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The Quality of Water: Problems, Identification, and Improvement

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Within the next two or three decades, water problems in the United States, particularly in the western region, may well constitute a greater crisis than does energy today.[1] The major difference between the water and energy crises is that there are no known physical substitutes for water in satisfying direct demands by people, but there are many known substitutes for petroleum in producing energy. This probably means we must learn how to live with our current water supply endowments through managing water in terms of its use, development and conservation.

Similarities between the present energy crisis and the expected water crisis emphasize increasing scarcities and increasing costs. Water is a necessity of life and constitutes an essential resource in most economic activities. Thus, increasing costs and scarcities of water are likely to bring profound effects upon economic progress affecting production, employment, income distribution, investment, and debt retirement in affected regions. Since approximately three-fourths of the world's area is covered with water, augmented by moisture fall and aquifers on and under the remaining one-fourth of the earth's surface, what is the basis for future concerns about water?

One answer was implied in the words of Coleridge's ancient mariner who, while dying from thirst, lamented "Water, water everywhere but not a drop to drink." This answer concerns water quality. The ancient mariner was served well by the transportation service of the ocean water that carried his ship, but the same water did not possess the quality to quench his thirst.

Irving Fox reminds us that "In the minds of many people, the existing and potential degradation of water quality is our foremost water problem" (4, p. 32). This problem is magnified by the many and increasing uses for water and their vastly different water quality requirements. The solution to water quality problems rests with water quality management. This solution provides opportunity for avoiding the expected water crisis in the future.

Limited to discussion of water quality, this paper strives (1) to describe the nature of water quality problems, (2) to investigate possible means for identifying water quality requirements for uses of water, and (3) to consider how water supplies may be managed in meeting future water quality demand requirements.

Origins and Nature of Water Quality Problems

Traditionally, water (as well as air and soil) has been used to assimilate, dilute, and recycle the residual wastes of human activity. But there are limits to the capacity of water to assimilate, dilute, and recycle all of our garbage. Currently, these limits are being violated through uses of technologies and practices associated with production, fabrication, distribution, and consumption of materials.

Presently, our use of technology affecting water quality is exceeding our ability to manage the quality of water. As an example, an estimated 30,000 chemical compounds are in use today with an estimated 1,000 new chemical substances created each year (10, p. 9). Most of these substances have been developed and put into use without adequate provision for their effects upon water quality. These are only examples of some of the substances and materials that may affect water quality.

Historically, natural resource scarcity has been interpreted in measures of quantities or resources, i.e., gallons of water, depth of soil, barrels of oil, etc. Increasingly, however, we are realizing that scarcity of water and other resources is largely a function of quality. This realization is part of a much larger syndrome developing in our culture that holds qualities are, within limits, more important than mere quantities. This syndrome is rejecting largeness and quantities in favor of qualities. For example, the longest river, the largest reservoir, the largest university, and the largest corporation, which Americans have bragged about in the past because of largesse or efficiency, are under serious indictment.

The total quantity of water, for example, may be abundant or even superfluous, but we may not have available sufficient water of a particular quality to satisfy a particular use-demand. The water may be too salty—as was the case with the ancient mariner—too hot, too toxic, etc. for a particular use. As a consequence, a use process may be made more costly, a use may be diminished, or a use may be precluded entirely because requisite quality is lacking, even though there is an abundant quantity of water in the aggregate.

As state and national governments proceed to take action in water quality management, costs of quality improvement are likely to meet resistance from many of the same people who previously supported quality enhancement efforts. As costs of pollution control press on producers, as prices of products reflecting pollution control costs press on consumers, as pollution control taxes press on taxpayers, and as pollution control measures restrict individual freedom in resource use, voluntary support and enthusiasm for water quality improvement may well diminish.

Such resistances may thwart quality improvement unless facts are ascertained and made available to people regarding (1) proposed water quality standards, (2) costs of achieving these standards, (3) benefits from quality improvements, (4) incidences of costs and benefits in terms of who pays them and who receives them in both short and long terms, and (5) nature and effects of antipollution regulations and controls upon individual freedom and choice (15).

