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Project Summary

PCBs in Saginaw Bay: Development of Functional Indices to Estimate Inhibition of Ecosystem Fluxes

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Saginaw Bay is among the most polluted bays in the Great Lakes. For many years the Large Lakes Research Station of the US EPA has examined many aspects of this ecosystem, from phytoplankton community characteristics to contaminant levels in fishes. As a result, when it became desirable to determine the impact of an organochlorine contaminant like PCB, it was not necessary to study the ecosystem in detail. Phytoplankton species and densities were known, zooplankton species, densities and feeding habits had been investigated.

This study produced new information on the two most basic fluxes in any aquatic system, the flow of solar energy into the phytoplankton and the flow of chemical energy into the zooplankton. The use of phytoplankton gross photosynthesis to estimate the inhibition by contaminants of the first flux mentioned was developed for marine communities. In comparison, the use of zooplankton ingestion rates to estimate the inhibition by contaminants of carbon flow into secondary producers is new and was developed for this investigation.

The International Joint Commission's (IJC) Science Advisory Board and, specifically, the Ecosystem Function Working Group, is currently examining the use of such measures of functional impairment as water quality indices. Thus, the announcement of the results of this study is timely with regard to ecosystem management in the Great Lakes.

This Project Summary was developed by EPA's Environmental Research Laboratory-Duluth, Large Lakes Research Station, Grosse Ile, MI, 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

Aquatic ecosystems of the Great Lakes are threatened by approximately 50,000 chemicals of commerce from the United States and Canada; at least 2000 may have adverse biological effects and only 200 have been studied. Contaminants such as chlorinated hydrocarbons are especially predisposed to concentrate in food chains because of their partitioning into lipids of lower organisms and because of their later food chain concentration by apex predators. Waters of the Great Lakes contain 2 to 300 ng l^{-1} PCB; this major contaminant is concentrated about 1 million times in apex predators. Generally, PCBs inhibit organismic as well as ecosystem metabolism and thus ecosystem productivity. Since the complex food webs of Lake Huron involve hundreds of phytoplankton taxa and tens of zooplankton taxa, we developed and utilized two ecosystem functional indices for measuring contaminant inhibition. These were measures of the inhibition (and sometimes stimulation) of algal photosynthesis and of zooplankton grazing.

Methodology

^{14}C-bicarbonate was used to measure phytoplankton gross photosynthesis. PCB concentrations of 5-500 ng l^{-1} above

control levels were injected into experimental test samples of phytoplankton incubated at depth of collection. Inhibition of photosynthesis was expressed as a percentage decrease relative to control values This simple test is a functional (rate impacted) index of ecosystem inhibition at trophic level one (phytoplankton). In a similar treatment, ^{14}C tagged algae, fractionated into nannoplankton and netplankton size ranges (<20 μm and >20 μm dia.), were fed to zooplankton, and filtering rates were calculated. Then, similar tests were performed in which experimental containers also contained PCBs Thus, the relative depression of grazing by PCBs was measured for all major taxa of zooplankton.

Conclusions

Eight important conclusions were reached about the Saginaw Bay ecosystem. With regard to phytoplankton photosynthesis, dichlorobiphenyl was selectively more toxic to nannoplankton than to netplankton. This is an important conclusion, since Great Lakes food chains are based on small nannoplankton algae. Secondly, dichlorobiphenyl metabolites (unspecified) were more toxic to phytoplankton than the parent isomer. This finding suggested problems similar to those encountered for other man-made organics. In addition to selective toxicity by phytoplankton size, we found that PCBs inhibited photosynthesis of diatoms and green algae more than blue-green algae; unfortunately, diatoms and small greens are the most grazed components in this ecosystem. Zooplankton grazing was also inhibited by PCB metabolites, and especially when detritus was present, as it is in most productive waters of the Great Lakes. The above findings were based on exposures to PCBs above normal environmental levels encountered in Lake Huron.

Inhibition of algal photosynthesis by ambient levels of PCBs was examined for dichlorobiphenyl, hexachlorobiphenyl, and purified metabolites, including hydroxylated PCB and furans. Ambient levels of PCBs inhibited nannoplankton productivity. In the hexachlorobiphenyl series, the hydroxylated PCB and furan were more inhibitory to photosynthesis than the parent isomer, with a seasonal range of inhibition of -2 to -93%. At depth, these same contaminants stimulated gross photosynthesis, probably by increasing algal respiration and net production. This was a totally new result. In the dichlorobiphenyl series, the metabolic products inhibited photosynthesis in surface waters from -6 to -22%, much less than the higher chlorinated compound

Lastly, we compared grazing in western Lake Erie to that in Saginaw Bay. In Lake Erie, grazing as a control on alga populations was almost as effective as in oligotrophic Lake Huron, whereas grazing was greatly depressed in Saginaw Bay Apparently the Lake Erie ecosystem is in much better condition than that o Saginaw Bay.

We conclude that functional ecosystem inhibition by such toxic chemicals as PCBs is a most serious problem. Our results clearly indicate that levels of PCBs must be held below 5 ng l^{-1}, and we suggest this level as an appropriate water quality objective to the IJC. In addition, we suggest that more attention be paid to the effects of PCB metabolites on natural communities. It may also be inferred that the lack of zooplankton grazing in an ecosystem like Saginaw Bay is related to unknown inhibitory compounds with a mode of action similar or identical to that of PCBs.

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The complete report, entitled "PCBs in Saginaw Bay: Development of Functional Indices to Estimate Inhibition of Ecosystem Fluxes," (Order No. PB 84-133 008; Cost: $13.00, subject to change) will be available only from:
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