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Project Summary

Laboratory Ecosystems for Studying Chemical Fate: An Evaluation Using Methyl Parathion

Harvey W. Holm, Heinz P. Kollig, Lita M. Proctor, and William R. Payne, Jr.

The use of complex microcosms as tools for testing mathematical models of pollutant fate was evaluated by determining the transport and transformation of methyl parathion in two 8-compartment, continuous flow microcosms designed to enhance the effects of different degradation processes. Objectives were to develop different chemical and biological environments by adding inorganic nutrients, glycerol, contrived sediments, and natural sediments sequentially to compartments down the length of the channel; to determine whether the microcosms established stable states during the experimental periods; and to determine whether the fate of methyl parathion was related to environmental characteristics of each compartment.

Observed differences in chemical treatments were reflected by differences in community structure and community function. Statistical comparisons of bacterial and total microbial biomass revealed significant differences (α = 0.05); compartments with organic and inorganic nutrient additions were generally grouped separately from those with only inorganic nutrient additions. Relative rates of diurnal dissolved oxygen change were also significantly different between those compartments with different nutrient additions. Inclusion of natural and contrived sediments had few significant effects on the structure or function of the water or aufwuchs communities. Stable state, with respect to critical nutrient concentrations and relative estimates of community metabolism, was generally established in each compartment from the date of methyl parathion introduction into the laboratory ecosystems. The downstream compartments generally achieved stable chemical states later during the experimental period than the compartments nearer the influent.

The consistent increase in percentage loss of methyl parathion in the water column in each successive compartment was apparently related to the different nutrient treatments. There was no pattern in methyl parathion disappearance in the aufwuchs during the first experiment; however, there was an apparent relationship between methyl parathion loss and bacterial biomass in the aufwuchs during the second experiment. No methyl parathion was detected in the natural or contrived sediments. Results of subsidiary studies with aufwuchs communities to examine second-order transformation rates of methyl parathion demonstrated wider variation in the rate coefficients than previously reported results with suspended communities.

This report covers a period from October 1, 1978, to September 30,

1979, and work was completed as of September 30, 1980.

This Project Summary was developed by EPA's Environmental Research Laboratory, Athens, GA, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The USEPA's Environmental Research Laboratory in Athens, Georgia, houses a controlled environment chamber that contains a two-channeled flume subdivided into eight 250-liter compartments. The two series of channeled microcosms were operated on a 12-hr light/12-hr dark cycle, with controlled physical and chemical parameters (light, temperature, water turbulence, inorganic and organic nutrients) and received inocula of mixed microbial communities from local bodies of water. Each of the eight compartments, designated as a continuously stirred tank reactor (CSTR), was designed to test a specific process being modeled or to enhance processes not included or inadequately modeled (Figure 1).

Methyl parathion was introduced during the initial experiment at a concentration of 42 $\mu g/1$, and during the second experiment, at 50 $\mu g/1$. Methyl parathion was selected as the test compound because (1) the transformation rates and equilibrium constants were known, (2) measurable transformation occurred within the residence time established for each CSTR, and (3) methodology was available for determination of methyl parathion in the water, aufwuchs, and sediment.

The specific objectives of both investigations were (1) to characterize the periods of stable state in each CSTR, based upon analysis of nutrient concentrations and community metabolism; (2) to determine whether chemically different environments were established in each CSTR; (3) to evaluate the effects of different nutrient treatments and sediment types on the biological composition and function of the water, aufwuchs, and sediment communities; and (4) to determine the fate of methyl parathion in the channeled microcosms.

Results

The associated confidence intervals ($\alpha = 0.10$) of the total dissolved phosphorus, total dissolved inorganic nitrogen concentrations, and diurnal dissolved oxygen flux generally demonstrated non-significant differences in each CSTR through the duration of each experimental period. Although CSTRs 6 through 8 achieved stable states later into the experimental period than CSTRs 3 through 5, mean values of critical nutrient concentrations and estimates of oxygen metabolism indicated that stable states were established in the CSTRs generally after 6 to 8 weeks of community development, at which time methyl parathion was introduced and sampling was initiated.

Inorganic nutrients were introduced into CSTR 3 in an attempt to stimulate autotrophic community development in both CSTRs 3 and 4; glycerol was added to CSTR 5 in order to enhance the development of heterotrophic communities in CSTRs 5 through 8 (Figure 1). Statistical analysis of total dissolved phosphorus and total dissolved inorganic nitrogen concentrations demonstrated that CSTRs 3 and 4 differed from CSTRs 5 through 8, indicating that chemically different environments were correlated to system treatment.

Effects of the different nutrient treatments on the structure of the suspended or aufwuchs communities were generally observed to be significant. During the second study, significant differences ($\alpha = 0.05$) were generally observed in the mean suspended bacterial biomass estimates of CSTRs 3 and 4 as compared to the

