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United States Environmental Protection Agency
Research and Development

Chesapeake Bay Program
Annapolis MD 21403
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EPA

Project Summary

Ware River Intensive Watershed Study

Gary F. Anderson, Cindy Bosco, and Bruce Neilson

The Ware River Intensive Watershed Study includes examinations of runoff from small catchments, instream transport of runoff, and their impacts on estuarine water quality.

Runoff quantity and quality were monitored for row crop, residential and forested lands in the Ware basin for the period of October 1979 to July 1981. Loading rates have been calculated for both baseflow and stormflow contributions at each study site.

Concentrations increased during stormflow periods for all water quality constituents except dissolved silica. On the average, this increase was an order of magnitude greater than the baseflow concentrations for particulate materials, and by a factor of two for dissolved constituents. Concentrations of total phosphorus, nitrogen, and dissolved ammonia were substantially higher in the runoff at the two agricultural sites than at the residential and forested catchments. The residential catchment had high concentrations of dissolved nutrients and BOD_5 in both baseflow and storm runoff. Areal loading rates were more a function of runoff quantity than concentration. The residential site, which produced the greatest amount of storm runoff, also had the highest loading rates for all constituents except phosphorus and suspended solids. The well drained upland farm produced the least runoff of the four catchments monitored.

Baseflow accounted for a significant portion of the total flow at the forested and residential catchments, especially during winter months when the water was high. Nearly half of the total flow came from ground water during the study period. However, storm runoff produced 83 and 70 percent of the total phosphorus and nitrogen loads, and 62 and 91 percent of the BOD_5 and suspended solids loads, respectively. Although only 13 of 114 site-events had rainfall greater than 5 cm, these accounted for more than 50 percent of the measured storm runoff.

Results from the study of estuarine waters indicate that the Ware River contains a moderate amount of nutrients. However, during summer months, some of the nutrients, particularly inorganic phosphorus and organic nitrogen, reach levels associated with moderate enrichment. The Ware is typical of other small tributaries of Chesapeake Bay: nutrient levels are higher at low tide, the estuary is more homogenous laterally than longitudinally (with respect to nutrients), and vertical gradients exist for dissolved oxygen, total phosphorus, and suspended solids.

The phytoplankton are generally phosphorus limited, except during the annual spring phytoplankton blooms (April 1979 and March 1980), when uptake of inorganic nitrogen by plankton causes the system to be nitrogen limited. Impacts of nonpoint source pollution are slight and short-lived in the estuary. This appears to be due to dilution by Bay waters and sedimentation in the upstream marshes. Thus, impacts are typically observed only in the shallow upstream portions of the estuary.

This Project Summary was developed by EPA's Chesapeake Bay Program, Annapolis, MD, 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 objective of the Ware River Intensive Watershed Study was to characterize the contribution of various land uses to the nonpoint source loadings into the Ware River and Chesapeake Bay. The quality and quantity of runoff for the major land uses and physiologic features of the watershed were measured over a two-year period. During that period, the nature, extent, and duration of storm water impacts on the water quality of the Ware River estuary were also measured.

Procedure/Methodology

The sites selected for the study were occupied by land uses typical of the Chesapeake Bay region: a forested site, a residential site, and two row-crop agriculture sites. These types of uses occupy about 87 percent of the land area in the Ware basin.

The undisturbed, mixed forest site was selected primarily because the catchment was exclusively forested yet easily accessible for study. It has moderate slopes but poorly drained soils underlying the debris on the forest floor.

The low density residential site is occupied by a small subdivision located adjacent to the shoreline of the estuary. It was selected in part because the homes have septic tanks and stormwater runoff control through a series of roadside ditches.

The two row-crop agricultural sites are in typical corn and soybean rotation using fertilizer application and herbicides to control weeds. The lowland site has poorly drained soils, whereas the upland soils are light, erosive, and well drained. Relief is more pronounced at the upland site.

Of the four sites, three have continuous base flows during winter due to high water table conditions. The upland agriculture site exhibits no baseflow. Flows at all sites were monitored by installing H-flumes in the drainage-ways.

Flowmeters were installed at each flume to continuously monitor baseflow and stormflow conditions. Automatic composite water samplers were used. The sample was paced by the flowmeter to deliver an aliquot of sample to a single container at a pre-set increment of flow. In addition to runoff monitoring instruments, a recording rain gauge sensitive to 0.01 inch was installed at each site.