These issues will be and are being decided in legislative, executive, and judicial processes of government. However, under our form of government, support for and enforcement of these decisions rest with the general citizenry. Their support and compliance in turn depend upon how well citizens are informed regarding these very important yet very complicated issues. How well people are informed, in turn, depends upon availability of relevant information and upon how well this knowledge is made available to citizens. As I understand it, this is an important purpose of this conference.

As a citizen, I am deeply concerned about the deterioration of our water quality. At the same time, I am optimistic concerning our ability to produce the facts and analyses needed in developing remedial policies and programs. Such policies and programs should seek (1) to improve the quality of our water and (2) to engender widespread understanding and acceptance by diversely affected groups of people, concommitantly. This is not an easy task.

In our attempt to comprehend and interpret water quality as a major public policy goal and in its relationship with other public goals, three difficult but strategic questions arise and demand answers. First, what are the measures of water quality that can serve as policy and program goals and at the same time engender widespread and continuing public understanding and support? Here I am thinking about the general nature of standards and targets for water similar to those needed in defining and achieving such goals as economic growth, full employment, income distribution, and inflation control. Second, what are the costs, both monetized and nonmonetized, of achieving and failing to achieve specified standards of water quality? Third, who pays the costs, with and without achievement of standards of water quality, and who gets the benefits?

Answers to these questions are difficult, but I believe they are essential in developing policy and programs in water quality management. In pursuing answers to these questions, it becomes apparent that the nature and level of standards are directly related to the nature and magnitude of costs. The nature of costs, in turn, determines their incidences, that is, on whom the costs will fall. The nature, magnitude, and incidence of costs affect the determination of quality standards and their achievement. In answering these questions, possible trade-offs and side effects with respect to other national goals, including production, full employment, inflation control, and income distribution will be revealed (3).

Water Quality Variability

The quantity theory of water emphasized in and perpetuated through the various doctrines of water rights, with few exceptions, has tended to ignore variations in water quality and to treat all water alike. However, instead of being homogeneous, water is extremely heterogeneous in terms of its properties, its technologically permitted uses, and its economically demanded uses.

It becomes helpful, at least from an economic viewpoint, to regard water as differentiated in kinds and grades determined by its quality (1). Thus, supply and demand functions of water are each regarded as consisting of numerous quality oriented segments, each segment characterized by relatively homogeneous quality. This concept is further examined in the following two topics concerned with quality variations in supplies and in demands.

Quality Variations in Water Supplies

Water's chemical formula, H_2O, has tended to impute a homogeneity to each unit of water that does not exist. Actually, water is a very complex resource with large variations in its nature from one unit of supply to another unit that affect its use (14). Water occurs in three distinct forms: solid, liquid, and gas. Most substances contract when frozen, but water expands. Water possesses a very high heat capacity and surface tension. It dissolves many compounds that thereafter remain in solution. Thus, water has been called the "universal solvent." The character of water has been further complicated by the discovery of three isotopes for both hydrogen and oxygen that form thirty-three different substances.

In addition to its indigenous characteristics, water serves as a vehicle of transport for many exogeneous materials that become introduced into water through natural as well as human actions. Suspended silt from soil erosion is one of these materials that through adsorption and absorption serves as a transport agent for numerous residuals from fertilizers, pesticides, and other compounds. Thus, various water sources and supply segments possess different properties that must be analyzed in terms of the uses to be made from the water.

Quality Variations in Water Demands

Various demands for water require different water properties and vary in their toleration of particular properties **(13).** For example, living cells may require the presence of certain minerals in water, whereas battery cells may not tolerate the same minerals. Even organisms vary in their mineral requirements and toleration of minerals. Quality of water must necessarily be viewed in terms of a particular use if quality is to be manageable. Different qualities are required (or tolerated) for animal consumption, navigation, power, irrigation, food processing, air conditioning, recreation, manufacturing, and other uses of water. Even within each of these major categories, demands are specialized. Within manufacturing, for example, beer, aluminum, paper, and synthetic fiber production each possess important quality differentiations.

