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IMPORTANCE OF BENEFIT IDENTIFICATION IN EVALUATING WATER POLLUTION CONTROL PROGRAMS

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Abstract

Most economic studies dealing with water pollution abatement programs are carried out without properly identifying the benefits in physical terms. This is particularly so for policies and programs concentrating on abatement of one particular pollutant. Before benefits can be expressed in a dollar common denominator, they must be measured first in physical terms, namely the degree of water quality improvement for water consumption (uses). Water quality is dependent on physical, chemical, biological and aesthetic attributes of the water. Reducing one pollutant may have no effect on water quality if other pollutants keep the water unfit for use.

The paper explores the concept of water quality, how it is measured, and its significance for economic benefit evaluation. Examples from the literature are used to show how easily economic benefit evaluation can go astray if benefits are not measured in physical terms but are assumed to take place. Physical benefit evaluation is also a prerequisite for sequencing the abatement of various pollutants. Economic benefits do not solely depend on degree of water quality improvement, but also on water use. Water uses and users can differ greatly among watersheds, a fact commonly overlooked in most studies. The relevance of identifying physical benefits as well as (potential) uses and users for targeting limited funds for water quality improvement is illustrated. It is shown that targeting based on proper benefit identification and sound economic evaluation can deviate greatly from physical targeting criteria usually promoted.

Introduction

After the second world war, water pollution control has assumed an increasing importance in Canada. At both the federal and provincial levels ministries of the environment, whose mandates still include water pollution control, were instituted. Large amounts of private and public funds are now being spent on pollution abatement. In spite of progress made, there is still confusion on how to effectively combat water pollution with the scarce resources available. Part of the confusion stems from the complicated nature of the problem. Not only do technical, physical, biological, and aesthetic aspects loom large, but economic, fiscal, and administrative needs must also be considered. Contributions of the natural and social sciences have not been well integrated into the solution of the problem.

A major policy question is how to control water pollution so that the nation gains not just ecologically and aesthetically but also economically. Not all abatement programs result in welfare gains for society. The above question is significant because funds to finance such programs are scarce and choices must be made on how best to spend limited monies for environmental improvement. A lack of clarity exists about the effect of water pollution abatement on water quality. Too often it is assumed that a reduction of any one pollutant which exceeds tolerable levels will result in water quality improvement and will therefore be beneficial to society. Moreover, it is frequently assumed that if choices must be made because of funding shortages, efforts should be directed to waters with the highest pollution levels. It will be shown that both assumptions may be erroneous. Implementation of policies based on such assumptions can lead to considerable waste of private and public funds.

Water quality is not necessarily improved by reducing one particular pollutant, as will be explained below. If water quality does not improve, such abatement does not consequently bestow any benefits on society. The magnitude of a change in water quality is the pivotal element in benefit evaluation, not the reduction in one or more pollutants. Reduction in pollutants may or may not improve water quality. The paper will explore water quality and requirements for quality improvement in greater detail.

Difficulties in benefit-cost calculations of water quality improvement are twofold; those associated with identification and measurement of water quality improvement and those associated with evaluating the improvement in terms of a dollar common denominator. Since few markets and hence few prices for water quality improvement exist, valuation is often undertaken through estimating synthetic or proxy prices. Several techniques exist to derive these shadow prices. This paper will not deal with such value estimation techniques. Instead, we will concentrate on problems associated with identifying benefits as well as on the impact of benefit identification for discriminating among abatement projects. If benefits are not properly identified, even the most sophisticated valuation technique will come up with a wrong answer. Since benefits can be derived only from water quality improvement, the link between pollution abatement and water quality is crucial and will be explored in greater detail.

The purpose of this study is: (1) to show that water quality improvement is not necessarily synonymous with reducing any one pollutant, as is often assumed, (2) to explore the relationship between pollution abatement and water quality improvement, (3) to show the necessity of proper benefit identification for determining socio-economic benefits of quality improvement and (4) to show the importance of economic evaluations for directing abatement efforts.

The paper is organized as follows. Since water quality is pivotal in benefit identification, the concept and measurement of quality is first explored. Then the relevance of water quality for benefit evaluation is examined. The next section deals with the efficiency of pollution abatement which is highly dependent on proper benefit identification. This section also covers problems associated with targeting, particularly under limited budgets for water pollution control. Lastly, some pertinent implications for environmental policy and management are considered.