Samples were routinely collected during dry periods when baseflow occurred in order to characterize loadings during non-storm conditions. Base flow and runoff samples were analyzed for total and dissolved phosphorus, total and dissolved Kjeldahl nitrogen, BOD_5, suspended solids, total and dissolved ammonia nitrate-nitrite nitrogen, and dissolved silica.

Estuarine water quality was studied to determine how it is affected by runoff. Sampling stations were established throughout the Ware River estuary and were sampled semi-monthly throughout the 27-month study with runabouts; submersible pumps were used to bring sample water on board. In addition, several intensive surveys were conducted on the River to provide a comprehensive picture of how water quality varies temporally and spatially in response to various inputs. Monitoring was conducted to study the diel nutrient dynamics surrounding the spring chlorophyll *a* maximum and the response of the estuary to sunlight, tidal oscillation, and organic pulse loads caused by runoff.

Results/Conclusions

Results of the land-use studies can be summarized in two ways: 1) the individual loads for each site are summed for all the events monitored during the 22-month period, and 2) each individual storm load is divided by the rainfall for that particular event to yield a mass pollutant per unit rainfall value for each storm. The second method is important because a statistical representation of the storms can be made and compared, as well as extrapolated to other years and other rainfall records. The first only provides an absolute comparison among the sites.

Although nutrient concentrations in runoff from both agriculture sites were significantly higher than at the other two sites, so little runoff occurred that the total loadings are lower than at either the forest or residential catchment. The reduced flow (an order of magnitude below the other sites, probably due to the fact that much of the rainwater is lost to percolation into the rapidly permeable soils) more than compensated for the higher pollutant concentrations in the runoff. An exception is phosphorus, however, that was highly enriched in runoff from the cultivated fields. Suspended solids coming from the denuded land were also very high.

The forest and the lowland residential sites have significant per area baseflow which was comparable in quality. The baseflow loading at these two sites was quite significant. Some of the similarity in water quality could be the result of the large number of trees on both occupied and vacant lots in the subdivision. Stormflow from the residential site, however, was greater than that from the forest on an areal basis. The manmade ditches and impervious surfaces (about 10 percent of the surface area at the residential site) were expected to accelerate surface runoff there. Since nutrient concentrations were generally higher in stormflow, the stormflow loading rates and combined loading rates were higher for the residential catchment. Another notable feature of the residential catchment was the high loading of dissolved nutrients in baseflow, particularly orthophosphorus and nitrite-nitrate. This striking difference between the baseflow quality of residential and forested catchments may be due to leaching from nearby septic tank drainfields in the residential area.

Baseflow accounted for 35 to 60 percent of the total flow from the forested and residential sites. However, because nutrient levels were higher in runoff, roughly 70 percent of the phosphorus, nitrogen, and BOD_5, and over 90 percent of the suspended solids loadings occurred during stormflow. If the upland agriculture site were considered as well, these values would increase, since no baseflow was observed at the site during the study.

Dissolved silica is lower in runoff because it is undetectable in rainwater. The source of this nutrient is the weathering of mineral particles, particularly that caused by the groundwater flowing through soils. Therefore, both loads and concentration are higher during baseflow, although silica is still present during stormflows, when surface runoff and silica rich groundwater are combined. The silica loading rate from the upland agriculture site was negligible, since there was no groundwater contribution to the surface flow there.

Loading rates have been calculated for individual storms which account not only for the catchment size but also the amount of rainfall. From these statistics, valid comparisons can be made which utilize the few storms sampled at the two agriculture sites. Although the two agriculture sites did result in the highest individual storm loading rate, the mean and median rates were greatest for the storms at the residential catchment. That is, most of the time the loading rate is highest at the residential catchment and, occasionally, a very high rate occurs at the other sites. Occasional high rates are important and were responsible for most of the total load at the two agriculture sites. Analysis of individual storms did not show any relationship between amount of rainfall and runoff or loading.

