Bulletin 26:

ECONOMICS OF AIR AND WATER POLLUTION

Edited By

William R. Walker

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William R. Walker, Director
Water Resources Research Center

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PREFACE

It is increasingly apparent, even to the casual observer, that the problems associated with air and water cannot be solved by the specialist in one discipline. Neither can we separate various aspects of a problem and solve them independently and hope to put the solutions together and have solved the problem as a whole. It therefore seems important that persons working in these two important areas of the environment have some appreciation and understanding of the factors outside their area of speciality.

In the seminar "Economics of Air and Water Pollution," an initial effort was made to bridge a portion of the gap between the technical and economic areas. Since most of the persons working in the field of air and water are technically oriented it seems appropriate to expand their horizons into the field of economics rather than to aquaint the economist with the more intricate details in the technical field. At the present time there are fewer economists working actively in the environmental field.

This seminar was designed for engineers and administrators whose primary responsibilities were air and water pollution. The course was oriented to economics for the noneconomist. The speakers were very effective in reducing economic theories and "jargon" to manageable proportions. Within the time span of three days the participants were exposed to many of the economic considerations related to their work. With this small beginning it was hoped that the engineers and administrators attending acquired greater insight into the broad economic factors related to air and water pollution.

The interest expressed in the seminar seems to indicate that the ideas and concepts discussed should have greater exposure and not be limited to those attending. The creation of this Bulletin is a small effort to give the seminar content a larger audience.

William R. Walker
Director

PREFACE

It is increasingly apparent, even to the casual observer, that the [illegible] associated with air and water cannot be solved by one group of [illegible] working separately and in [illegible]. [illegible] independently, and [illegible] to put the [illegible] together and to [illegible] them as a whole. It therefore seems important that persons working in one important phase of the environment have some appreciation and understanding of the factors outside their area of specialty.

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William H. Walker
Director

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David Allee [1]

Water Resources Research Center, Cornell University

With a smile on my face, let me start with a slight caricature of these three professionals. The engineer knows what the problems are (i.e., things that can be taken care of with his technology). He designs the solution to that problem, and tells what amount of cash must be found and for what it will be spent. The economist justifies the solution which the engineer has produced with a flurry of irrelevant statistics on employment. If it is a water project he will have to mumble something about a benefit-cost ratio but won't say much about who gets the benefits and nothing about who pays the costs. And the administrator is the one who hired the other two to do his job for him.

We would be halfway to an understanding of the necessary interdisciplinary nature of these professions in air and water pollution control if you think of these as functions which indeed could be, and sometimes are, embodied in one man. What should we mean by these terms? Consider the following roles.

Engineering should insure the technical validity of a manageable range of solutions that are significantly different in terms of nonmeasurable social values as well as measurable values. Economics should assist in the identification of the differences between solutions, especially in terms of measurable effects, and shows how the non-measurable effects relate to the decision. There should be an indication of the incidence of these effects at least in terms of the organized and potential interest groups that are or could be involved. Administration involves the identification of problems and the task of drawing out of the technology and evaluation methodology the meaningful choices. Administration also has to interpret the social and political significance of the measurable <u>and</u> non-measurable values to these choices. It also attempts to manage the process by which consenus within the organization being administered and outside of it can be reached. Finally, the administrator takes the "heat" from inside and outside the organization for the degree of professional prostitution of the other roles that were necessary to achieve the consenus.

These functions are potentially conflicting--the one causing more work and loss of prestige and influence for the others. Or they can be so mutually supportive that they completely submerge under, all under one. My instincts tell me that the best is when there is a kind of dynamic tension between these roles.

But I'm not sure that this is very meaningful unless we take a closer look at just what the challenges are in environmental control. What are key decisions in this field going to be like and where will these roles fit in? And you may keep in mind that if I were to retitle this paper, I think I might add Ecologist to the other roles. But perhaps that will really have more significance in the future than it seems to command today.

The challenge we face is summed up in how we will answer this question: When is it worth it to make a businessman, or a homeowner, or a community do some things they wouldn't do otherwise? The essence of environmental control is that it represents a series of situations where even enlightened self-interest and personal responsibility to the welfare of society may not be enough incentive for optimum individual action and performance. The problem is one of judging when it pays to trade higher costs and lower profits, public funds and energy for environmental gains--the gains from cleaner air, cleaner water, pleasanter landscapes, and the several other aspects of environment. But these questions become real only when we <u>not only</u> ask <u>how</u> shall we answer them <u>but who</u> will answer them. <u>How</u> cannot be separated from <u>who</u> except as an academic abstraction.

Over the next decade we will face these challenges in the task of balancing two great equilibrium systems. Since 1776 we have become accustomed to thinking of the market for goods and services--the private economy--as an equilibrium system. The dynamics of change express themselves through supply and demand with prices bringing about an equilibrium so that there tends to be a balance between what is value by consumers and what is supplied by producers. With adequate competition, or at least the threat of it, on the supply side and adequate, effective consumer choice (i.e., income and knowledge) on the demand side, we have some confidence that the results of the market provide a kind of an optimum. These are certainly conditions that are well met in some sectors, the food business for example, and less well in other sectors of our economy. But doubt undermines this faith in the market not only when there is inadequate competition or inadequate choice. Doubt creeps in if all costs of production are not borne by the producing firm or if all benefits are not borne by the purchasing consumer. Faith in the market can't go very far beyond the incentives that prices provide. Pollution is a cost of producing some products that are not fully borne by the firm that discharges the wastes. An apple orchard in bloom produces visual amenities that are not paid for by the consumer of the apples. The market cannot express the incentives required to limit pollution or reward the improvement of the view.

The other great equilibrium system which I suggest we will have to consider more and more is less familiar to most of us. Ecologists may have been studying eco-systems almost as long as economists have studied markets but it is perhaps only in recent years that very many people have looked to this equilibrium system as a source of insights into the problems that face society. The energy of the sun is used by many different primary producers of living material. These plants, whether on land or in water, are the basic units in a complex web of life. Man fits into this web, drawing his subsistence from it, managing it and being affected by it. This is a large part of man's environment at issue here.

Men have asked–at least as long as recorded history: Does our whole environment provide the full measure of quality of life of which it is capable? We have asked this of our religions and of our governments. We have questioned for many decades the quality of social justice. The black revolution is a current manifestation of this questioning. And surely these are also questions of environment. But our task here is a bit circumscribed. We are concerned with questioning the quality of life in two related ways; <u>first</u>, the physical qualities of our living environment and <u>second</u> the relation of man to his natural environment. These include the way we build our cities, the future of agriculture in urbanizing areas of the nation, the provision of open spaces and natural beauty, recreation areas, wildlife management as well as the questions of how clean should which bodies of air and water be? Tomorrow we shall discuss the second.

In all of this questioning the problem of social controls on the various parts of our society keeps coming in. When is it worth it to cause someone to do something that he would not do otherwise? How to decide this and who will decide it? The significance of the eco-system is that better understanding of how it works–the study of ecology–is going to undergird many if not most of the controls that will be proposed to manage the balance between our market system on the one hand and the natural system on the other hand. It will pay us to learn a new language here. The parallels to economics are striking. Where in the market we have firms competing, in an eco-system we have species competing. Where price is the device that produces a balance, energy and nutrients do the job. Your wastes are some algae's supper. The market for a product is much like a habitat for an animal. This room is part of the habitat for man; and if we look around, we may find a few other organisms of interest. Where competition and consumer choice suggest an optimum is likely, we look to comparing diversity with simplicity, stability with instability. Just as we can have an equilibrium in the market that provides acceptable or unacceptable levels of employment, so also we can have eco-systems whose mix of species and characteristics are more or less acceptable.

The values of the market are familiar. Production and employment, and stability in both, are accepted as "good." But are these always good when in getting them we harm natural systems that provide us with other values? Can we get rationality into public decisions about such questions? Can we put "harm" and "good" into human terms? I think we can and I'm sure that we are trying and will even more in the future.

This is complex enough when there is a direct use involved. A scale of uses that are reflected in water quality standards is commonly drinking, swimming, fishing, boating, and looking--going from the most restrictive for pollution to the least. Fishing can usually be further sub-divided into several levels of species mix that require different levels of oxygen availability, temperature, nutrient levels and related habitat qualities. But as a few sanitary engineers have learned to their sorrow from the outraged conservationists, our ways of looking at uses, at water quality standards and doing something about them, are not well grounded on our understanding of aquatic eco-systems. The even broader significance of this to public decision making is that direct uses do not include all of the values that society places upon natural eco-systems.

Indirect use values are the sleeper in the system. It's difficult enough that drinking, swimming, fishing, boating and looking are values which are only reflected in market prices to a trivial degree; they are largely unmarketed benefits of our environment--benefits like the view of the apple orchard in bloom. But in addition they are indirectly valued by people who want the option of using the environment whether in the future for themselves or simply for everyone. This is a very real source of demand for environmental quality. Some people are willing to sacrifice income to have quality there. And it goes deeper than simply holding open the option for such uses as swimming and fishing. There are those--more all the time as our knowledge of ecology spreads--who value natural systems maintained at a high level of quality for their own sake, usually expressed by a diversity species and incidently including the more prestigious sport fishery and wildlife species. I need only remind those familiar with the history of the forest preserves in New York to illustrate the potential demand for these kinds of indirect values.

Obviously, we have to grapple with the values that people hold. They exercise these values when they participate in decisions at either the private or public level. Values about these two equilibrium systems are very much involved in the challenge presented by the environment. We can't ignore the extremes involved, but we can't live by them either. "This stream (i.e., every stream) should be returned to its natural state." "Any real and conceivable cost for pollution control is worth it if it avoids even the risk of upsetting the balance of nature." "People have to understand that without farmers and the food industry, we couldn't eat (and some couldn't work)." "Free enterprise is what made us great and any controls on the businessman will destroy it and us."

Some clearly find these, and many similar value laden statements, true or at least useful enough to be used. Others point out that if you see things so clearly you just don't understand the problem. I'd suggest that these statements represent values that by the nature of things can't all be met completely and one to the exclusion of the other. The challenge is to manage the two systems so that we get the most from both the economy and the natural environment. This requires an implicit if not explicit common denominator between values. And it means searching out the places where one inhibits the full development of the other and weighing carefully the exchange of values involved. This is a management challenge of the first order. It strains our scientific understanding, our technology and particularly our political processes and administrative resources.

Why be so concerned with values? It is because when the problem is to get people (firms, agencies, communities, etc.) to do things that they wouldn't do if left to themselves much of the argument seems to be in terms of values. Can we settle these problems in terms of rights and obligations? An economist might suggest it is a complex and subtle problem of the incidence of benefits and costs--and the task is one of finding some mix that leaves the whole society better off.

Who pays the costs, bears the burdens and how? Who gains the benefits? Who cares? If the benefits and costs are received by the same decision maker the incentives to act are probably acceptable. But if they are borne by different people conflict is likely. Upstream it is "the discharge of effluent into the receiving waters." Downstream it is "their crap is going into my water!"

But is the set of actions for which we can most easily get agreement likely to include the ones that are best for society on grounds other than getting agreement? The point is that the distribution of power--the ability to influence decisions--will on occasion be distributed in a way that is not consistent with an optimal pattern of benefits and costs, except under unusual conditions or with what I find unacceptable definitions. I can't accept the role of the passive public servant who simply bends with every change in the political winds, nor do I expect, can you? The analyst's and technologist's roles have a special obligation here, to point out the system, when they can, that certain courses of action are more in the public interest than others. It is to help accomplish this that many of the analytical techniques for the application of economics to public decisions have been developed. They are certainly imperfect. They are certainly subject to gross misuse. They have some unpardonable biases-not the least of which are market based values-some economists defend with too much arrogance. But isn't this usually true of the tools of the critic-yet who will suggest we do without critics?

When is it worth doing something about pollution? The engineer can identify some technical alternatives, the economist can help estimate some of the values and show where others fit into the problem. But the basic decisions and the evaluations of many of the key values have to be left to an administrative or political determination. Expecting the technicians and the analysts to do this is consistent with a trend toward technocracy.

Whether at local, state or federal levels, regardless of who participates in the process, professional, administrator or politician, making these decisions is going to be difficult. It is aimimg at a moving target of the most elusive kind. People's values are shifting all the time. For example, the trend is now for conservationists to form in local groups to take a direct interest in protecting some set of features of their local environment. Conservationists in the past seem to have been more concerned with distant problems and inclined to ignore their own backyards. Technology is shifting--making old options obsolete and producing new sources of concern. But these aren't the only things that keep the target hazy.

To take liberties with an economic principle--how do you evaluate what something is worth to someone when he knows that it won't be denied to him if he doesn't pay his share? And most environmental quality situations have this aspect to them. That apple orchard in bloom may be worth a lot to the view but can you imagine the farmer taking up a collection to help pay for it. The corollary is that I need more of a lot of things if I can get you to pay for them. Such things make the picture hazy but don't change the fact that real values are there in that picture and responsible men must try to see them.

And in general we, as a group, probably overly discount values that are conjectural, in the future, dispersed over a lot of people instead of concentrated and thus very important to a few, or non-marketable. This provides a constant source of second guessing or back pressure in the system. Conjectural events have a way of sometimes coming true. The future has a way of becoming today. Always giving way to the very concerned few may lead to changes in the rules that may over-penalize them. Ignoring non-marketable values undermine confidence in the market system. Thus, again responsible action to control the environment probably requires urging the whole system to give more attention to the risk of conjectured consequences of present action or inaction, to take more interest in the future, to give more weight to the unorganized and silent interest and to the non-market values.

Enough on the problems of "when" and the difficulties of deciding "when." How to decide and who will decide are just as pertinent. I think that most of these kinds of interpersonal problems are solved by some social processes that might come under the term neighborliness. And the limits on neighborliness as a social control device provide an important part of the challenge in deciding what to do. Most of us want to be "good" neighbors, and we are quite willing to define this to some degree in the terms of our neighbors. It is pleasant to be able to conform to their expectations. But the neighborhood is limited to the effectiveness of face-to-face communication. Reflect on what you might expect to be the difference in the way a locally owned and managed plant might relate to the community as opposed to a nationally owned plant. The community may be much more tolerant of neighbor Jones' problems in cleaning up his wastes and it would seem that Jones, once he realized that the neighbors cared, would be more responsive to their interests. The national firm may evoke less sympathy and its response will be far less likely to be conditioned by face-to-face neighborly social pressure.

A local industrial waste committee is one of a number of pollution control devices which we have studied. In a case study of such a group, we noted that they used a formalization of this "neighborliness" approach coupled with another idea--the ethic of "doing the job right." In this case the committee could varify for the polluter that the community was concerned in the damage that his particular wastes were doing; and since it had access to the best industrial technology involved, it could define what "doing the job right" meant in that particular industry. Most of the firms were locally owned and locally financed. Some of those hurt by the pollution were other businesses in the community. And the local financial institutions were represented on the committee. From our vantage point it looked like this committee had been quite successful in controlling those pollution problems which were local in nature, but there was little evidence, if it turned out that the losers from the pollution were not local, that this group could do very much about it. Also, not everyone, particularly some of those who feel they are still being hurt, agree with our judgment. But in this case study area we concluded that using only local resources they couldn't do significantly better.

Local police power controls have been suggested in the study area. Some combination of land use zoning, conditional permits, discharge standards, environmental quality standards, monitoring and inspection, enforcement officers, formal penalties, and the like, could, in theory, take care of the problem. But we concluded that this locality–a rural county in this case–simply did not have the administrative and political resources to insure that such formal approach would in fact produce better results than the informal approach already in use.

Arbitrary "yes" and "no" controls are easy to administer. In between implies two kinds of needs, at least; (1) technical competence and (2) political support that is so broadly based that the parties at conflict are a relatively small part of the political structure. Performance standards, odor emission levels, chemical concentrations, visual esthetic standards, permits that contain conditional operation and process requirements imply that to be effective someone has to know what he is doing on a technical level. Politically to steer a middle path between "anything goes" and "nothing goes" you have to be strong enough to have both sides of any particular fight mad at you. This seems easier at higher and higher levels of government.

In our case study we were dealing with agricultural industries as the polluters. As long as the rural or old established portion of the community and the agricultural interests were in control we saw no likelihood of controls being adopted and continued use of the "neighborliness" approach. If the opposing interests, that for simplicity we might call urban, got into positions of influence, the possibility of controls that simply said "No" seem to be the only possibility unless administrative resources were increased greatly, and in this case the only realistic source for such an increase in resources that we could see as likely was from the state.

I would be very concerned if the points I've made so far suggested that we should give up on local government in environmental control. I don't see how we could if we wanted to–like Mount Everest, it's there. And it has potentials that must be exploited but we need to be realistic about what it can accomplish. We have done some looking at irrigation as an industrial waste disposal technique. One question was how many waste producing plants had enough land near enough to them to be used as a "living filter."

We found that in New York, at least, that a great many do, and perhaps most do in terms of volume of nutrients and oxygen demand. But how do we get the wastes from the plants to the land on which it might be spread? For the individual plants this would be a much more difficult task than for a public district. It could acquire rights of way and the disposal area through condemnation. It could more easily finance it and so on. But I think we need to be realistic about what local governments can achieve.

In any case, the point I have been trying to get out is that the administrator's position is not neatly defined. The constraints on him are substantial and must be recognized if we are going to be realistic about how he relates to the use of technology and systematic ways of simplifying choices in social value terms.

The reality is that any system of government of which I am aware involves specialization by agency in terms of problems and approaches. There is fragmentation and substantial antimony on the part of these agencies but also real limits on their scope for choice. New technology tends to be only a small shift from the old since large changes usually will not be supported. Action approaches seek goals, not that approaches are chosen to meet goals. In the typical agency the engineering, economics and administrative functions are sharply circumscribed. The challenge is to (1) help these agencies break out of these constraints and (2) give the comprehensive planning agencies the capacity to approach the ideal of broadly specified design evaluation and choice.

To conclude I would like to quote from a recent paper by Dr. Keith Cannan (of the National Academy of Sciences) where he suggests how decision-making in government does or should proceed:[2]

> *"In the mysterious ways of a democratic society, the public comes to recognize an environmental situation that it is not content to tolerate and decides that something should be done. The technical experts are called in to decide what things*

can be done. An appropriate executive authority must then decide which of the things that can be done offers the prospect of the greatest benefit at the least cost or risk. Finally, the politician faces the decision as to which of the things that are technically and executively feasible are the most expedient in the prevailing climate of public opinion."

Technical experts in this case would include both the functions of the engineer and the economist, indeed of a variety of other disciplines that can contribute to the identification of what things can be done and evaluation of their differing effects including the comparison of benefits and costs. And these alternatives are apt to be very wide and large in number. In fact, technologists typically offer a narrow range of choice if any at all. In this they are taking over part of the role of the administrator or politician, preempting the policy making role. With this the expert must accept the risks of being a decision maker. He must ask if he is indeed willing to take that responsibility. Society must continuously ask if it is willing to give him responsibility. Recognize that (1) evaluating more alternatives is more expensive, (2) that reducing the alternatives considered is a comfortable dodge to facing up to the social valuation problems, (3) that reducing the range of alternatives also avoids the inherent evaluation of risk and uncertainty, and (4) that public decisions makers may feel forced to shift the burden of choice on to others. But doesn't it seem well worth striving for broader, more effective choice making?

FOOTNOTES

1. Associate Professor of Resource Economics, Department of Agricultural Economics, State University of New York College of Agriculture; and Associate Director of the Cornell University Water Resources and Marine Sciences Center.

2. Quoted by Walter Lynn in "Technology and Public Decision Making" in Proceedings of the Water Resources Planning Conference, May 16-17, 1968, sponsored by the New England Council of Water Center Directors, Boston, Massachusetts – from whom some of the following arguments have been taken.

EXTERNALITIES AND THE QUALITY OF AIR AND WATER

Otto A. Davis and Morton I. Kamien
Department of Economics, Carnegie-Mellon University

Awareness of deterioration in the quality of our air and water is now commonplace. We all know from newspaper accounts and television newscasts about the conditions of Lake Erie and the Potomac River, to mention only a few among many bodies of low quality water. Likewise, knowledge that smog conditions prevail in Los Angeles and New York City, as well as in most other major urban centers, is widespread. Along with this awareness have come demands for new laws prohibiting the discharge of contaminants into the air and the waters, and for stricter enforcement of existing laws. As individual's we seem to be paying relatively more attention to the air and water dimensions of the quality of the environment than we did before in selecting a place to live and work.

For effective management of air and water quality insight into the various facets of the problem should prove useful. Explanation of the physical dimensions of the picture--the sources of air and water pollution, the chemical and biological reactions that take place in water and in the atmosphere when contaminants are discharged, the effects of pollution on health, on agriculture and industry - is the domain of the engineer, the bio-chemist, and the physican. To the lawyer and political scientist falls the task of explaining the relevant laws. From the economist we expect an apprasial of the cost-benefit facet of air and water quality management. Our aim in this paper is to explain the costs and benefits associated with any desired level of air and water quality in the context of modern economic concepts. It should be understood that it is not our intention to sight dollar figures allegedly reflecting the damage caused by air or water pollution in this or that area or for the nation as a whole. While such figures undoubtedly do lend perspective to the magnitude of the problem they are not terribly useful for explaining the existence of the problem. We shall instead, be speaking of real or opportunity costs and the divergence between real costs to society and real costs to individual economic entities.

To achieve our objective it is necessary to present some rudimentary notions regarding the competitive market system as a vehicle for the allocation of resources. Every economic system, be it of the free enterprise variety such as ours or of the mixed government directed and free-enterprise type found in Great Britian and the Scandinavian countries, or of the completely government controlled variety as in the Soviet Union, is confronted with the question of how to "best" allocate resources-raw materials, land, and labor. Because resources are ordinarily available only in limited amounts their diversion into the production of a certain class of goods and/or services results in a diminution in the production of other goods and/or services. This basic insight leads immediately to the concept of opportunity or real cost. The real cost of producing a given item is the sacrifice of another good or service that might have been produced with the resources employed. The reason for emphasizing the term real cost is to draw attention to the fact that the nominal or money cost of an item does not always reflect the opportunity cost of the item. So, for instance, if nominal prices of all factors of production including intermediate goods were doubled and consequently prices of all final goods and services were doubled, the nominal cost of any item would double but the real cost remain the same.

Knowledge that allocation of resources to the production of automobiles precludes the use of the same resources to produce, say, washing machines does not in itself reveal how the resources should be used. The determination of the quantities of automobiles and washing machines to be produced can be accomplished by the assignment of relative values to the two items and the maximization of the total value of their production. Notice that maximization of the total value of the two items means that the total value of the relevant resources is maximized and that resources withdrawn from the production of automobiles must be used to produce the largest number of washing machines possible. Unless the last condition is met the total value of the two items means that the total value of the relevant resources is maximized and that resources withdrawn from the production of automobiles must be used to produce the largest number of washing machines were not being produced with the resources released from automobile production it would be possible to increase the total value of the output. To put it another way, production must be efficient-the sacrifice of other goods and services entailed in the production must be as small as possible under existing technology. Needless to say, these remarks apply as well to the case of many commodities.

There are many alternative ways of assigning relative values to all the potentially producible commodities. At one end of the spectrum of possibilities is the assignment of values by a committee or even a single individual on behalf of all the members of the society. At the other end of this spectrum is the assignment by each individual or family group relative values to all commodities and the aggregation of these valuations via some mechanism. Our present form of economic organization is closer to the latter end of the spectrum than the former. We believe in consumer sovereignty–the right for each individual to place his own valuations on all commodities–and we might add in producer sovereignty–the right for each producer to produce whatever he wishes. There are of course various laws and regulations that circumscribe these rights, yet by and large, the individual in his capacity either as a consumer or a producer has considerable freedom of choice. Tacitly, we suppose in adhering to consumer sovereignty that individuals act in their own best interest and that they have the necessary information and mental capacity of doing so. Even if these assumptions are somewhat heroic, we are even more reluctant to accept the proposition that any single individual or committee is better able to determine what is in the best interest of other people.

