AutMoNet 2002
Automation in Water Quality Monitoring

Vienna, Austria, May 21-22 2002
University of Agricultural Sciences

On line Po river water mussel monitoring

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prof. G. Badino**, Ing. L. Meucci*, d.ssa D. Giacosa*

* Società Metropolitana Acque Torino SpA,, Corso XI febbraio, 14 - 10100 Torino, Italy
e-mail info@smatorino.it; lorenza.meucci@smatorino.it

** Dip. Biologia Animale, Università di Torino, Via Accademia Albertina, 17 - 10100 Torino, Italy
e-mail guido.badino@dbe.ur.ito.it

Introduction

Proper management of the drinking water sector makes it necessary to constantly improve the water quality, in compliance with the current legislation concerning the protection of water sources (national legislative decree n° 152/99), while, at the same time, keeping the drinking water production costs under control.
The monitoring of surface water quality used as source of water supply is not a simple task since it is vulnerable to quality deterioration from natural causes (as for instance, storm events) and from anthropogenic pollution events (from industrial sources and spills).
Storm events are observable, and even predictable, while pollution occurs at unpredictable times, and is difficult to detect. The most advantageous way to monitor the water quality both as source and as supplied product, envisage continuous monitoring, by means of a multi task approach, including surrogates, specific parameters and biological (toxicological) test.
Continuous monitoring of individual chemical species or general physico-chemical parameters (Baldwin and Kramer, 1994) can provide a very rapid warning of changed conditions, or the occurrence of pollutants, but in generally the sensor more suitable to real time detection and warning are specific and expensive, and monitoring is limited by the availability of the proper sensor; on the other hand, the sensor for general physico-chemical parameters (as for instance temperature, conductivity, dissolved oxygen, pH) have poor value in warning for accidental pollution, but are interesting in long term environmental evaluation. Monitors using living organism as biosensors do not provide direct information in water quality changes, but detect a reaction of the organism to a harmful conditions.
Toxicological monitoring has to be carried out at the same time or where possible prior to chemical–physical monitoring, since it is capable of quickly identifying any changes in water resources and avoiding undesirable effects on living systems and, in particular, on humans. An application of a biological monitor using mussel is described for the toxicological water quality surveillance of a river water resource.

Methods

The Turin water company SMAT (Società Metropolitane Acque Torino Spa) produces about one fourth of the drinking water for Turin city from a surface source, namely the Po river.
At the intake area, located immediately upstream of the Turin city, the river water is moderately polluted, because of presence, upstream in the Po river, of industrial civil and zootechnical wastes; moreover the plants are vulnerable to sudden pollution phenomena since raw water intake cannot be disconnected from the river without interrupting drinking water production.
Among the other on line instruments, a mussel monitor is employed as early warning system to detect changes in the river water quality.
The monitored mussels are Unionidade namely *Unio elongatulus* Pfeffer autochthonous of the Po river. Previous works (Badinoet al. 1991) demonstrated their suitability in laboratory toxicity testing, and in particular their sensitivity to heavy metal pollution. The organism used have been taken from the Po river about 20 kilometers upstream the Turin city and in a lake from an abandoned gravel quarry near the Po river about 10 kilometers upstream the Turin city. The mussel are all adults and sexually mature; the range of length is 50- 70 mm, the corresponding age of 3-6 years, as assessed by the winter rings on the shell surface. Before the installation on the monitor, usually they are kept for at least one week in the Po river water entering the plant.
The system used (Mosselmonitor® by Delta Consult – The Netherlands) works with 8 mussels and is based on the measure of the valve distance.
The position of the shells is recorded, according to our settings, every 90 seconds. Two sensors are glued to every mussel one of each shell side.
A high frequency signal is sent to the first sensor (coil); this induces voltage in the sensor fixed on the opposite shell half with a strength inversely proportional to the distance between the two coils. The voltage is a measure of the position (opening) of the shell.

In normal conditions the mussel are “open” and they filtrate large volume of water to take up food and oxygen for their vital functions. In case of danger, for instance the presence of a predator or when the quality changes, the mussel close their shell and isolate themselves from the environment, avoiding the exposure to the adverse condition such as hypothetical polluted water.
Another atypical biological response to adverse condition is the increase in the frequency of opening/closure of the valves that can be read as a need for a better and/or more oxygenate water; normally this behaviour is observed when a foreign body enter between the valves and the mussel attempts to throw it out.
According to the valve position, recorded as percentage of the shell span, three different alarms are generated, namely closure (C), filtration decreasing (D) and hyper-activity (A).
The C alarm which means isolation form the environment for some mussel for a long time, occurs when a given number of mussels at the same time shows a shell relative closure; mussels in the “closed” position are not always entirely closed, a percentage of the maximum open position must be set, at which the mussels considered “closed”. If the mussel closes further than the set percentage, a timer is initiated, and if mussels re-opens the shell to a level higher than the set percentage, the timer is reset. The sensitivity of the system is increased with the “closed” percentage: in our settings closed percentage is 30. The alarm threshold is reached when the given number of mussel remains closed for a given number of minutes; to avoid the occurrence of false alarm we set a needed closure time of twenty minutes before alarm detection.
Decreasing average valve position (D alarm) is related to the decreasing filtration activity, and could indicate the presence of pollution in the water; it has to be considered a more sensitive alarm signal but it is demonstrated to be less reliable, especially after storm events, when the river water turbidity showed increase. Hyper-activity evaluation is a detectable alteration of activity, measured by means of the ratio of valve opening and closing in a period of time; this alarm showed to be very reliable in testing the system with toxicants, and is related to real suffering of the mussels.
The mussel monitor is working at the drinking water treatment plant intake for about five years.