Water quality suited for one use may be absolutely unsuited for another use. Thus, it appears there is little, if any, relevance for a universal water quality *standard.* Instead, quality *standards* should be developed in relation to specific uses to be made of particular water supplies at particular points or periods of time in the process of satisfying specific human wants. Such differentiations will likely extend to segments of the same water source, be it a stream, a lake, or an aquifer. In other words, the quality mix of a particular water supply must be analyzed in terms of uses to which it is put (12).

Projections for water demand are basic and necessary in providing essential elements of a normative and predictive framework for planning and carrying out water policy. However, these projections should not be considered as aggregates. On the contrary, they must be disaggregated into segmented quality differentiations derived from relevant use demand requirements (1).

Included as demand by uses are qualities by amounts of water demanded. Also included are the spatial and temporal occurrences of quality-linked supplies available for serving quality-linked amounts to the estimated demands. Finally, the cost dimension is involved in terms of least cost alternatives for gearing (bringing or keeping) supply qualities to demand qualities.

Regarding demands, one further point should be considered. This involves a more refined differentiation into direct demand and derived demand components. Such a differentiation becomes important in systems analysis involving regional accounts as well as in those allocations which must be made through ordinal rather than cardinal criteria. Thus, not only must we undertake to solve the complex problem of determining technical coefficients for water used as an input but also the even more difficult one of specifying the demand for water as a "final product," with all of the difficulties inherent in nonquantifiable parameters which must be ordered by ordinal criteria.

Identification of Water Quality Demand Requirements

Qualities of water may be affected by human use or they may be produced in the natural state. One set of qualities within a natural supply of water may satisfy a particular use but may preclude another use. Furthermore, one use of water may leave a residue or an effluent within the water it has used that diminishes or precludes another use and that increases the cost of subsequent use of the same water.

This would constitute water pollution, which is a supply related concept. In economic terms, water pollution means a change in a characteristic(s) of a particular water supply such that additional costs, either monetized or nonmonetized, must be borne by the next use and the next user either through diminishing or precluding the next use or through forcing the next use (1) to absorb more costs in cleaning up the residue left by the initial use or (2) to develop a new source of water supply.

Externalities and Water Quality

One user of water may be in a position to retain the benefits from use while shifting costs to other users by lowering water quality. If that user had to bear the shifted costs, the motivation would be to use the water in a manner consistent with quality demanded by other users.

On the other hand, a user of water may be in such a position that if an outlay is made to maintain or improve water quality, the benefits from the outlay which shift to other users could not be captured by the user. If such benefits could be captured, the user would be motivated to make outlays which would maintain or improve the quality of the water after it leaves that use. Such terms as "side effects," "spillovers," "fallout," or "free-rider" have been applied to such shifts of costs and benefits.

These conditions are termed externalities by economists. The rationale for this term is that the consequences of the actions are external to the firm or industry responsible for the actions. Externalities are classified as economies and diseconomies. Beneficial effects are called external economies and harmful effects are called external diseconomies. Both have in common the phenomenon that the incidences of the effects are shifted beyond the user that causes them. The reason for this shift may be of either spatial, structural, or temporal origins, or a combination of reasons.

For example, a nuclear reactor in power generation uses water to disperse heat. If the increase in temperature adversely affects another use, say fish reproduction and growth, this effect is an externality of the power plant—in this case, an external diseconomy. We call it thermal pollution. On the other hand, if the effect of heat dispersion by the power plant is to warm up the water so that the water is more useful for swimming, an externality would be created; this instance would constitute an external economy since the next .use would be favorably affected.

Although the problem of external economies is important, external diseconomies appear far more important in water quality management. For example, wastes from manufacturing or from chemical fertilizers, pesticides, and livestock moving into streams, lakes, or aquifers may foreclose other uses entirely or make other uses more expensive to undertake. Or they may endanger life and health of human beings.