Our assertion that each individual is capable of placing his own valuation on each and every good poses difficulties when it comes to aggregating the valuations of many individuals. The essential difficulty arises because even if individuals express their valuations of the various commodities in terms of numbers the scales they use may be different. Consequently it is meaningless to add the numbers together. For example, it makes no sense to add centimeters and inches directly to determine the length of some object. However, with the use of transformation 1 inch equals 2.54 centimeters the two units of length can be made conformable for addition. Unfortunately we have no way of transforming one individual's valuation of the commodity. The upshot of all this is that we cannot determine what commodities should be produced and thereby how the available resources should be allocated by maximizing the simple sum of individual valuations. Because of this economists have substituted another criterion for the determination of how resources should be allocated. This criterion is called Pareto Optimality and asserts that an allocation of resources is optimal if no reallocation could make some members of society better off without making others worse off. Thus, if the constellation of commodities produced is such that any change designed to increase the well being of one individual must be detrimental to the well being of another individual, then the original constellation of goods and the underlying allocation of resources is Pareto Optimal. On the other hand, if it is possible by reallocating resources to make some individual better off without effecting the well being of others than the original allocation of resources is not Pareto Optimal.

It should be noticed that the Pareto Optimality criterion allows for many alternative allocation of resources, or what is the same thing, commodity production configurations. For it is possible that departure from a commodity constellation consisting of many colored television sets and few bath tubs will make some people better off only at the expense of others being made worse off. Likewise, a constellation of commodities in which the proportion of colored televisions and bath tubs is reversed may also be Pareto

Optimal. The upshot of all this is that Pareto Optimality is an efficiency criterion which in itself does not tell us which commodities should be produced. It does tell us however, that any resource allocation that does not meet this criterion can be improved upon. In other words, Pareto Optimality requires that there be no waste in the utilization of resources and the distribution of commodities among individuals.

The question as to what should be produced and in what quantities most modern economists have concluded cannot be answered within the confines of economics as a science. Ultimately that question can only be resolved by value judgments as transmitted through political processes. The reason for this has already been touched on before, namely our inability to summarize in any coherent manner the valuations of many individuals. Recognition of this point should be regarded less in the spirit of a shortcoming in modern economics but rather as casting suspicion on those who blithely pretended to know what is "best " for the country and that their views have a scientific basis.

Though we are not able to answer the question regarding how much of each commodity should be produced, which in the context of air and water quality management means that we are unable to say what the "right" quality standards are, we shall be able to say something about the best way of attaining any prespecified level of water and atmospheric quality levels via the Pareto Optimality criterion.

The device we use for allocating resources that is compatible with consumer sovereignty is the market mechanism. We allow individuals to express their relative valuations among different commodities by purchasing those they desire more and declining to buy those they like less . We rely on producers movitation for high profits for the production of those goods presently most preferred by the public and a change in the mixture of commodities produced as consumer's tastes or incomes change. It is evident that the real market place does not always operate so smoothly. If a firm is isolated from competitive pressures it tends to become less responsive to consumer needs. Also, firms attempt to alter consumer taste via advertising. In short, in reality the market place has many shortcomings. The government tries via anti-trust legislation, truth in advertising bills, and the dissemination of information to mention only a few methods, to counteract these faults. The important point to note in connection with some of these maladies is that they are shortcomings of the market place in practice but not in principle. We shall not be concerned with them here, though they may be responsible for a substantial misallocation of resources. Instead, our major concern will be with failures of the market place which may be thought of as being more fundamental.

Under ideal conditions a competitive market structure would result in a Pareto Optimal allocation of resources. This statement may be regarded as the fundamental theorem of modern welfare economics. The proof of this assertion requires some subtle mathematical reasoning far beyond the scope of this discussion We can, however, sketch briefly on the intuitive level the reasons underlying this theorem. According to the definition of a perfectly competitive economy the production decisions of any single firm cannot affect the market price of the item in which it is dealing nor the prices of the factors of production it is employing. Likewise the purchasing decisions of any single consumer cannot affect the prices of the products being bought nor can the individual as a supplier of factor services effect the prices of these services. We also suppose that each individual selects the types and quantities of commodities to purchase in accordance with an attempt to maximize satisfaction or utility and that each firm choose the type and quantity of output to produce and the composition of productive factors required so as to maximize profits. Thus, when an equilibrium allocation of resources has been achieved in a competitive system – an equilibrium allocation being one from which there is no tendency for further change – and consequently a corresponding equilibrium mix of commodities, each individual will have been maximizing utility and each firm profits, any change in the commodity mix that benefits one individual will have to hurt another. For if this were not so, then the new mix of commodities would be more profitable than the old and firms seeking to maximize profits would find it worthwhile to move to this commodity mix. But this movement away from the original commodity mix would contradict the motion that it was an equilibrium mix as posited. Ergo, every competitive equilibrium allocation of resources (there may bemore than one) is Pareto Optimal.

To arrive at the conclusion that perfect competition will lead to a Pareto Optimal allocation of resources several qualifications are tacitly imposed. Specifically, absence of decreasing cost industries, - a situation wherein the cheapest way of supplying the market for a certain product is to have one firm produce the entire output - of public goods, - a commodity with the property that is consumption by one individual does not diminish the amount available for consumption by any other individual, e.g., radio waves or television signals – and finally, technological or nonpecuniary externalities is required. Presence of any one of these features in the economy can cause a perfectly competitive system to allocate resources in a non-Pareto Optimal way, unless they are compensated for in some way. Unfortunately all three requirements are violated in the real world, often simultaneously. The rest of our discussion will focus on the meaning of the last requirement and how its violation may lead to a departure from Pareto Optimality.

While the literature distinguishes many kinds of externalities, it is necessary for the purposes of this essay to identify only two types. These are technological (or non-pecuniary) and pecuniary externalities.

Let us first deal with the concept of the pecuniary externality. When deciding whether or not to purchase an item an individual will ordinarily take into account his own desire for the item, its price, and his budgetary situation. It will be rare indeed, and generally only in the case of a monoposony, that the individual might even consider that his decision to purchase can contribute to and maybe even increase the demand for that product and thereby cause its price to rise. Of course, in most instances the individual's purchase of a commodity is such a small fraction of the total amount sold that his decision has a negligible impact on price, although the totality of decisions is certainly of importance. Whenever an individual decision does have an effect upon price, it is important to note that not only does he, but also all other purchasers, have to pay the resulting increase or decrease. This change in price, caused by individual decisions, is termed a pecuniary externality. If the individual decision causes the price to rise, which is the usual case associated with an increase in demand, then the phenomenon is a pecuniary external diseconomy to other consumers. Whenever the decision caused the price to fall, which might be illustrated by a decision to join a group travel arrangement which is not yet at capacity, then the phenomenon is termed a pecuniary external economy to other consumers. Of course, by symmetry, a pecuniary external diseconomy to consumers is a pecuniary external economy to sellers, while a pecuniary external economy to consumers is a diseconomy to sellers.

The important point to note here, however, is that pecuniary externalities, be they economies or diseconomies, pose no problem for the market economy. ~~Indeed~~ WHERE, they are the central ingredient ~~of the market place~~. Changing demands cause prices to rise and fall, generally according to whether demand increases or decreases, and the resulting alterations on prices are the essential feature of a market place which rations the available goods and services to those whose willingness to pay indicated that they need them most.

Technological externalities are quite another matter. These refer to more or less direct effects, which are not priced, which one decision unit might impose on another. Technological externalities can, and in many instances do, prevent the marketing mechanism from functioning in such a manner as to lead the economic system to a position of Pareto Optimality. In such instances, of course, there exists the theoretical possibility that action can be taken to improve the society in the sense that one or more citizens can be made better off without anyone being made worse off. Some examples may serve to illustrate what is at issue here.

Since both of the authors reside in Pittsburgh, it may be appropriate to begin with the example of the manufacture of steel. For the purpose of exposition, imagine that there is no smoke control ordinance. Then, according to the process which is employed, more or less smoke may be discharge into the atmosphere as a by-product of steel production. Insofar as the manufacturer is interested in profits, and most are, there is motivation to choose that method of production which is most profitable without regard for the associated level of the discharge of smoke. The point is that the manufacturer can be thought of as envisioning the opportunity to dispose of smoke as another resource which contributes to the production of steel. The justification of viewing disposal as another resource is that a reduction in the discharge of smoke could only be achieved by either adopting an alternative and more expensive method of production which emits less smoke or by using the same process but with the addition of smoke control devices. Either alternative involves the use of additional resources such as labor and capital. While these additional resources are not free, there is no charge for the emission of smoke into the atmosphere so that there is little if any motivation to attempt to limit the usage of the resource which might be called smoke disposal.

Although the discharge of smoke into the atmosphere might be viewed as a free resource by the firm, it is certainly not without consequence to those residing within adjoining communities. Not only does smoke contribute to the more rapid deterioration of the exteriors of buildings and certain kinds of equipment – which will certainly mean that compensatory resources will have to be spent in more intensive cleaning, maintenance and repair – but it certainly contributes to smog which probably has a direct~~, though not yet fully documented,~~ effect upon the health of at least some of the residents of the community. In other words, to the community at large the discharge of smoke into the atmosphere is not a free resource. Instead, smoke disposal is costly. This situation, where the firm does not bear the full costs of its actions, is an instance where private costs diverge from social costs. The essential point to notice about the situation as it has been outlined here, however, is that without some kind of action the steel producer has nothing more than possible humanitarian concerns, which conflict with his interests in profits, to make him take into account the fact that the discharge of smoke imposes costs upon his neighbors. The discharge of smoke is a technological externality. Without some kind of adjustment the system will not be at a Pareto Optimum so that there exists the theoretical possibility that at least one person may be made better off without making anyone else worse off.

Of course, smoke is not the only cause of smog. One of the most often mentioned contributors today is the automobile. In order to understand fully the nature of the relevant motivations, imagine the situation prior to the establishment of the regulation which requires that smog control devices be installed upon all new cars. It is obvious that if consumers demand and are willing to pay for smog control devices, the automobile industry would develop and sell these devices in much the same way that it develops and sells special conveniences and optional equipment. The competition among the various manufacturers, foreign and domestic, compels the producers to try to give the public what it wants. Would the public demand smog control devices? The answer can be found by examining the consumer's motivation.

Imagine for the sake of argument that the auto industry had developed an effective smog control device which it offered as optional equipment for all new cars. A person who was considering whether or not to order this option for his new car might reason as follows: Suppose I purchase the smog control devices for my new car. If I purchase and everyone else also purchases, then we will have less smog in the city. On the other hand, my individual car can add only a negligible amount to the smog problem so that if everyone else purchases a device and I do not do so, then the smog will be diminished by almost exactly the same amount and I will have saved the cost of the device. Hence, if everyone else purchases a device, I will be better off if I do not get one installed on my car. Now presume that no one, with the possible exception of myself, purchases a device. Obviously, there will be a smog problem. However, if I purchase a device the problem will not be noticeably different since my individual car contributes only negligibly to the situation and I will be out of the money which I paid for the smog control device. Hence, if no one else purchases, I should not purchase either. Obviously, the analysis is the same if some of the other people purchase and some do not. Conclusion: I will be better off, no matter what other people do, if I do not purchase a smog control device.

Since all potential new car buyers will reason roughly as the representative individual above, the result is that there will be a zero demand for smog control devices. Hence, in the absence of some kind of regulation or collective decision, the automobile manufacturers will have no motivation to develop and market smog control devices. This conclusion holds even if, and it is an if, everyone would be better off if all cars were equipped with smog control devices. The point is that for each prospective purchaser of a device, the benefits from his purchase are widely dispersed while the costs accrue to him. Thus the technological externality associated with the exhaust of a car can prevent the unregulated market from leading the system to Pareto optimum.

For the final example of this section, consider the problem of the pollution of Lake Erie. Biologists tell us that Lake Erie is dying and that it has "aged" 15,000 years in the past half century. The problem is complex. It was long believed that the major source of the pollution stemmed from the fact that raw sewage and industrial wastes are dumped into the lake. A major source of the raw sewage is antiquated systems, some of which are combined sanitary and storm sewers so that the overflow runs into the lake during periods of rain. For the moment, and for the purpose of discussion, imagine that the entire problem of pollution is caused by the raw sewage so that treatment, which could remove the organic material which otherwise is broken down in the lake by a biological process which consumes its oxygen, could solve the problem. The now familiar dilemma would act to frustrate a pure market solution. Each municipality or sewage district would reap but little of the benefits of its own efforts at treating the sewage, but it would bear the full costs of that treatment. Hence, similar to the above case of a customer considering the purchase of a smog control device, each would come to the rational decision to continue to allow the raw sewage to flow into the lake even though all might be better off if all installed modern systems with treating devices. Thus the technological externality reflected in reverse in the failure to receive the full benefit of one's expenditure for treatment – the fact that the decision making entity does not bear the full costs of its decision to forego treatment and allow a flow of raw sewage – results in a failure of a pure market solution where no financial incentive to come to the opposite decision is offered from a higher level of government.

In actuality the pollution of Lake Erie is much more complex phenomenon than is indicated by the above discussion. Even after treatment to remove indigestible solids and to break down organic material so that the sewage is discharged as mostly inorganic products, the residual inorganic matter contains large amounts of nitrate and phosphate which, instead of being swept harmlessly to the sea, tend to remain in the lake long enough to fertilize monstrous growths of algae which use up to an estimated 18 times as much oxygen as the present flow of organic matter from inadequate sewage plants. Thus the standard treatment of sewage, which is aimed at the organic matter, is not likely to solve the problem even if such treatment were accomplished. One might suggest that one of the "essential" nutrients such as the phosphate should be removed from the waste so that the algae would not grow, and this suggestion brings us to the economics of the situation. Some two thirds of the phosphorus in municipal waste, which is roughly three quarters of the total wastes, stems from detergents. Even if the housewife or commercial laundry knew that the detergent used for the wash contributed importantly to the pollution of the lake, which they probably do not know, would there by any incentive to economize on the use of detergents or demand a kind which contained less phosphorus? Again the familiar dilemma appears. Even if they knew of their contribution to pollution, each could rationalize that their own contribution was negligible, that the benefits to be derived from an individual decision to try to perform the wash in such a manner as to contribute less phosphorus to the sewage was too small to be measured, that the costs of this kind of action was not negligible, so that the rational decision would be to ignore the entire situation. Thus the manufacturers of detergents would have no incentive to try to develop products which contain less phosphorus, the municipal sewage systems would have no more incentive than the previous instance to attempt to remove the material, and the result is that the pure market solution would be to continue the pollution of the lake. Thus the existence of this technological externality – the fact that those causing the pollution do not bear the full costs of their actions – can cause the market mechanism to lead the system to a situation which is not Pareto optimal.

In conclusion it is important to emphasize that nonpecuniary externalities alone do not lead to a failure in the market mechanism. It is the absence of markets wherein information regarding the consequences of technological externalities can be transmitted that creates the difficulty. Remedies for this situation consist, in one way or another, of means for communicating the relevant information.

PUBLIC V. PRIVATE GOODS

Charles Goetz

Department of Economics, Virginia Polytechnic Institute

As is well known, the principle concern of the economist is to study the means by which scarce resources may be allocated to the best possible uses. A simple way of specifying the allocative efficiency criterion is merely to say that scarce resources, such as air and water, should be devoted to only the most valuable of their alternative uses. Under many circumstances, including some but not all externality situations, the normal profit-making incentives of individual trade will serve to ensure that the supplies of air and water will ultimately find their way into their most valuable uses. Unfortunately, under other circumstances which are increasingly encountered in modern society, a peculiar form of interdependency arises such that the normal market methods of determining air and water usage are short-circuited. It is for the reason that I wish to discuss briefly with you today the concept of a "public good" as the economist narrowly defines it. As you will see, the "publicness" of a good does not, as the economist sees it, have any necessary connection with the government sector or what is normally regarded as the needs or desires of society in general. Rather, public goods will be explained as goods which embody an interdependency aspect which leads to a serious form of economic decision-making dilemma among individuals.

Ordinarily, economic decision makers will be willing to register bids for the right to use resources which they consider valuable. If such a bidding process occurs, the individual, group, or firm which has the most valuable use for air or water rights will in fact, ultimately wind up using these rights. We can see this from a simple example. Suppose that there is an industrial installation upstream in a river and a fishery operation downstream. We may further assume that the industrial use contemplated is a chemical process which discharges pollutants into the river such that the downstream area will become unsuitable for the fishery. Our example thus contains not only two competitive uses for the water involved, but also what would usually be considered an externality relationship between the chemical complex and the downstream fisheries.

What values will the chemical and fishery industry, respectively, place on the use of the water? The answer to this question, of course, lies in how much profit each of the businesses would forego if they do not get to use the river's water in their production process. Let us suppose that the profits of the chemical plant will be $200 less if it does not get to pollute the water, whereas the profits of the fishery will be $100 less if it does not get to use unpolluted water. This result strongly implies that the addition to output realizable from polluting the water is more valuable to consumers than the addition to output that would be forthcoming if the water is not polluted.

In this present case, the necessity of a market-type process to allocate the water rights depends strictly upon the initial legal definition of the property rights to the use of the water. In the situation where the use of the water is unregulated, the rule that "possession is nine points of the law" will hold and the chemical complex in essence owns the water, since it is the use into whose hands the water first comes. The river will then be polluted by the chemical complex and an externality will be imposed upon the downstream fishery. Note, however, that this is an optimal use of the water resource and an economist has no grounds with quarreling with the pollution; polluting the water with chemicals just happens to be the economically most efficient use of the water.

If, as is now increasingly more common, the property right to clean water is vested in the downstream use by a statute which forbids an upstream user from emitting pollutants without the permission of the downstream user, a trade process will be necessary before allocation becomes optimal; the chemical plant must now buy the right to pollute the water from the fishery. The chemical plant, rather than do without the water, should be willing to pay any price less than $200. For any price above $100, the fishery owners will increase their profits over what they would have made by using clean water for fishing by accepting the offer of the chemical plant to pay compensation for the pollutants emitted. A basis for mutually profitable trade thus exists and we would expect to find the rights to the water usage to be transferred by the fishery owners to the chemical plant owners in return for compensation of somewhat between $100 and $200 dollars.

Whichever way the property rights regarding water pollution are defined in the original legal regulations, therefore, trade will bring about an economically satisfactory solution. It should be apparent that the analysis will be quite analogous if we reverse the numbers, placing a value of $100 on the chemical use and $200 in the fishery use. In this latter case, regardless of the original property rights, individual profit motives will ensure that the water is maintained in a clean state so that it can be used as an input in the fishery industry. The first case is merely slightly more interesting because it illustrates the rarely understood fact that the continuance of a negative externality, in this case water pollution, is perfectly consistent with economic efficiency; economists would, under the first set of circumstances, have no sympathy for what would doubtless still be the bitter complaints of the fishing industry.

In the cases just described, complicated questions of value judgments, legal rights, or even cost-benefit analysis do not become pertinent. The desirability of pollution was decided by a relatively straightforward market test of the values created or destroyed by pollution. Obviously, there is something unrealistic about this analysis, since in the real world we know that pollution problems are not rectified in the matter described. The reason is that my previous remarks contained an extremely strong implicit assumption: that the chemical complex and fishery in question are the only two competing uses on the river in question. In relaxing this assumption, we introduce the concept of a "public good" and see how the allocative efficiency incentives tend to disappear because of a new interdependency which arises.

Let us slightly modify our last case so that there is but a single chemical complex which places a value of $100 on the use of the river's water, but, instead of one fishery which values tne water at $200, there are now two fisheries each of whom values the water at $200. On one hand, this change has actually doubled the value of the water in its unpolluted form as would be used by the fisheries. From the economic standpoint, it therefore becomes twice as desirable as before that the water remain in its unpolluted state. On the other hand, it is now seriously to be doubted whether the necessary bribes or compensatory payments will be paid to the chemical complex in order to induce it not to pollute the river waters. This reason is that the water is likely to satisfy the two conditions by which the economist finds a so-called public good.

One of these conditions is that of jointness, by which we mean the ability of one physical unit of the good to provide services to more than one user. Jointness, although it is a somewhat unusual characteristic of goods, does not by itself cause serious difficulties. But the use of river water is not only joint but also non-excludable. Non-excludability denotes a defect in the property rights attached to a good. There is no incentive to pay for the right to use a good unless, in the absence of such payment, one will be excluded from the right to use the good in question. However, it is frequently impossible to exclude users from the benefits derivable from certain goods. This is true in our case of the freely flowing river. It is impossible for the one fishery to buy the right to clean water from the chemical complex without simultaneously making the cleaner water available to the second fishery also. It scarcely needs to be said that this non-excludability characteristic is one that water frequently shares with air, so that my comments about water pollution are almost directly applicable to air pollution.

Non-excludability creates what is called the "free rider problem." Each fishery owner will now recognize the possibility of refraining from making monetary bids to the chemical complex for the water rights, and yet still being able to "free-ride" on the clean water rights which may be bought by the other fishery. Under these circumstances, rational bargaining behavior dictates that each fishery owner pretend disinterest in making any payments for the resource rights to the water in its unpolluted state. The "let George do it" syndrome occurs. If the two-fishery case is not sufficiently convincing, imagine the case wherein we have not two but 100 fisheries as the downstream users. The incentive to attempt to free-ride will then be extremely strong and the possibility of cooperative action by the fisheries will become very low. The water will remain polluted, despite the fact that its use for fishing purposes is overwhelmingly the more valuable economic use.

Note that this dilemma depends strictly upon the lack of excludability and not on the fact that there is more than one interested party or potential buyer. Indeed, if the fishery that paid to remove the pollution could also exclude other fisheries from using the clean fishing water, then it would be possible, by charging a toll up to $100 per user, to make a large profit by being the <u>first</u> to bid for the rights to the clean water. Due to the non-excludability, the optimal position remains that of the free rider rather than that of an entrepreneur who makes a money bid in order to switch the use of the resource from the chemical complex to that of fishing.

We have already seen how the public good aspect of resources such as water (and air) will impede an interdependent group of users from registering a bid for the use of the resource in question. A slightly different interdependency problem arises on the selling side of the market. In order to see this, let us now modify our last example so that there are not one but two chemical complexes on the river, each placing a value of $50 on the use of the water upstream. Although this modification leaves unchanged the total social values of the two respective competing uses, the probability of efficient resource transfer usage has now been rendered even more improbably than before. The two upstream chemical complexes exercise a form of joint, non-excludable ownership in the sense that either factory can continue to pollute the water even if its opposite number wishes to cede this right in return for a profitable compensation from the downstream users. This creates a severe bargaining difficulty which we may call the "hold out problem." The maximum that either of the upstream factories may hope to gain from the sale of the pollution rights to the downstream users is equal to the sum of the values to the downstream users minus the amount (in this case $50) necessary to compensate the other chemical factory for the foregone usage of the water. Neither factory will, of course, cease polluting the water for less than the amount of cost saving it receives from continuing to pollute the water. But the range between this minimum figure and the maximum possible gain referred to before may be quite considerable. Because each factory owner has what amounts to a veto over any transfer, it will be rational for each factory owner to take an extremely hard bargaining stance, wherein he attempts to extract the maximum possible amount of the gains from the resource trade, not only from the downstream users, but also from his "co-ownership" of the upstream pollution right.

We have now painted a very much dimmer picture of the prospects of efficient resource allocation, one which is more in accord with real-world experience. The principle difficulty is that resources such as air and water tend to satisfy the definition of a "public good" as the economist uses that term in its strict technical sense. Note, however, that our examples of a struggle over the use of public goods involve the strictly private interests of chemicals versus fisheries. This usage is deliberate. The layman may object that his interest is in public goods in the wider sense of those goods which benefit "society" as a whole. On this point, the economist is forced to counter-argue that an attempt is being made to prejudice the argument by the use of the emotionally charged, arbitrary terminology. However our previous examples also involved social interest in the sense that they counterpose the interest of chemical users against drinkers of water, beneficiaries of clean air, or enjoyers of environmental aesthetics. Attempts to allocate air and water use by giving priority to so-called social goods over private goods are based upon a completely illusionary dichotomy, since all uses of air and water are private in the sense that they benefit individuals and most uses of air and water are social goods in the sense that they benefit groups of individuals, whether larger or smaller.

The public goods problem shows why the market processes will fail in the application of normal value tests to air and water pollution. The principle alternative is an attempt to impose efficient allocation through government action or regulation. From the standpoint of the economist, the ideal goal of such government action is clear: It should be to simulate the result that would have emerged from a market in air and water pollution externalities if the public good interdependency problem did not exist (the first example we discussed). Other speakers in the program will address themselves to the difficulties of the cost-benefit analysis involved in such a simulation. Nonetheless, at this juncture I would also like to take note of a public goods versus private goods problem in cost-benefit calculation.