Although the principles determining water quality apply equally to surface and ground water, quality always refers to a particular water body. Water use, an important factor affecting economic benefits of water quality improvement, also refers to a particular water body. The most obvious geographic extent of a surface water body is a watershed. However, smaller areas may be considered if water quality differs greatly within a watershed. Entire drainage basins could also be considered. A drainage basin approach is called for if water quality in upstream watersheds affect water quality downstream in the basin and if downstream water use is important. Another approach lies in delimiting an entire water system, incorporating both surface and ground water because of their interdependence. For the purposes of this paper, which are mainly expository, the focus is on surface water by watersheds.

Water Quality

Central to benefit evaluation of water pollution control is water quality. Water quality is defined in terms of its fitness for a specific use, since each use has specific quality requirements. Water quality is dependent on physical, chemical, biological, and aesthetic attributes of the water. Each of these contains various elements, called quality parameters. For example, the physical characteristic includes sediment content, dissolved and suspended solids, temperature, and stream flow. The chemical characteristic includes nutrients, heavy metals, pesticides, dissolved oxygen, and hydrogen ion concentration (pH). Fecal coliform bacteria, algae growth and amoebae are elements establishing the biological characteristic of water quality. The aesthetic characteristic contains quality parameters such as odour and visual attractiveness. The term quality parameter encompasses more than the term pollutant. Since water quality for certain uses can also be affected by variables such as streamflow, temperature, dissolved oxygen, and pH levels, the term parameter is preferred over the term pollutant.

Measuring Water Quality

The level of water quality for a specific use k depends on the level of the various quality parameters affecting that use and can be expressed by the following vector:

$$X_k = \{p_{k1}, p_{k2}, \ldots, p_{kj}, \ldots, p_{km}\} \qquad (k = 1 \ldots m;\ j = 1 \ldots n) \qquad \text{(a)}$$

X_k is the water quality vector for use k and p_{kj} is the magnitude of the jth quality parameter affecting use k. These quality parameters are measured in physical, chemical and biological units such as degrees Celsius, milligrams per litre (mg/l), and organisms per 100 ml.

Water quality can be measured in various ways. One way is to establish a standard $\overline{p_{kj}}$ to denote the level of tolerance for the jth parameter in use k. If the level of quality parameter j in use k exceeds the standard $\overline{p_{kj}}$ $(p_{kj} > \overline{p_{kj}})$,the water is unfit for use k. Note that any one quality parameter may make the water unfit for use k. If only one parameter exceeds its standard for use k while all others are below their standards, the water is still unfit for use k. Classifying water quality by means of one standard for each parameter is often preferred when dealing with toxic chemicals and bacteria affecting health. In that case, the level of the toxic chemical or of the bacteria cannot exceed a set standard. If it does, the water is rated unfit for those uses affecting health.

In general, water quality is better measured in various classes, scales or grades. The water is not necessarily either fit or unfit for a particular use, but less of a pollutant is generally better than more. For this grading system a water quality parameter index I_{kj} for each parameter affecting use k can be constructed. This is done by means of water quality index functions, as explained by Ott (1978) and Willis *et al.* (1992). These functions translate the level of parameter j in use k into a water quality parameter index. These indices are normally scaled from 0 to 100, higher numbers indicating better water quality (Dinius, 1987).

Water quality can now be expressed as a vector of water quality parameter indices as follows:

$$W_k = \{I_{k1}, I_{k2}, \ldots, I_{kj}, \ldots I_{kn}\} \qquad (k = 1\ldots..m; \qquad j = 1\ldots..n) \qquad \text{(b)}$$

W_k is the water quality vector for use k expressed in parameter indices. This vector of individual quality parameter indices for use k must be translated into an overall water quality index Q_k. This is done by the following aggregation form:

$$Q_k = g(I_{kj}) \qquad (k = 1\ldots..m; \qquad j = 1\ldots..n) \qquad (1)$$

Q_k is the overall water quality index for use k

g represents a general aggregation form

I_{kj} is the quality index number of the jth quality parameter for use k.

