six weeks. In addition, it has been confirmed that the Mosselmonitor® is sensitive to disturbances of the 'in situ' effluent quality. During the research, several disturbances were created by adding low concentrations of IWWTP influent to the effluent. At mixing ratios of 1 to 3% (by volume), a larger number of mussels were closed than under normal conditions (see Figure 1). After finishing the dosage, the mussels opened up again.

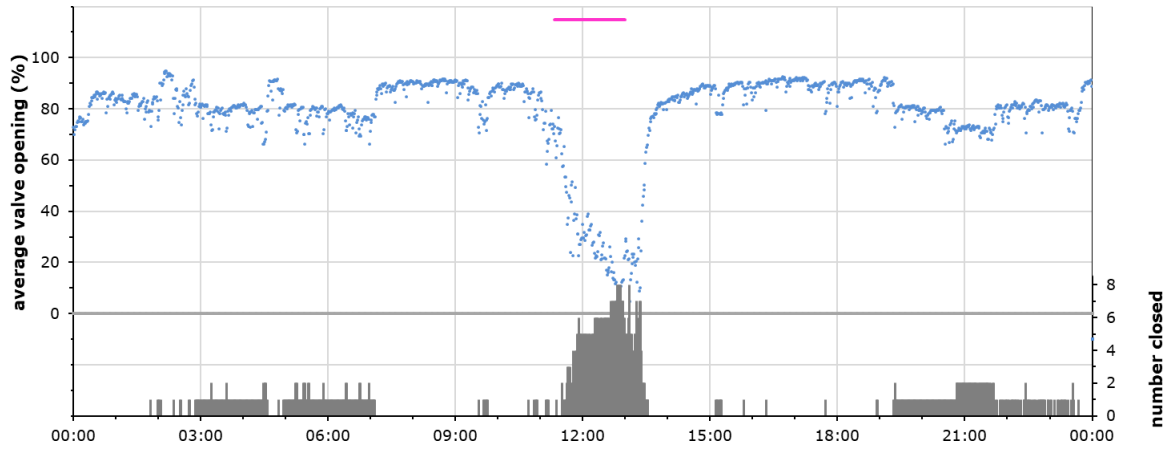

Image 1. Effect of influent dosing (3% v/v) to effluent on the shell-position pattern of the mussels and the number of closed mussels. The magenta line indicates the period of dosage

In practice, the sensitivity of the biological monitoring system is partly determined by the alarm settings. The 'closed alarm' seems to be the most relevant for Sitech's situation. This means that alarms are triggered when a certain number of mussels remain closed at the same time for a certain period of time. The number of mussels (out of eight) and the duration of simultaneous closure are the adjustable parameters. The sensitivity decreases, as does the risk of false-positive alarms, when the number of mussels that are included is higher and/or the closing time increases. Figure 2 shows the average shell opening (0–100% open) and the number of mussels (1–8) that were closed simultaneously over the three-month period of the study. This data can be used to determine the relationship between the 'closing time' and 'number of mussels closed simultaneously' settings on the one hand, and the number of alarms on the other hand (Figure 3). The optimal alarm settings vary depending on the situation or location. In the case of the Sitech IWWTP, the settings will be submitted to the competent authority for approval.