Risultati e discussione

Toxicity test

Simulation of pollution due to some toxic substances at different concentrations have been carried out in the first two years. The concentrations of the investigated pollutants were selected on the basis of the Maximum Allowable Concentration for some compounds reported in the European Directive (CE/778/80) for water intended for human consumption. An average of four concentrations were prepared for each pollutant, addend in increasing order in the water monitored, in order to verify, during the period exposure (usually 24 hours) if and when alarms occur, their type and lasting.
Table 1 reports for each toxicants tested the sensitivity of the system expressed as the lowest concentration producing alarm (LCPA) and the types of alarm generated at the different concentration tested.

Evaluation and minimisation of the influence of monitoring of environmental and operating conditions

The behaviour of the bivalves showed to be related to some extend on some environmental parameters as for instance dissolved oxygen and temperature of the water, minor influence seems to be extended by turbidity, flow rate of the water, noises and vibrations. Moreover the activity of the mussels showed a circadian rhythm. The important role played by dissolved oxygen in keeping a favourable environment to the mussels was observed during the fluctuations of this parameters following natural events and was also confirmed through schedule tests. Observation under hypoxic conditions were carried out in all seasons, confirming the data obtained in natural events. The records obtained were of C alarm, lasting as long as 15 hours a day, especially during the summer . To overcome the problem of false alarm detection due to hypoxia, an aeration device has been added in the monitoring tank, which showed no relevant interference on normal monitor conditions.

Furthermore a constant flow rate in the monitoring tank showed less vibration in the filtratory behaviour of the mussels, improving the reliability of the system .
Temperature must be taken into consideration in setting the monitoring parameters, as this has a strong influence on the behaviour of the testers. In spite of the fact that daily fluctuations in temperature do not usually exceed the interval of two degree in monitoring conditions, and therefore do not cause anomalies in the behaviour of the bio-sensors, seasonal variation have show the need to set different parameters related

to the seasonal conditions. Therefore in order to avoid false alarm detection instrument setting have been modified, based on temperature values.
For alarm C, three temperature ranges were identified for changing the number of bio sensors needed for triggering the alarm. During summer months (T=20-24°C) the longer photo period favours greater filtering activity. Therefore the simultaneous closure of four of eight mussel is significant. Vice versa during the winter T=<10°C all vital functions slow down, therefore, in order to avoid excessive false alarms, the sensitivity of the mussels must be reduced by increasing the number of closed bivalves to six out of eight for the alarm to be triggered.

During intermediary season (T= 10-20°C) the optimal number of closed mussel for triggering the C alarm is five out of eight.
Type D and A alarm are less prone to seasonal variations.
A detailed analysis of the data and the subsequent changes made to the method of acquiring results has led to a considerable reduction in the occurrence of undesired false alarm. Between the end of 1996 and the beginning of 1997 an over sensitive recording protocol resulted in 324 hours of false alarm in just four months, most of which were unjustified. This was attributed to the application of *standard* acquisition parameters, suggested by the suppliers, that had been suitable in similar situation in which, however, another biosensor had been used, namely the *Dreissena polymorpha*. This species is the sensor most commonly used to bio monitor surface waters, but it is not indigenous in Italian fresh water. The experience gained from this study of the behaviour of *Unio elogatulos* and on how the system works has made it possible to reduce the total number of unjustified alarm during 1998-1999, to less than 6% using the toxicity tests as a reference.

Toxicant	LCPA	Detected Alarms
Cadmium	5 µg/L	A, D
Copper	50 µg/L	C, D
Mercury	5 µg/L	C
Zinc	100 µg/L	C
Nickel	50 µg/L	C
Lead	250 µg/L	C
Aluminium	400 µg/L	C, D
Ammonia	1 mg/L	C, D, A
Nitrate	50 mg/L	C, D
Nitrite	600 µg/L	C, D
Laurylsulfate	200 µg/L	C
Terbumethon	100 µg/L	C

Po river water pollution detection

The early warning activity of mussels detect some real pollution accidents occurred in the Po river: for instance, in September 1998, a C alarm was detected for five hour and was related to the presence of greasy spot on the river surface, and in January 1999 many C alarm, lasted globally for fifteen hours, were related to surfactants in the river water.

Pollution survey

As aforementioned, the mussel monitor is employed, among other continuous monitoring instruments, as early warning system to detect changes in the quality of the Po river entering the treatment plants. Detected alarms are automatically sent to the tele-control unit of the plants, and the personnel is quickly warned.
A continuous operating surveillance service alerts the team of specialist of water quality monitoring; in the case of suspected pollution accident, usually they apply the flow chart procedure reported in , in order to quickly assess the degree of risk of the event and to activate all control measures to assure the safety of supplied water. As can be observed the toxicity evaluation plays an important role in the assessment, but remains a part of the multi-task evaluation, and alarms for biosensors employed need to be confirmed in a frame evaluation.

Conclusion

In conclusion, the use of a on line mussel monitoring system showed to be advantageous in the control of a river water at the drinking treatment plant intake. As a matter of fact, it shows an high degree of automation and requires few maintenance operations, furthermore, it could be set at different sensitivity threshold .
Unio elongatulos on the other hand shows many features of the “ideal biosensor” being autochthonous of the environment examined, easy to find and needing no special care; furthermore, this mussels showed adequate sensitivity to both in toxicity testing as well as in normal monitoring conditions.