In dealing with chemicals and fish products, we have been discussing the use of water as a public input good used in production processes which ultimately yield goods or final products which are sold in a normal market. However, air and water may also be used as inputs in processes which yield as their outputs final products which are themselves public goods. For instance, it may be impractical to employ exclusion procedures which would make it possible to levy charges on the users of water for recreational purposes such as swimming or fishing. Exclusion is even more difficult when benefits are principally aesthetic in nature. Public goods outputs from the use of air and water complicate matters because we have no very reliable yardstick as to the value of such outputs. If the use of air or water will produce more fish or chemicals, we can estimate the value of such uses by multiplying the increase in production times the market price of the product involved. There are, as you will doubtless hear later, certain technical reservations about such a procedure, but the analysis does possess considerably more information than in the case of public goods outputs such as recreation and aesthetics.

Because these latter public goods outputs are not priced in a market, we know only that they are valuable but not how valuable. This immeasurability of the benefits from air and water usage for public goods contributes to possible biases in either direction. On the one hand, it may be more difficult to "sell" such uses of air and water when it is impossible to base a benefit estimate on concrete, tangible facts such as market prices. On the other hand, proponents of such uses often tend to place very large values on the benefits involved and such large value estimates cannot be subjected to a reliable test for such exaggeration.

Finally, a closing comment on air and water as public goods in the layman sense in goods controlled or regulated by the government. As all men of practical sense are aware, a market concept of economic efficiency in the sense expounded above is most decidedly not the principal motivational force of the political process. Politicians and bureaucrats do not make their decisions on the basis of cost-benefit analyses conducted on the principles that economists would ideally advise. Politics has been defined as the "authoritative allocation of resources," but it has been less than 15 years since scholars first began to study the allocative process within the public sector in the same fashion that they have explored the market aspects of externalities. Although it is not my place to speak at length on this subject today, let me at least note that the political process or political decision-making has been found to have its own allocative biases affecting air and water control. Many of these public sector biases are traceable to more complicated forms of what we have already seen in the market as externality and public goods interdependency problems. I close, therefore, by thoroughly endorsing the view that the market works very poorly in determining the economically efficient quantities of air and water pollution. But, although government intervention frequently improves matters, I leave you with the thought that an economic efficiency analysis of the public sector would also suggest occasional cases when government intervention is the worst, and not the best, of two evils.

MARKET FAILURE – WHY EXTERNALITIES ARE NOT ACCOUNTED FOR IN THE MARKET

A. Allan Schmid[1]

U.S. Department of the Army (Civil Works)

Man affects his environment; the environment also affects man. We are beginning to realize that the quality of man's life has as much to do with good views, clean air, and a wilderness retreat as with convenience floods, rapid communication, and interior decoration; but is there any reason to believe people want a different mix of these products than they now receive? Do current economic institutions reflect how people want to use their resources? Do people know what effects their environment has on them, for instance, the effect of flood additives, offensive views, inhuman and cold spatial arrangements, or few contracts with nature?

Economist John Kenneth Galbraith made his answer to these questions poetically clear.

> *"The family which takes its mauve and cerise, air-conditioned, power-steered, and power-braked automobile out for a tour passes through cities that are badly paved, made hideous by litter, blighted buildings, billboards, and posts for wires that should long since have been put underground. They pass on into a country-side that has been rendered largely invisible by commercial art. (The goods which the latter advertises have an absolute priority in our value system. Such aesthetic considerations as a view of the countryside accordingly come second. On such matters we are consistent.) They picnic on exquisitely packaged food from a portable icebox by a polluted stream and go on to spend the night at a park which is a menace to public health and morals. Just before dozing off on an air mattress, beneath a nylon tent, amid the stench of decaying refuse they may reflect vaguely on the curious unevenness of their blessings. Is this, indeed, the American genius?"*

Is Galbraith a snob with unusual tastes, or is it conceivable that many others share this view but have not been able to communicate their demands? There could be a communications failure between producer and consumer if either can create a benefit or cost for which he cannot collect or be charged. If an upstream chemical company puts in waste treatment facilities, the downstream fisherman and others will benefit. If the chemical company cannot collect for the benefit it has created, it will ignore the effect when making future investment decisions. If the fishermen and other stream users can't communicate their desire to retain the benefit created, a frustration of real economic demand and a malallocation of resources results.

In many cases when a situation such as this arises, the upstream company lets the downstream user know that certain benefits are available at a price; or, conversely, the downstream user offers to reimburse the upstream company for certain benefits. In this way the consumer reveals his preference and willingness to pay to the producer.

A Product Analysis

Certain types of products, however, are such that buyers tend not to reveal their preferences. These are products, which if they exist for one buyer's consumption, they exist for all. One person's consumption of the product does not affect the quantity available for others' comsumption. Economists call these products "public goods." The classic example is national defense. If a missile system protects you from foreign attack, others can benefit without having to pay. Consequently, people refrain from revealing their preferences and willingness to pay, hoping someone else will make the necessary expenditure. Obviously, all potential beneficiaries must act as a group or not at all. (Unless through social pressure charitable contributions can be encouraged, but this has proven insufficient in many cases). This is the reason people may not be getting the mix of products they want. They may be spending more on certain goods they do not want while waiting to obtain free public goods.

The distinguishing characteristic of public goods is that one person's consumption does not detract from the quantity available to others. In many cases it may not be possible to control access to such goods so as to exclude people who will not pay. This is not always true, however. The number of television sets tuned to a given signal does not increase the cost of producing the signal. One person's consumption does not detract from others. Yet it is now possible with electronic scramblers to produce signals which only those who pay can receive.

Conversely, there are products which are such that it is costly to exclude people who do not pay for each use but which are not public goods. Use of hunting grounds is an example. A landowner may find it very costly to charge each hunter who uses his land. This might be the case even if additional hunters increase costs and one hunter affects the amount of game and the characteristics of the hunting experience for another hunter. This situation may cause the landowner to treat his product as a public good and make no additional charge for each use, though it adds to his total costs. The error in undercharging frequent users as opposed to infrequent users may be less than the cost of policing for fencing and gate keeping.

Many features of our natural environment have public goods' aspects that raise questions as to the efficiency of our usual market institutions to reflect consumer demand. Unfortunately, one of the responses to this has been general apathy. If the avenues of decision making are not available, people lose interest. Products of our environment are lost by default. Many citizen groups recognize that they would prefer a different environment and set of products from the economy, yet they feel powerless to do anything about it.

Group Action

A better environment can be produced, if people really want it. Certain changes in our decision making institutions are required, however. Let's look at some of the ways decisions regarding use of public goods can be made. All involve group decisions through the political process: (1) Public subsidy in part or whole to private producers; (2) tax benefits or penalties; (3) prohibitions by criminal law or requirements, such as licensing or subdivision controls; (4) change in the types and distribution of property rights held by individuals or groups which affect claims for damages in the courts; (5) public enterprise with or without the use fees; and (6) social pressure and appeals to charity.

Now that we have developed a rationale for group action with reference to public goods and listed several alternative types of action, let's examine a particular case.

One type of air pollution is visual pollution. There has been a fairly widespread clamour against the use of billboards on roadsides. Certainly the quality of a trip is affected by the view from the car window. The constructor of the sign creates an effect on individuals for which he is required to make no compensation. This effect is external to his decision making. Present property law requires only that the builder obtain the permission of the landowner where the sign is to be located. The problem exists in the fact that a sign or a good view has public goods' aspects. If a good view exists, all motorists benefit whether they help pay for it or not. If one landowner sells the right to build a sign, he detracts from the ability of all other landowners to sell their rights to those who might be willing to pay not to have signs.

If the property right with reference to constructing signs rests with the landowner, it ultimately rests in the hands of the first owner in an area who decides to sell space to a sign maker, since he affects all other landowners. Furthermore, an individual motorist is not motivated to indicate his willingness to purchase the right not to see signs. If anyone pays to accomplish this, all will benefit whether they pay or not. Motorists must act as a group because this is a public good, but how?

Assume that the property right lies in the hands of the landowners. If the motorists want a view without billboards, they must purchase an easement. They will have to act as a group through elected public officials; and whatever decision making rule prevails (majority or otherwise), all will pay a tax. A question arises, however, as to the incidence of the tax. In this case a gas tax would make payment somewhat related to use and thus exclude the individual who never uses the roads.

Now, remove the assumption that motorists must buy out the landowners. Assume the landowner must purchase the motorist's property right to an unimpeded view. Again motorists must act as a group. One cannot sell without affecting the rights of others.

Where should the property right lie initially--in the hands of motorists or landowners? One view on this question appeals to some prior natural state and advocates that the natural state be maintained and rights distributed accordingly. Since there were no billboards in the days of the Indians, the property right belongs with motorists. The sign builder must buy them out. (A similar argument is often made in the case of water use). But, this view denies man the freedom to determine his environment and relegates him to always adjusting to it. No natural state is sufficient to establish the current property right. This choice belongs to the people.

Does it really make any difference where the initial property right lies? Would not the transactions of the market eventually put the resource in the hands of those who derive the greatest value from it? If the property right is given to motorists, they must consider the sign builder's bid an opportunity cost. If the bid exceeds their own utility, they will sell the property right. The property right or resource would also be retained by the sign builder if he was the original owner, since his utility would be higher than what motorists would bid. There are two instances where the location of initial ownership makes a difference.

The first is a situation in which initial resource ownership comprises a large enough share of the owner's total income so that his choice of products is influenced. A poor man having access to clean air might not be willing to give up that access or right for less than $1,000. Yet, if he did not have the right, he would not be willing to pay anything for it because his income is low. In this case, initial distribution of the property right will greatly affect the eventual use of the resource even if there is a market.

The second instance in which initial distribution makes a difference is where the cost of collecting the payment offsets any superiority in willingness to pay that one group has over another. For example, group "A" is willing to pay more for a resource than individual "B". However, group "A" has the costs of reaching a group decision and collecting a payment. These costs may be great enough so that when subtracted from the amount group "A" is willing to pay, the group would be outbid by individual "B".

There are no easy answers to either of these situations. Both involve the question of income distribution. Both are a source of conflict in our society, but they must be faced and compromised in the political process.

To summarize this case, it appears that at present construction of billboards and chemicals is too cheap. The opportunity cost of using the resource in other ways is not considered by builders. Public response to this situation has been to bribe states to pass prohibitions against billboards and to set water and air pollution standards. To pass a prohibition is to put the property right in the hands of the motorists and other viewers through an agency of state government. A prohibition may imply that use of the resource for an unimpeded view has infinite value. No matter how much sign builders or waste disposers might be willing to pay to build on a certain stretch of road or stream, their bid will be ignored. When a prohibition is enacted, public owners are denied the ability to utilize the resource in the most valued fashion. For example, the limited sale of sign rights or waste disposal rights might produce revenue which could be better used for other public good which is not a natural resource good like libraries. In this case, the charge for use of the publicly owner resource is a cost, not a tax or penalty.

A Market Analysis

If consumers want more natural environmental products which are public goods, they must be willing to act as a group and bid for resources. A change in property rights distribution may even be necessary in some cases. In addition, current public expenditures must be examined. Perhaps certain expenditures cannot be justified on the basis that they are public goods. In what sense are camp sites provided at less than cost by the government justified as public goods? Would not private firms offering this product in the market be adequate to reflect peoples' demand? Is camping a good for which people are reluctant to express their willingness to pay? The total cost of providing for each occupant of a camp ground is significantly related to the number of spaces available. For a given camp ground, more and more occupants cannot be added without affecting its value and cost of development and maintenance. All the benefits of camping may not be captured by the camper himself, however. Perhaps he is a better man at work when he returns and his employer and fellow employees indirectly benefit. But, is this transmittal of benefits likely to justify public payment?

One often reads or hears that camp sites provided by states must be greatly increased to cope with long waiting lines at present sites. A long line can be expected for any free or below cost product the government might choose to distribute. The existence of a long line itself does not indicate that people would pay for this product as individuals or as a group. Camping is used here only for illustration to pose the question: Are we using public money for things which have few public goods' aspects while other items go begging? Are we spending too much public money to subsidize vacation or weekend reaction and too little on products which affect the quality of life of much of our population in every day life? Do we have a rural and extensive natural resource development bias?

Public enterprise can be justified in certain instances even thougn attaching zero fees to the product involved cannot. Camp grounds may be one such public enterprise. A private developer may encounter problems in obtaining necessary land at reasonable prices. Certain landowners retain their holdings in hopes of extracting high prices for key tracts. A case can also be made in certain instances for the long term insurance features of public ownership that will not succumb to short term changes in demand for a resource, which when developed for other uses cannot be reasonably returned to more natural uses. These and other facts may argue for public enterprise and ownership, but provision of a free good though tax money need not necessarily follow. In the case of urban renewal, the public uses its power to assemble; and while there is considerable subsidy involved, the operation is put back in private hands.

There may also be strong public goods' aspects which require public money and no extra user charge. This does not necessarily mean, however, that the operation must be a public enterprise. A private firm could be paid by the public for its service.

Public debate over policies for natural environmental features tends to split into two polar positions. One extreme considers private, market goods and services as the only valid economic activity. The second extreme considers various natural resource products in a field by themselves with infinite value that can be compared to no other set of commodities. Both views are questionable. A good life requires a number of products, the demand for which cannot be expressed in market bargaining. While this demand must be expressed through the political process, it does not mean that costs and benefits should not be weighed. There are few things a society can afford to put in a class by themselves and regard as having infinite value. Obviously, there is a point where one stops and compares the cost of further improvement with the value of other lines of investment also contributing to a good life and its preservation. Market and nonmarket decisions must at some point be related. This is accomplished by group decisions with regard to property rights and rules of the market as well as directly in government spending and directives.

FOOTNOTES

1. On leave, Departments of Agricultural Economics and Resource Development, Michigan State University.

EFFLUENT CHARGES

Clifford Russell

Resources For the Future, Inc., Washington, D. C.

The literature written by and for economists in water quality problems is full of favorable material about effluent charges.[1,2] On the other hand, the history of actual efforts to curb water pollution suggests that practical men have more often turned to stream or effluent standards and assimilative capacity allocations in choosing their policies. The popularity of effluent charge schemes among economists is not difficult to explain; they represent an extension of the very useful notion of market prices into an area in which the absence of normal, functioning markets is the major problem. As such, charge schemes allow, in principle, the attainment of the goal of "effluent resource allocation" which economists are persuaded is a worthwhile one. The relative unpopularity of this approach among politicians and administrators is not, of course, evidence of their perversity or fondness for "inefficiency," but rather reflects primarily the considerable practical difficulties in the way of implementing a system of efficient changes for industrial and municipal waste discharges to watercourses. The purpose of this paper is to attempt to set out the case for effluent charges and to indicate several of the difficulties attending their actual use. At the same time, we shall try to point out the extent to which these difficulties seem to be amenable to solution by advances in economic analysis, engineering and technology, and changes in public attitudes.

The Theoretical Role of Market Prices

As indicated above, the economist's enthusiasm for effluent charges is based on his enthusiasm for markets and market prices in general.[3] Under certain assumptions about the behavior of firms and individuals, the attention which ought to be given to the judgment and desires of individuals, and the existing technical and institutional possibilities, market prices become the key links in a vast and complex system of trials and errors tending to produce an economy which is efficient in the two following (equivalent) ways: (1) for given use of resources (coal, farm land, labor services, etc.) we are getting the greatest possible amount of output/enjoyment, and (2) for a given level of output/enjoyment, we are using the smallest possible amount of resources. Prices are the signals which tell firms to produce more of one thing and less of another; that assist the consumer in making decisions about how much of what to consume; that spur people to get out of farming and into computer programming and so forth. If the many caveats, with which this branch of economics abounds, are not violated, the efficient state of the world will come about when prices indicate the technical (or phychological) costs of producing (or consuming) an additional small amount of each good or service in terms of the other goods and services produced. Thus, "at the margin" as economists are want to say, if we must give up (for technical reasons) a small amount of x, say Δx to make Δy of y, the value of the amount given up, $P_x(\Delta x)$, must equal the value of the amount obtained, $P_y \Delta y)$ (where P_x and P_y are the market prices of x and y respectively). For every consumer, it must be true that the ratio of his psychological valuation of a small change in his consumption of x to that of his psychological valuation of a small change in his consumption of y must equal the ratio of the price of x to the price of y. These conditions may be restated in various ways and extended to show what must be true for the relation of production inputs to production outputs, etc. For our purposes, however, it is sufficient to notice that the dumping of wastes into a water body is, in general, a case of what the economist calls a "technological externality" -that is, a condition in which producers of wastes are linked to producers and consumers of goods by technological relations which are not reflected in any markets and hence for which there are no market prices to aid in socially beneficial decision-making "at the margin."

The idea of effluent charges is, then, to create a market-like situation in which the relevant decisions of firms and consumers will reflect the costs they impose on each other by dumping waters into streams or other bodies of water. (It should be noted that we can equally well discuss this in terms of the benefits they would confer on each other by ceasing to dump wastes into streams). If we think of the reduction of waste output as a good, we want to have a basis for making efficient decisions at the margin about producing an additional unit of this good, i.e., removing another pound of BOD from the waste stream. As we have seen above, to make such decisions we need to know the value of the goods given up and of the goods chosen for production. (Another way of looking at this question is to note that by cutting back on waste discharges, we are reducing employment of the factor of production we may call "waste assimilative services of the environment.") When we institute an effluent charge we provide producers with a signal relevant to their production decisions about the good "waste removal." On the other hand, prices are signals to consumers, and we want effluent charges to reflect consumer preferences among the various possible goods even though there is no market in which BOD removal by upstream waste disposers is bought and sold. It is the job of the appropriate "authority" to set up an effluent charge (or payment) scheme in which the unit value of the water discharge equals the benefits which would accrue to those affected by the removal of an additional unit of waste by the polluter at the equilibrium which would exist in a free market.[4] These benefits could include, for example, improved recreation opportunities, lower water treatment costs and a more pleasing visual environment. Thus, we are saying in a sense that though for various reasons individual consumers cannot or will not react to market prices for pollution control, if they did react, and could buy these services from firms, their desires and the technological possibilities of the firm would be such as to bring about the chosen price at the equilibrium in the effluent removal market.

It is necessary to suggest a general qualification to this explanation of the desirability of effluent charges based on their efficiency features, that is, on their ability to reproduce the desirable results which we normally associate with markets. This qualification is that society's ranking of a particular outcome of the unimpeded market process will depend on the distribution of income on which the outcome is based. Thus, for example, the particular mix of goods produced in a given economy over some period will reflect the distribution of purchasing power over people of different tastes. This distribution will, in turn, be the result of historical processes, of current conscious efforts to change the distribution (such as the Federal Income Tax and Social Security payments), and of other current programs which, willy nilly, also alter the distribution of income (as defense expenditures tend to distribute income toward the owners of and workers in armaments industries). How highly we evaluate the mix of goods clearly depends on our view of the "fairness" of the underlying income distribution. Of particular relevance for environmental quality management programs is the possibility that the benefits of improved water quality, for example, are enjoyed largely by those whose family background, education and present income levels prepare them to take advantage of new recreation activities. Thus, it is probably largely members of the middle and upper middle class who enjoy the benefits from upgrading the fish population of a particular stretch of river from carp to trout or bass, for these are the men who have been brought up to admire the "sport fish," who have learned to enjoy fishing with artificial lures and who can easily afford the fly rods and waders necessary to reap the new benefits. Those to whom a fish is a fish and a dough ball as much fun as anything may receive no fishing benefits from the higher stream quality, but they do help to pay the costs through higher prices for goods in general.

A really optimum social state, then, includes a judgment that the interpersonal distribution of income is such that we can not improve the welfare of any man, as weighted by his "deservingness," without lowering the weighted welfare of one or a group of others at least as much. This is in addition to the efficiency conditions. Since we are always faced with either accepting the actual distribution of income or specifying ways of changing it (without harming the efficiency conditions in the process), our prescriptions for increased efficiency through effluent charge schemes must be seen as reflecting our judgments about the existing distribution of income.

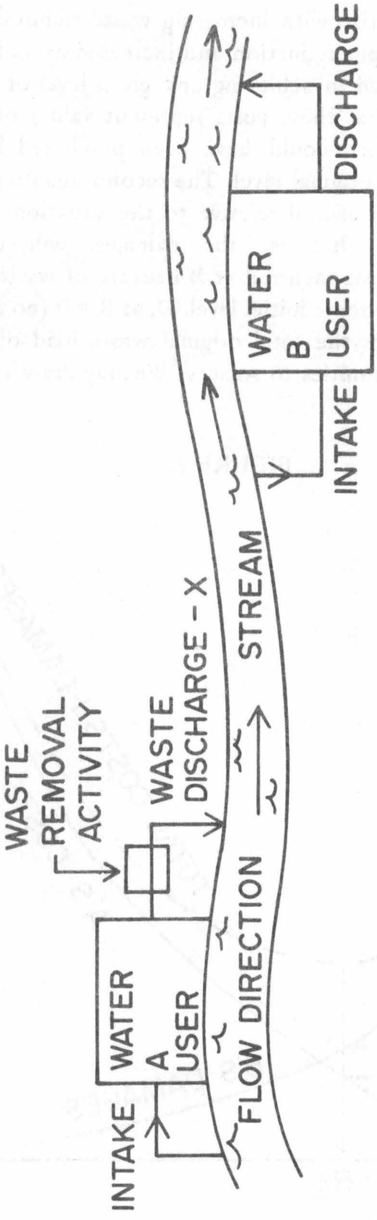
Effluent Charges in a Simple, Illustrative Case

To illustrate the rather abstract discussion above, let us consider a very simple example of the possible application of effluent charges. Let us assume we are dealing with a stream on which are located two (and only two) water-using activities, A and B. Both also discharge wastes into the stream, but since A is upstream of B, only A's wastes are of concern.[5] For simplicity, let us also assume that a single waste material is involved, and hence that a single quality parameter is a complete enough description of effluent and stream quality. Call this effluent x and let the units be pounds per day generated.

In this very simple case, even in the absence of intervention by a governmental unit, action by the two parties is liable to produce a (relatively) efficient solution. This may come about either because of a suit for damages or an offer to pay for abatement on the part of B. The actual solution will depend on the existing law and on the relative profitability to each party of the solutions considered.[6] Thus, for example, if the law of the relevant jurisdiction defines reasonable upstream use to exclude any quality degradation noticeable by the downstream user, B will be able to force A to reduce his discharges or makes some compensating payment. If, on the other hand, A represents an activity specifically exempted by statute from the damages caused by its wastes, an attainable solution will almost certainly be one in which B bears the costs, either through a payment to A to reduce his discharge, or through increased expenditure on intake treatment, extra recreation facilities, or whatever.