Kneese concludes that "a society that allows waste dischargers to neglect the offsite costs of waste disposal will not only devote too few resources to the treatment of waste but will also produce too much waste in view of the damage it causes" (9, p. 43).

Externalities are powerful concepts developed by economists as a body of theory within welfare economics, with tools of analysis having application to water quality. Starting with the work of Pareto, published in 1909, to the work of A. C. Pigou, published in 1920, many economists have devoted attention to development of theory and tools that may now be transferred to water quality analysis. Pigou's work was motivated in part by the apparent adverse effect of smoke from English factories upon the English laborers and their families, an external diseconomy.

Water Quality Criteria

What does this reasoning have to do with developing quality standards for water? It suggests two necessary criteria, which are (1) the next use test and (2) the test of reversibility.

The first criterion, the next use test, holds that undesirable quality changes (or pollution) occur when the effluent or effect of an initial use adversely affects the next use to which the water may be put in meeting needs of people (i.e., quenching thirst, swimming, fabricating aluminum, etc.). If there are no adverse effects on any next use(s), then there is no cause for concern and no particular need for setting a quality standard. There are no costs shifted to another use. On the other hand, if the initial use creates adverse effects (external diseconomies), monetized or nonmonetized, on the next use(s), then the quality standard should reflect the costs, monetized or nonmonetized, to the next use as well as benefits gained in the initial use. This approach constitutes the basis for the "next use" model for deriving and testing environmental quality standards and has been applied in several of our recent Iowa studies on water quality (6, 7, 11, 16).

The second criterion, that of reversibility, means that a use of water should not result in an irreversible state of quality.[3] This criterion appears desirable in the formulation of quality standards in order to retain options for water use that may not be apparent at the moment but that may become viable through future technological developments and increases in demand. If irreversibility of water quality is permitted, certain future use options may become foreclosed.

Through application of these two criteria, two deductions may be made that possess important implications for policy and programs. First, only the irreversible criterion may be used as the basis for universal water quality standards. Second, the next use criterion means that quality standards will vary from area to area, from time to time, and from use to use, depending upon the actual and potential existences and requirements of other next uses. The latter deduction appears most likely to constitute a major concern for developing water quality standards for policy and programs.

Now, let us turn our attention to possible answers to the second question posed earlier, namely, "What are the costs, monetized and nonmonetized, associated with achieving or failing to achieve specified standards of quality?" The next use approach described earlier in developing quality standards also has a role to play in identifying, measuring, and assigning costs associated with water quality.

Water pollution, as defined earlier, results in additional costs to the next use(s) in the form of a reduction of quality of water for the next use, if there is a next use. If there is not a next use, there is no need for a quality standard and therefore no costs of pollution control arise, as stated previously.

Application of Water Quality Criteria

To illustrate application of the next use model to developing and costing environmental quality standards, let us take an example from a study in the Nishnabotna River Basin of western Iowa (11). Present use of resources for agriculture production in this basin delivers an estimated 10,600 milligrams of suspended sediment per liter of water annually to the river channel.[4]

Let us first assume that the two previously stated criteria, when applied in this basin, reveal that (1) soil and water resources used by agriculture are kept within reversible limits and (2) no other next use of the water is adversely affected by agricultural use. It would follow, then, that the optimum use of the basin resources for agricultural purposes is also optimum for the area, the state, and the nation insofar as the suspended sediment load of the watercourse is concerned. In other words, there are no external diseconomies generated by agricultural use.

Next, let us introduce additional uses of water in the stream in the form of (1) municipal demands for potable water, (2) warm water fish habitat, and (3) contact recreation (i.e., skiing and swimming), which would tolerate only an estimated 150, 75 and 37.5 mg/l of suspended sediment, respectively.

Through application of parametric linear programming to the quality constraint of suspended sediment per liter, the annual direct costs to agriculture within the basin in meeting the quality standards for the three specified next uses were estimated (in 1970 dollars) at $9.59, $9.66, and $9.74 million, respectively. This would translate into an average annual cost of around $2,400 per farm operating unit in the watershed.

