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Evaluation of an Automatic System for Detection of Toxic Substances in Surface Water Using Trout

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Since continuous monitoring of a wide spectrum of potential pollutants in water by physico-chemical methods is technically and economically impracticable, biological monitors are finding a widespread use. The need for these devices had led to the development of several types of biomonitors using fish, daphniae, algae and bacteriae as indicator organisms.

In order to control the intake of surface water for a drinking water treatment plant from a canal with heavy shipping traffic a system had to be selected which could operate under widely fluctuating conditions (turbidity, temperature etc.). The final aim being the protection of the drinking water consumer it seemed preferable to investigate a biomonitor using fish as indicator organisms since toxicity data on fish can be more easily extrapolated to mammals than results obtained with organisms having a lower level of bioorganisation.

A system similar to the one developed by Poels (POELS and VOORBURG 1974; POELS 1977) has been constructed and has undergone testing on river water for several months using rainbow trout as testorganisms. Since it was able to function properly it was thought worth while to find out its sensitivity towards potential pollutants.

EXPERIMENTAL

During the experiments on pollutants the biomonitor was operated in closed circulation. All experiments were carried out at 7°C $\pm$ 1°C. The temperature was kept in the desired range by means of a cryothermostat. The water which has been used was artificially reconstituted, had a pH of 8,0 $\pm$ 0,1 and a hardness of 250 mg $CaCO_3$/litre. It was obtained by adding 1 ml of solutions A and B and 10 ml of C to one litre of demineralised water.

A. 400 g $CaCl_2.6H_2O$, 36 g NaCl, 11 g $NaNO_3$ dissolved and made up to 1 litre.

B. 189 g $MgSO_4.7H_2O$, 99 g $NaSO_4$ dissolved and made up to 1 litre.

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C. 34 g $NaHCO_3$ dissolved and made up to 1 litre.
All fish used were rainbow trout (Salmo gairdneri R.) weighing between 150 and 250 grammes.

Avoidance reactions, loss of condition or death of the fish were monitored by a set of photo-electric cells placed at the dowstream end of the flow through aquarium.

Eight chemicals have been tested : Cadmium as 3 $CdSO_4.8H_2O$, zinc as $ZnCl_2$, potassium cyanide, ethylparathion, malathion, carbaryl, captan and dinitroorthocresol (DNOC). Some of the products were chosen because they are being discharged in the river (cadmium, zinc and cyanides), others were selected to represent different groups of widely used pesticides. The products used were analytical reagent grade except captan which was dosed as a 50 % wettable powder.

They were dosed in order to obtain the desired concentration in five minutes. Concentrations of the toxicants were measured by different techniques : flame atomic obsorption for cadmium and zinc, selective electrode for cyanide and appropriate colorimetric techniques for other products. In those cases where concentrations decreased due to adsorption to glass walls or volatilisation they were kept within a 20 % margin of the desired concentration by continuous dosing of the toxicant with a peristaltic pump.

RESULTS AND DISCUSSION

Results for different products are tabulated in Table I in which concentration used, time till death and reaction due to avoidance or loss of condition(alarm) are brought together.

For five compounds a clear response was obtained. For cadmium, zinc and ethylparathion no conclusive evidence of reaction was observed. The results obtained for parathion was somewhat expected since in static toxicity parathion was shown to be of relatively low toxicity (JUNG 1973). The low activity in rainbow trout of the liverenzymes responsible for the conversion of parathion to the more toxic paraoxon might explain this result (DEWAIDE 1971).

Only for one product (KCN) a response was seen which could be a attributed to avoidance or loss of condition. This might lead to the conclusion that monitoring these reactions offers little advantage over monitoring death, however in experiments by other investigators loss of rheotaxis has been demonstrated for a.o. coppersulphate, lindane and sodiumselenite (POELS 1976).

TABLE I

Reactions of rainbow trout to different toxicants

PRODUCT	CONCENTRATION (mg/l)	ALARM (hours + minutes)	DEATH (hours + minutes)
KCN	1,0 (CN^-)	0.15	1
	0,4 (CN^-)	0.30	1.15
	0,1 (CN^-) (3 experiments)	-	-
CARBARYL	1,5	-	4.15
	1,5	-	5.30
MALATHION	2,0	-	3
	5,0	-	1.30
DINITRO ORTOCRESOL	0,30	-	12
	0,25	-	19
CAPTAN	0,25	-	6
	0,50	-	5
ETHYL PARATHION	3,0 (3 experiments)	-	-
3 $CdSO_4.8H_2O$	1,0 (Cd) (3 experiments)	-	-
	3,0 (Cd) (3 experiments)	-	-
$ZnCl_2$	1,5 (Zn) (3 experiments)	-	-
	3,0 (Zn) (3 experiments)	-	-

