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THE RESPONSE OF AQUATIC ORGANISMS TO MIXTURES OF TOXICANTS

E. R. Christensen, C.-Y. Chen and J. Kannall

Department of Civil Engineering, University of Wisconsin–Milwaukee, Milwaukee, Wisconsin 53201, U.S.A.

A multiple toxicity model for the quantal response of organisms is developed. The model is an extension of Hewlett and Plackett's (1959) theory for two toxicants, and is based on a multivariate normal distribution of the response vs. the logarithm of the action tolerances (Christensen and Chen, 1984). It is applicable to macroorganisms with a tolerance distribution, and to microbial synchronous growth when population growth rate is used as a response parameter. However, it is proposed to be valid also for microorganisms originating from a single clone and experiencing non-synchronous growth. The application of single variate probit, logit, and Weibull expressions (Christensen, 1984; Christensen and Nyholm, 1984) is demonstrated using Selenastrum capricornutum and Synechococcus leopoliensis exposed to lead, zinc, nickel, arsenate, potassium, and polychlorinated biphenyl (PCB) congeners. The bivariate model is tested on zinc-nickel mixtures. In the case of two toxicants, there are two parameters: similarity parameter λ and correlation coefficient ρ. The similarity parameter λ is one for similar joint action which may occur when reaction sites are overlapping, and zero when two toxicants act on different biological systems. The correlation coefficient ρ is one for full correlation of cell division tolerances (single clone, synchronous growth), and zero for the case of uncorrelated tolerances (mixed culture). The case of $\lambda = 1$; $\rho = 1$ is characterized by the term concentration addition. Results regarding the action of Ni and Zn on Selenastrum are shown in Fig. 1. Ionic concentrations are obtained using the computer program MINEQL (Westall et al., 1976). Single variate assays with model curves providing the best fit are shown in Figs. 1 a,b. Relative growth rates in the presence of both Ni and Zn are shown in Fig. 1 c. The model curves are based on single variate Weibull parameters and various values of λ and ρ. The experiment was designed such that, for each point, Ni and Zn would give the same growth rate reduction, e.g., 10%, acting separately. The best fit is obtained for $\lambda = 1$; $\rho \simeq 0.9$ indicating that the joint action is concentration additive or nearly so. From extensive calculations and experiments we draw the following conclusions:

1. The Weibull model provides generally a better fit than the probit and logit models to the growth rate based on cell number as a function of toxicant concentration.

2. Synechococcus is more sensitive (EC50) to Ni, Zn, and Pb than Selenastrum. Also, the slopes (reaction orders) in the linear transformations are much steeper for Synechococcus with Ni and Zn than for Selenastrum. However,

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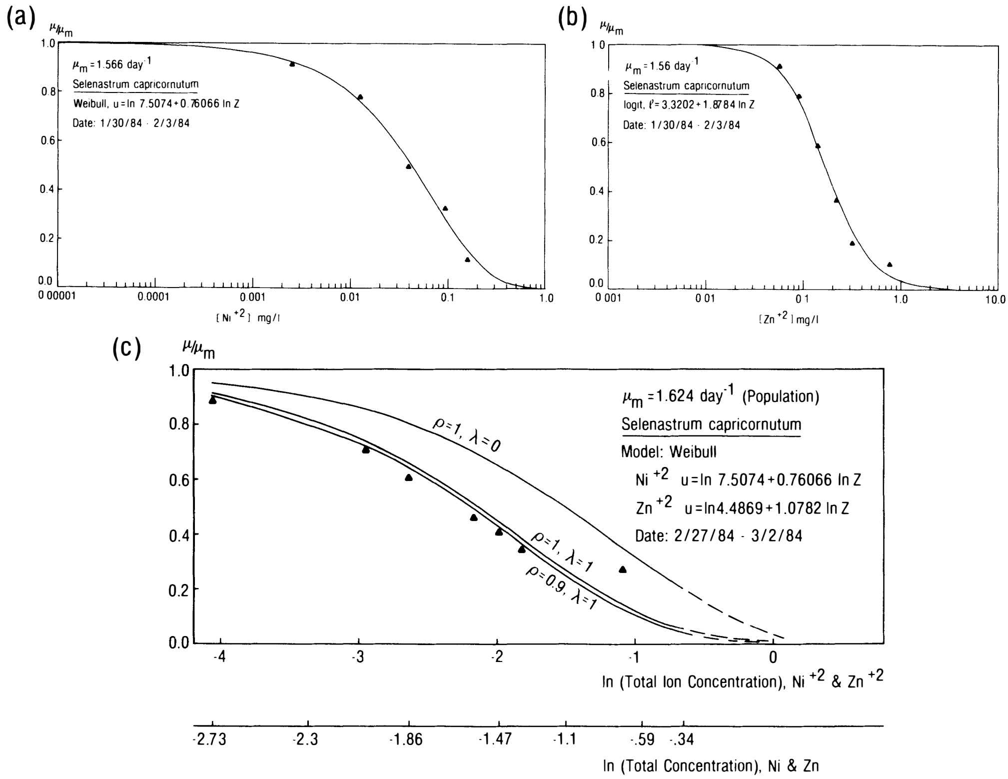

Fig. 1. Results of algal assays with (a) Ni^{2+}, (b) Zn^{2+}, and (c) these metal ions in combination.

<u>Synechococcus</u> is extremely tolerant to As(V) compared to <u>Selenastrum</u>. Of several PCB congeners tested, only 33'44' showed noticeable toxicity to <u>Synechococcus</u>.

3. We have developed multiple toxicity versions of the single variate Weibull, probit, and logit models. It is shown that the joint action of Ni and Zn on <u>Selenastrum</u> is of the concentration additive type with correlation coefficient $\rho \simeq 0.9$ and similarity parameter $\lambda = 1$.

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