In another study, effects on net farm income caused by direct outlays and reduced income (opportunity costs) from complying with these specific water quality standards ranged from estimates of $1,200 to $14,000 (in 1977 dollars) per farm per year, depending upon factor costs including energy costs, product prices, technologies applied, delivery ratios, and other variables (16).

Since the watercourse also serves as a possible transport agent for residues from pesticides, fertilizers, and feedlots that are found in the basin, the above method could be used to generate quality standards with their associated costs for each type or combinations of types of pollutants found in the water and in or on suspended silt in relation to quality demands for next uses.

Similarly, this method of analysis could be extended to analyze air quality standards within an airshed where silt by itself, or other pollutants for which silt serves as a transport agent, are found. If additional quality standards were established for these other pollutants in air and water other than the suspended silt actually used in the above studies, the pollution control costs to farm operating units would be increased proportionately.

This method demonstrates a procedure for developing quality standards along with the costs of achieving the standards. Furthermore, the analysis helps test water quality standards for next uses as to whether or not pollution control measures are worth the costs. In the process, trade-offs between uses and levels of pollution control could be developed.

Let us now turn our attention to possible answers to the third question stated earlier, namely, "Who pays the costs and who receives the benefits, with and without achievement of standards of environmental quality?" Continuing with our river basin analysis, let us examine who might be expected to pay the costs if the next use were contact recreation carrying the most stringent quality requirement (i.e., 37.5 mg/l sediment), which would cost the watershed's agriculture an estimated $9.74 million annually (in 1970 dollars) and which would average about $2,400 per farm operating unit annually (11).

There are several possible groups on whom these costs might fall, including (1) initial use (farm operating units), (2) next uses (contact recreation, fishing propagation, municipal water supply), (3) consumers of products and/or services produced by initial use and/or next uses, (4) taxpayers, and (5) combinations of groups.

Frequently, the assertion is made that the polluter, in this case the initial use, agriculture, should bear all the costs of farm operations, including any externally imposed costs on other uses. However, if there were no other next uses and if the soil and water resources remained within the reversible range, there would be no costs assignable against the initial use (or any other use) since no water quality standards would be violated. In this instance, the watercourse with its 10,500 mg/l suspended silt load might be performing a beneficial use in diluting, disintegrating, and recycling residues of the initial use.

Also, it is usually assumed that increased costs to a firm resulting from pollution abatement would be passed to consumers in the form of higher prices for the products.' However, for the agricultural entrepreneur, this option is not available since farm firms tend to be price takers, not price makers, operating as .they do in the most nearly perfectly competitive of all real world markets.

Ultimately, however, higher costs of production caused by pollution control measures, unaccompanied by product price increases, would tend to force farmers, presumably marginal farmers, out of farming. Eventually, production would tend to decrease, which would in turn rend to be accompanied by increases in product prices which would indirectly reflect pollution control costs.

If pollution control measures result in reductions in the use of pesticides, fertilizers, and other production-increasing technologies, yields per acre and yields per labor hour would presumably decrease, causing increasing per unit output costs which would most likely be reflected in reduced production followed by increased prices to consumers.

Such consequences of setting and enforcing pollution control measures could be expected to result in reverberations beyond agriculture and the consumer. For example, industries providing technological inputs in the form of fertilizers and pesticides would be affected. Also, agricultural exports from the U.S. could be reduced, with effects on the terms of trade between the U.S. and other nations.

It should be noted that if one state legislated pollution control costs on its producers of a product that was also produced in other states wherein producers were not encumbered with such costs, the state with the legislation would discriminate against its own producers and tend to benefit producers in other states in terms of their net income.

Quality Measurement Problems

Along with externalities, the problem of measurement is crucial in water quality management. Traditionally, water has not been allocated through the market system as have most other factors, products and services. Certainly, water quality is not reflected in market values to an appreciable extent. Judging from the changing size of national, state, municipal, and other governmental budgets, an increasing share of the nation's resources is allocated through institutional rather than through pricing processes. This creates problems in resource management but these problems are not unfamiliar to the resource economist and are not outside the science of economics.