In a more complex situation, however, legal or bargaining solutions are unlikely to be achieved. Assuming intervention by some level of government is necessary in the simple case, what would be the nature of an effluent charge solution? The keys to this will be two functions related to the pounds of X removed from A's waste (call this removal R). In our example, we will ignore for now variability in streamflow and assimilative capacity and assume that A's waste removal is related in an unvarying way to the waste load at V's intake. Given sufficient knowledge of the situations of A and B, the market

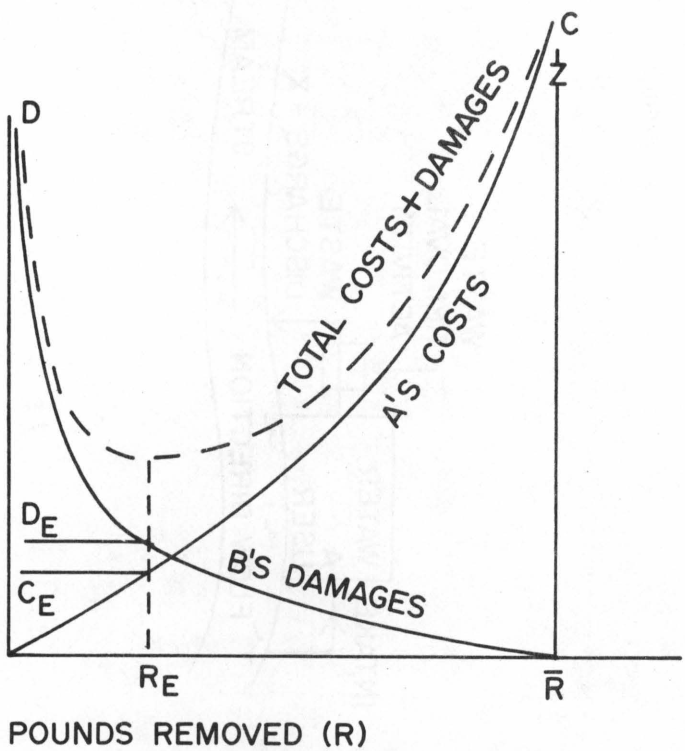
Figure 1



INTAKE
WATER
A
USER
WASTE
REMOVAL
ACTIVITY
WASTE
DISCHARGE
FLOW DIRECTION
WASTE DISCHARGE – X
STREAM
INTAKE
WATER
B
USER
DISCHARGE

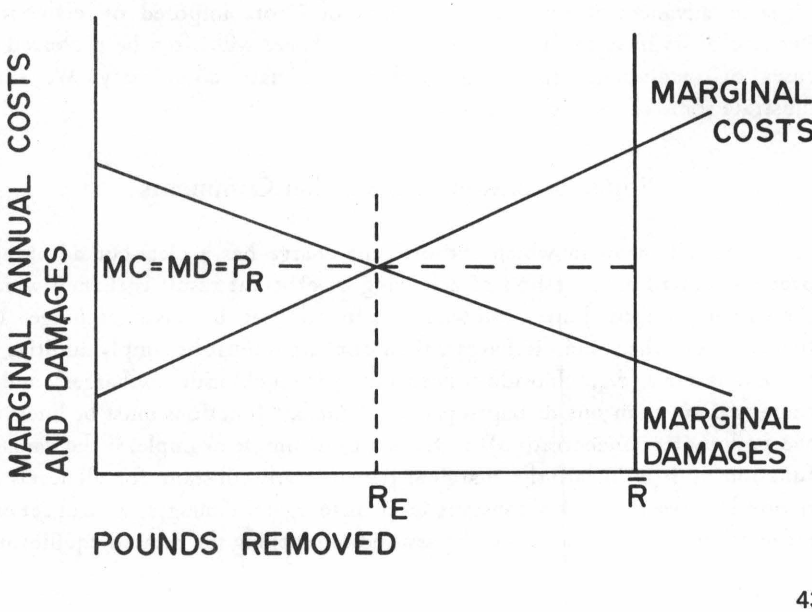
and technological conditions confronting them, and so forth, we may define two curves related to the degree of waste removal: total costs incurred by activity A and total damages incurred by activity B as functions of R. A's costs will generally rise with increasing waste removal and will reflect the combinations of output reduction and increased uses of other inputs, such as labor and capital used in achieving any given level of waste reduction. The important thing is that these costs represent values of goods other than R (waste removal) which could have been purchased by leaving the waste discharge of A at its original level. The second quantity related to R will be the damages at B measured relative to the situation in which no waste is discharged by A. That is, the damages will represent the lower production/higher costs incurred at B because of waste discharge at A; they will fall with R from some initial level, D, at R = 0 (no removal), approaching zero as R approaches the total original waste load of A. These, too, then represent lost opportunities to society. We may draw a graph of the situation as in Figure 2.

FIGURE 2



In figure 2, $\bar{R}$ represents total removal of all wastes from A's effluent; D is the level of damages suffered at B when there is no removal by A; C is the level of cost required to achieve complete removal. (This might be very large indeed). In the absence of intervention, we have assumed that no removal would be undertaken and, hence, D dollars per year of damages would be suffered by society. Total removal would cost society C dollars per year. As our curves are drawn, however, there is some degree of removal R_E which will cost C_E and leave residual damages D_E where the sum $C_E + D_E$ will be a minimum.[7] That is, considering the curve labelled "total," the sum of costs and damages, we find it has a minimum at R_E. At this point , resource allocation is most efficient. As we should suspect from the earlier discussion, the condition for this efficiency to be reached is that the damages we avoid by removing a very small additional amount ΔR in addition to R_E are just balanced by the increased costs we incur (and vice versa for a small decrease). Were we at a level of removal greater than R_E we could save more in costs at A than we incurred in damages at B by cutting back a small amount on removal. (The economist says that at the equilibrium marginal damages equal marginal costs--with proper allowance for sign). We may graph the marginal situation as in Figure 3. Notice that <u>total</u> damages do <u>not</u> in general, equal total costs at the equilibrium.

FIGURE 3



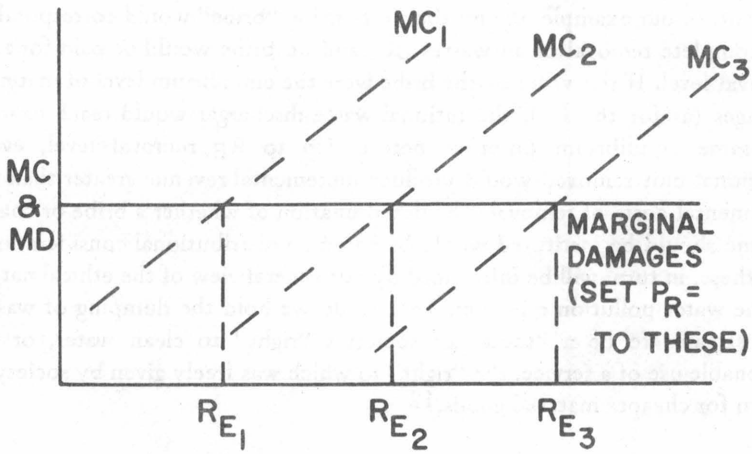
The equilibrium in this "removal market" is, then, marked by the relation: marginal damage equals marginal cost. If there were a market for R, the equilibrium price would be this annual incremental cost or damage (call it P_R). And so, finally, we come to the effluent charge. By charging A the price P_R per unit of waste discharge at A, we would induce the socially desirable (efficient) result that A would remove R_E pounds from his raw waste before discharge. We may count on this because we have assumed that A acts rationally and with full knowledge of his cost curve. Thus, he will reduce waste discharge until the point at which his cost for an additional unit of removal equals the charge. And, note that it is "cheaper" for society to have him do so, since it would cost more in terms of other goods and services lost to remove the next unit than would be saved in downstream damages avoided.

Before going on to consider some complications and extensions of this simple example, it is worth noting that if we have this kind of complete knowledge, we may obtain the desired result by setting the requirement that R_E pounds per day be removed from A's waste discharge; that is, by setting an effluent standard or quota. At the other extreme, when the problem is so complex and our knowledge so limited that our ability to find the efficient solution is in serious doubt, there is again no particular reason for preferring charges to standards. Note, however, that an existing effluent charge will serve as a continuing spur to greater waste removal whenever technical advances lower the costs of removal. There will be no spur to take advantage of such advances if there is a standard or quota imposed on effluent.[8] Because of its incentive effects, an effluent charge will often be preferred in cases of incomplete knowledge and intermediate complexity. We shall illustrate some of these cases below.

Some Extensions and Further Comments

One situation in which the effluent charge has a clear-cut advantage over a standard as a method of achieving an efficient result is that in which the damages imposed are a known linear function of the waste discharges. (If there is more than one discharger, then discharges must be simply additive in the watercourse (e.g.: chloride concentration from chloride discharges); and if there is more than one damaged party, all damage functions must be linear in the pollutant's concentration). In terms of our simple example, if the damage function at B is linear, the marginal damages are constant for all levels or removal. If we know this constant level of marginal damages, we can set our effluent charge equal to it and be assured of reaching the desired equilibrium result even without knowledge of the cost function at A. This example is graphed in marginal terms in Figure 4. No matter which cost function is accurate, the appropriate "shadow price" is still P_R.

FIGURE 4



In a multiple discharge-multiple use example with these simple linearity and independence assumptions, we may calculate the appropriate effluent charge for each discharger by calculating the marginal damages attributable to him. Our assumptions insure that these marginal damages will be accurate over the whole range of possible discharges from a particular firm or city and independent of changes in the discharges at the other points.[9] To the extent that the assumptions hold "approximately," it may be considerably cheaper and easier to proceed using this technique rather than to work to get very large amounts of data and the necessarily very complex optimizing models necessary to solve explicitly for P_R and R_E.

It is interesting to note in passing that a method which is in a sense the obverse of the one just discussed has been used to assist in making decisions about the quality level to be required in a stream. To apply this method, no explicit information need be available about marginal benefits, but costs must be known and, in fact, are usually related to levels of quality in various reaches of the stream. Then, by specifying several different sets of stream standards, it is possible to estimate the marginal cost curve for quality improvement in, say, the critical reach. Picking a standard, and the implied marginal cost, tells us how large the marginal benefits must be to justify that level of control. It then becomes a matter of judgment on the part of the decision makers whether or not a particular quality level is justified by their rough estimate of the possible marginal benefits.[10, 11]

It is also worthwhile pointing out that one could just as well pay the upstream waste discharger a fee for each unit of waste he removed from his effluent. In our example, the maximum possible "bribe" would correspond to the complete removal of all wastes ($\overline{R}$), and no bribe would be paid for zero removal level. If the value of the bribe were the equilibrium level of marginal damages (as for the fee), the rational waste discharger would reach exactly the same equilibrium point as before. Up to R_E removal level, every additional unit removed would produce incremental revenue greater than the incremental costs of removal. The determination of whether a bribe or charge scheme should be instituted would be based on distributional considerations, and these, in turn, will be influenced by our general view of the ethical nature of the water pollution question. That is, do we hold the dumping of wastes into streams to be a "theft" of society's "right" to clean water, or the reasonable use of a service, the "right" to which was freely given by society in return for cheaper material goods.[12]

Complications and Problems in Application

Unfortunately, the world with which a river basin commission or other water-quality management agency must deal will not be as simple as the world of our discussion example. But the difficulties encountered in any attempt to apply a system of effluent charges may usefully be divided into three categories according to whether they bother the economist, the practical man, or both. We assume for this purpose that the economist is interested in his ability to produce a conceptually correct system, whether or not the information is available to implement it and no matter how complex the actual computations required. The practical man, on the other hand, is assumed to be concerned with instituting some kind of charge scheme to take advantage of its incentive effects of which he is convinced. He will not be upset by a bit of arbitrariness here and there, but he will be very sensitive to the costs of data collection, computation, metering and billing, and he will not be in a position to ignore the problem of political feasibility.

As for the economist, there seems to be one problem that will be a concern essentially only to him. That is the problem of joint costs and damages arising from the fact that in actual situations there will be a number of physically and chemically interacting residuals generated, discharged, and then borne along by the stream. Thus, BOD, COD, suspended solids, dissolved solids, heat and nutrients may all be problems in a particular basin. But the costs of treating waste water for BOD, for example, cannot, in general, be separated from the costs of treating for suspended solids and those relating only to the volume of water treated. Thus, assignment of costs to each residual will be an essentially arbitrary exercise. At the other end, similar comments may be made concerning the damages. Thus, for example, heat and oxygen deficit interact in causing fish kills, and there is a "joint-damage" problem. Our practical man is willing, in these cases, to make essentially arbitrary divisions of costs and damages between the various residuals.

Both of our protagonists will be bothered to some extent by problems of benefit measurement which will arise because some of the most important benefits from pollution control are what the economist calls "public goods." That is, they are goods, like national defense, which cannot be appropriated and sold unit by unit in some market; goods for which my consumption does not subtract anything from what is available for you to consume. Thus, a public good is shared in consumption--we each consume an amount equal to the total supply. In particular, the aesthetic improvement resulting from higher water quality will fit the public good description perfectly. In addition, however, the recreation benefits may effectively be public goods because of the traditional bias in this country toward free access for the public to water-based recreation facilities.

Because of the peculiar nature of public goods, it is in each citizen's interest to conceal his true preferences concerning the amount to be provided if there is a chance that he will be charged according to his desire for the good. By concealing his own feelings, he guards against a payment on this basis, but counts on others to reveal preferences which will produce an amount of the good satisfactory to him. In the water pollution context, as we have noted, the aesthetic benefits of quality improvement are classic public goods, while some forms of recreation may also exhibit these attributes (as swimming from public beaches where no attempt is made to collect a fee and for which crowding is not yet a problem). Consequently, important parts of the benefits (damages avoided) from pollution control will be in essence undiscoverable from any market or market-like processes. This will certainly interfere with finding a truly optimal charge set.

A further problem involving our lake of knowledge is that of the possibility that our present decisions will allow processes to go forward that in time will create irreversible changes in the environment. Thus, it is possible that a set of effluent charges based on our best present understanding of the ecology of watercourses will still allow some progressive changes to take place which after some threshhold level has been passed will imply a permanent change in the character of the water body. Such a possibility can only be dealt with by building some allowance for this uncertainty into our charges or standards; by making them "tougher" than current knowledge would seem to justify. This problem is currently of particular concern to ecologists, but economists are becoming more aware of it.[13] Practical conservationists have, in effect, been saying this for years.

Another set of difficult problems of concern to both men will revolve around the explicit introduction of time into our model. On the one hand, over time the mix of activities and the sizes of individual activities in our basin can be expected to change. This raises the question of how to reflect this economic change in the effluent charges. Should all activities pay higher charges when a new water-using activity opens downstream? Should the new activity pay a charge itself? Should a new upstream firm share in an existing "bribe" system or, instead, be required to pay a charge? Solutions to these problems are primarily matters of obtaining agreement about what is fair. More difficult are the problems which arise because treatment plants are generally cheaper per unit if built large. This tends to make it desirable to build in excess capacity when a plant is constructed, but this, in turn, raises the question of who should pay for the unused capacity–the present users? potential future users? And how are such potential users to be identified? A final problem raised when time is explicitly considered is that of the variation in the physical system, especially streamflow, which is irregular and essentially unpredictable.[14] It is clear that a single set of charges based on a single level of streamflow will not reflect the differences in assimilative capacity of the stream, for at higher flows it may be that larger waste loads can be dumped upstream while maintaining the same damage level downstream. On the other hand, it is equally clear that, with present technology, to have a hundred or a thousand different charge sets corresponding to as many streamflow conditions would almost certainly cost more in administration (metering and internal adjustments by dischargers) and policing than would be gained. Presumably, there is some relatively small number of charge sets (perhaps one for each season or month) which captures some of the variation in flow without placing ridiculous burdens on the waste dischargers (or the streamflow forecasters).[15]

The practical man will, however, be troubled by other aspects of the problem of setting up an (approximately) efficient effluent charge scheme. The fundamental problem is that the amount of information required to set up such a system is enormous. In the real world, damages are probably not even approximately linear functions of pollution levels, and there are many water-using and waste-discharging activities on any stream. Obtaining data on costs and damages will be tremendously expensive even in the absence of the public-good problem and time variability of flows. Beyond the initial data gathering effort, there will remain the (expensive) necessity of monitoring the performance of the discharges on some regular basis. These considerations account, in large part, for the paucity of real world examples of such schemes.[16]

In addition, the non-linearities in the damage functions mean that the finding of an appropriate charge set, given the requisite information, is no easy task. Specifically, the marginal damages attributable to a single discharger will be a function of the level of discharge of other activities as well. A particular charge for activity A based on particular assumptions about these other discharges (B, C, ...) will not, in general, be consistent with the solution for the "optimal" level of discharge at B for the effluent charge on B based in part on the discharge at A. This kind of interconnectedness may be handled through mathematical programming techniques which amount essentially to successive approximations to the overall optimum. Whether or not a single optimal solution can be found for a particular problem will depend on the shapes of the cost and damage functions it contains. For example, if the average costs per unit of size decrease with larger scale, as they do for treatment plant construction, there may be many combinations of values for charges at which the program will think it has found "the" optimum. Assuring ourselves that we have, in fact, found the best solution under these circumstances is difficult and expensive. But computation may be very expensive even if no problems of so-called "local optima" are encountered. The time required to solve a programming model on a digital electronic computer goes up roughly with the cube of the number of interconnections and physical relations one must take into account. In a loose way, then, we can estimate that a five-times more complex system will be 125 times more expensive to solve.

Finally, even if the expense of data collection and computation can be met, the practical man may be faced with an extremely difficult task in trying to obtain the required political approval for his scheme. One even suspects that the more efficient (for the economist) the scheme, the greater this difficulty. This will be true partly because popular notions of equity are likely to be antagonistic to the kind of space-varying charge (or bribe) sets which will reflect the differential contributions to downstream damages of different upstream polluters.[17] There may also be adverse reaction to paying a price for what has always been a free good. Certainly this reaction is observed in the eastern United States when water meters are installed and the marginal cost of water goes from zero to some positive number.

Effluent Standards and Charge Schemes

One situation in which effluent charges may be very useful is in the administration of schemes based on stream standards. The charges in such cases will not be those based on the opportunity costs represented by downstream damages, for here the standard will represent a prior decision to reduce the pollution level to some fixed point (usually defined under particular flow conditions), and the aim will be to find the least-cost way of doing so. Since nothing is said about damages avoided, there is clearly no necessity that any chosen standard be <u>optimal</u> in the sense discussed at the beginning of the paper. But, given the difficulties in obtaining information about downstream damages, it seems reasonable to expect standards to play a continuing important role in pollution abatement.

Once a standard has been set, the aim is to minimize costs, and we may utilize a charge scheme in the following way. We calculate the marginal cost of meeting the standard by non-treatment methods available to the public authority, such as low-flow augmentation.[18] This represents the social cost of the standard if attained only through action of the public authority (or, alternatively, is an indication of the size of the social benefits which would be necessary to justify the standard). This cost becomes our effluent charge, and the individual activities react by removing waste up to the point at which their marginal costs equal the charge. Note that if the methods open to the authority are relatively very cheap, little individual treatment will be done and the collective measures will be taken. If collective actions are relatively expensive, more of the treatment will be private.

An example which approximates this situation and in which effluent charges have proved relatively popular is the construction of joint municipal-industrial treatment plants. We think of the standard here as the requirement that all waste discharged into a certain stretch is to be treated to the secondary level. One way of accomplishing this is for all the domestic and industrial wastes over that stretch to be treated in a single, large plant. The industrial waste dischargers may be permitted to use this plant on payment of a service charge equal to the marginal cost of the installation. This charge will encourage them to take in-plant steps to reduce waste discharge up to the point at which the marginal cost of additional in-plant removal equals the service charge.

In practice, there are several complications to this rather tidy scheme. First, there are, of course, several "wastes" of interest. In particular, most service charge schemes concentrate on volume, BOD load, and suspended solids load. But, in fact, some of the treatment plant costs are joint costs of handling two (or all three) of these and any breakdown of costs is inevitably arbitrary. Second, most municipalities are anxious that their treatment ventures cover costs, and hence the service charges are constructed on the basis of average rather than marginal costs. If average costs are greater than marginal costs (as they probably are for increases in size due to volume of effluent), then average cost pricing results in too great an effort by individual dischargers to reduce their sewage volume. If average costs are less than marginal costs, average cost pricing will result in too little effort by firms to reduce their waste loads.

In spite of these difficulties (which, again, bother the economist more than the sanitation commissioner), there are a number of such charge systems in operation, and the pollution control literature contains several articles detailing the steps by which the costs are estimated.[19]

In summary, one may suggest that while at present practical difficulties may make effluent charge systems relatively difficult to set up and administer, advances in our knowledge of the benefits of quality management, in the relevant areas of technology and in public understanding of the situation promise to make possible their wider acceptance, and thus to allow environmental quality management authorities to take advantage of the efficiency advantages of such systems. Of the three areas of advancement, public understanding is perhaps most important, for it involves changing some traditional notions of "equity" and discrediting the claim that an effluent charge is a "license to pollute." Both these matters, in turn, will rest on the ability to convince the public that waste disposal is a legitimate, even a necessary, use of the environment and hence that the question is not one of pristine purity versus ultimate filth, but of a balancing at the margin of costs of removal against the benefits of cleaner air and water.

FOOTNOTES

1. The work most frequently referred to in this area is probably Allen V. Kneese, The Economics of Regional Water Quality Management (Baltimore: The Johns Hopkins Press, 1964). This work has been expanded and revised by A. V. Kneese and B. T. Bower, Managing Water Quality: Economics, Technology and Institutions (Baltimore: The Johns Hopkins Press, 1968).

2. The following discussion is set in the language of the water-quality-management field. The points that are made are, in general, applicable also to air quality management problems. Indeed, the matters of complexity and practicability are perhaps even more in question for air pollution because of the nature of the external physical system with which one has to deal.

3. See, for example, Bator, "The Simple Analytics of Welfare Maximization," in American Economics Review (March 1957), pp. 22-59.

4. Economists have named "as if" charges of this sort "shadow prices" -- i.e., they are those prices which would exist at equilibrium in a free market.

5. We need not be specific about the nature of these activities at this point. One could be an industrial plant and the other a town or center for recreational boating, for example. Note that in a lake or estuary (or in air pollution) this simple upstream-downstream relation no longer holds, and we can foul our own nests.

6. The classic discussion of these possibilities is that of Coase, "The Problem of Social Cost," Journal of Law and Economics (October 1960), pp. 1-44.

   There are, of course, limits even in simple cases to the usefulness of recourse to law. The typical delays at all stages of the trial and appeal process may, for example, be so great as to seem to the damaged party to outweigh the possible value of a favorable judgement.

7. If both curves were concave from below, one or the other end point (0 or $\overline{R}$) would be the best attainable point, but this raises other complications it would be best to ignore here.

8. It should be noted here that it matters in what form a standard is imposed. Requiring, say, secondary treatment removes all flexibility from the individual decision maker; he has neither the incentive, nor the option to look for lower cost removal methods. A quota on the amount of discharge, on the other hand, still provides a spur to finding the lowest cost method of staying within the quota. Flexibility is not destroyed.

9. A numerical example of such a case is given on pp. 62-67 by Kneese, op. cit..

10. See the discussion of the choosing of Delaware River standards in Kneese and Bower, op. cit. pp. 224-235.

11. It is quite likely in our present state of knowledge that the benefits of a higher standard will, at best, be defined only in physical terms. It may be, for example, that our knowledge extends to the survival rate of migrating shad for different dissolved oxygen levels over various times and reaches. An evaluation of these data in dollar terms will be implied by the chosen standard.

12. The case for symmetry of bribes and charges has not been without its questioners. If we view Coase, op. cit., and Kneese, op. cit., as the most influential statesmen for the position, we find their conclusion questioned in "Asymmetry Between Bribes and Charges," by Kamien, Schwartz and Dolbear, Water Resources Research, Vol. 2, No. 1 (1966), pp. 147-158, on the basis primarily of the authority's inability to choose a maximum bribe (zero-level of waste discharge) in the dynamic real world and with only imperfect knowledge of the dischargers revenue and cost situation. Subsequent contributors to the discussion (Tullock, "Asymmetry Between Bribes and Charges: A Comment," Water Resources Research, Vol. 2, No. 4 (1966), pp. 854-856; Freeman, "Bribes and Charges: Some Comments," Water Resources Research, Vol. 3, No. 1 (1967)) have pointed out that the claimed asymmetry was, in fact, introduced by the authors' suggested method of calculating a maximum bribe. These is, of course, still some question of administrative feasibility.

13. John Krutilla makes a very persuasive case for exercising this kind of caution in dealing with the environment in "Conservation Reconsidered," American Economic Review, September 1967, 777-786.

14. It may be possible to forecast that summer and fall flows will be less than winter and spring flows almost always, and to say that tomorrow's flow will be very close to F cu.ft. per second, based on today's flow and knowledge of precipitation. But the average daily, weekly, or monthly flow over any particular time period, for example, will be a random variable. And our statements about them will necessarily be even more circumspect.

15. The problem of allowing for variations in assimilative capacity is, of course, not unique to effluent charges. Any attempt to allocate discharge quotas according to changing conditions runs into similar difficulties of administration.

16. The most widely known and longest operating effluent charge systems are those used by the river authorities in the Ruhr area in Germany. See Kneese and Bower, op. cit., pp. 237-253. See Ed Johnson, "A Study in Economics of Water Quality Management," Water Resources Research, Vol. 3, No. 2 (1967), for a suggested system for the Delaware.

17. Thus, it is unlikely to be acceptable to charge firm A 4 cents per pound of BOD and city B 2 cents; and explanations based on the chemistry of the stream and the location of damage receptors are not likely to change the situation over the next several years. This same problem applies to individual effluent standards and seems to be one of the major considerations behind the kind of blanket secondary treatment standards which the federal government has insisted on from the states.

18. In principle, we are interested in the cost increments related to increments in each discharger's waste load since only in this way will the actual charge set reflect the variable assimilative capacity of the water body.