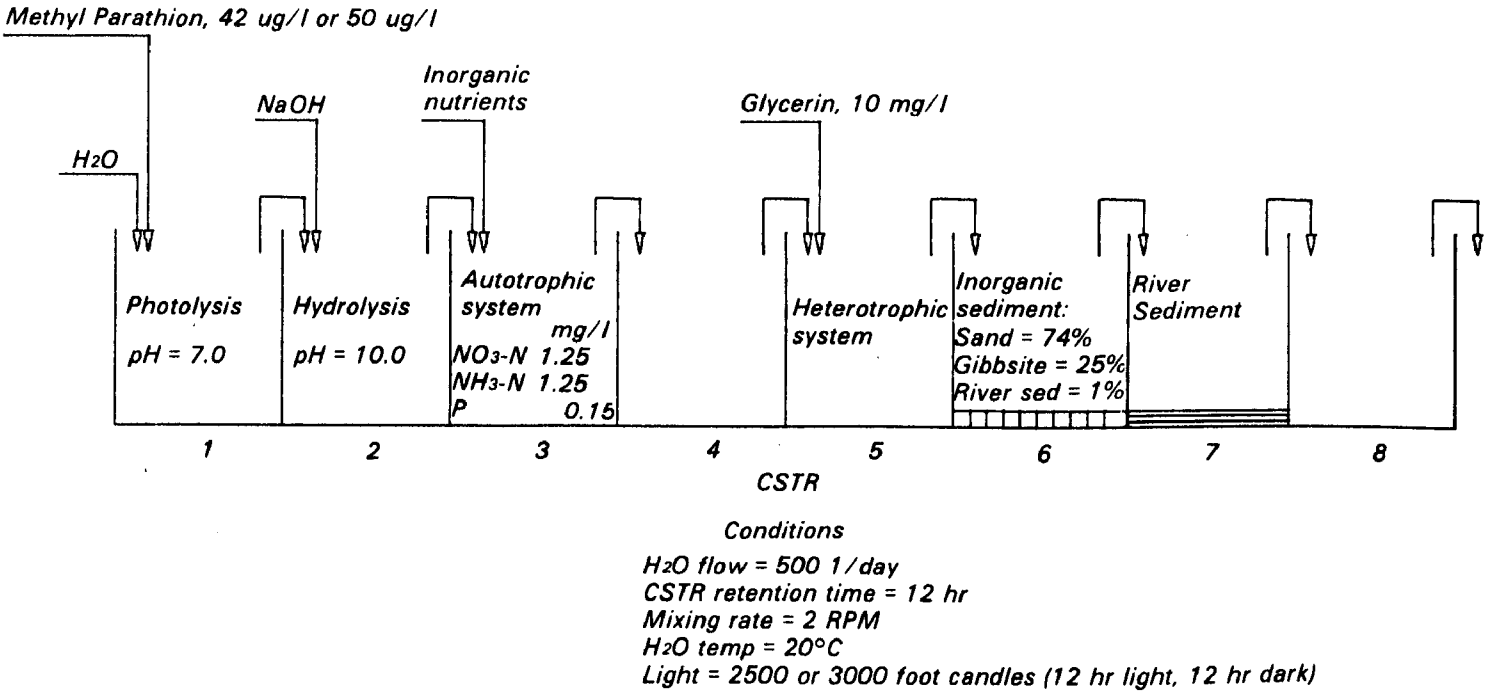

Figure 1. *Experimental conditions of each channel.*

downstream CSTRs with bacterial biomass generally higher in the downstream compartments. In the aufwuchs, significant differences (α = 0.05) were observed in the mean concentrations of bacterial biomass, ash-free dry weight, and cellular ATP concentrations during the second experiment with higher biomass values observed in CSTRs 3 through 5. Rates of diurnal dissolved oxygen flux during the second study exhibited differences between CSTRs 3 through 6 and CSTRs 7 and 8. Higher rates of dissolved oxygen flux were observed in CSTRs 3 through 6 signifying higher rates of metabolic activity in these compartments.

Contrived and natural sediment substrates were introduced into CSTRs 6 and 7, respectively, to investigate the effects of sediment type on methyl parathion fate and biological composition of the suspended or aufwuchs communities (Figure 1). Statistical evaluation of biomass estimates demonstrated few differences in the biomass estimates between the natural and contrived sediment communities or in the standing crop of the suspended and aufwuchs communities in CSTRs 6 and 7. During both investigations, no methyl parathion was detected in either of the two sediment types.

Although the pattern of methyl parathion disappearance was not similar in the two investigations, transformation of methyl parathion in the water column generally appeared to be related to the inorganic and organic nutrient treatments. The largest percentage of methyl parathion loss occurred in CSTR's 5 through 8. Methyl parathion transformation in the aufwuchs exhibited no pattern during the initial experiment but was apparently related to bacterial biomass in the aufwuchs during the second experiment. Although first-order transformation rate coefficients did not vary widely, second-order microbial transformation rates of methyl parathion by aufwuchs communities varied by approximately two orders of magnitude between the two studies. During the first experiment, K_b values ranged from 7.5×10^{-8} to 1.6×10^{-8} ml/cell hr^{-1}, while during the second study K_b values ranged from 1.0×10^{-8} to 9.0×10^{-11} ml/cell hr^{-1}. This variability may be a result of changes in the percentage of specific degraders in the microbial communities.

Conclusions

Based upon the results obtained from the two investigations of methyl parathion fate:

- stable aquatic communities were established in the two channels during both experiments;
- inorganic and organic nutrient treatments generally affected both community structure and community function;
- few differences were observed in the biomass estimates between the natural and contrived sediment communities;
- inclusion of natural and contrived sediments generally had little effect on suspended and aufwuchs community composition;
- percentage loss of methyl parathion, which was larger in the downstream compartments, appeared to be related to the difference in nutrient treatments; and
- second-order methyl parathion transformation rate coefficients from aufwuchs communities demonstrated wider variability than studies previously reported from suspended communities.

*The EPA authors **Harvey W. Holm** (also the EPA Project Officer, see below), **Heinz P. Kollig, Lita M. Proctor,** and **William R. Payne, Jr.**, are with the Environmental Research Laboratory, Athens, GA 30613.*

The complete report, entitled "Laboratory Ecosystems for Studying Chemical Fate: An Evaluation Using Methyl Parathion," (Order No. PB 82-231 952; Cost: $18.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Environmental Research Laboratory
U.S. Environmental Protection Agency
Athens, GA 30613

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