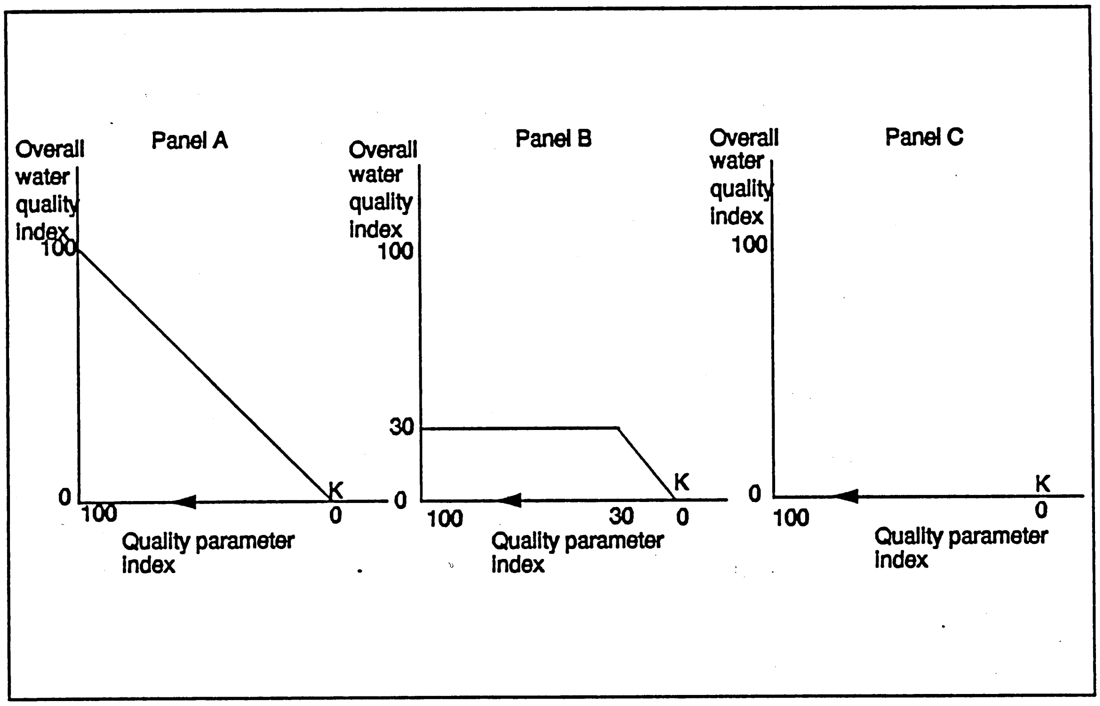
The functional form chosen for aggregating the individual parameter indices into an overall water quality index for each use is the "minimum operator rule" (Ott, 1978). This rule states that the overall water quality index for use k is equal to the smallest quality parameter index number from among all individual parameters affecting use k. This implies that the quality parameter that most limits use k is the one that determines overall water quality. The minimum operator rule thus can be expressed as:

$$Q_k = \min (I_{kj}) \qquad (2)$$

Willis *et al.* (1992) distinguish five classes. Very poor water quality for a particular use has an index range of 0 to 29.9 while perfect water quality ranks 100. Between these extremes are three more intermediate quality ranges: poor, good, and very good. It is important to note that the quality parameters affect the various uses in different ways. Therefore the index number given to a particular parameter can vary from use to use. Some parameters do not even affect all uses. In that case the magnitude of the parameter is irrelevant for water quality for that particular use.

Graphical and Numerical Illustrations

The effect of a reduction in one particular pollutant on water quality for a particular use can be graphically illustrated in the following three panels. The index of that particular pollutant (quality parameter) is depicted on the horizontal axis, while the vertical axis represents the overall water quality index. Note that at the origin the overall water quality index is zero and the parameter index is 100. Suppose the parameter index is currently zero as indicated by K.



Panel A shows that the parameter under consideration is either the only one or the only limiting parameter affecting that use. Any reduction of the pollutant will increase water quality. If the reduction results in a quality parameter index of 100, overall water quality becomes perfect. In panel B the quality parameter under consideration is the only limiting factor till the quality parameter index reaches 30. Further reductions will not improve the overall water quality index beyond 30 since one or more of other quality parameters affecting that use now become the limiting factor(s). Panel C indicates that no improvement in water quality is possible through any reduction of the pollutant under consideration, since other limiting parameters are present from the outset.