Since the main aim of using a biomonitor is the protection of a surface water intake for drinking water treatment, it is important to know which margin exists between the concentration at which a reaction is obtained and the dose toxic to mammals. Although the results have been obtained in a limited number of experiments and therefore do not take into account interindividual differences in reactions to toxicants, they nevertheless give an indication about the range in which effects can be expected. Evaluation of the results has been made by calculating the relation between the concentration (in mg/l) needed for the drinking water consumer (weighing 70 kg and drinking 2 litres/day to absorb the LD_{50} (determined on experimental animals) and the concentration at which an alarm is observed in the biomonitor. The values obtained are : KCN 130, carbaryl 60, malathion 875, DNOC 580, captan 67.200. Since they have been calculated in relation to LD_{50} values they do not allow for any safety margin. They neither take in account any removal by natural or artificial treatment processes. No such values could be calculated for ethylparathion, cadmium and zinc. For cadmium and ethylparathion it will not be greater than ten and cannot be considered satisfactory. If these substances have to be monitored in a reliable way alternatives will have to be looked at. Therefore results obtained in several other monitors have to be compared with ours in spite of the limited number of substances commonly evaluated and differing conditions during testing. Results obtainad with the following monitors have been considered :

A. Positive rheotaxis flow through monitor
B. Measurement of opercular rhythm (MORGAN 1977)
C. Oxygen consumption by bacteriae (AXT 1973)
D. Oxygen production by algae (GELLER AND MACKLE 1976)
E. Mobility inhibition of Daphniae (GELLER AND MACKLE 1976).

Results are summarized in Table II, they are expressed as concentrations resulting in an unambiguous response in twenty-four hours unless stated otherwise. In addition to the results mentioned under B it should be added that other authors (SLOOFF1977; MILLER 1977) have found a positive response using a similar monitor with rainbow trout at 25 and 30 μg/l Cd respectively.

TABLE II

Results from different biomonitors

SUBSTANCE	A	B	C	D	E
CYANIDE	400 (1/2h)	10	40	>5000	1500
CARBARYL	1500 (5 h)	1000	-	-	-
PARATHION	>3000	100	-	20000	50
COPPER	500 (2 1/2h) (Poels, 1976)	50	250	10000	4000
CADMIUM	>3000	100	1000	100000	2000
ZINC	>3000	-	1000	1000	>10000
MERCURY	750 (Poels, 1976)	10	100	1000	100

A. Rainbow trout - POSITIVE RHEOTAXIS
B. Micropterus salmoides - OPERCULAR RHYTHM
C. Pseudomonas fluorescens - OXYGEN CONSUMPTION (1 hour)
D. Haematococcus pluvialis - OXYGEN PRODUCTION (2 hours)
E. Daphnia pulex - MOBILITY INHIBITION (LC_{100} < 4 hours)

Comparison of the results learns that :

1° In most cases monitoring of opercular rhythms is a more sensitive parameter than loss of positive rheotaxis. For cyanides, carbaryl and copper positive rheotaxis monitoring offers sensitivity nearly as good as obtained through opercular rhythm monitoring.

2° In those cases where the flow through monitors produce non satisfactory results (cadmium, parathion) opercular rhythm monitoring and daphniae mobility inhibition can offer interesting alternatives.

3° For the substances tested, bacterial oxygen consumption and algal oxygen production using the organisms described do not offer any advantage over biomonitors using fish.

REFERENCES

AXT, G. : Gewässerschutz - Wasser - Abwasser, 10, 297, 1973.

DEWAIDE, J.H. : Metabolism of xenobiotics, Ph. D. dissertion, Nijmegen, 1971.

GELLER, W. and H. MACKLE : Uber ein automatisches Biotestsystem zur Wasseruberwachung auf toxische Stoffe, Tagung deutschsprachicher Limnologen, Innsbruck, 1976.

JUNG, K.D. : G.W.F. Wasser/Abwasser 114, 232, 1973. presented at the Swedish Netherlands Symposium 1975.

MORGAN, W.S.G. : Prog. Wat. Tech. 9, 703, 1977.

MILLER, W.F. : The development of the WRC biological monitor, paper presented at the Practical Aspects of Water Quality Monitoring Systems Conference, Stevenage, 1977.

POELS, C.L.M. : Flow through system for the continuous monitoring of raw water using trout, International Water Supply Association Congress, Amsterdam, 1976.

POELS, C.L.M. : Biological Monitoring of Water and Affluent Quality, ASTM STP 607, J. Cairns Jr., K.L. Dickson, and G.F. Westlake Eds, ASTM, 1977.

POELS, C.L.M. : and J. VOORBURG, H_2O, 7, 38, 1974.

SLOOFF, W. : H_2O, 10, 567, 1977.