19. For example, R. E. Roderick in "Rate Structures for Industry," Journal of the Water Pollution Control Federation (JWPCF), Vol. 34, No. 4, (1962) which takes the common approach of distinguishing between the costs based on volume and concentration and between users and "benefitted properties." Basically, the aim is to apportion the costs of providing treatment among volume, BOD, and suspended-solids loads

with allowances for peaking capacity costs, and for collection system size as related to property area served rather than water use and disposal. (This latter factor may be handled through the property tax). The actual charge scheme is constructed by considering each of the parts of the system individually and allocating costs among the various categories mentioned above. These divisions are based on rough rules of thumb, not on analysis of empirical cost functions, and the concern is always with average rather than marginal costs. This division is also carried out for operating of cents per 1000 gallons or per pound for application to all system customers. A similar system is advocated by J. F. Byrd in "Combined Treatment," Proceedings of the 16th Industrial Waste Conference, Engineering Extension Series No. 109, Engineering Bulletin, Purdue University, 46, 2 (1962). The general cost-division point is made by K. V. Hill in "Fair Sewer Service Charges for Industrial Wastes," JWPCF, Vol. 33, No. 2 (1961), pp. 198-201. A five-part charge is set out without background justification but with some indication of its effect in spurring industry to take internal control measures by R. Dean Smalla in "One Way to Control Industrial Wastes," Waste Water Engineering, Vol. 4, No. 3 (March 1967), p. 75.

THE USE OF SUBSIDIES FOR WASTE ABATEMENT

Hugh H. Macaulay

Department of Economics, Clemson University

An Economic Evaluation of Water Quality

Earlier speakers have told you how water quality can be considered as an economic good. It is scarce and people cannot have all of it that they want. Some would like to use water to carry away wastes, and this process will use up water quality by lowering it. Steel mills, paper mills, and municipalities are examples. Others want to enjoy the benefits that come from high quality water even though their use may not reduce the quality. Those who use water for boating, swimming, fishing, and picnicking are examples. They too value the services of water.

If we were concerned with land and land use, instead of water and its use, we would not consider the problem to be so difficult. In fact, we use land for most of these same purposes. Some people wish to dispose of their garbage and they do so by dumping it on certain tracts of land. Others want to use land for recreation such as camping, hiking, golfing, or picnicking, and they find land set aside for this purpose. If we have been able to resolve these conflicts with regard to the use of land, why cannot they be resolved in the use of water?

There are at least three features that make water use more difficult to handle than land use. The first problem is one of cultural lag. In many parts of the United States in the past, water has been in adequate supply so that people could have all that they wanted without seriously affecting the rights of others to enjoy a similar fulfillment of all their desires and needs for water. In other words water was a free good. In humid regions we have not yet fully adjusted to the change that makes water, or at least water of high quality, scarce. An example would be a statement I recall being made by Mayor Wagner during the campaign for mayor of New York in 1956. When the question arose as to whether New Yorkers should have meters put on residences to measure and permit a charge for the quantity of water consumed, he commented that New Yorkers have a right to water. Since he did not plan to charge for larger quantities of water consumed, he implied that New Yorkers had a right to unlimited amounts of high quality water for drinking and other uses. When there were few people and many streams, it was possible for people to have all the water of high quality that they wanted.

Now that the relationship is reversed and we have many people and few streams (or, more accurately, a relatively high ratio of people to streams), it is not possible for people to have all of the high quality water that they would like. A rationing device needs to be introduced. Yet policy is often still couched in terms of unlimited clean water for everyone.[1]

A second source of difficulty stems from uncertainties over ownership and the right to use streams. A comparison with land is again appropriate. Land is usually privately owned and the owner makes every effort to see that it is used only by those persons who value it most. These are the persons who will pay the highest rent. Ownership of our larger waterways, however, is considered to vest in the government and such waterways are considered to belong to, and to be freely available for use by, all the people. The government historically has not taken steps to see that cities, industries, and individuals did not overuse and pollute streams by their use of these waterways for waste disposal. As a consequence, streams have been used as though they were free when in fact they were scarce, because the owner failed to watch over the efficient use of his property.

The third factor that has contributed to the pollution problem is often classified as externalities, or social costs. This means that the action taken by one or more consumers or firms results in higher costs being imposed on innocent third parties. The point has been widely discussed in economic literature and has been covered in earlier sessions of this conference. Traditionally the problem has been dealt with by suggesting that the cost-creating action be abandoned or changed so that no external costs result. More recent theory argues that in essence the problem is one of two parties each trying to use a scarce resource, and that the solution providing the most efficient use by both parties would be one where the value of the marginal unit is the same to each party. In more concrete terms, this means that wastes might be put into a stream until the value to the upstream firm of the last unit so deposited, as measured by the least expensive alternative of eliminating it in some other fashion, is the same as the cost this unit will create for those living downstream.

This is not really a very difficult concept. We run into it daily. When there is a limited number of shirts, the greatest good will be gotten from them if they are distributed so that each person pays the same price for the last shirt he buys. If someone would be willing to pay \$5.10 for one more shirt, when shirts are selling for \$5.00, one of the \$5.00 purchasers would become a drop-out in the market as the new buyer entered. Until all buyers placed the same value on the last shirt they bought, some gain could be had by shifting the distribution of the good.

A marketable good customarily does not run into this problem because the goods are allocated as a result of bidding. However, when property rights do not exist, one consumer may use the good without reference to its value to others. This is what happens in the case of pollution. One user, the plant upstream, uses water quality without having to bid against others who want it. The plant discharges its wastes into the stream. However, as Coase has observed[2] the argument, if not the stream, flows both ways. If those downstream are given the right to prescribe water quality to suit their desires, this will impose costs on those upstream.

There is thus some optimum level of water quality, where neither party will be wholly satisfied, but where the total level of satisfaction, measured as best we can in dollar terms, will be greatest. This situation is no different from that which we encounter in the thousands of other transactions we make. Seldom do we get all we want of any good.

Systems for Achieving Optimum Cleanliness

If one assumes that there is an optimum level of waste discharge that can be determined, the next question is how best to go about achieving this level? Stated differently, this means how will we go about limiting the amount of waste that people want to discharge into streams?

At least three systems are often proposed. First, there may be a system of taxes or charges such as has been discussed earlier today. The person, firm, or municipality discharging wastes is told that the last units of these wastes are causing x dollars of added costs on those downstream. The discharger must therefore pay that amount per unit of his waste put into the stream. This is sometimes referred to as a tax, but is more appropriately called an effluent charge.

A second means of dealing with the problem is the obverse of the charge, namely the subsidy. If persons are discharging wastes into streams and damaging others downstream, we may, instead of charging the upstream firms, as just discussed, offer to pay them if they will stop the practice or at least reduce their waste discharge. This might be described as the "carrot" approach as opposed to the "stick" method. People do customarily respond to rewards. Wages, bonuses, promotions, grades, and flattery have been known to prove effective. It is this approach that later we shall deal with at length.

The third method is the one most widely employed. Rules and regulations are promulgated to deal with the problem. Firms are told that they will be permitted to dump a prescribed amount, or no amount, of waste into the stream. The system is popular with the legislative and executive branches of government because it permits some member or members of those branches to decide what is best and then to put it into effect, often with the added benefit that certain groups can be rewarded and others denied rewards in the process. The regulation solution is used in agriculture, in railroad and truck transportation, in the allocation of radio and television channels, and in the distribution of import quotas such as in the case of oil.

Regulations have the advantages of being relatively simple to administer and of lending a degree of certainty to the situation. They have the disadvantages of being relatively inflexible, perhaps more responsive to pollitical pressure than to economic pressure, and bestowing an economic advantage on those granted the right to discharge some wastes, as compared with those who may have this right either denied or restricted.

Arguments Given for Subsidies

We have so far tried to establish that water quality, as well as many other natural assets, is scarce and so needs in some manner to be allocated among those who wish to use it. Secondly, we have noted that this can be done by a price system whereby we charge for such use or, what is the same thing in reverse, by paying people not to use the scarce resource, or by regulating its use whereby we grant to different individuals or groups the right to use a certain amount of the scarce resource. We shall concentrate our attention for the rest of this paper on the subsidy approach.

Several of the arguments that have been offered in the literature will be reviewed. You will note that some are based on arguments of equity while others are based on arguments of efficiency. These same considerations appear in most of our other economic decisions. We support a price system because of the efficiency with which it allocates goods. However, we frequently feel that some particular good is not distributed in an equitable manner and so new restrictions may be put on its use. For example, wages are often determined in the market but a minimum wage keeps the level from falling below what some would think is fair. Rent ceilings, farm subsidies, and tariffs are examples of the triumph of someone's concept of equity over efficiency.

Pollution Abatement Equipment Does Not Contribute to Production

"Pollution abatement equipment is nonproductive and therefore polluters should not have to finance such equipment."

This argument appears frequently in congressional hearings on water quality. Businessmen, as might be expected, cite it favorably; congressmen frequently use it; some governors have supported it.[3] It is argument based on equity.

The statement is often made and just as often never elaborated upon. It is apparently an obvious point. Yet, what is productive equipment? The statement has a ring about it similar to the earlier Physiocrats who felt that only farmers were productive; and Karl Marx and Adam Smith who felt that those who provided services, like ministers, lawyers, and college professors, were not productive because nothing tangible emanated from their efforts.[4]

Examine a typical firm, however. It spends money for machines, raw materials, lubricants, adding machine tapes, wall-to-wall carpeting for executive offices, tickets to football games for select salesmen and their customers, and, what begins to strike close to home, garbage collection. Economic theory, as well as common sense, tells us that a firm will buy many inputs, even Muzak, until the increase in output of final product due to the last unit of input bought is the same per dollar spent for each input. Indeed, each of these odd expenditures must contribute to production of cold rolled steel, eighty square cloth, or whatever the final product may be, or management should not make the expenditure.

It is true that the expenditures by management depend on the world as it is, or as man has made it. For years, the South has been hot, unlike Blacksburg, where spring stays all summer. Workers endured heat. But then something happened. Either coolness became cheaper to manufacture or workers' tastes changed so that they preferred some less pay and much less heat. At any rate, plants were air-conditioned. Facing the world as it existed, managers did not complain that this was a nonproductive expenditure. Indeed, they may have argued that productivity was higher per man hour. You can make up hundreds of other instances. If thieves begin to steal from a plant, it is necessary to hire watchmen. If hurricanes are prevalent, roofs must be more firmly attached. The proper argument is not that these expenditures are nonproductive; it would be more accurate if the businessman stated his belief that nature should not have imposed such burdens on him, or if the burdens are imposed by man-made laws, that the expenditures do not generate benefits that are worth much to others.

Pollution Abatement Benefits Those Downstream

"It is unfair to ask the firm to bear the cost of cleaning up effluent when those downstream will be the beneficiaries."

This argument is also one of equity rather than efficiency. It too is frequently cited and has enough truth in it to be readily accepted. However, a closer examination reduces its effectiveness.

If a firm upstream is asked to clean its effluent, our previous analysis indicated this should be because those downstream are being damaged to a greater extent than the benefit to those upstream will justify. All this means, however, is that undue burdens (external costs) have been imposed on those downstream. Cleaner water will benefit those downstream, but this is because those persons are already, from an economic standpoint, unjustifiably suffering external costs created by other parties upstream.

If persons downstream have been suffering from pollution and the optimal economic solution calls for cleaner water from upstream sources, this means that those downstream have suffered unjustifiably in the past. To ask them to pay for reduced pollution is heaping insult upon injury. Persons downstream may be required to pay for the greater cleanliness, as is suggested by many, but they should not also have to pay the costs that should fall on those upstream. To argue that they should is only an expression of some person's value; it does not rest on economic efficiency.

Consider a similar case that might arise in the use of city property. Without zoning regulations, a person may decide to raise pigs on his property. If this action imposes greater costs on the neighbors than it yields in benefits to the city farmer, it should be halted. If the injured neighbors are forced to compensate the farmer for his abandoned project, this is an implicit recognition of the property rights that the farmer had to raise pigs. Unless these property rights have been explicitly given to him, there is little reason to compensate him for their removal. Stream rights are very often not sufficiently definite and certain to allow a person to claim compensation for a change in his situation.

Rather than viewing the loss as a setback, he might view the previous period as one of temporary productivity and profit. In this light, the argument might be stated, "For years the upstream firm has dumped wastes into the stream and has thus imposed costs on those downstream. Now the firm will have to clean up its wastes, but fortunately it will not be forced to compensate those downstream for earlier costs imposed on them."

Increased Costs for Abatement May Drive Some Firms Out of Business

"If firms are forced to clean up their effluent, the added expense may drive some out of business, so firms should be subsidized to help them meet this new added expense."

This description of conditions may well be accurate. Firms in the past may have disposed of their wastes by putting them into streams, which spared them of any waste treatment costs. If forced to treat these wastes, some firms may now find that their expenses exceed their revenues and they will be forced out of business, either immediately or in the long run. This will involve a loss in investment by the owners and, what is often considered more important, a decline in employment opportunities for workers. Since people are reluctant to see an increase in unemployment, this argument often carries great weight.

At base, however, this argument really revolves around another question. Can the firm meet all the costs associated with producing the product? In effect, the firm has in the past produced a final product and sold it at a price that covered all costs except waste disposal. These costs were being imposed on others downstream when the waste was discharged into a watercourse. If, under this situation, the industry has expanded with firms entering the industry until the last firms are just covering all their costs, then any new burdens, such as waste treatment, will send their total costs above total revenues and they will be forced to abandon operations.

The problem is not so general as it might appear. In any given industry, customarily some firms will operate more efficiently than others. Through adjustments in profits, prices paid to other factors of production, and the price at which the final product is sold, most firms will be able to meet the new waste abatement costs. Some few firms, ordinarily referred to as marginal firms, will not be able to meet these costs and may be forced out of business. If this is the case, it means that the firm cannot pay for all the factors that it is using, including the water quality which it is using in production and which it must now replace before discharging any effluent, and from all this produce a product that consumers value more highly than the cost of the inputs. In brief, it costs more to produce the product than the product is worth. If the firm is subsidized in its abatement cost, society is in effect saying that it is willing to put up with inefficiency in production so that workers and owners of capital do not have to move their resources to new occupations. As in the case of most other arguments, it may be equitable to have workers employed in a given plant, but it may not be economically efficient.

This same type of problem appears daily in the operation of the economy. A small business may rent a store in a downtown area or a farmer may rent some land on which to farm. If conditions change and each of these plots of land becomes more valuable, perhaps because of increased pedestrian or automobile traffic, the landowner will have better opportunities for renting his land and will ask higher rents. If the small business or the farmer is unable to meet these new higher charges, he moves to a new location or abandons this type of economic activity. The land then goes to the renter who will pay the most for it and presumably will get the most out of it.

There is a fine point to this problem that might bear mention in passing. John Moes and James Rinehart[5] have argued that in some cases local subsidies for industrial development might be justified. They give as an example the case where minimum wage laws keep a labor surplus area from attracting industry with low wages. If the locality grants a subsidy, this in effect lowers the real wages received by workers in the community. They may be paid at the minimum wage, but their taxes are increased to provide the subsidy.

In an analogous case, a plant faced with a new requirement to clean its effluent will be faced with higher costs. If wages and other costs are inflexible and cannot be reduced, the plant may have to close. However, if a subsidy is given, financed by the local community, the effect is to spread the cost of these improvements over those who are benefiting from the continued operation of the plant. A subsidy given at the local level may thus be justified on grounds of efficiency as well as on grounds of equity.

<u>Subsidies Produce the Same Effects as Charges Do</u>

"If a given level of waste discharge can be attained by an effluent charge, the same result can be obtained by a subsidy of like size."

This argument says that by using a charge or a subsidy there is no differential effect on the level of operation of the firm and therefore no effect on economic efficiency. A firm that will be discouraged from discharging a certain amount of waste by a charge of $1 per unit of waste discharged will be equally motivated if offered instead a subsidy of $1 for every unit of waste not discharged. With the subsidy, the firm in effect loses a dollar every time it discharges a unit of waste, which is the same effect it would experience if it were to pay a dollar for every unit of waste discharged. Since there is no effect on efficiency, the decision should rest on considerations of equity.

If one assumes that there will be no difference in the price of the final product produced or in the cost of operation of the firm, i.e., the demand and supply conditions do not change for the firm, then the two approached do yield the same result. However, these assumptions are not realistic and will be discussed at greater length below when we cover the arguments usually presented against the use of subsidies. If it should later be shown that charges and subsidies do not produce the same results, this argument falls.

Arguments Against Subsidies

It can be seen from the above that most arguments in support of subsidies rest on grounds of equity. Some groups feel that certain producers should not have to bear the cost of pollution abatement because this imposes an unfair burden on them.

The arguments against subsidies, which will now be discussed, center more around considerations of efficiency. People express their desires to buy and sell through the market. Given a distribution of income and the tastes of both producers and consumers, some pattern of output will evolve that will meet the needs and desires of members of society. The efficiency arguments against the use of subsidies will be based generally on the idea that by subsidizing some activity, we encourage it and the overproduction of some associated product, at the expense of some other good that society values more highly in the market. Fundamental to this idea is the economic concept of scarcity. If society produces more of one good, it must produce less of some other. The net effect may be less total output.

Subsidies Cause a Misallocation of Resources Because the Burden Falls on Taxpayers Rather Than Consumers

"A subsidy for pollution abatement leads to a misallocation of resources because the burden is borne by the taxpayers rather than by those who consume the product."

When we buy an economic good, the price we pay should cover the cost of all resources that went into its production. In this way we can be sure that the value to the final consumer is greater than the value of all the resources that went into its production and that might have been used instead to produce other goods. To illustrate, if the government or some charitable organization paid all the labor costs associated with the production of some given product, say household furniture, then consumers would buy the product so long as its value to them was greater than all costs of production except labor. Yet labor is a cost of producing household furniture. As a consequence of the increased sales of household furniture, labor would move from the production of food and clothing into the production of such furniture. As a result of these shifts, people would forego goods they valued highly and buy instead goods whose value, because of the subsidy, was lower.

To return to pollution and subsidies, we find similar principles applying. If a charge is placed on the effluent discharged, reflecting the actual damage caused by wastes put into the water, this would raise the price of the final product. A subsidy, however, keeps the buyer of the final product from bearing part of its cost of production, with results already described. For this reason, economists generally prefer a charge to a subsidy because of the more favorable effects on the allocation of resources.

Subsidies Do Not Produce The Same Effects as Charges; They Encourage Greater Output

"Rather than there being an identity of the results that stem from charges and subsidies for waste disposal, there is in reality a difference in their effects."

As has been noted above, if one assumes that the price and sales volume of the final product being sold does not change and that the costs of production faced by the firm do not change, then the charge and subsidy will yield the same results. However, a subsidy reduces the average total cost of operation for the individual firm and makes it possible to produce the product at a lower cost. The charge, on the other hand, has the opposite effect. Given assumptions of competitiveness in the industry one would expect that the final price of a product would be lower under a subsidy and more of that product would be consumed than would be the case under a charge.

It is true that an individual firm, in the short run, is likely to be faced with the same marginal cost and demand functions under a subsidy as it would under a charge. However, the industry will be affected differently by these differences in treatment, and this will eventually be reflected back to the firm. The result is what we have already discovered in the preceding section, that there will tend to be a lower price for the final product and greater production of it under a subsidy than would be the case under a charge. Unless this is a product that society has independently determined should be produced in greater quantities at public cost, this will produce an economic loss by encouraging the production of one good at the expense of another.

Subsidies Do Less to Encourage the Discovery of More Efficient Means of Waste Disposal Than Do Charges

"If the amount of the subsidy is determined in part by the cost of waste treatment undertaken by the firm, the firm has little incentive to reduce its processing costs, for this would in turn lead to a reduction of the subsidy. A charge, however, encourages the firm to find the most economical means possible for eliminating wastes."

This means that the subsidized firm that produces wastes is not encouraged to develop more efficient means of waste disposal or a change in processing that would eliminate the waste production. If it did, its subsidy would also be reduced. It might find itself no better off than before the improvement. Faced with a charge, however, the firm will profit if it finds any cheaper mean of disposing of wastes.

The subsidy fails to reward the producer for any inventiveness on his part to reduce pollution. The change may reduce pollution but it may also reduce the subsidy. The charge, however, makes him the beneficiary of any such change. In this case, a penny saved is a penny earned.

The Size of a Subsidy is More Difficult to Determine Than the Amount of a Charge

"It is often difficult to determine the size of the subsidy; indeed it is more difficult than determining the size of a charge."

In the case of a charge, its size is determined by the damage being imposed downstream. While this may be difficult to compute, it is presumably a definite sum. The amount of the subsidy, on the other hand, is more likely from a practical standpoint to depend on an equilibrium between the damage being caused downstream and the cost of eliminating wastes from upstream plants. It might be expected that subsidies would tend to be more negotiable than would charges.

For example, although the discharge from an upstream plant may cause damage to those downstream of an additional $1 per added unit of effluent, the upstream firm may plead that it costs $2 per unit to eliminate this waste. There should be some equilibrium quantity and price at which the two costs would be equated, but the determination of this price depends in part on acceptance of the upstream firm's statement as to its costs.

Consider for example the problem that might have arisen in the 1930's in the case of railroads. Steam locomotives generated and poured out much smoke. Suppose that a subsidy had been given to the railroads to reduce smoke production at the same time railroads were finding diesel locomotives to be far more efficient than steam ones. A subsidy might have discouraged the introduction of diesel locomotives and encouraged only the substitution of oil for coal in generating steam. On the other hand, the subsidy might have been a pure bonanza to the railroads who could have pled that they had undertaken a costly replacement program to reduce pollution. Certainly arguments would have arisen annually over the size of the subsidy. A charge, however, would have been one of the facts of life faced by firms that they would be forced to meet as best they could.

The Form of a Subsidy May Produce Misallocative Effects

"A subsidy in a particular form may promote a particular kind of waste treatment rather than some other system that would be more efficient."

Accelerated depreciation for waste abatement equipment is a good example. Assume for example that a plant was producing a given amount of waste and that a subsidy were to be offered to reduce waste discharge. Assume further that for each unit of waste removed, the cost under the system using predominantly variable costs is one-half that under the system that involves building a large treatment plant and incurring few variable costs. If then a subsidy is given in the form of a tax credit for equipment purchased but with no provision for a reduction in taxes due to supplies bought, it may well pay the plant to reduce its wastes by building a large expensive permanent facility rather by some periodic treatment. As an extreme example, if wastes could be removed by hiring a person once a week for a $5 payment to remove certain suspended solids or if these solids might also be removed by the construction of a plant costing $5,000 and having an expected life of two years but having zero operating costs, a tax credit of 100% would make the plant the least costly method of removal.

Forms of Subsidies

Most of the theoretical literature dealing with subsidies assumes that they will be given as a certain amount for each unit of waste withheld. In more practical terms, however, the forms proposed are varied and not always directly related to this concept. Rather, subsidies are proposed in forms that will reduce the cost of operation of firms that attempt to clean up wastes, although the amount of assistance given and the amount of waste withheld are not necessarily closely related to one another. We shall look next at some of the forms that have been proposed most often.

Accelerated Depreciation

It is usually assumed that the removal of wastes will require the construction of some permanent facility. Tax laws recovering depreciation normally prescribe the rate at which such a facility can be written off. However, a number of states and the federal government have proposed that waste abatement facilities may be written off at more rapid rates or, what is often the same thing, over a shorter period of time.

In effect, this amounts to a benefit to the firm in the form of an interest-free loan over some period of time. For example, assume that an asset will be written off over a five-year period rather than over a normal life of ten years. Depreciation charges will be high during the early years and tax payments will be commensurately low. However, after the asset has been written off during its first five years, no further deductions are available during the remainder of its life. During these latter years deductions will be smaller and taxes will be higher. Assuming that there is no change in tax rates, the same amount of money will be paid in taxes under each of the two depreciation plans. However, the pattern of low payments in early years under accelerated depreciation makes it possible for the firm to take the money saved on tax payments in these early years and earn interest on it. In later years the taxes can be paid, but the interest earned may be kept. From this description, it should be apparent that the government has in effect loaned the firm money at no interest rate, allowed the firm to earn a return on these funds, and later requested repayment of the funds. The net advantage to the firm is the return it can realize before it must repay the loan, i.e. pay the taxes that earlier had been postponed.

The value of this tax advantage depends on at least three factors: The rate of return the firm can achieve on its investment; the difference in the amount of tax that would normally be due in the early years of the life of the asset and the amount that would be payable under the accelerated plan during the early years; and finally the length of time that elapses before final restitution of tax payments is made.

The value of this tax measure can be computed in two ways. One may find the present value of tax savings at some prescribed rate of return under the two plans, normal depreciation versus accelerated depreciation. The difference in these present values represents the cash value to the firm of the provision for accelerated depreciation. Alternatively, one can calculate the differences in tax payments for each year under the two plans and compute the interest that could be earned on money saved by the lower earlier tax payments until their eventual repayment. These two computations should lead to the same results.