A numerical example will illustrate how water quality levels are estimated in a watershed. The example is taken from the Kettle Creek in southern Ontario and relates to water quality determination for sport fishing. Average levels of major parameters affecting sport fishing for the most critical months of June, July and August between 1988 and 1992 are presented in column 2 of Table 1. This column represents vector (a). Functional forms from Willis *et al.* (1992) are used to calculate the quality index for each parameter affecting sport fishing. The numerical results as well as qualitative interpretations are expressed in the first 4 rows of columns 3 and 4 in Table 1. Index numbers in column 3 represent vector (b). The lowest index is for residue particulate and the highest for dissolved oxygen. Consequently, the most limiting parameter is residue particulate. The minimum operator rule is used to estimate overall water quality for sport fishing as expressed in equation (2). The corresponding index is found in the last row of column 3 in Table 1 and is consequently identical to the index for residue particulate, the most limiting parameter.

TABLE 1

AVERAGE QUALITY PARAMETER LEVELS AND THEIR INDICES AND CORRESPONDING WATER QUALITY INDEX FOR SPORT FISHING IN THE KETTLE CREEK, 1988 - 1992

Quality parameters and water quality	Mean parameter levels	Indices	Quality classification
Residue particulate	75.5 mg/l	0	very poor
Temperature	22.9 degr. Cel.	48	poor
Dissolved oxygen	9 mg/l	100	perfect
Phosphate	0.277 mg/l	19	very poor
Overall water quality		0	very poor

Greater numbers of sport fish species and their levels can be supported, the better the overall water quality for sport fishing is. It can be seen from Table I that overall water quality for sport fishing in the Kettle Creek is very poor. An increase in any index other than that for residue particulate through improving the corresponding quality parameters will have no effect on overall water quality relative to sport fishing. To improve water quality for this purpose, a reduction in residue particulate and phosphate is needed such that their indices reach at least 30, thus improving water quality for sport fishing from very poor to poor.

Measuring Water Quality in Canada

The above index analysis is not used in Canada. Instead the standard approach is used for all quality parameters. Water quality thus is determined by those parameters exceeding their standards which are measured in their own units of measurement. Therefore water quality is seen as either fit or unfit for a particular use. Suppose a particular use is affected by five quality parameters, four of them being below and one exceeding parameter standards. The result is that the water is considered unfit for that particular use. As indicated, a standard is a rough indicator for most uses, because generally the water is neither fit nor unfit but displays various degrees of fitness. This bears important consequences for benefit evaluation because willingness to pay for water quality improvement depends on the degree of improvement.

Difficulties and Shortcomings in Water Quality Determination

The determination of water quality is based mainly on the natural sciences, which is of crucial importance to economic evaluation of water pollution control programs. Apart from developing water quality functions, other difficulties still remain in water quality evaluation, among them those related to space and time components of quality. The most obvious spatial unit of measurement is a watershed, although quality can differ greatly within a watershed. In that case the watershed must be subdivided into sub-watersheds. Quality also changes over time due to many factors such as rainfall or snowmelt which occur randomly over time. In that case quality is determined by the expected value of the probability distribution of the quality parameter levels over time. Many shortcomings exist in water quality measurement and more work is still needed in this area (Bodo, n.d.). For the remainder of this paper water quality is assumed to be homogeneous within a watershed, not because this reflects reality, but for ease of exposition.

Water Quality and Benefit Evaluation

Danger of Unilateral Approach

Reliable water quality information is essential for benefit evaluation of water quality control. Economic benefit evaluation is, however, often pursued in isolation of water quality improvement data. Many policies and programs exist or remedial actions recommended that concentrate on the reduction of one particular pollutant, usually from one particular source. Reduction in sediment loading from agriculture is a case in point. Benefit evaluation of such programs and activities usually assumes that water quality improves with a reduction in sediment loading (Clark, 1985; Nielson, 1986; Fox and Dickson, 1990; Agriculture Canada, 1992; Fox *et al.*, 1993;). Evaluation is then based on the paradigm expressed in Panel A. From the previous example, as noted in Table 1, it is obvious that water quality can only improve if sediment is the parameter that most limits water quality for a particular use and if the reduction is large enough to increase the sediment index to at least the next grade. If indices of other parameters occur at the same or a lower grade as that for sediment then a reduction in sediment alone has no effect on water quality. If the index of residue particulate increases to 30 through sediment reduction but the phosphate index remains far below 30, perhaps because phosphate pollution from other sources remains unabated, no water quality improvement for sport fishing will occur. Even at zero sediment loading the water is still very poor for sport fishing.

