United States
Environmental Protection
Agency

Robert S. Kerr Environmental Research
Laboratory
Ada OK 74820

Research and Development

EPA-600/S2-83-008 Apr. 1983

EPA

Project Summary

Economic Benefits of Controlling Water Pollution in an Irrigated River Basin: Methodology and Application

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The primary objective of this study was to develop an analytical procedure for estimating benefits of water pollution abatement in a multiple use river setting. The setting for the analysis was the Yakima River Basin of South-Central Washington State.

An analytical model consisting of a water quality submodel and an economic submodel was developed. The water quality submodel consisted of three elements: parameters (dissolved oxygen, temperature, sediment, etc.), water quality index functions, and an aggregation rule. Each water quality parameter affects one or more of the physical, chemical, biological, or aesthetic characteristics of water. The water quality index functions translated the measured levels of parameters into numerical values of quality for specific water uses. The aggregation rule combined the numerical values of water quality into an overall water quality index for each use.

The economic submodel viewed water as a multiple use resource, with each use having its own quality requirements. The submodel consisted of two types of value functions, willingness to pay for water quality improvements, and minimum acceptable compensation for water quality degradation.

The analytical model was tested and demonstrated by assuming to improve each water quality parameter as it became limiting until the river reached a hypothetical state of perfection for all uses. Next, the model was used to consider three programs of water quality improvement: stream flow augmentation, reduced sediment levels, and reduced nitrate levels. The estimated social benefits from flow stream augmentation exceeded the social benefits derived from programs reducing sediment or nitrate levels. Stream flow augmentation actually led to improvements in all water quality parameters due to the dilution effect of the added water quantity. For both stream flow augmentation and reduced nitrate levels, the annual benefits fell short of estimated annual costs. No measures of cost were available for the sediment control program. These findings imply that present water quality standards may be too high, and achieving these standards may not be economically efficient. However, lower standards of water quality may be economically efficient to achieve.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, 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

In recent years, water pollution control has become a significant activity throughout the world, particularly in the developed countries. The United Nations has designated the decade of the 1980s as the International Drinking Water

Supply and Sanitation Decade. Several nations have committed themselves to better water quality in the years ahead and have adopted water quality improvements as national goals.

In the United States, reducing the amount of pollution from irrigation return flows is a national goal (P.L. 92-500 and P.L. 95-217). Federal, state, and local governments spend billions of dollars to improve the quality of water receiving residuals from numerous sources, including irrigation return flows. The different water uses (household, agriculture, industry, fisheries, power generation, recreation, and others) and the ever-increasing population are placing greater demands on both quantity and quality of water. The time has come to incorporate water quality as a legitimate economic concern. This study develops a conceptual framework for estimating the economic benefits (social value) of abating water pollution in an irrigated river basin.

Economic Aspects of the Problem

Improving the quality of water receiving irrigation return flows or any other form of pollution is not a costless endeavor. Such costs may take many forms including foregone agricultural production. Water quality improvement is an economic problem requiring individuals and society to make choices among economic alternatives. Not improving the quality of water also has social costs in terms of foregone opportunities and associated disutilities.

Water quality management is an economic problem because it requires individuals and society to make choices about resource allocation. To make rational choices about water quality improvements, individuals and society need information on the magnitude of benefits and costs of water quality improvements. Without this information, it is impossible to say *a priori* whether society is providing too much or too little water quality improvements for its members.

Despite the increasing effort to improve water quality, information on the magnitude of benefits from water quality improvements has been scarce. Technical and empirical problems have contributed to the scarcity of benefit estimates for water quality improvements. The economic literature does not specify what technique should be used to quantitatively measure water quality. Also, the lack of markets for water quality presents conceptual problems in determining the value of water quality improvements.

Traditional economic analysis usually deals with homogeneous goods and the question of quality seldom arises. Quantification problems are confounded by the fact that water quality also has attributes of a public good. Quality improvements, once made, are equally available to all water users. Hence, they cannot be exclusively provided to people who are prepared to pay for them without incurring costs to exclude nonpayers. The costs required to exclude those unwilling to pay for the services may exceed the revenues generated by exclusion.

Despite the lack of quantitative measures for water quality and market prices for its value, society still demands cleaner water. There is a genuine need for the development of a conceptual framework that (1) provides a scheme for quantifying water quality and (2) does not rely on the availability of market prices for water quality in order to estimate the benefits (social value) that society attaches to cleaner water. This study is an attempt to develop such an approach.

Objectives of the Study

This study addressed the problem of measuring the benefits of water quality improvements (pollution abatement) in a multiple use river setting. Three objectives guided the research effort. The first objective of the study was to review the literature for relevant theory, methodology, and analytical procedures for estimating the benefits of pollution abatement in a multiple use river setting. The second objective was to develop an analytical procedure for estimating benefits guided by information from the literature review. The third objective was to apply the methodology developed to a case study in the Yakima River Basin of South-Central Washington State, where irrigation return flows are the main source of water pollution in the Yakima River.

The Analytical Model

An analytical model consisting of a water quality submodel and an economic submodel was specified for estimating benefits of water pollution abatement. The water quality submodel determined the overall quality of a given body of water for different uses. It consisted of three elements. parameters, water quality index functions, and an aggregation rule. The parameters defined water quality as a multidimensional vector, with each component representing some aspect of the physical, chemical, biological, and aesthetic characteristics of water. The water quality index functions translated the measured levels of parameters into numerical values of quality which water users could understand. The chosen minimum operator aggregation rule provided a way for combining the numerical index values of water quality and parameters into an aggregate water quality index for each water use.