Nutrient concentrations are generally low in the Ware River estuary, especially when compared to freshwater tributaries or to larger, more urbanized systems. Even following significant rain events, extremely low nutrient concentrations for silicates, total phosphorus, orthophosphates, suspended solids, organic nitrogen, and nitrate-nitrite-nitrogen were found in the estuarine mouth waters. Moderate nutrient enrichment levels were generally found upstream, where low TN:TP values are attributable to point source wastewater discharge.

Nutrient water quality at the mouth fluctuated little with the tides; however, temporal variations in nutrient concentration were seen elsewhere in the estuary within a tidal period; especially in the brackish region. Maximum values for total Kjeldahl nitrogen, ammonia-nitrogen, total organic carbon, and total phosphorus occurred at times of low water slack; minimum values were present at high water slack. Nitrate-nitrite-nitrogen concentrations were generally below detection limit throughout the estuary during the survey. At no season or station were anoxic conditions encountered in the estuary. However, there was a distinct longitudinal gradient present in the estuary: the percent saturation of dissolved oxygen was significantly higher at the mouth than in the upstream reaches. The study average showed 90 percent oxygen saturation present at the mouth; the upstream station had only 70 percent.

Freshwater storm influence was found to be minimal near the mouth of the estuary, whereas the upper reaches of the estuary showed significant responses evident in salinity gradients. During periods of increased freshwater flow, a two-layer circulation system may exist. Results indicate that the estuary is essentially well mixed, predominately by tidal processes, especially in the upper reaches.

Recommendations

The impact of runoff on the Ware River estuary appears to be slight, occasionally moderate, and relatively short-lived. Nutrient loading of rates vary for each land use site and fluctuate seasonally. The rates are a function of runoff quantity and increase accordingly with streamflow. Further study is needed to determine patterns of loading rates with rainfall. The data presented can be used in conjunction with those from other watershed studies to calibrate mathematical models of land runoff for the Bay. It is suggested that further watershed studies monitor subsurface flow to adequately characterize low-lying coastal watersheds.

Gary F. Anderson, Cindy Bosco, and Bruce Neilson are with the Virginia Institute of Marine Science, Gloucester Point, VA 23062.
***David Flemer** is the EPA contact (see below).*

The complete report consists of two parts, entitled "Ware River Intensive Watershed Study:"

"1. Nonpoint Source Contributions," (Order No. PB 83-253 187; Cost: $14.50, subject to change)

"2. Estuarine Receiving Water Quality," (Order No. PB 83-253 195; Cost: $14.50, subject to change)

The above reports are available only from: (costs subject to change):
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Project Summary

Ecosystem Responses to Alternative Pesticides in the Terrestrial Environment

Eric Goodman, Matt Zabik, Jeffrey J. Jenkins,
Robert M. Kon, and Renate M. Snider

A conceptual model was developed to describe aspects of the fate and effects of a pesticide in an orchard ecosystem. In order to refine, parameterize, and test a mathematical model based upon this conceptual model, a program of field and laboratory experiments was undertaken. The environmental behavior of azinphosmethyl was studied in a Michigan apple orchard watershed to gather data for the model on initial distribution within the orchard, vertical movement of the pesticide under the influence of rainfall, loss from the orchard with runoff, and the effects of the pesticide on several invertebrate populations. The estimated proportion of a low-volume application initially distributed within the orchard averaged .624 (standard deviation of .149) over three seasons (1976-1978). Examination of residues reaching each layer showed the majority of the dislodgeable residues were distributed to the trees and grass-broadleaves. The litter-moss and soil contained residue levels roughly ten times lower than tree leaf residues. Runoff studies indicated loss, via this route, of less than 1% azinphosmethyl residues present in the orchard. The generalized model developed, entitled the Pesticide Orchard Ecosystem Model (POEM), includes as a special case the model for the azinphosmethyl applications under the conditions of this field study. POEM also includes facilities for altering parameters to describe effects of other formulations, other pesticides, other application procedures and/or other field conditions.

This Project Summary was developed by EPA's Environmental Research Laboratory, Corvallis, OR, 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 work presented in the full report is one portion of an effort to characterize the dynamics and effects of an example compound in the terrestrial environment, utilizing primarily field measurements and the methodology of systems modeling and simulation. Data collection, model refinement, and revised experimental design were done iteratively, yielding a model that is parameterizable and data that are relevant to the problem being attacked.