The 1954 Internal Revenue Code made it possible for most firms to depreciate assets under accelerated schedules. This reduces to some extent the value of even more rapid depreciation that is proposed under most bills dealing with pollution abatement. Mantel has made some calculations of the advantage of rapid depreciation versus certain other forms of depreciation.[6] He concludes that in the purchase of a $1000 asset a firm would save $193 if it could write the asset off immediately rather than depreciate it at a straight line rate over a ten-year period. These sums assume a tax rate of 50 percent and a discount rate of 10 percent. If the comparison is made between immediate write off and depreciation according to the sum-of-the-years' digits, the net saving is $150. Since the latter figure is a more realistic comparison, we may say that under these assumptions an immediate write off results in a saving of 15 percent of the cost of the asset.

It can be seen that accelerated depreciation may help in pollution abatement by reducing the net cost to the firm of machinery and equipment used to treat wastes. But the provision does not offer assistance where treatment could be done more efficiently by using chemicals or other expendable supplies. Even under this most favorable assumption, immediate write off versus sum-of-the-years' digits depreciation, the net advantage is only a 15 percent reduction in the cost of pollution abatement equipment.

There is another problem that often arises with these expenditures. The question concerns whether or not a given piece of equipment qualifies for the special tax treatment because it is concerned with pollution abatement. Several problems arise in this respect. Equipment may be bought to reduce pollution by processing the effluent and realizing some saleable product from the processing. States have been reluctant to grant special tax treatment for equipment that produces a marketable good. Second, pollution may be abated by an alteration in the manufacturing process which will produce less effluent. Yet all of the equipment involved may be regular productive equipment and none particularly oriented toward pollution abatement. There may be some question as to whether or not such equipment should qualify for the special tax treatment. Third, a plant may find it economical to make certain changes in processing or even in its effluent treatment because of changes in technology or changes in market conditions. Thus, it may become profitable to use some compound other than water as a carrier for dyestuffs. Or it may become profitable to reclaim certain wastes, regardless of tax considerations. Yet the tax laws might well apply to these circumstances and produce a net windfall to those so fortunate as to be in an industry where these changes are taking place. The situation is analogous to the diesel locomotive example cited earlier.

Accelerated depreciation is popular at both state and federal levels. In the 90th Congress 107 bills were introduced to permit more rapid depreciation of pollution abatement facilities. While none of these have been enacted at the federal level, at least nine states have adopted laws permitting more rapid depreciation.[7]

Tax Credits

Closely related to accelerated depreciation is the proposal that firms be granted a tax credit for pollution abatement equipment purchased. Most people who deal frequently with tax matters from either a theoretical or practical perspective recognize the difference between a deduction and a credit. However, the distinction still eludes millions of voters who are invited to evaluate these provisions in proposed bills and to voice their opinions to their elected representatives.

The form in which a tax credit is expressed may appear disarmingly unimportant. Yet its value is easily computed and may be significant. For example, if businessmen were asked to choose between a 50 percent deduction for an asset to be given in each of the first two years of its life and a ten percent tax credit to be given in only the first year, it could well be to the advantage of many firms to take the tax credit rather than the higher percentage deductions. The credit constitutes a flat deduction from the tax bill. The deductions normally constitute a reduction in the income subject to tax.

If a ten percent tax credit is given for the purchase of pollution abatement equipment, this means that the purchaser may deduct from his tax bill in the year of purchase an amount equal to ten percent of the price of the equipment. He may continue to take all other deductions as though no new provision were enacted. In other words, the tax credit comes on top of all other provisions. It is obvious that in this case the tax credit amounts to the reduction by ten percent in the cost of the asset to the buyer. The government has in effect paid this portion. Once again, this provision is popular at both federal and state levels. In the 90th Congress 100 bills were introduced proposing tax credits for pollution abatement equipment at rates ranging from 14 percent to 25 percent. Although none of these has been adopted, pollution abatement equipment did receive a tax credit at one time when most other equipment did not. When the seven percent investment tax credit was suspended by Congress in late 1966, pollution abatement equipment was exempt from the suspension. In other words, such equipment continued to qualify for the tax credit although most other equipment did not. The suspension was removed in early 1967 and since that time the tax credit has applied to nearly all investment equipment.

Perhaps the most unusual tax credit is one enacted by the State of Oklahoma. It provides a tax credit of 20 percent of the purchase price of pollution abatement equipment to be taken each year for a period of five years. Over that term then a firm will be able to reduce its tax bill by the full amount it paid for such equipment.[8] With the exception of interest considerations, the state in effect purchases the equipment. If pollution can be abated by fixed capital equipment, one would expect Oklahoma shortly to have clean water in all its streams.

Other Provisions

Both the federal government and individual states have enacted other measures to assist firms in their pollution abatement activities. The federal government has a program whereby grants and contracts are given for research, development, and demonstration projects. These are, as the name implies, awarded to find new ways for waste treatment, and are not generally available to firms whose problem is solely the reduction of waste discharge.

The federal government also makes grants to states, municipalities, and interstate and intermunicipal agencies to assist in the construction of waste treatment works. However, private firms may choose to have their effluent processed by the government agency receiving the grant and so firms may benefit indirectly from these reduced costs.

States have offered a wider variety of forms of assistance. Some exempt pollution abatement equipment and certain other purchases from sales tax, others from property taxes, others from franchise taxes. Still other states subject such equipment to tax rates that are lower than normal. California has in one case declared a moratorium on interest payments on funds loaned to certain municipalities to purchase specific abatement equipment. As of the end of 1968, there were at least 29 states with tax laws providing special treatment for pollution abatement equipment. The argument that there should be some assistance given to industry in its effort to reduce pollution apparently has widespread support.

We noted earlier the wide variety and large number of political figures and interested citizens who spoke in favor of assisting business in attempting to reduce pollution. In at least one instance where the question was put directly to the people, however, public support apparently was lacking. In the fall of 1968, the citizens of Texas were asked to approve a constitutional amendment which would provide for exemption from property tax for equipment installed to eliminate or abate air or water pollution, if the investment in such equipment met the state's standards. The prople rejected the proposed amendment.[9]

Conclusions

Clearly people and firms should not be allowed to dump into streams all the wastes that they generate. There is some optimum quantity of wastes that can be disposed of in this manner. Some treatment of wastes must be undertaken by individuals and by firms. Among those who must clean up, hope seems to spring eternal that the burden may be passed on to someone else or that other parties will help pay their cleansing costs. The case for subsidies will doubtless be argued vigorously.

In general, however, the economic ends of the society will be served best if those who impose costs pay for them. In the broad context of Coase's discussion of social costs, this means that the greatest economic efficiency in the use of water quality will be realized if firms bear the burden of those costs they put on others, and also those costs that they incur internally to clean their effluent and reduce the cost previously imposed on others. The market works efficiently when costs can be imputed to and levied on those who create them. Hopefully a system imposing such direct charges will eventually be possible in the case of water quality.

FOOTNOTES

1. The Water Quality Act of 1965 states, "The purpose of this Act is to enhance the quality and value of our water resources and to establish a national policy for the prevention, control, and abatement of water pollution." P.L. 89-234, 79 Stat. 903.

2. Coase, R. H., "The Problem of Social Cost," Journal of Law and Economics, Vol. III, October 1960, pp. 1-44.

3. Examples of supporting statements may be found in U.S., Senate, Committee on Public Works, Senate Report No. 1367, 89th Congress, 2nd Session, p. 14, and U.S., House, Committee on Government Operations, House Report No. 1330, 89th Congress, 2nd Session, p. 15.

4. Smith described as unproductive not only the sovereign and all the officers of war and justice who served under him, but also "churchmen, lawyers, physicians, men of letters of all kinds; players, buffoons, musicians, opera-singers, opera-dancers, &c." Smith, Adam, An Inquiry into the Nature and Causes of the Wealth of Nations (Modern Library edition), p. 315.

5. Moes, John E., "The Subsidization of Industry by Local Communities in the South," Southern Economic Journal, Vol. XXVIII, October, 1961, pp. 187-193. James R. Rinehart, "Rates of Return on Municipal Subsidies to Industry," Southern Economic Journal, Vol. XXIX, April, 1963, pp. 267-306.

6. Mantel, Howard N. and Ruth P. Mack, Industrial Incentives for Water Pollution Abatement, a report prepared by the Institute of Public Administration for the U.S. Department of Health, Education, and Welfare, February, 1965, pp. 36-40.

7. Commerce Clearing House, "State Tax Law Supplement," Water Control News, Vol. 3, December 9, 1968, pp. 5-8.

8. Ibid., Vol. 2, October 30, 1967, p. 33.

9. Ibid., Vol. 3, October 22, 1968, p. 1, and November 25, 1968, p. 4.

BIBLIOGRAPHY

Bramhall, Davis F. and Edwin S. Mills, "A Note on the Asymmetry between Fees and Payments," Water Resources Research, Vol. II, Third Quarter 1966, pp. 615-616.

Commerce Clearing House, "State Tax Law Supplement," Water Control News, Vol. III, December 9, 1968, pp. 5-8. See also "Special State Tax Provisions," Ibid., Vol. II, October 30, 1967, pp. 41-44. Vol. 2, October 30, 1967, p. 33. Vol. 3, October 22, 1968, p. 1, and November 25, 1968, p. 4.

Coase, R. H., "The Problem of Social Cost," The Journal of Law and Economics, Vol. III, October, 1960, pp. 1-44.

Kamien, M. I., N. L. Schwartz, and F. T. Dolbear, "Asymmetry between Bribes and Charges," Water Resources Research, Vol. II, First Quarter 1966, pp. 147-157.

Kneese, Allen V. and Blair T. Bower, Managing Water Quality: Economics, Technology, Institutions (Baltimore: The John Hopkins Press, 1968).

League of Women Voters of the United States, "A Consideration of Federal Financial Incentives to Industry for Abating Water Pollution," August, 1966.

Mantel, Howard N. and Ruth P. Mack, Industrial Incentives for Water Pollution Abatement, a report prepared by the Institute of Public Administration for the U.S. Department of Health, Education, and Welfare, February, 1965.

Moes, John E., "The Subsidization of Industry by Local Communities in the South," Southern Economic Journal, Vol. XXVII, October, 1961, pp. 187-193.

Rinehart, James R., "Rates of Return on Municipal Subsidies to Industry," Southern Economic Journal, Vol. XXIX, April, 1963, pp. 167-306.

U.S., House, Committee on Government Operations, "Views of the Governors on Tax Incentives and Effluent Charges," House Report 1330, 89th Congress, 2nd Session, March 16, 1966.

U.S., House, Committee on Ways and Means, Legislative Calendars 90th Congress, December 31, 1968.

U.S., Senate, Committee on Public Works, Senate Report No. 1367, 89th Congress, 2nd Session, July 11, 1966.

MARKET MODIFICATIONS AND THE GOVERNMENT GRANTS ECONOMY

Ronald M. North

Department of Agricultural Economics, University of Georgia

"The life cycle of the committee is so basic to our knowledge of current affairs that it is surprising more attention has not been paid to the science of comitology. The first and most elementary principle of this science is that a committee is organic rather than mechanical in its nature. It is not a structure but a plant. It takes root and grows; it flowers, wilts and dies, scattering the seed from which other committees will bloom in their turn. Only those who bear this principle in mind can make real headway in understanding the structure and history of modern government" (4, p.37) The Wall Street Journal (9) recently reported in a feature article the problems of local (big city) governments which have increased demands for the sharing of federal revenues, preferably through the device of grants-in-aid to existing city organizations and not to independent organizations. Interviewed big-city mayors in Atlanta, Minneapolis, Pittsburgh, Denver and others are actively seeking additional spending money from federal revenue sharing schemes for health care, job training, educational services and facilities, urban renewal, antipoverty, model cities and public utilities improvements. Why? The cities are presumably unable to tax heavily the current residents and unable to incorporate effluent suburbs because of pocketbook opposition from the suburbanites and political opposition from the city minorities invisioning greater control. A mayor's greatest remaining source of pride may be the ability to get federal funds for his city. Federal-city cooperation is an important aspect of air and water pollution control efforts in America today. Grants-in-aid from the federal government to cities, states and other local governments are quite common. In fact, grants-in-aid are now discussed in terms of a new phenomenon dubbed the grants economy. This grants economy is not necessarily private market or price oriented.

Grants-in-aid are defined as payments in either cash or transfers in kind (things and services) to help a state or local government administer federal government policies, programs, services or activities. Although the grant may be conditional, that is, subject to the performance of certain services and/or standards, the recipient state or local government ordinarily is not required to repay the grant-in-aid nor to perform very stringent services.

The Advisory Commission on Intergovernmental Relations, established originally in 1953 to deal with the administration of grant-in-aid programs, summarized the conditions leading to increased emphases on federal grants and revenue sharing.

> *"Dating from the establishment of the Republic the division of authority and responsibility between the National Government and the States has been debated more frequently...than any other feature of our government system.*
>
> *...At home, the role of government has increased its scope with problems of national economic growth and stability, with accelerated population mobility, particularly, into and around large urban areas, and with the people's insistence on more and improved governmental services of all governmental levels." (8, p. 1)*
>
> *"The Commission recommends:...*
>
> *1. . . . .*
> *2. Modification of State and Federal grant-in-aid programs to provide incentives to small local governments to join together in administering the function being given grant assistance.*
> *3. Authorization to county governments individually or jointly to establish service corporations or authorities, where clearly necessary and with appropriate safeguards.*
> *4. Authorization to municipalities and counties to adopt optional forms of local governments" (8, p. 13).*

The commission further recommends that the states enact legislation requiring reviews, approvals, coordination studies, reports and cooperation among existing local governments and existing or proposed special districts where taxes, services or grants-in-aid are involved (8, pp. 17-20). The recommendations point to continuing pressures for more grant programs, especially those that result from or in new or multi-unit local government organizations for accomplishing tasks such as pollution control.

Man has created a crisis with respect to continued unrestricted use of his environment. The environment is not deemed sufficiently resilient to absorb and recycle the continued effluents and trespasses of humans at current rates of growth in population, technology and affluence. Comprehensive evaluations of the consequences of man's unprecedented rates of effluent discharges and trespasses on the natural environment and consumption of natural resources are needed to develop acceptable alternatives to the complete eutrophication of the environment. We must find acceptable and effective means of managing both man's environment and man's relations with that environment.

The model, private market system in which consumers freely choose goods and services and producers freely choose resources to optimize satisfaction or profits respectively is not entirely adequate to optimize environmental quality presently nor in futurity when both consumers and producers are able to avoid the consequences of their pollution. The model, private market system can be modified or extended to include certain collective actions for collective benefits. These collective actions may be voluntary, enforced or compromised according to the institutional arrangements used to both determine and guide the collective actions for environmental quality management. Collective actions by environmental polluters and pollution evaders may include the economic incentive approach or the regulatory approach or shades of both, that is, the carrot or the stick or both. The choice depends on the existing governments and organizations for collective actions, the urgency of the pollution crisis and the generally prevailing degree of emphasis on maximizing or minimizing individual sovereignty.

Our present direction seems to be a compromise wherein a degree of individual and local sovereignty is traded for non-local (federal) economic incentives such as federal grants, loans and tax writeoffs which relieve polluters individually of the direct consequences of their pollution actions at some small sacrifice of local control of the terms of pollution programs. This direction for water quality control problems is a special form of the traditional "let George, or in this instance, let Sam, do it." The conditions under which we are expected to manage our water and air quality are by conscious choice not those of the model, private market economy wherein the consequences of consumption, production and trading activities are direct, personal and immediate.

We have already modified the model, private market economy for coping with matters large and small of a collective nature which includes pollution abatement. Our real problem then is not necessarily further market modifications but the development of measurements, devices and institutions which will accomplish the necessary levels of air and water quality with efficiency and equity. Kenneth Boulding has suggested two ideas which professionals and citizens alike need to consider with respect to environmental quality problems.

In the first instance Boulding suggests that the model, private market economy, an econosphere, in which production and consumption levels measure the success of the economy, may not be relevant at all to the future society (1, pp. 3-14). He describes a spaceship economy without unlimited stocks of anything for either extraction or pollution. Boulding's spaceship economy is an obviously closed ecological-economic system wherein production-consumption levels may be minimized rather than maximized as presently is the case. People must then make conscious, and perhaps market valued, choices of whether to extract or pollute. The major maximization objectives would be those of human and environmental quality or "states of being." The ideas that production and consumption are economic bads and that we may live in a closed econosphere, though familiar to ecologists, are quite strange to economists and perhaps to most citizens of this age.

Clearly we do not now have the appropriate measures or tools or systems to work objectively with these questions of quality in a closed economy. Our future concerns may not be so much with market failures and externalities but with more positive approaches, one of which may be a system to measure quality and quantity balances and tradeoffs similarly to measures of energy balances and tradeoffs in the biosphere.

We will need better physical, biological and economic measures but we will need most of all to develop better measures and values of individual and group preferences for quality and of behavior with respect to limited and strange natural resources. The effectiveness of prices, which now reward or cost individuals and society directly in the market economy, may be reduced should the spaceship economy materialize or even if the grants-in-aid should become a major source of funds for public goods and the latter is practically a certainty in the near future.

Mr. Boulding's second contribution to this area of market modifications suggests that there is developing a "grants economy" in which market forces, especially prices, are not effective allocative devices.[1] There is apparently a developing grants economy but specific proposals of how to cope with the problems created in the market system are quite scarce. It seems that, by default, we may allow the grants economy to discover its own way of operating within the market economy with respect to questions of efficiency and distribution.

These grants-in-aid could be used to alleviate or reduce the seldom considered but potentially controversial questions of rights and equity of polluters versus non-polluters. We are inclined to consider pollution as an economic bad in which polluters are the agressors and imposers against extractors or users individually and society collectively. However, consider the question of whether or not extractors and users of clean air and water may not in fact be imposing on those who wish to discharge effluents to the air and water. Surely under prior appropriation doctrines polluters could establish use rights. At this stage grants-in-aid could be useful devices to purchase, within a flexible market system, either pollution or extraction rights and no substantial market modifications are necessary outside of the existing public use powers such as condemnation which may be necessary to attain appropriate economies of scale in water supply and treatment operations. It would be appropriate to note the thoughts of alternatives to increasing grants-in-aid and government involvement are occasionally in men's minds.

Professor Stigler (5, p. 9) wrote in 1961 that, "we have accepted the desperate faith that only government can solve our problems." Furthermore, "if the government does a thing badly, give it more money, more men and more power - and more duties." Professor Stigler was less concerned with the problems of externalities, market imperfections and limited local tax sources for public goods and more concerned with "the principle that the good society gives each individual...priority of individual freedom and responsibility."

Federal grants-in-aid are constant threats to local control, local responsibility and local decision making. This could be a net advantage in Mr. Boulding's closed, spaceship econosphere of the future or in those present circumstances where individuals and local governments are obviously less wise than federal administrators with respect to air and water quality matters and other pressing needs. This presumes omniscience on the part of the grant administrators.

The principle fallacy underlying the increasing demands for larger grants-in-aid for more numerous purposes is that belief that everyone can get more money for local uses through grants-in-aid than from local taxpayers directly. A second fallacy of excessive dependence on grants-in-aid is the frequent unwillingness or inability of grant program administrators and grant terms to distinguish between legitimate needs for services and selfish desires for a fair share of the grants, nor among community differences in needs and abilities.

The market system, through price incentives, readily distinguishes between needs and desires on the basis of willingness and ability to pay. Should grants-in-aid become a significant source of funds for local environmental quality management communities must either accept the amorphous result or develop non-price criteria for differentiation. Benefit-cost and cost effectiveness analyses have been proposed and are used but these are in large measure dependent upon an operating market and price system for input and output values. This approach attempts to adapt the grants economy to the market economy with significant modifications to the market system.

It would be possible to allocate grants for air and water quality control on the basis of; (1) the expressed desire of the community as registered by referendum for a specific project, specific grant, funds and specific grant terms, and (2) the expressed ranking, again by referendum, of need priorities within the community for all grant-in-aid programs and for all non-grant needs. Expressed preferences would be a much better substitute for or aid to the price system than the present allocations on the basis of the political leadership preferences or the mere existence of a knowledgeable grantsmanship staff to prepare requests and proposals which win grants. Presently, many grants-in-aid are acquired by the political leadership without the consent of and often without full disclosure to the local citizens on matters of great concern to the local citizens. How often do local citizens consent by direct referendum to the acquisition of federal grants for planning, for airports, for community facilities, for model cities, for urban renewal or for other grant programs? Local citizens are most likely to be urged to obtain the maximum amount of federal grants without regard for absolute or relative needs or consequences. <u>The Texas Water Plan</u> (6, p. V-7) suggests "...that the federal government <u>should</u> and <u>would</u> finance the entire Texas Water System." Furthermore, "it is proposed that a clean water fund be established...to abate and prevent pollution and to also maximize the amount of federal grant funds that may be obtained by Texas" (6, p. V-10). Would this same attitude prevail within a market system dependent on local tax funds only for these purposes or even with a surrogate for the price system in the form of a public preference referendum for either local or grant funds?

Effects of Grants-in-Aid

Federal grants-in-aid and direct expenditures produce the same effects on local economies when expended under similar conditions. There is no evidence to support claims of differences in either efficiency or distribution on the basis of whether funds were grants or direct expenditures. Federal expenditures (grants and direct investments) may be made for one or all of the following purposes:

1. promote regional economic development,
2. enhance general economic development or activity,
3. change the distribution of welfare,
4. meet the direct consumption needs of the federal government.

Grants-in-aid are usually directed to the first three purposes. Presently available measurements are not convincingly accurate with respect to the degree of success attained by any expenditure for any or all of these purposes.

Grants may result in an erroneous decision with respect to use of local funds when grants are for specific purposes such as a sewer system when education would yield a higher return (to local and federal funds) or when education has a higher subjective priority in the absence of federal grants. This phenomenon may lead to overbuilding and over investment in federally financed projects at great expense in terms of foregone alternatives.

Haveman (2, pp. 118-124) concludes that grants (expenditures) to inefficient purposes or projects are detrimental to the nation and to the recipient. If the federal purpose of a grant is allocation of income then grants to projects which are economically inefficient are also less efficient in obtaining income transfers than both the more economically efficient projects and direct transfer payments.

Haveman (9, p. 52-155) further suggests a list of criteria which may be used to allocate grants to attain various degrees of equity among recipients.

These criteria include the distribution of grant funds to groups or areas for water supply and water quality improvements:

(1) in proportion to total federal taxes paid,
(2) on a straight per capita basis,
(3) on a welfare need basis,
(4) on a prior appropriation basis through funds exhaustion,
(5) on a patronage or pork barrell basis.

These suggested distribution criteria avoid completely the usual market measures of willingness and ability to pay through various user charges and the real demands for water and air pollution control as opposed to imagined needs on the knowledge that grants are available. This approach to grants distribution and measurement of success or failure, if followed, does not require any market modifications since the market system is ignored as a potential indicator of the demands for these public goods.

Kneese and Bower (10, pp. 71-76, 173-292) have been more specific in recommending conditions of efficiency and distribution for optimizing grants or investments in water quality improvements. They also recommend specific approaches to accomplish water quality objectives in the forms of (1) regional facilities and management to attain economies of scale, (2) a system of subsidies and/or user charges in lieu of costly effluent standards, enforcement actions and litigation and (3) a continuous management system to adapt new technology to water and air quality problems, including changes in settlement patterns to better use the natural assimilative capacities of the air and water.

It is an important point that research scientists such as Kneese, Bower, et. al. agree in principle and application with some members of the political community such as the Advisory Commission on Intergovernmental Relations. This means that these ideas could become elements of active policy very shortly even with some opposition from local governments which do not favor the regional approach to water quality management proposed by the Scientists and the Advisory Commission.

Current Status of Federal Grants-in-Aid

Presently, the Federal grants-in-aid are quite small relative to the total Federal budget, about 10 percent of the total, but growing (Table 1). Federal grants and shared revenues to state and local governments for water quality improvements comprise less than 3 percent of the total of all grants - about 563 million dollars in 1969 (Table 3). These grants are expected to increase substantially to meet the needs specified by the Federal Water Pollution Control Administration, especially if additional funds should be released from defense purposes.