Professor Gaffney has expressed relevant views on this problem as follows:

> Economics, contrary to common usage, begins with the postulate that man is the measure of all things. Direct damage to human health

> and happiness is more directly "economic," therefore, than damage to property, which is simply an intermediate means to health and happiness . . . money is but one of many means to ends, as well as a useful measure of value. . . . "Economic damage" therefore includes damage to human functions and pleasures. The economist tries to weigh these direct effects of people in the same balance with other costs and benefits (5, p. **38).**

There exist four major alternatives for dealing with the measurement problems in water quality management: (1) expand and create market mechanisms for differential water pricing by qualities or grades, (2) develop institutional pricing through synthesized market prices and costs as weights assignable to water grades or qualities, (3) take legal action through legislation and/or executive order with a public welfare basis, and (4) combinations of the three.

Achieving Water Quality Supplies to Satisfy Demand Quality Requirements

According to Irving Fox, "The institutional structure bearing upon water quality preservation and enhancement, although varying somewhat from state to state, may be briefly characterized as follows" (4, p. 32), and I paraphrase his characterizations. First, persons damaged by water pollution may seek redress 'in the courts under common-law procedures. Second, states may enact waste discharge regulations through either effluent standards or stream standards with federal government approval of standards for interstate waterways. (In addition, I would add actions by state departments of environmental quality and the federal Environment Protection Agency and other governmental pollution control agencies, to set and enforce water quality standards.) Third, tax incentives could be provided by state and federal governments to encourage reduction in waste discharges. Fourth, grants and loans from federal and state agencies could aid in construction of waste treatment facilities. Fifth, organized groups representing a wide array of interests may influence formal decision-makers.

A decade ago, Fox concluded from his examination of the institutional structure for water quality management:

> It would appear that a basic deficiency in the institutional structure for water quality management is that it fails to illuminate (a) the technical opportunities for improving quality in the most economical fashion and (b) the alternative arrangements for distributing costs and returns so that a basis for agreeing upon an appropriate pattern will be available for consideration. In addition it seems questionable, at least, that the decision-making machinery operates with dispatch and efficiency; the implementing arrangements, for the most part, are incapable of operating integrated regional plans, and feedback mechanisms are of limited effectiveness (4, p. 34).

More recently, Anderson et al. have attacked regulatory forms of quality determination and enforcement:

> Direct regulation, relying heavily upon centralized standard setting and enforcement, is vulnerable to inefficiency, enforcement difficulties, and unpenalized delay. As Ward Elliott has remarked, "direct regulation is geared to the pace of the slowest and the strength of the weakest." The shortsightedness of current programs suggests beginning a search for programs which emphasize more than end-of-pipe controls, capital-intensive solutions brought about by massive subsidies, and technical standard-setting for a variety of sources of environmental harm by large federal and state bureaucracies (2, p. 9).

Looking to the future, there exist several approaches to managing water quality supplies in satisfying water demand quality requirements. Returning to the reasoning developed earlier in the next use concept, there are five options implicit in the concept as follows:

1. The polluter (first user) assumes full cost of external diseconomies generated, thus motivating the polluter to reduce pollution.
2. The polluter (first user) shifts water use to other sources (or other technologies) from which external diseconomies causing pollution do not arise.
3. The next user assumes costs of the polluter's external diseconomies and proceeds to clean up the water quality to the level required by the next user's use demand.
4. The next user shifts water use to another source that remains unpolluted (or to other technologies) in terms

of the next user's quality demand requirement.

5. The polluter (first user) and the next user(s) join efforts and share costs in improving the water quality to the level required by the next user's demand quality.

Traditionally, the third option has been followed, that is, the next user of water assumes the costs of the polluter's external diseconomies and proceeds to clean up the water to the quality level that satisfies the next user's quality demand. This has meant that the polluter (first user) has used water uneconomically, all users considered, since the polluter did not pay the full cost for water pollution. It has also meant that the next user had to pay an additional cost increment which was probably passed to consumers of the product, depending upon market conditions.

