Bull. Environ. Contam. Toxicol. (1991) 46:387–391

Bulletin of Environmental Contamination and Toxicology

Ecological Control on the Basis of Biological Object Response

K. V. Genjatulin

All-Union Centre for Surface and Vacuum Research, USSR State Committee for Standards, Moscow, USSR

The paper develops a biological control method for water pollution control. The paper presents results of a study on testing chemical pollutants of water (river and sea) on the basis of studying their response to them by the three different (as to their resistance to toxics) microorganism test cultures.

The influence of chemical pollutants (petroleum products, SSAS, heavy metal salts) upon the test cultures has been analysed by construction of mathematical models (test culture response function).

MATERIALS AND METHODS

Used as test objects were microorganisms that mostly have properties necessary for a speedy, continuons round the year and relatively inexpensive quality control of natural and sewage water.

Intestinal bacteria E.coli was used as test object (this is one of the indicative microorganisms for solving the problem of water biological pollution) as well as viruses phages T_1 E.coli and the polyc virus (Type 1) introduced by common sewage into surface water reservoirs.

The choice of chemicals is determined by its wide spread in industrial sewage and the water it pollutes, and by the fact of different direction of its impact upon the selected test cultures.

As such sulphurous copper salt (having become already a standard substance), petroleum and synthetic surface -active substance (SSAS) - sodium alcylsulphate - were used.

Test cultures length on survival was registered as the test reaction. Determining this parameter is related to establishing test culture population. The isolation and titration of test cultures were performed according to the accepted methods (Voroshilova et al.1964; Reference book 1981).

The main research purpose was to find the mathematical relation between test culture response to impact of single chemicals and their different combinations, or mixtures. Quantitative determination of test culture response was based on constructing the response function as a polynomial:

$$y = b_0 + \sum_{1}^{k} b_i x_i + \sum_{i,j}^{k} b_{ij} x_i x_j \qquad (I)$$

Random evaluations of regression coefficients (b_i) have been made by results of the full factor experiment with two-level factors using the Yates algorithm. In order to verify effect value the dispersion and the special graphical analysis methods have been used (Genjatulin 1984; Genjatulin and Isaev 1984).

RESULTS AND DISCUSSION

On the basis of the mathematical analysis performed the expressions were obtained for the response of the test cultures assayed to the action by different ranges of chemicals concentrations. Toxic influence was studied starting upwards from a zero (control) concentration up to more than hundred LCA (limit concentrations available) for petroleum (LCA = 0,3 mg/l) and several hundred LCA for SSAS (LCA = 0,5 mg/l), and ten LCA for the copper salt (LCA = 0,1 mg/l, Cu^{2+}) (Genjatulin 1985).

Table 1 illustrates these mathematical relations obtained in a general form. From the equation given there the effect of influence could be seen (positive, negative or none) caused by a pollutant on a test object (single toxic subctance or a mixture). The direction of influence determines the sign of the regression coefficient while the value of the latter corresponds to the influence effect. Thus the minus sign before b_1 indicates depressing influence of the copper salt (line N 1). The coefficient (b_1) characterises the effect of influence upon the bacteria and phage within the salt concentration range given in the table. As one can see in the table, viruses are the most toxic resistent. In a more vivid way the regularities obtained are shown in graphs in Fig.1, where the values of the response function of the bacteria (I_b), phase (II_p) and virus (III_v) are given along

Table 1. Influence of chemicals on test cultures

Chemical pollutant	Concentration (LCA)	Mathematical model response of E.coli	phage	viruses
Copper salt (x_1) (x_2-water medium factor: x_3 - quantity of cells: x_i-other factors)	0 - 0,5 and more	$y=b_o-b_1x_1+b_{12}x_1x_2+f(x_i)$	$y=b_o-b_1x_1+f(x_i)$	$y=b_o+b_{13}x_1x_3$
SSAS (x_1) (x_i - other factors)	0-100	$y=b_o+b_1x_1+f(x_i)$	$y+b_o+f(x_i)$	$y=b_o+f(x_i)$
	more	$y=b_o+b_1x_1+b_{13}x_1x_3+ +f(x_i)$	$y=b_o-b_1x_1$	
Petroleum (x_1) (x_i - other factors)	0-60	$y=b_o+f(x_i)$	$y=b_o+f(x_i)$	$y=b_o+f(x_i)$
	more	$y=b_o-b_1x_1+b_{12}x_1x_2+f(x_i)$	$y=b_o-b_1x_1+b_{13}x_1x_3$	$y=b_o-b_1x_1+f(x_i)$
Mixture	0 -1 (SSAS)	$y=b_o-b_2x_2+b_{23}x_2x_3+f(x_i)$	$y=b_o-b_2x_2+b_{23}x_2x_3$	$y=b_o-b_2x_2+ b_{23}x_2x_3+f(x_i)$
SSAS(x_1)+copper salt (x_2): (x_3 - water factor x_1- other factor)	0 - 1 (Cu) 0-200(SSAS) 0 - 1(Cu)	$y=b_o+b_1x_1 - b_2x_2+ +b_{23}x_2x_3+f(x_i)$	$y=b_o-b_1x_1-b_2x_2+ +b_{12}x_1x_2$	$y=b_o+b_1x_1+b_{23}x_2x_3 + f(x_i)$