The Federal Water Pollution Control Act as amended by the Water Quality Act of 1965 (P.L. 89-234) required that the Secretary of the Interior "...Make a comprehensive study of the economic impact on affected units of government of the cost of installation of (effluent) treatment facilities, and a comprehensive analysis of the national requirements for and cost of treating municipal, industrial and other effluent to attain such water quality standards as established pursuant to this act..." (7, p. 1). Economic impact was defined as (1) the estimated dollar amounts necessary for state and local governments to finance the structures and programs to attain the specified water quality standards and (2) an evaluation of the ability and willingness of state and local governments to secure these funds.

The capital costs of providing sewage treatment plants and sanitary collection sewers to meet the water quality standards during the period 1969-1973 were estimated to be $8.2 billion and $6.7 billion respectively by the Federal Water Pollution Control Administration. P.L. 89-234 authorized the federal government to provide up to $3.5 billion as grants-in-aid and direct expenditures for the capital costs of the waste treatment facilities. Nationally, additional grants-in-aid are available under various regional and community development types of legislation. The federal government with present spending rates on programs for water quality improvements of about $0.5 billion per year with the maximum authorized spending of $3.5 billion under P.L. 89-234, could defray about $6.0 billion of the estimated $14.9 billion of capital costs required for sewage collection and treatment between 1969 and 1974 (7, pp. 2-9).

The federal government can grant up to 55 percent of the capital costs of urban waste treatment facilities if state governments contribute a minimum of 25 percent of the costs. Local governments provide as little as 20 percent of the capital costs for these facilities. These ratios of expectations of 70 to 80 percent federal grants or loans are born out by results in other programs. Federal funds now comprise about 13 percent of all state and local revenues (Table 2). Furthermore, many individual projects and programs are almost entirely funded from federal sources while others, such as federal aid highways receive more than three-fourths of the expenditures from federal grants. Community desires for projects and programs are rapidly expanded when these federal grants-in-aid are readily available to defray the major portion of the costs. The preferences for projects with large federal grants-in-aid arise even within communities and for projects (such as water and sewer systems) where very nominal and equitable user charges would recover capital and operating costs at or above market rates of discounts. This means that it is financially feasible, through reasonably equitable user charges, to construct many water quality improvement projects, even in relatively low density areas, with funds from the private capital markets. However, the federal grants-in-aid will quite certainly speed up water quality improvement projects and allow communities to shift priorities for local public funds to competing uses which are not heavily funded from federal sources.

Community willingness to accept federal grants-in-aid for water supply and effluent disposal facilities, both of which could be self-liquidating from user charges, was illustrated from research on municipal financing of these systems in rural communities of Georgia. Waldas (10, pp. 92, 99 found that 83 percent of the municipalities in Georgia had financed water supply and effluent collection-treatment facilities from 1946-1966 through the issuance of revenue bonds and certificates and general obligation bonds at a mean interest rate of 3.87 percent. Repayment records were perfect. However, 57 percent of these communities which planned new or expanded systems in 1967 were expecting to acquire funds from Federal grants and loans and only 27 percent planned to issue revenue or general obligation securities.

This research also confirmed that prevailing interest rates for these small, unrated communities were approximately 1.0 percent higher than generally prevailing rates for municipal issues rated by Moody's (10, p. 64). Fifty-seven percent of the municipal issues for water and sewer facilities in Georgia were for less than $100,000. Proponents of expanded federal grants for water supply and quality management cite these conditions, i.e., high interest rates for small, unrated communities and the presence of large economies of scale for these facilities, as adequate justification for grants on both equity and efficiency criteria.

The available evidence points to increasing levels of grants-in-aid to state and local governments for water and air quality improvements. Furthermore, it seems that pressures are being increased by scientists, professionals, citizens and some local government officials to shift Federal grants for existing government units to quasi-governmental commissions, authorities and organizations, all supra to existing governmental entities with respect to a specific function only. For example, a river basin commission established for water quality improvement purposes would transcend the affected local government only for water quality management issues.

If we continue to adhere to an econosphere in which production, consumption and prices are the tools of measurement for both efficiency and distribution we must become more adept at integrating the grants economy into this market system through expanded benefit-cost analyses. These expanded benefit-cost analyses should use the latest techniques of input-output and systems analysis to include both local and national goods and bads in the analysis.

If we wish to ignore the market system in the grants economy we should work to allocate grants on compromised bases for efficiency and equity. One alternative would be a superagency for the specific purpose of allocating grants on the basis of a weighted set of criteria to include among others:

(1) past performance with local and grant funds,
(2) ability to pay based on relative wealth,
(3) willingness to pay based on relative efforts and/or tax contributions,
(4) an objective (dollar value) and subjective (need contention) justification for funds,
(5) evidence of the expected contribution of the grant to the national economy,
(6) evidence of local preferences for each specified project for which grant funds are requested.

It is unlikely that we will disregard the grants economy and return to market system provisions of state and local utilities such as water and air quality conditions. It is also unlikely that the near future will see direct Federal expenditures for air and water quality improvements replace the system of grants and some local sovereignty with respect to project initiation and management. Additional emphases must be placed on developing measurement devices for evaluating the goods and bads associated with a grants economy which does not now consider the full range of alternatives and furthermore does not adequately reflect local preferences for either benefits or costs. These local preferences both benefits and costs could be approximately learned through a referendum system similar to that currently used for other local issues such as schools or streets.

Table 1. Direct Federal Expenditures, National Income Accounts, and Grants-in-Aid to State and Local Governments, 1930-1969

Categories of Expenditures	1930 1939	1940 1949	1950 1954	1955 1959	1960 1964	1965 1969
	(billion dollars)					
Total Expenditures	NA	NA	323.0	410.8	524.0	761.4
Annual mean	7.0[a]	49.7[a]	64.6	82.2	104.8	152.3
Grants-in-Aid, Total	NA	NA	13.2	21.5	39.5	77.0
Annual Mean	0.7[a]	1.1[a]	2.6	4.3	7.9	15.4
Percent of expenditures	10.0	2.2	4.1	5.2	7.5	10.1

[a]Based on incomplete annual data.

Sources: Statistical Abstract of the United States, annually for data after 1955. Historical Statistics of the United States, Colonial Times to 1957, Series Y357-714 for data before 1955.

Table 2. State and Local Revenue from all Sources and from the Federal Government, for all purposes, 1930-1969

Sources of Revenue	1930 1939	1940 1949	1950 1954	1955 1959	1960 1964	1965 1969
	(billion dollars)					
Total State and Local Revenue	NA	NA	NA	228.5	344.7	463.5
Annual Mean	9.2[a]	15.4	31.4	45.7	68.9	92.7
Total From Federal Government	NA	NA	NA	21.6	40.6	60.4
Annual Mean	0.7[a]	1.1	2.7	4.3	8.1	12.1
Percent from Federal Government	8.2	7.1	8.7	9.4	11.8	13.0

[a]Based on incomplete annual data.

Sources: Statistical Abstract of the United States, Annually for data after 1955. Historical Statistics of the United States, Colonial Times to 1957, Series Y357-714 for data before 1955.

Table 3. Federal Grants-in-Aid and Shared Revenue to State and Local Governments, 1939-1969

Category of Expenditure	1930 1939	1940 1949	1950 1954	1955 1959	1960 1964	1965	1966	1967	1968	1969
	(Million dollars annually)									
Total	749	1,095	2,722	4,310	8,122	10,904	12,960	15,240	18,362	20,297
Agriculture	---	---	---	---	532	518	369	448	599	644
Rural water and waste disposal*	---	---	---	---	0	0	1	11	27	34
Housing and Community Development	---	---	---	---	426	559	626	768	1,185	1,813
Water sewer and neighborhood facilities*	---	---	---	---	0	0	0	7	105	162
Natural Resources, Total	---	---	---	---	272	298	345	390	498	617
Waste treatment works and pollution control*	---	---	---	---	62	75	89	99	140	191
Watershed protection and flood prevention*	---	---	---	---	57	58	69	72	77	69
Fish and wildlife restoration and management*	---	---	---	---	20	20	22	23	25	32
Land and water conservation fund*	---	---	---	---	1	1	3	22	56	75
Other grants	---	---	---	---	132	144	162	174	200	250
Total water quality improvement type grants*	---	---	---	---	140	154	184	234	430	563
Percent of all grants	---	---	---	---	1.7	1.4	1.4	1.5	2.3	2.8

Sources: Statistical Abstract of the United States, Annually for data after 1955. Historical Statistics of the United States, Colonial Times to 1957, Series Y357-714 for data before 1955.

FOOTNOTES

1. The importance of the grants economy was discussed by Mr. Boulding and others during an open panel discussion at the Southern Economics Association Meeting, Washington, November, 1968.

BIBLIOGRAPHY

1. Kenneth E. Boulding, "The Economics of the Coming Spaceship Earth" in Henry Jarrett (editor), Environmental Quality in a Growing Economy, Johns Hopkins Press, 1966.

2. Robert H. Haveman, Water Resource Investment and the Public Interest, Johns Hopkins Press, Baltimore, 1965.

3. Allen V. Kneese and Blair T. Bower, Managing Water Quality: Economics Technology, Institutions, Johns Hopkins Press, Baltimore, 1968.

4. C. Northcote, Parkinson, Parkinson's Law or the Pursuit of Progress, London, John Murray, 1957.

5. George J. Stigler, "Private Vice and Public Virtue," The Journal of Law and Economics, 4:1-11.

6. The Texas Water Plan, The Texas Water Development Board, Austin, Texas, 1968.

7. ——————— The Cost of Clean Water: Economic Impact on Affected Units of Government, Federal Water Pollution Control Administration, United States Department of the Interior, Washington, 1968.

8. ———————"The Advisoy Commission on Intergovernmental Relations," Circular M-17, Washington, 1968.

9. ———————"Revenue Sharing..." Wall Street Journal, Dow Jones Publishing Co., New York, April 21, 1969.

10. Hqward Waldas, The Financing of Small Municipal Water Systems in Georgia, M.S. Thesis, University of Georgia, Athens, 1968.

CONTROL - LAWS AND REGULATIONS - PROPERTY RIGHTS

Gordon Tullock
Department of Economics, Virginia Polytechnic Institute

As I suppose all of you know, I am an amateur economist. My formal training was in the law and in Chinese and my knowledge of economics has been picked up casually and on my own. One of the early landmarks in my study of economics came while I was studying Chinese at Yale University. I saw a large book entitled Human Action, and subtitled A Treatise on Economics. Although I had never heard of its author, I bought it and read it with great profit. My particular point in bringing it up today is not the general merits of the book, but the fact that it was there that I was first introduced to the concept of external economies and external costs. In a way, by reading this book in 1950, I got ahead of the bulk of the economics profession. Externalities, it is true, had been discussed before, but they did not play the gigantic role in economics discussion then that they do now. In fact, I recall a long discussion in 1956 with a friend of mine who had just taken a Ph.D in Economics from the University of Chicago in which I discovered he had never heard of externalities at all.

The present rate of concern with externalities does not involve any great improvement in our theoretical position on these matters. In fact, the few pages presented by Dr. Von Mises in Human Action are still a perfectly good, a perfectly modern statement of the theory; in fact it has been reprinted unchanged in the third edition. The change has come with the realization of just how important these problems are and in particular of just how important they are for decisions as to whether or not we should have governmental action in any particular area.

I have written a good deal on this subject elsewhere and would like to turn to a different matter here. One of the interesting characteristics of the economics of externalities is that it tells us a good deal not only about government activities but also about property itself. In order to discuss the matter simply, I would like to turn back to the 19th century and consider the situation when they first began to drill for oil. At the time, little was known of the geology of oil; but we now know something about it, and I have drawn in a cross section of the situation which they encountered. Under the ground there was an oil pool, probably fairly large compared to the size of the farms above the ground. I have indicated the pieces of land and the boundaries between them by the vertical lines in the surface. Under the common law, as it existed at that time, the owner of a piece of property owned the surface and a wedge shaped piece of land directly under the surface all the way to the center of the earth and a gigantic expanding wedge out to the "farthest star above his land." These legal prescriptions as to what a person who owned land actually owned may have been more a matter of romantic terminology than anything else to the English judges who originally stated them, but nevertheless that is what the law said. There is no doubt that anyone in those days would have felt himself very seriously and quite rightly aggrieved if anyone had prohibited him from digging a hole into his land.

Nevertheless, if I put in oil well A, I would be pulling oil not only from directly under my own piece of property but from under neighboring pieces of property. The same would be true of oil well B. The only practical way in which the other property owners could prevent me from drawing oil out from under their property would be to put wells down of their own and thus exactly counterbalance my withdrawals by withdrawing themselves. This clearly would not be a very efficient way of using the oil. For one thing, you couldn't conserve it; secondly, for various reasons having to do with gas pressure and the method in which the drills were driven, the actual total product of the pool if it is handled by a large number of people who have driven individual wells into it is only about 20% as great as its total technological product if it is managed as a unit.

These are things which were not known definitely to the judges and legislators of the days when oil was first discovered. Indeed, even today there are great mysteries about oil. No one has any clear idea as to its origins, for example. In the late 1800's it was thought that the oil was either some kind of an underwater stream or a pool, and very early it was realized that wells pulled oil not only from directly under the land in which the oil well was drilled but from under its neighboring pieces of land. At this point the courts and the legislatures were faced with a very difficult problem, and I do not think we can blame them for having reached a very poor solution. They had very little in the way of reliable scientific advice, and for that matter the correct solution to this particular problem from the standpoint of pure economics has only been discovered relatively recently.

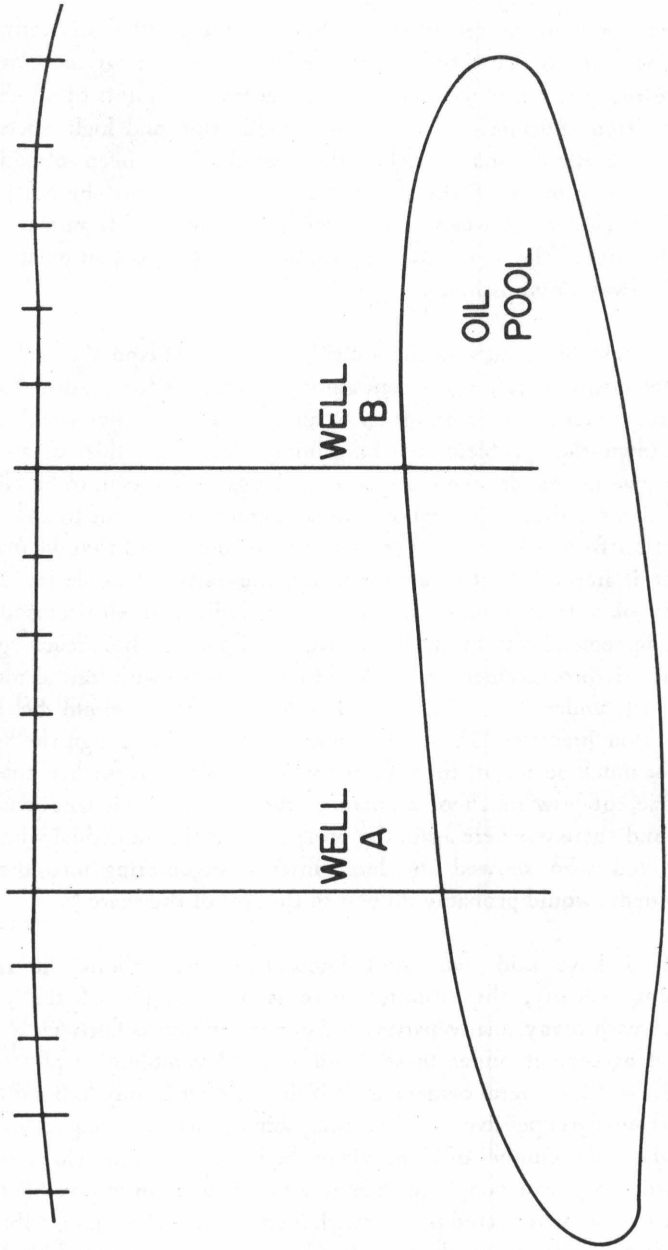
There were a variety of things they could do. Firstly, they could try to guess how much oil well A was pulling out from under the plots of land adjacent to it and require the owner of well A to compensate the owners of these plots. This in the state of geological knowledge available in those days was impossible, and I suspect it would be impossible in the state of geological knowledge which we have today. A second thing they could have done was to have simply impounded all oil pools; changing the law so that the state owned all the underground resources. This presumably would have required some kind of condemnation proceedings and would have been extremely expensive. Further, it would have been extremely difficult at that time to make any real estimate of the value of the undergound resources and hence the payments would have probably been either greatly in excess or greatly less than the actual value of the oil. Nevertheless, this was a possibility.

A third thing they could have done, and something clearly which they didn't think of (in fact it wasn't thought of by anyone until rather much later) was something that was done by private entrepreneurs in the dryer parts of the west. Many desert areas have underlying them water pools which can be used to irrigate the land. In general, the desert area was available in very large plots to an enterpreneur who wished to buy it. A businessman, therefore, would buy a very large tract of land, enough to completely cover or almost completely cover an underlying water pool. He would then separate the ownership of the water from that of the surface. He would create a corporation which owned the water for each plot of land he sold on the surface he would attach one share of stock in the corporation. Thus, he obtained unified control over the water supply and divided control of the surface. Forcing the people who owned land over the oil pool to enter into such a corporation might well have been a sensible idea. In fact, in recent years the State of California actually considered a constitutional amendment which would have done just that. Unfortunately, it was voted down. But again, I cannot see that the courts are to be terribly blamed for not trying this particularly difficult operation.

In fact, what the courts and legislatures did was to adopt what they called the "wild animal law." Under the common law a wild animal belongs to the owner of the property on which it is found. They held, by analogy, that oil would belong to the owner of the property on which it was extracted. This meant that in essence anyone could drill a well and pull oil out from under his neighbor's property and everyone was motivated to build as many wells as he could on his property and run the oil out as fast as possible. This was a wholly unfortunate decision, but it is easy to see how the courts and legislatures fell into it.

This decision naturally led to gigantic waste. The wells were run without any concern at all for the future, because if I saved oil in my particular property, this simply meant that my neighbor would draw more oil out. The result was a set of conservation laws and what amounts to a

Verticle Cross Section of Oil Pool



government operated cartel with the Texas Railway Commission acting as the principal cartel manager. It has all the disadvantages of the cartel and does not even obtain technical efficiency because the number of wells partially determines quotas. Therefore, most people put down far more wells than they are really required to remove the rather small amounts of oil which they are permitted. Further, it has meant cartellization and high prices for the consumer; certainly much higher than would have been obtained from rational management of the pools. Nevertheless, it must be admitted that granted a choice between extraction under the wild animal rule and extraction under the Texas Railway Commission's aegis you must prefer the Texas Railway Commission.

It might be asked why the individual holders of land above the pool did not enter into a private agreement among themselves for a rational allocation of the oil resources. This brings us to an area of economics which is not too well known–the problem of bargaining. Although this is an area of comparative ignorance, there are certain things which seem to be fairly clear. One of them is that in general obtaining unanimous consent to any economic proposition from a large number of people is so difficult that we may as well consider it impossible. Characteristically, the early oil pools lay under the property of a great number of people. Any individual who refused to enter into an agreement with his neighbors would, if his neighbors reach agreement, reap gigantic profits since he would be permitted to withdraw as much oil as he wished under the wild animal rule, and they would be following conservation practices. Thus, the person who refused to sign the agreement would be much better off than if none signed. There was further, the problem of course, of how much of a share in the oil well each landowner would obtain and there was here again the prospect that the individual who held out longest and who showed the least interest in entering into the pooling arrangements would probably do best in the size of the share.

As I have said, we don't know too much about the theory of bargaining. Clearly, the situation here is an example of the prisioner's dilemma with many, many parties and our experience is fairly clear. You just can't get agreement under these conditions. "Assembling" a plot of ground which is held by several owners, even if the number is only half a dozen or so is an extremely expensive and time consuming process. Trying to do the same thing where the number of owners is in the hundreds would characteristically be regarded by most people in the real estate field as an impossible task. This fact, of course, is reflected in the much higher prices that can be obtained for large plots of land which are already under one ownership. Generally speaking, the price for which some suburban householder can sell his house and lot is very much less than 1/100th of the price he could obtain for a solid plot of land a hundred times as large as his house.[1]

What we have been discussing so far, which seems fairly simple and straightforward, is an example of a rather strong externality. An externality occurs when some individual's action or the action of some individuals who have entered into a contract among themselves affects the utility of others. As Dr. Von Mises explains: "The legal concepts of property do not fully take account of the social function of private property." There are certain inadequacies and incongruities which are reflected in the determination of the market phenomena.

Carried through consistently, the right of property would entitle the proprietor to claim all the advantages which the good's employment may generate on the one hand and would burden him with all the disadvantages resulting from its employment on the other hand. Then the proprietor alone would be fully responsible for the outcome. In dealing with his property he would take into account all the expected results of his action, those considered favorable as well as those considered unfavorable. But if some of the consequences of his action are outside of the sphere of the benefits he is entitled to reap and of the drawbacks that are put to his debit, he will not bother in his planning about all the effects of his action. He will disregard those benefits which do not increase his own satisfaction and those costs which do not burden him. His conduct will deviate from the line which it would have followed if the laws were better adjusted to the economic objectives of private ownership. He will embark upon certain projects only because the laws release him from responsibility for some of the costs incurred. He will abstain from other projects merely because the laws prevent him from harvesting all the advantages derivable.[2]

Oil is clearly a case in which the laws with respect to real estate as they existed at the time that oil was discovered were extremely inappropriate to this recourse. A new externality had been discovered, and changes in the law were desirable. Unfortunately, instead of changing the law we set up a regulatory commission. The regulatory commission was, no doubt, better than leaving things as they were under the existing law, but this is saying very, very little. What we see here is that the laws which we have with respect to property themselves are not a fixed, unvarying, and perfect structure. Frequently, they should be changed. Changes can come from innumerable causes (we will discuss more later) and are basically simple responses to the necessity of minimizing the number of externalities. I should say, parenthetically, that it is impossible to design a property law which eliminates all externalities and hence the state will always have a role in dealing with those externalities which cannot be dealt with by property rule. It surely also has an important role, however, in defining and periodically changing the laws of property.

Let us, however, before turning to discussion of possible changes in the law, consider another externality–a very recent one. A short time ago I was visiting a small and rapidly growing town in a dairy farming area. I visited an apartment of a friend on the outskirts of the town and discovered that upon looking out of his window I found a pasture with a couple of trees located in the near foreground and a wooded hill in the background. It was winter, and I commented to him that the view must be very beautiful in the summer. He replied that this was so, but in warm weather there was a rather serious difficulty. The field was used as a pasture by a nearby dairy farmer, and the cows had the tendency to congregate in the shade of the two trees directly under his window. Congregating there, they unfortunately brought with them a cloud of flies which proceeded to cause various annoyances for my friend.

Here, clearly, we have a new externality. A hundred years ago no one would have noticed that keeping livestock caused flies for the neighbors because substantially everybody kept livestock and standards of sanitation being what they were flies were very common in any event. Today; most cities have laws against keeping livestock within city limits, except under very, very stringent conditions. As a result of these laws, most people do not keep livestock and the odors and flies are not inflicted on their neighbors. This new externality developed almost entirely as the result of changing tastes. We have simply become more sanitary for a variety of reasons than we used to be. Furthermore, it is very hard in this case to see how the laws of property could be adjusted to take care of the matter. One could hardly prohibit flies from flying across the boundary between two pieces of property. Laws prohibiting people from keeping livestock in cities are probably the appropriate solution.

It should be noted, however, that there is another way of dealing with the problem and which I observed in one rather expensive California suburb. In this particular suburb most of the people were living on one to two-acre plots and apparently it was socially required to keep horses. There were, however, very few flies, and there was very little in the way of odor from the horses. The reason was simply that under modern circumstances people who were very well off as the people in this suburb were had the technological possibility of keeping both flies and odors down in their own property if they were keeping a horse. They had a very strong motives to do so because, of course, the flies and odors would affect them more than their neighbors. As a result of this, as I say, practically everybody kept a horse, and there was practically no externality. In an area where the individuals were not as well off as these were, anyone keeping a horse might have been quite a nuisance to his neighbors because keeping the fly population down is very, very difficult. Thus, we have a case in which we begin with no externality because people don't notice flies, proceed to a situation in which there is substantial externality because people do worry about flies, and then finally to another situation where it is technologically possible to abolish the flies and therefore the keeping of livestock does not create an externality. Clearly, this is a case in which the laws should be changed to keep the individuals at the top of their preference mountain.