From an economic viewpoint, the first option possesses certain advantages. The first user, the polluter, might bear full cost for use of the water in maintaining a level of quality which meets the needs of the next user. Economists have been giving this option attention for many years. For more than a decade, Kneese and others have been concerned with effluent charges geared to the achievement of water quality goals (9).

Recently, economists have teamed up with lawyers to develop means for environmental quality management relying heavily upon economic incentives. According to Anderson et al.:

> In this strategy, a legislature authorizes a money charge on environmentally harmful conduct; by raising the costs of continuing that conduct,. the charge helps persuade the entity causing the harm to adopt less costly, more environmentally acceptable means of achieving its goals. Charges could be used in this way to combat a great variety of environmental problems **(2,** p. **1).**

These charges provide economic disincentives to pollute. The authors point out that charges in pollution control have long been associated with water quality enhancement proposals and action in European countries and the United States. Applied specifically to water, these charges fall into the following categories: (1) "effluent charges intended to cause sources to reduce their discharges enough so that legislatively set water quality goals would be achieved," (2) "use of charge revenues to finance quality standards or other goals," and (3) "charges in conjunction with effluent standards" (2, p. 1).

Although the charges approach to water quality achievement has been used in Czechoslovakia, the Ruhr Valley in West Germany, East Germany, Hungary and other countries throughout the past decade, the United States remains in the proposal stage. Under two recent proposals, known as Meta System and Bower-Kneese, the Federal Water Pollution Control Act's 1983 standards would be replaced with effluent charges (2, p. 66). The Meta System is designed to, achieve the same level of ambient quality as would the 1983 standards, but using a charge mechanism. The latter system (Bower-Kneese) is intended to establish the principle of polluters paying for their use of public resources and to provide incentives to enhance abatement levels after achievement of the 1977 standards (2, pp. 66–67).

Summary

Increasing degradation of water quality is rapidly becoming our foremost water problem and threatens to succeed energy as a national crisis in the future. Water quality degradation is exacerbated by increasing demands for quality water and by the proliferation of technologies and substances polluting water supplies. Traditionally, water has been used to absorb, dilute, and recycle residuals and wastes of civilizations. Currently, capacity of water to perform these garbage functions is being exceeded.

The quantity theories of water contained in our water rights systems have not focused attention on water quality. However, aggregate supply functions of water are becoming meaningless and superseded by capacity of particular water supplies to meet quality-oriented demands within particular regions.

In managing quality-linked supplies of water, three important questions arise. These pertain to (1) measures of water quality consistent with water quality demands and with other goals of the economy, (2) costs of achieving and failing to achieve specified levels of water quality, and (3) who pays the costs and who gets the benefits of water quality enhancement.

Historically, polluters have been able to shift the cost of pollution to other subsequent users of water. This behavior has resulted in serious deterioration of water quality and misallocation of resources. Current water quality enhancement policies and programs have concentrated on the establishment and enforcement of quality standards. These procedures have brought only limited success.

Current proposals would create economic incentives to improve water quality and economic disincentives to pollute water through a system of charges levied on polluters commensurate with the costs of water quality enhancement. These approaches have been used successfully in several European countries and warrant testing in the United States.

Notes

1. As the senior federal administrator charged with responsibility in the area of resource management, Secretary of the Interior Cecil Andrus expects this water crisis to occur (10, p. 4).

2. Under the riparian doctrine of water rights, the flow of water past the premises of the riparian continues unchanged in quality as well as undiminished or unaugrnented in quantity.

3. Irreversible state of quality refers to the economic and not necessarily to the physical conditions of water.

4. Of course, the annual amount and density of suspended sediment does not represent the amount and density at any particular time. The actual amount at any particular time may be more or·less than the level tolerated by environmental standards. However, in the absence of available data refined to time application, the annual estimate was used throughout the study as a proxy for more refined data. As more refined data become available, they may be substituted for these proxies.

5. This assumption depends upon supply and demand conditions for particular products in terms of price elasticity of product demand.

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