The economic submodel derived the values of water quality changes for different uses and users, and viewed water as a multiple use resource, with each water use having its own water quality requirements. Individuals were assumed to derive satisfaction from the characteristics of water quality such as clarity, odor, taste, etc. A water quality control program might change the magnitude of one or more of these characteristics to affect the value of that water for individual users.

The economic submodel consisted of two types of value functions derived from a survey of water users. One function related the water users' willingness to pay for water quality improvement to water quality levels. The other function measured the water users' minimum acceptable compensation for degradation in water quality.

The Empirical Application

The Yakima Basin of South-Central Washington State was chosen as a study area for testing and demonstrating the application of the procedure developed. Three water uses (irrigation, recreation, and sport fishing) and eight water quality characteristics (suspended and settleable solids, fecal coliform bacteria, dissolved oxygen, water temperature, nitrates, phosphates, stream flow, and turbidity) were selected to demonstrate the application of the analytical model.

Based on the review of scientific literature and interviews with knowledgeable researchers, the characteristics of water quality considered to be important are (1) for agricultural water uses, sediment, water temperature, and stream flow; (2) for recreational water uses, fecal bacteria count, water temperature, stream flow, nitrates, phosphates, and instream turbidity; and (3) for fishing use, fecal coliform bacteria count, dissolved oxygen, stream flow, water temperature, nitrates, phosphates, and turbidity.

The model was tested and demonstrated with a series of assumed water quality improvement programs in which the limiting water quality characteristics for each type of water use were sequentially eased. The model was then applied to three typical water quality improvement programs: flow augmentation, reduced sediment levels, and reduced nitrate levels. For the stream flow augmentation and nitrate reduction policies, estimates of the social cost of achieving acceptable water quality levels were available for the Yakima River from previous studies, allowing a comparison with estimates of benefits for these programs.

Results

Sequentially easing the limiting water quality characteristics or parameters for each of the three water uses until the water quality was near perfection for all uses yielded additional benefits exceeding $2.5 million annually, based on the willingness to pay measure. Recreationists and fishermen received over 90 percent of these benefits.

The social benefits derived from increasing stream flow 151 percent over current levels were estimated to be $2.3 million annually, based on water users' willingness to pay. The annual social benefits from reducing nitrate concentration in the lower Yakima River 68 percent from its current level were found to be $1.2 million, using the same measure of value. The total benefits from reducing sediment levels 85 percent and turbidity levels 70 percent amounted to only $0.7 million annually. Previous studies had estimated that programs to increase stream flow or to reduce nitrate levels could each cost as much as $12 million annually. Hence, the cost of these programs greatly exceeded their estimated benefits, at least if carried to the level of quality considered in this analysis.

Conclusions

The additional social benefits from stream flow augmentation were substantially less than the social costs incurred in augmenting the flow. Similarly, the additional social costs from reducing the concentration of nitrates 68 percent outweighed the social benefits by a factor of approximately 10:1. These findings imply that water quality standards may be too high, and achieving these standards may not be worthwhile from the standpoint of economic efficiency. Probably, the marginal social costs and benefits of pollution abatement could be equated at lower levels of water quality. In any case, water quality standards should be set where marginal social benefits from water quality improvement equal marginal social costs of such improvements.

Limitations of this Study

This study suffers from two major weaknesses due to data limitations. First, this study ignored the possibility of interactions that may exist among pollutants that are simultaneously present in water. The interactions existing between pollutants may be antagonistic or synergistic. In the empirical water quality submodel it was assumed that the effect of one pollutant was independent of the others. A search of the authoritative works on water quality revealed very little on the nature of interactions that may exist among pollutants. It was often difficult to even find a quantifiable effect of one pollutant on water uses and users. As more information on interactions among water quality parameters becomes available, it can be incorporated into this analysis.

The second weakness of this study is that the empirical measures of benefit from pollution abatement did not account for non-user benefits (e.g., option value) and secondary benefits. To this extent, the estimated social benefit of water pollution abatement in the lower Yakima Basin are too low.

However, the major purpose of this study was to provide a procedure for relating the physical, chemical, biological, and economic aspects of water quality to one another for better resource management. This procedure has been demonstrated, but some significant improvements remain to be accomplished.

Despite these limitations, the procedure developed in this study for quantifying water quality and estimating monetary benefits of water quality improvements has numerous potential users, including local, state, and federal agencies responsible for water quality management. Also, individuals and institutions may be interested in this work for the general conceptual framework that is provided in addressing other similar situations.

Recommendations

More research should be undertaken to investigate the effect of different pollutants on water use and users. There is insufficient scientific information on damages caused by water pollutants and the effects of the interaction of water pollutants upon water quality. The lack of basic scientific data on pollutant damages stands in the way of sound economic analysis and decision-making about water quality management.

Two aspects of the procedure developed in this study need improvements. The water quality index functions need refinement to more accurately relate levels of water quality parameters to the usefulness of the water. Also, better means should be devised for obtaining information from water users about their perceptions of and reactions to changes in water quality. In addition, all of the points described as limitations to this study could be improved with more and better research efforts.

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The complete report, entitled "Economic Benefits of Controlling Water Pollution in an Irrigated River Basin: Methodology and Application," (Order No. PB 83-164 756; Cost: $17.50, subject to change) will be available only from:
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