The study of pesticide dynamics through *in situ* field studies is difficult due to the lack of natural or planned experiments (inability to control much of the variance, i.e., climatic conditions) and the relatively high levels of error associated with field data. Modeling techniques were employed to aid in the understanding of the necessarily large amount of field data needed to construct a "meaningful" picture of the pesticide's fate.

Description

The field experimental program used to investigate the distribution, attenuation and movement of the organophosphate insecticide azinphosmethyl, O,O-dimethyl-5-(4-oxo-1,2,3, benzotriazin-3(4H)-ylmethyl) phosphorodithioate (Guthion[R]), in a Michigan apple orchard is given in Chapter I. The compound was followed from its spray application through the orchard vegetation/litter/soil environment and into aquatic systems. The form of the model describing azinphosmethyl movement and attenuation, as well as data handling procedures and the derived rates, is presented in Chapter II. Observations were made concurrently within the same orchard to examine the effects of azinphosmethyl on several ground-dwelling invertebrates, including detailed studies of the isopod *Trachelipus rathkei.* Field and laboratory data collected on *T. rathkei* were used to develop a model describing its ecobiology and temporally-distributed pesticide-induced mortality. The output of the fate model described in Chapter II was used to determine the time-course of azinphosmethyl exposure.

In Chapter III the field experimental program used to determine azinphosmethyl airborne residues is presented. A multi-component kinetic model used in the assessment of the contribution of airborne loss to the overall attenuation of deposit residues is also described.

In Chapter IV, movement and attenuation of azinphosmethyl are examined as a function of environmental conditions. A computer simulation is described which allows the user to predict the fate and effects of azinphosmethyl on several types of organisms.

Chapter V describes the results of the field sampling program for invertebrates in the orchard plots, providing information on the effects of azinphosmethyl spraying (additional material on the isopod *T. rathkei* is found in Chapter IX). Chapter VI contains the results of a laboratory assessment of the toxicity of azinphosmethyl and diazinon to various invertebrates. Chapter VII briefly describes the models developed for spiders, earthworms, and springtails. Chapter VIII presents a detailed description of the ecobiology of the isopod *Trachelipus rathkei,* while Chapter IX describes the effects of the azinphosmethyl spray program on the *T. rathkei* field population. Chapter X presents the model for *T. rathkei,* including both its general life cycle and its response to pesticide exposure.

Appendix A documents the data analysis procedures employed locally at Michigan State University to parameterize the model. Appendix B is the users' guide for the Pesticide Orchard Ecosystem Model (POEM) described in this report.

Recommendations

(1) Further work to refine, parameterize, and test the components of the POEM model, or similar models, for other pesticides and other conditions should be undertaken. In many cases, the current forms are derived based on sparse data in the literature. While predictions based on these forms may be informative and useful in some contexts, they are not likely to be very accurate for predicting actual fate and impacts of pesticides until they have been carefully refined based on currently non-existent data. Nevertheless, the present model may be helpful, because it allows the user to determine the implications of various sets of assumptions about pesticide dynamics and effects.

(2) Work on models for the long-term effects of pesticide exposure on populations of invertebrates should be continued. While this study includes a reasonable model for effects of azinphosmethyl on isopods and less refined models for collembola, earthworms, and spiders, the methodology should be extended and refined through application to other pesticides and organisms.

(3) The model presented here does not provide an overall indicator of the ecosystem-level impact of a pesticide in a particular situation. While impacts on individual populations are likely to be key components of any sound measure of overall impact, the importance and role of each population in the ecosystem must also be defined and incorporated in the measure. Research aimed at identifying key populations and modeling their functions should be undertaken. The search for integrating measures or indicators of ecosystem stress or damage for terrestrial systems should be broadened and intensified.

Eric Goodman, Matt Zabik, Jeffrey J. Jenkins, Robert M. Kon, and Renate M. Snider are with Michigan State University, East Lansing, MI.
***Jay D. Gile** is the EPA Project Officer (see below).*

The complete report consists of two parts, entitled "Ecosystem Responses to Alternative Pesticides in the Terrestrial Environment:"
"A System Approach," (Order No. PB 84-162 726; Cost: $25.00)
"POEM Source Program, Sample Data, Sample Runs (Magnetic Tape," (Order No. PB 84-162 734; Cost: $790.00)
The above report and magnetic tape will be available only from: (cost subject to change)
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