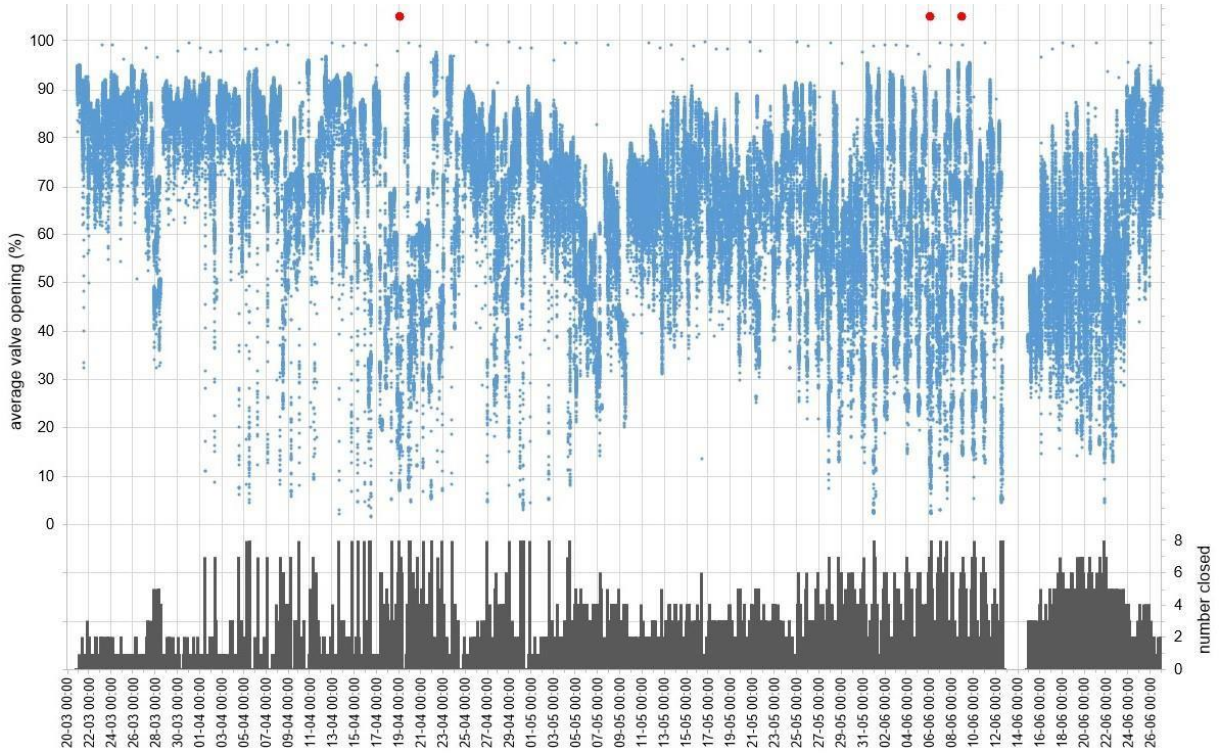

Image 2. Average shell opening (0–100% open, average of 8 mussels) and the number of mussels that are simultaneously closed (1–8) during the 3-month period of the study of the Sitech IWWTP effluent. If an alarm setting of '7 mussels closed at the same time for 60 minutes' was set, three alarms would have been triggered during this period (red dots). Periods for maintenance and testing are not included in the data.

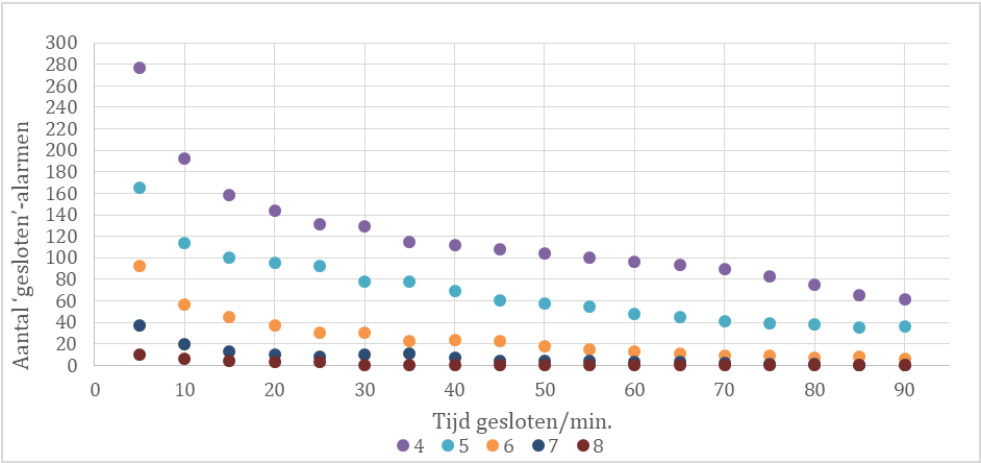

Image 3. Relationship between, on the one hand, the 'number of mussels closed simultaneously' and 'duration of simultaneous closure' settings and, on the other hand, the number of alarms triggered during the 3-month study period of the Sitech IWWTP effluent.

Conclusion

The Mosselmonitor® has satisfactorily passed the tests for the situation of the Sitech IWWTP. The mussels remain vital when they are continuously exposed to effluent and they show significantly different shell position patterns (more mussels close simultaneously) when the water quality deteriorates (due to the addition of untreated influent). This provides the basis for even better quality control through the early detection of abnormalities, even if the specific substances are not (yet) known.