If sediment is the only parameter affecting a particular use, then a reduction in sediment will result in a benefit regardless of other pollutants in the water. For example, a reduction in sediment loading avoids the necessity of periodic dredging of harbors and waterways. Moreover, maintenance costs of water-using machinery and appliances will be reduced by a decrease in sediment loading.

Assuming that sediment is the most limiting factor affecting quality in a particular watershed, an x percent reduction in sediment loading from agriculture still might not lead to an x percent improvement in water quality. Sediment concentration does not necessarily depend on loading only from agriculture, but could come from other sources as well. If these other sources remain unabated, water quality may improve only slightly or not at all.

It is crucial in water quality improvement for a particular water use that the indices of all quality parameters in the same lowest grade affecting that use be simultaneously improved. Moreover, efforts must be concentrated on all major sources, particularly if reduction in loading from one source is incapable of producing noticeable quality improvement. Benefit evaluation of improving one particular quality parameter cannot concentrate exclusively on that one parameter. It must include all relevant quality parameters in order to determine whether or not water quality improves for the uses under consideration. If no water quality improvement occurs, the benefits of improving one parameter are zero. The consequences for benefit evaluation are obvious. If it is assumed that water quality improves proportionally with a reduction in loading of sediment from one industry, i.e., agriculture, then the benefits will be highly overestimated if other quality parameters prevent water quality improvement and/or if sources other than agriculture contribute to loading of sediment.

Another frequent error is to assume that even if water quality improves at the same percentage as that in a reduction of loading, the economic benefits of quality improvement will be the same wherever they occur. Economic benefits of quality improvement are highly dependent on the potential number of water uses and users as Ribaudo (1986) showed. Uses and users as well as water quality vary among watersheds.

Incorrect Benefit Calculations

Examples of incorrect benefit calculations abound in the literature. Some findings in a recent Agriculture Canada report (1992) are illustrative. The report quantifies the benefits of a reduction in sediment and phosphorus loadings from farm fields in southern Ontario. One of the benefit components considered is recreational swimming. Average recreational benefits are estimated at $.11/ha in southern Ontario for a 40% reduction in phosphorus loading. It is implied that this figure can be applied to any watershed in southern Ontario. Suppose that benefits of water quality improvement are required for a specific watershed, for example that of Kettle Creek. Apart from the error in equating total willingness to pay for phosphorus reduction among all watersheds, no recreational benefits can be obtained from phosphorus reduction at the mouth of the Kettle Creek since the bacteria content there is too high. The report fails to quantify the base phosphorus level and the effect of phosphate reduction on water quality for swimming. These differ among watersheds. Moreover, the report fails to quantify the number of potential users (swimmers) in each watershed and their willingness to pay for phosphorus reduction. By ignoring the effect of such reductions on water quality and on the demand for water quality improvement in each watershed, benefits from water quality improvement cannot be accurately ascertained. The benefits from a reduction in phosphorus loading for swimming in the Kettle Creek watershed are really zero instead of $4620 annually as calculated in the report, based on an estimated cleared agricultural land base of 42,000 ha.

Reduction in water treatment cost for domestic use is a further benefit of water quality improvement. The report quotes a cost reduction of water treatment at $2.97/ha for 40% reduction each in sediment and phosphorus. This figure is meaningless for the Kettle Creek watershed. Phosphorus treatment occurs neither at Port Stanley Treatment Plant nor at the St. Thomas Water Supply System (two treatment plants for the two towns in the Kettle Creek watershed), since phosphate levels are below the standard for drinking water. The plants are located on the shore of Lake Erie. The water is, however, treated for sediment. The main cause of turbidity, which is as high as 450 FTU (Formazin Turbidity Units), is from shore line bank erosion and waves stirring up particles from the bottom of Lake Erie.[1] Even if sediment loading from farm fields were reduced to zero, the turbidity at the plant would not be affected. Hence zero benefits are obtained for water treatment from a reduction in phosphorus and sediment loading from farm fields. Still the Agriculture Canada report estimates a cost reduction of $124,740 annually for the 42,000 ha contained in the Kettle Creek watershed.