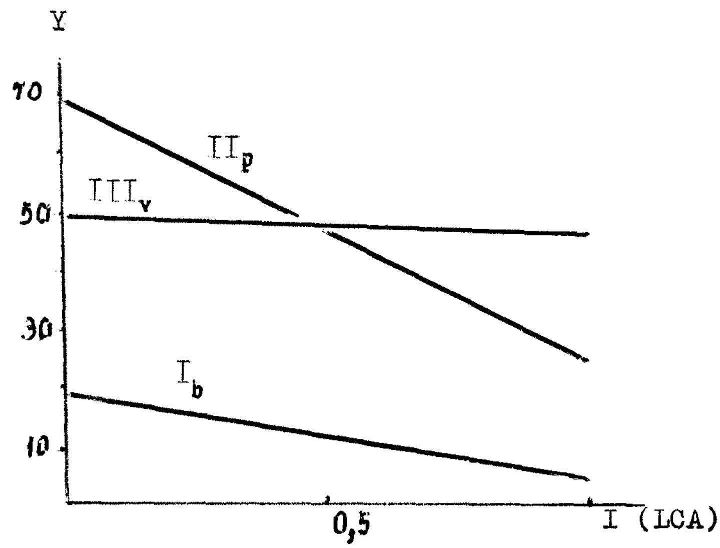

Figure 1. Test cultures Response to Cu.

vertical axis, changes of which are caused about by increased copper salt concentration (concentration values in LCA are given along the horizontal axis).

At the same time bioassaying results expressed in mathematical form allows to solve the problem of selecting the most resistent forms of microorganisms (and other biological species) on the quantitative basis. One of the requirements concerning microselection for indicatory role, i.e. intented to indicate biological water pollutions, is that these microorganisms should be somewhat superior in survivability and resistance to the impact of various chemical factors. As seen from the diagram, under polluted conditions in water (river water in our case) bacteriophages as virus indicator are better than the E.coli bacteria.

The same regularity was seen on the basis of a mathematical representation of the response function and in case of water pollution by other toxic substances with the corresponding range of their concentrations taken into account. These results are in good agreement with reference data related to microbiological methods of biological water pollution control.

Viruses were as before the most resistent both to the depressing and activating impact. They did not respond to all the SSAS concentrations tested, and petroleum pollution of up to 60 LCA. Some insignificant response function change was observed with viruses when there was a mixture of the substances in water. SSAS activated the bacteria at all the concentrations tested. SSAS failed to influence the bacteriophages up to 100 LCA. At still higher concentrations phages were acutely affected in a depressive way. Up to 60 LCA petroleum produced no significant influence upon the bacteria and phages (cf.Table). At higher concentrations depressive influence of petroleum on both cultures was noticed (minus sign before b_1). The influence of chemicals mixture upon test cultures in some concentration combinations is given and partly explained in the table. A more detailed analysis is given in a separate paper (Genjuatulin 1985).

Drawing up of mathematical response models allowed to determine the resistance of the bioassays used within a wide range of concentrations of both single pollutants and their various combinations.

The mathematic relations envolving response of test cultures varying in their toxic resistance could be used both in bioassaying and in connection with the indicatory value of different microorganisms whose resistivity could change in dependence with the water condition change caused by chemical pollution factors.

A multifactor experiment results of which have been processed by regressive analysis methods using computer facilities allows to obtain the full picture of the chemical composition of toxic substances present in the water assayed.

REFERENCES

Genjatulin KV (1984) Using graphic mathematical statistic methods to analyse the impact of chemical environmental pollutants on microorganisms. Hygiene and Sanitation 3 : 65-70.
Genjautlin KV, Isaev AB (1984) Construction of response mathematic models of biological objects. Metrology (Moscow) 3: 16-25.
Genjuatulin KV (1985) Diagnosis of chemical water pollutants on basis of response of biological objects (microorganisms). Autoessay Diss., MSU,23.
Reference book of sanitary microbiology (1981). Kishinev: 206.
Voroshilova MK, Dzevandrova VI, Balajan MS (1964) Laboratory diagnostic methods of enterovirus infections.Moscow. Medicine : 127.

Received June 25, 1990; accepted September 13, 1990.