

Assessment of phenolic compound perturbations of a nitrifier microbial association maintained within a continuous-flow multi-stage laboratory model

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Abstract

To facilitate rapid examination of the environmental impacts of selected molecules on cycling processes inherent to aquatic ecosystems, a multi-stage model ecosystem was developed.

Nitrification was chosen as the criterion for assessing the inhibitory effects of perturbant molecules on a microbial association maintained within the model. Inhibition of nitrification proved to be a sensitive indicator of both phenol and 2,4-dichlorophenol toxicity. Perturbant compound fate was determined by direct analysis and the relationship between residual concentration and nitrifying activity was assessed. Phenol, in concentrations of 20 and 60 mg·ℓ⁻¹, attenuated within the model and it was apparent that low concentrations (<4 mg·ℓ⁻¹) must be reached before nitrification proceeded. 2,4-dichlorophenol in concentrations of 10 and 20 mg·ℓ⁻¹ was found to persist and inhibition of nitrification resulted. Biodegradation data of perturbant compounds were, thus, considered important requisites for assessing potential impacts on aquatic environments.

Introduction

Laboratory model micro-ecosystems have increasingly found application in ecotoxicological studies to determine the potential impacts of anthropogenic substances on aquatic ecosystems (Porcella et al., 1982; Freitsch, 1991; Scholz and Müller, 1992; Hunter et al., 1995). Ranging in size, configuration and complexity, laboratory models have sought to provide simple analogues of natural ecosystems in which characteristic structural and functional properties can be simulated (Wimpenny, 1988).

Since micro-organisms play an integral role in ecosystem dynamics, evaluation of the effects of pollutants on mineral and nutrient cycles has been proposed as a means of assessing the impacts of compounds released into the environment (Bitton and Dutka, 1986; Cairns et al., 1992). Organic matter decomposition, nitrogen transformations, sulphate reduction and methanogenesis have all been considered (Blum and Speece, 1992). The premise is made that inhibition of micro-organism-mediated processes will have a direct bearing on the functioning of an ecosystem as a whole and will, therefore, reflect aspects of "ecosystem health".

To facilitate examination of environmental impacts of selected xenobiotic compounds on cycling processes inherent to aquatic ecosystems, a multi-stage model ecosystem was developed (Hunter, 1996). A primary aim was to establish a population of nitrifying bacteria within the model, as these species have been recognised as sensitive and rapid indicators of ecotoxicological perturbation (Williamson and Johnson, 1981; Blum and Speece, 1992).

In unperturbed aquatic environments the nitrogen cycle usually maintains a balanced state (Welch, 1992). Microbial

transformations such as ammonification, nitrification and denitrification are the regulating mechanisms which contribute to the overall self-purification capacities of an aquatic environment. Disruption or inhibition of these transformations can result from severe organic loading (substrate inhibition) and/or toxic pollutant compounds and can lead to the accumulation of intermediates such as ammonia, nitrite and nitrate (Dallas and Day, 1993). All of these latter molecules have been found to be either toxic or to impair water quality when allowed to accumulate. Elucidation of the factors controlling and inhibiting these regulatory processes is thus important in understanding and predicting the potential impacts of perturbant compounds on aquatic environments.

To test the efficacy of the model ecosystem for rapid ecotoxicological assessments a series of experiments was undertaken to determine the individual perturbation effects of phenol and a halogen-substituted phenol, 2,4-dichlorophenol, on the nutrient cycling processes operative in the model. Nitrification was chosen as the criterion for assessing the inhibitory effects of the selected molecules on the established microbial association and was monitored by nitrite and nitrate concentration analyses. Residual phenol and 2,4-dichlorophenol concentrations were assayed to determine their fates within the model.

Materials and methods

Laboratory model configuration and operation

A full description of the model has been given previously (Hunter et al., 1995). The model had four identical channels, 3 m in length, 36 mm wide and 95 mm deep, each consisting of 75 chambers. Each chamber had an operational volume of 122 ml (36 x 36 x 95 mm). Duplicate channels were constructed from Plexiglass and built-in unit blocks of 2 x 25 chambers. The units were supported by a steel framework and were arranged in tiers. Each unit was angled at 15° to create a weir flow effect to facilitate mixing of

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