Abatement Sequencing

If the indices of more than one quality parameter are in the lowest grade, one might be inclined to think that water quality improvement must start somewhere and that it does not matter which parameter to tackle first as long as all indices within that grade are ultimately improved. The sequence does, however, matter. The proper strategy is to start with the most limiting parameter, provided that a net benefit can be obtained. If indices of more than one quality parameter fall within the same lowest grade, then all should be attacked simultaneously. If parameters are reduced separately over time, the benefits of the first parameter improvement to be carried out will not emerge until the last limiting parameter has been improved to a higher grade. Due to discounting, the longer that benefits of quality improvement are postponed, the lower the present value of net benefits becomes.

Benefit evaluation that assumes that water quality improves proportionately with an improvement in each parameter will go astray if improvement of several limiting quality parameters is carried out in sequence. Under such erroneous evaluation assessment, benefits supposedly occur immediately after parameter improvement and as often as the number of parameters to be improved. In actuality, benefits occur only when the index of the last limiting parameter has increased to the next higher quality scale. Water quality does not improve each time the number of limiting quality parameters present are changed. This kind of evaluation

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1 *Personal communications with Port Stanley Treatment Plant superintendent, John L. Bolt and St. Thomas Water Supply Systems (London Office) superintendent Michael Auger.*

results in gross overestimation of benefits through double-counting and errors in time phasing of benefits.

Abatement Efficiency

Water pollution control must be considered from different viewpoints. The economic aspect is of prime importance. It determines efficient use of scarce resources in pollution abatement. In most cases water quality improvement is expected to result in gross benefits. These are equivalent to what people are willing to pay for such improvement. Sacrifices are usually necessary to improve water quality. If no budget constraints on costs exist, then water quality improvement should be undertaken only whenever and wherever a net benefit can be realized. As noted earlier, in many instances abatement programs without any concomitant improvement in water quality are promoted. Obviously such courses of action are inefficient. Even when and where water quality improves, the costs of such improvement may outweigh any benefits. Economic benefits vary greatly among watersheds depending on number of potential uses and users, existing water quality, and the degree of improvement. These can differ greatly among watersheds. Economics is imperative in directing improvement efforts by discriminating among intended policies and management plans. Only those policies and plans leading to an efficient use of resources, that is to a surplus of benefits over costs, should be executed.

Efficiency calculation becomes even more important if money budgeted for water quality improvement is scarce. With current tight government budgets this scenario is of great immediacy. All levels of government are heavily involved in water quality improvement. Public authorities usually perform degradation remediation measures through treatment of degraded water supplies. Degradation prevention at the source, on the other hand, involves government funds through among others tax write-offs and subsidies. With prevailing limited budgets, water quality improvement programs must be ranked in order of net payoff for society (Ribaudo, 1989).

Budgets are usually predetermined for general water improvement purposes but are too limited to cover all eligible projects.

Targeting Under Limited Budgets

Suppose a provincial Ministry of Agriculture has set aside a specific amount of money to prevent or mitigate stream sedimentation. The allocated funds will be spent for subsidizing use of non-inversion primary tillage practices. Typically, the budget is not sufficient to provide subsidies to all farmers switching to these practices. The question then becomes how to distribute the subsidy such that maximum payoff is obtained from the limited budget. Many studies, particularly those concentrating on sediment control from agriculture, indicate that the highest payoff is obtained where the reduction in loading per hectare per unit cost is highest (Nielsen, 1968; Fox and Dickson, 1990; Fox *et al.*, 1993). Usually these areas also show the highest loading levels. From the section on water quality it becomes obvious that such direct relationships may not exist. Large reductions in sediment loading from agriculture may not improve water quality in every watershed. That depends on the level of sediment from other sources and on the index levels of other parameters affecting quality. Even if water quality should improve, economic benefits of such improvement may differ among watersheds.

Subsidies can be allocated in an infinitely large number of ways. It becomes impractical if not impossible to calculate the benefit-cost (B/C) ratios for all possible scenarios. Short cuts are needed. A first step is to eliminate all watersheds where water quality does not improve irrespective of the amount of attempted sediment reduction, because of presence of other limiting parameters. Then, probably two scenarios should be considered. The first scenario assumes that all tillage is switched to non-inversion in watersheds where water quality will improve by sediment reduction. B/C ratios can then be calculated for included watersheds. The denominator of the B/C ratio is made up exclusively of the subsidy. Possible on-farm costs associated with the switch not covered by the subsidy must be deducted from the numerator, the benefits of sediment reduction. For this scenario the subsidy should be provided for the watershed with the highest

B/C ratio and for other watersheds with successively lower ratios until the budget is exhausted.

This scenario contrasts with the other one where the subsidy is provided for those areas in a watershed with the highest loading levels per ha., provided that water quality will improve. A similar scenario is favoured by Fox and Taff (1990). In that case more watersheds can be covered with the fixed budget than under the first scenario. B/C ratios for a particular watershed are expected to be higher under this latter scenario than under the previous one. Again watersheds with the highest B/C ratios for a given budget will be targeted. Total net benefits from scenario 1 must now be compared with those of scenario 2 in order to determine which scenario offers a higher payoff from the fixed budget. Scenario 2 is not necessarily the better one. Large reductions in sediment/ha in certain watersheds may have a low benefit because of limited water usage and small number of users as well as high concentrations of other pollutants, and perhaps because of high on-farm costs resulting from the switch. On the other hand, small reductions in sediment/ha can result in high benefits because the number of potential water uses and users are large, sediment is the only limiting factor affecting water quality, or on-farm costs of switching practices are low or even negative.

The above economic targeting criterion differs greatly from the criterion most often advocated, namely that targeting should be directed to areas where loading levels per hectare are highest (Dickinson *et al.*, 1990). This is a physical targeting criterion. Such targeting may not lead to environmental improvement if other contaminants keep the water unfit for use. Even if water quality improves, such targeting can lead to an inefficient use of resources from society's point of view. Even the use of economic studies incorporating the proper benefit-cost criterion will also contribute to a waste of resources if they are based on faulty assumptions about water quality improvement and about benefits obtained from such improvement. It is erroneous to assume that a reduction in a particular percentage sediment loading per hectare in a watershed always results in an equivalent percentage of water quality improvement in that watershed, and that the economic benefits of water quality improvement are the same wherever they occur. With such faulty assumptions, the benefits of sediment reduction are not properly identified.

Conclusions

Several policy implications can be drawn from the above. First, benefit evaluation of water pollution control is essential in advising on strategies of environmental management and environmental policy formulation. A haphazard approach to water pollution abatement can result in substantial costs for society without matching benefits. The economic aspect of water pollution control therefore looms large, particularly in a situation of tight government budgets. Water pollution control should neither be left solely to water quality experts from the natural sciences nor to economists. Often, water quality experts do not see the ramifications of a haphazard approach to abatement, while economists rarely familiarize themselves with the nuts and bolts of quality improvement. It is important that economists work closely with water quality experts, because water quality improvement is fundamental to economic benefit evaluation.

A second policy implication relates to coordination and centralization in decision-making. Agencies or ministries focussing on one particular quality parameter often lose sight of other quality parameters which make water unsuitable for particular uses. Some kind of centralized decision-making system focussing on overall water quality improvement rather than on individual pollutants is necessary. Coordination among agencies executing the program is also required.

Third, the sequencing in reducing individual pollutants is important. Sequencing requires a centralized approach. It cannot be left to individual ministries, municipalities or agencies, each dealing with one particular pollutant.

Fourth, benefit-cost studies are essential under limited budgets. Given tight government budgets for environmental improvement, maximum payoff from such funds should be obtained. Sound benefit-cost analysis requires proper benefit identification.

There are still many gaps in determining water quality standards or grades as well as in the evaluation of the benefits from water quality improvement. In addition, there are data gaps. Thus much subjective judgement enters into environmental management. A conceptual framework for making heuristic judgements is therefore of great importance. Such a framework has been developed in this article. It is far better to place reliance upon rough estimates of relevant concepts than to rely on more precise estimates of irrelevant concepts.

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