It should be noted however, it may be possible to deal with this kind of problem by a form of private contract rather than by law. Characteristically a man starting a new real estate development will be aware of the fact that he can sell his land for more to potential house owners if he takes care of the various externalities. He will, therefore, normally put into the deed a number of restrictions as to what can be done on the property. This makes his purchasers happier than they would be without the restrictions, not because each purchaser wants to be restricted himself, but because he prefers to be restricted himself if his neighbors are restricted to having both himself and his neighbors unrestricted. Unfortunately, these restrictions tend over time to become out of date. There is continuing change in the technology with which we live, and hence continuing change in what types of externalities we must deal with. It seems not impossible for real estate developers to put in their contracts a provision not only that the individuals are restricted in what they can do, but that these restrictions can be changed in some way so as to keep up with the changes in technology and taste.

But note, when we are saying this we are saying that private persons might be interested in establishing on their own some "government-like" institutions. Zoning, for example, could have been undertaken privately in this manner. The fact that we observe in some areas that this type of problem is taken care of by government regulation and in other areas it is taken care of by covenants in the deed, simply indicates the history of the plot of land. In those cases where the plot of land was originally obtained in a very large block for its present use, a covenant is sometimes sufficient. But in those cases where a change in technology has occurred after the land has been divided up into small plots, so that any effort to enter into a private contract to abate some particular externality would require unanimous consent and hence run into the impossible bargaining situation, there we customarily find a governmental agency imposing some kind of rule which is intended to minimize externalities. It is unfortunate but true that government agencies in carrying out their job of reducing externalities very frequently do a very bad job. Nevertheless, on the whole we are better off with these inferior rules reducing externalities than simply permitting the externalities to continue to exist. Further, in general government action with respect to externalities will be most efficient if they can think of some way of changing property law so as to "internalize" the externalities rather than impose direct regulation. Unfortunately, in many cases this is difficult or even impossible. Further, again unfortunately, government agencies are not too ingenious and hence frequently do not exploit the possibilities that do exist. And in any event there would be some cases in which it is impossible to design the law in such a way that the full costs of activities undertaken fall on the people who undertake them.

The most obvious cases of this type of difficulty of course concern air and water pollution which are so much in the news these days. In these cases someone [let us take the classical case and assume a factory which has a smoking chimney] is imposing some cost on other people [in the classical case housewives who wish to dry their laundry in the open]. Note that both the smoking chimney and laundry drying on the line are becoming things of the past with the development of technology. Nevertheless, the same problem continues to exist in different forms, and we may as well stick to the classical statement. Under these circumstances we could, I suppose, pass a law making it a trespass if any smoke or other impurity is added to the air on someone else's property and then blows on my property. The problem with this is that if we make it <u>any</u> impurity in the air, we simply abolish all use of mechanical power. We also abolish breathing. Most people don't notice the fact that they change the composition of the air somewhat by breathing, but they do; and if we completely ban air pollution, the ban would cover breathing.

The actual idea that most people who talk about pure air have in mind is more or less that traditional generators of impurities in the air may be continued to exist, or, perhaps, that some low maximum limit will be imposed. Thus, I am permitted to trespass on my neighbor's property by dumping pollution upon it up to some particular amount. Clearly, one can only have a political decision as to what amount will be permitted under this system. Nor is there any reason why we should be terribly upset about that fact. Designing and enforcing a law under which all pollution released into the air is trespass against the people over whose land the air is blown clearly would be impossible. We must restrain ourselves to simply putting some kind of upper limit on this particular externality. Naturally, the same applied to other types of air pollution, to water pollution, and for that matter to such things as simply making loud noises at three o'clock in the morning.

In this case, however, it must be pointed out that although we can control this type of externality by laws which simply prohibit generating more than a certain amount of whatever it is we are trying to restrict, the much more efficient procedure is to put a tax upon it. The law restricting air or water pollution has the disadvantage that there are some activities where the reduction in pollution is very, very expensive and others where it is relatively cheap. A tax (let us say, we put a meter in every smokestack and charge the factory owner so much per cubic centimeter of each type of pollution) will take care of this. Those factory owners who produce the type of pollution which is relatively easy to get rid of will get rid of it, and those who produce the type of pollution that is very hard to reduce will not. By choosing the tax level appropriate we can reduce pollution to any desired degree. Further, at the same time we obtain a revenue for the government, which in this case is obtained through restricting the production of something we don't want produced. Most taxes are unfortunately on things we would like to have produced. Thus, the tax in addition to bringing in revenue to the government reduces the total production of the economy in some way. A tax on something we don't want has the contrary effect, and in fact in many ways is a tax which actually confers benefit on society.

So far, this afternoon I have been discussing something which in a way is an unfortunate phenomenon. It is too bad that we cannot simply let the property institution operate in a relatively unsupervised way. Due to the existence of external costs and external economies we cannot. What we can do is to attempt to use the law in such a way as to make the property system work better rather than to impede the property system. This will involve, in some cases, changing the law in order to put all the costs and economics from some activity falling on the person who originates it. Now we should note that when we talk about changing the law of property, we are by that act itself generating an externality. If we are thinking of changing the law of property in the near future, then the person who buys land today is somewhat less secure in his purchase than he would be if we did not have this in mind. Thus, any program for changing the law of real property, and it must be admitted that we change it all the time in minor ways, must include in it some provision for full compensation for the people when the law of real property is changed. In essence if we decide that individuals should not own all the oil under their land because this leads to inefficient operations and that we are going to compel them to form a corporation, we should be prepared to pay them any costs they may incur as a result of this. As a matter of fact in this particular case they would not incur any net costs. The law change would not lead to any great advantage to them. In fact, you might rationally tax them very heavily in return for imposing this change in their property.

There are, however, many other cases where this would not be so. Let us suppose we return to my example of the dairy farmer whose cows inflicted flies on his neighbors. Clearly, a law prohibiting him from keeping cows from within, let us say, 200 yards of his boundary with the apartment complex would be a reduction of the value of the property to him. But note that the enactment of this law would benefit the owners of the apartment buildings. It is generally true that any law change which reduces the amount of externality will confer greater benefits than the costs which accrue from it. This in fact is a necessary precondition in welfare economics for the law being desirable. In the particular case of the oil wells, the people who benefit from the change in institution and the people whose property rights are changed in a negative way are the same people. Thus no compensation is necessary because the beneficiaries and losers are the same and the benefits are greater than the losses.

In those cases, however, where the people who benefit and the people who lose are different, then some kind of compensation procedure should be worked out. As a matter of theory, it should always be possible to put a special tax on the beneficiaries and use it to pay the cost to the losers. If there is a genuine welfare gain, it should make both of them better off. Thus, we can imagine a special condemnation proceeding which required the farmer to move his cows back 200 feet from the fenceline in return for some payment and a special tax on the apartment house owner to make this payment. In those cases where there are just two parties (my farmer and my apartment house manager) it is probable we would be better off to leave them to make their private bargains between themselves. If, however, there are many parties involved then the bargaining costs become too high.

There still is, however, a method not in general use in the United States, but which might be successful. The government could decide (roughly speaking) who would benefit and who would be injured from some proposed restriction on the use of property in some way. It could, then, announce some scheme for transferring money from the people who gain to the people who lose. The whole package could then be presented to a special election composed only of the people who are to pay the tax or to receive the benefits. There are clearly difficulties with this solution, but it seems to me that we should at least experiment with it. So far as I know, it has never been tried, and I suspect that if it were tried we would find that a great many people who now complain about such things as air pollution and water pollution would prefer the pollution to continue to paying their share of the cost of its abatement. However, this is simply an expression of my opinion, and is not the result of any empirical study.

In summary, the problem of externalities is a very difficult one. It does affect our property institutions in a very significant way. Designing optimal property law and appropriate legal restrictions on those externalities which cannot be taken care of in the property law is an extremely difficult task. For this task we need a good knowledge of economics as it now exists and a good deal of research to make our knowledge of economics better than it is today. It is unlikely that we will ever end up with a perfect solution to the problem. Nevertheless, we can clearly do much better than we do today. Among the improvements in our present practice is the improvement of the property law. It is unfortunate that this particular expedient is rather rarely adopted by the enthusiasts for elimination of various types of externality.

FOOTNOTES

1. This, of course, assumes that the plot is located where some kind of large scale use of land is rational, say at an intersection where a shopping center might pay.

2. Ludwig Von Mises, Human Action: A Treatise on Economics, (New Haven: Yale University Press), 1949, p. 650-651.

COST-BENEFIT ANALYSIS: SELECTED ISSUES

Roland McKean

Department of Economics, University of Virginia

Before taking up the particular issues that I am supposed to examine-the estimation of "subjective benefits" and costs inflicted on "other economic entities"--I wish to review the basic criterion problem of cost-benefit analysis. It seems to me that it is essential to recall the general difficulty of measuring costs and benefits before examining the particular difficulties of estimating special types of costs or benefits.

The basic criterion difficulty is that of valuing the inputs and outputs--the disadvantageous consequences and the advantageous consequences--of a proposal. This criterion problem is insoluble in the sense that, while we can individually attach values to a project's consequences, logic does not require anyone else to agree with our individual valuations. The reason is that there is no criterion or set of valuations that is necessarily correct from the standpoint of all members of a group. For individual A there is nothing inherently correct about (1) the policies preferred by individual B or the values implied by B preferences, (2) the policies chosen by the majority or the values implied by those choices, or (3) the policies that emerge from a voluntary exchange process or the values that emerge from this process.

If everyone approved a voluntary exchange system, there could be agreement on the use of market prices, or simulated market prices, as the value-tags for the costs and gains. But many of us approve using compulsion or the political process instead of the market in numerous instances. Implicitly, I suppose, we have in mind some social welfare function other than one that is consistent with voluntary exchange, and thus approve the use of some implicit set of value-tags other than market prices. The trouble is that there is little reason to expect agreement on one particular welfare function and therefore on one particular set of value-tags. In short there is no inherently correct criterion from the viewpoint of all members of a group--and no inherently correct valuations of costs and benefits. We can hope for a certain amount of agreement on the use of market price-tags, but there is nothing necessarily illogical about voters, Congressmen, or officials who prefer some other set of values.

So much for the general criterion problem. When we turn to "subjective" benefits, we are in still greater difficulties, for even if we agree on market prices as the relevant measures of value, we can disagree sharply about what market prices would be for "subjective" benefits if they could in fact be marketed. For the term "subjective" benefits means to me what the economist calls "externalities" or spillover benefits–beneficial consequences that do not pass through a market and for which we therefore have no direct evidence regarding how much people are willing to pay for them. Basically all items, from eggs and shoes to music and art, are valued subjectively. Items that are marketed, however, have market prices, and individuals adjust their rate of consumption until all persons who buy the items at all attach the same value, namely the market price, to an incremental or marginal unit. If an item is not marketed–as is the case with most noise-and-smog-abatement, many government-produced recreational services, and many aesthetic improvements–individuals do not adjust to a market price, and the values they attach to incremental units can diverge from each other greatly. One can attempt to estimate what people would pay for the services, to use indirect evidence to derive clues and estimates, but at best these are low-confidence estimates. As Harold Demsetz has emphasized, "the" problem in governmental cost-benefit analyses is the estimation problem, the acquisition of information that can substitute for the information provided by markets;[1] and when one tries to acquire such information, it turns out to be economical to settle for comparatively low-quality information.

For example, consider aesthetic improvements, such as the removal of billboards, the construction of attractive reservoirs, the screening of unattractive views, or the development of better landscaping. One might reason that in similar projects land values have gone up by $X per acre and that one can base an estimate for the proposed project on what happened to land values in previous projects. But there are at least two major difficulties. One is that, typically, several variables in addition to the aesthetic improvement will have played a role in the growth of land values, and one can rarely have much confidence in the particular amount attributed to beautification. Another difficulty is that each proposal is unique in many respects. One recreation or beautification project may <u>appear</u> to be quite similar to another, yet subtle differences may make one a huge success and the other a striking failure in terms of the values attached to the projects' services by those persons affected.

I don't mean to suggest that no decision can be reached. Decisions have to be made, and private developers often face similar estimation difficulties. What I am saying is that heroic judgments have to enter into the estimates, and we should recognize how uncertain these estimates are and how much legitimate disagreement there may be about them.

Another possible way of assessing aesthetic values might be to consult an expert panel. In the absence of observable market prices, this method too will lead to highly uncertain estimates (even assuming, it might be reemphasized, that one is trying to simulate market evaluation). Suppose an expert panel that knew nothing about the market value of Van Gogh's pictures was asked how much people would be willing to pay for those pictures. Or suppose the members of the panel did know the market values of existing paintings and were asked to evaluate "similar" works of art by a new crop of painters. I conjecture that the variance in the estimates would be high, that disagreement would be the rule rather than the exception.

Another important example of a "subjective" benefit is recreational services. Although there may be "similar" private facilities that are bought and sold or whose services are bought and sold, yet facility is unique in location and in other respects so that the market values depend heavily on what else is located nearby, on what slight differences in weather exist, on slight differences in accessibility to population centers. As noted before, some ventures, private as well as public, succeed and others fail even though they may appear to be quite similar.

One method of evaluating recreation services that has been suggested is to estimate differences in the amounts people are willing to spend for travel to and from the facility.[2] Those who come for the greatest distance may be almost on the margin, but those who travel smaller distances, it is assumed, would surely be willing to pay up to that larger travel cost for the recreational services themselves. An attempt is made to allow for the impact of other variables (e.g., income, population, proximity of alternative recreation facilities) on what people would be willing to pay, but it seems to me that inevitably the estimates must still be highly conjectural. When I think of applying this technique to estimate how much people would pay for shoes or movies or laundry services, I convince myself that again there would surely be tremendous variance and uncertainty associated with the estimates.

Other "subjective" benefits, by which I mean consequences of public investments that may be quite important but do not pass through a market, may include impacts on law and order, equality of opportunity, economic development of particular regions, mental adjustment, personality changes, juvenile delinquency, and crime rates. Indeed such impacts are pervasive when one considers governmental policies because it is often the aim of public projects to produce effects that is not economical for free markets to produce. Each benefit of this type poses these evaluation problems, for unless we agree on market value-tags and unless there are observable market prices, one can expect sharp disagreement about the value-tags.

The measurement problem includes not merely the valuations per unit, of course, but also estimating the number of units of each consequence that projects produce. For most of these "subjective" benefits, however, there are no easily defined or measureable units of the output that one directly values. For instance, what units of beauty or aesthetic improvement or recreational enjoyment is one trying to measure and evaluate in projects that yield these outputs? One almost has to settle either for estimates of the overall value or for estimates of small components in terms of physical units, such as number of billboards eliminated, acres of lake created, reduction of specific pollutant densities, volumes of air or water so treated, or a description of the physical recreational facilities created. Describing these components may be the best we can do in many instances, yet it is none too satisfactory or helpful. The procedure is somewhat like trying to help someone value shoes by saying that each pair has two shoestrings, two heels, and leather uppers. Thus measurement of many "subjective" or "non-marketed" benefits is extremely difficult both in terms of units of output and in terms of the value-tags to be attached to those units of output. The best that can be done is usually to present some fragmentary clues to the nature of the physical outputs or some highly uncertain estimates of their overall value.

Another part of the assigned topic is the examination of costs to other economic units. Again this means to me the costs inflicted on others that do not pass through any market and are therefore not voluntarily accepted because of an exchange. If a water-resource project uses up cement or labor, the project is imposing costs on other economic units, but if the rights to use these resources are purchased, then these costs are accepted by those economic units voluntarily in exchange for a quid pro quo. As a result, there are observable prices paid, i.e. measures of these costs, that serve satisfactorily if one approves a voluntary-exchange system. As noted before, logic does not compel anyone to accept this criterion or therefore these measures of cost. But even if we can agree on market prices as the relevant value-tags, we are in serious difficulty regarding those cost-items that do not pass through a market.

Moreover, there are a number of costs or sacrifices inflicted on households or taxpayers or business firms without getting their consent through a voluntary trade. Consider the dislocation of people because of a reservoir or zoning change or an urban renewal project on an anti-pollution project that affects costs and development patterns. The use of properties is usually purchased, though exercising the power of eminent domain makes the extent to which these are voluntary trades unclear. But the dissatisfaction with being relocated is not compensated for, and thus represents a cost inflicted on economic units that does not pass through an exchange process.

Another cost of this sort is the sacrifice imposed on many individuals as a result of the curtailed development of various communities--sacrifice in terms of reduced choice or cultural facilities or monetary loss. To be sure, this may be offset by gains bestowed on other communities in the form of accelerated development. The point here is that these costs (as well as these gains)–i.e., what individuals would pay to avoid the retarded development (or to have the accelerated development)–are particularly hard to evaluate since they pass through no market. Sometimes these gains and costs may be important in the eyes of most people, because projects are often undertaken in order to stimulate one area's development or cancelled in order not to retard some other area's development. The importance of these considerations becomes especially clear when a military installation is to be closed or an agency is to be moved (as in the case of the HEW regional office being moved from Charlottesville, Virginia, to Philadelphia, Pennsylvania). But projects other than directly moving an agency can yield similar effects: an anti-air-pollution policy may affect transportation costs and development patterns, or an anti-water-pollution plan may affect production costs and development patterns. I do not mean, of course, that transfers and "secondary benefits" should be added in with ordinary project costs and benefits. But these are consequences of projects that entail some sort of net cost or benefit, and what I am urging is simply that their magnitude is extremely hard to measure and evaluate, since these consequences are externalities that are not marketed.

There may also be costs to particular industries, and thence to consumers, that are not paid for as direct costs and that should be counted to be weighed against the benefits. Anti-pollution regulations are very likely, in fact, to increase the fuel, equipment, or transportation costs of specific industries, yet, since consent of these industries is not purchased, these costs may not show up as direct costs of the project. The benefits may far outweigh total costs, but nonetheless these costs should not be ignored. These costs may not be so hard to estimate, because there may be market transactions one step removed from the government project itself that will reveal the sacrifices with fair accuracy.

Costs are often inflicted by one government project on other government agencies or operations, and these too are costs that do not go through a market. Hence, unless the other agencies are forced to buy special resources so that at one step removed there are observable transactions, these costs may be very difficult to estimate. Suppose an anti-air-pollution measure disrupts a community's transportation system. To some extent the municipality may purchase extra facilities, which reveals the cost, but to a considerable extent there may simply be reduced effectiveness of the street and roads department, possibly the schools, or perhaps even the postal service. These sacrifices would not be revealed in any obvious fashion, and would be much more difficult to anticipate and evaluate.

As in the case of "subjective" benefits, it may be that, for those non-marketed cost items that are difficult to evaluate, the best one can do is to describe the physical consequences--the dislocation of X people, the projected expansion of community Y by Z population, the projected contraction of other communities by R residents. As is true for "subjective" benefits, though, these remote and fragmentary clues will not be too helpful. To sum up, the measurements and value-tags associated with these externalities, whether benefits or costs, are bound to be highly uncertain. As Demsetz has stressed, one of the government's major difficulties is this estimation or information problem.

The final feature of cost-benefit analysis listed as part of my topic is "social" costs and benefits. To me this simply means total costs and benefits, and the particular ones that are relevant to society or the group depends upon one's criterion. If one approves a voluntary-exchange system, his criterion will be what the economist calls Pareto optimality or, in other words, the particular point of economic efficiency to which voluntary exchange would lead. Each voluntary trade in which no one is affected without his consent makes at least one person better off without making anyone else worse off, and the criterion is to reach a position in which no one can be made better off without making someone else worse off. With this criterion, social costs are the sum of individuals' sacrifices, as viewed by the individuals themselves, that are brought about by a project, and the social benefits are the sum of individuals' gains, as seen by those individuals. In other words social costs are the total of amounts that individuals would pay not to have the project, and social benefits are the total of amounts that individuals would pay to have the project.

Thus I have been talking all along about one subset of social costs and benefits, namely, those that do not pass through a market. Coupled with the costs and benefits that do go through markets--i.e., resources and services that are purchased and used by a project, and beneficial outputs of a project that are sold to buyers--these would add up to total social costs and benefits. This would be true, that is, if one's criterion is Pareto optimality.

If the criterion is some other widely accepted welfare function, the costs and benefits could have quite different value-tags attached to them, but the total would be social costs and benefits: the total of all positive and negative values that people felt were relevant from the group's standpoint. As pointed out initially, however, it seems unlikely to me that there would be widespread agreement on a social welfare function other than one consistent with approving a voluntary-exchange system. If one's criterion was his particular conception of a social welfare function, the costs and benefits could have different value-tags from those discussed above, but once more the total would be social costs and benefits from that individuals' standpoint. (To use the economist's jargon, the relevant prices or marginal rates of substitution would be different from those discussed above). The difficulty is that there might be little agreement on this basic criterion, the maximation of this particular social welfare function, and the cost-benefit analysis might therefore exhibit information that would be relevant to only a small number of persons.

Where does all this leave us? It leaves us with a tool that may help decision-makers but that will rarely be able to point to "correct" choices. We can describe some of the consequences of projects in physical terms, we make subjective estimates of the value of these consequences; but we should try to make clear how much uncertainty should be associated with these quantities. We should stress that heroic personal judgments must be made about (1) many of the physical, sociological, and aesthetic consequences of alternative policies, and (2) the values to be attached to these consequences. Rarely will all persons agree regarding these personal judgments, and thus there will not be choices that are indisputably or inherently correct.

It leaves us also with the realization that cost-benefit analyses can be misleading or misused. Even without anyone being dishonest or consciously scheming, there is plenty of scope for making one plausible set of judgments rather than another set that might lead to far different exhibits. If anyone is tempted by confusion, haste, or inertia to use the exhibits mechanically, he could be misled. If the analysts, consciously or unconsciously, made the set of judgments reflecting special biases held for any of many possible reasons, they could misuse this tool.

Nevertheless, I wish to emphasize that in my view such analyses still have considerable potential value. We can learn in time to appreciate not only the costs of preparing cost-benefit analyses but also the limitations on the benefits, of such analyses. One virtue is that considering alternatives and their pros and cons systematically is the right way to look at, and think about, problems of choice. Even if there is no inherently correct choice from the standpoint of the group, even if all estimates are uncertain and some simply unavailable, such analysis is the right way for individuals to organize their thinking in deciding what policy each individual prefers. Alternative ways of thinking about choices have still less to commend them. Note that even in talking about cost-benefit analysis, one is drawn into discussing the pros and cons, and in deciding whether to prepare such analyses pertaining to particular alternatives, one is drawn into considering the costs and benefits of making the analyses. In effect, this paper is a primitive cost-benefit analysis of cost-benefit analysis.

Another, though related, virtue of such analysis is that systematic examination of costs and benefits helps one recognize more of the relevant project consequences than would armchair speculation. To economize, one does not want to look at only part of the consequences of his choices; he should seek to perceive all the major consequences that are relevant. (Strictly speaking, he should seek to trace out more of the consequences as long as he judges the prospective gain to be more than the prospective cost of this activity).

One valuable by-product of cost-benefit analysis is that it virtually shouts at us to recognize that <u>unique</u> needs are fictitious. The whole idea is to compare alternatives. It therefore seems to be diametrically opposed to the notion of unique requirements. The human mind is apparently prone to simplify life by leaping to conclusions like: we cannot sacrifice health so we have to eliminate air and water pollution, or we need exactly X thousand classrooms, or we must have a particular urban transit system. In reality, the amount of anything that we "need" depends upon how much of other needed things must be given up, i.e., depends upon the costs. Cost-benefit analysis by its very nature keeps reminding us of this.

Another useful by-product of cost-benefit analysis is its stimulus to the redesign or invention of alternatives. So often when a group starts out to evaluate a proposal, or a set of alternative proposals, the analysts find that some of the proposals are poorly designed. They find that some features are extremely expensive yet contribute little to the effectiveness of a proposal as a whole, that is, to the effectiveness of the "system." Or, they perceive that some new features might add greatly to effectiveness but little to cost. As a consequence, engineers or others in the group redesign the proposals. Clearly it is not very useful to evaluate a system that can be improved or to compare one intelligently designed proposal with another stupidly designed project. Sometimes this process results in the discovery of an entirely new and more effective policy.

The final and most widely recognized virtue of cost-benefit analysis is the fact that, despite the limitations discussed earlier, it can often provide some information that is relevant to the choices of most individuals in the group. For example, while most of us condone interfering with voluntary exchange and economic efficiency part of the time, the Congressional hearings suggest that Congressmen and voters do nonetheless attach considerable weight to the value-tags that emerge from market processes. I interpret this to mean that the fundamental criterion of people, at least in this country, includes fairly extensive approval of a voluntary exchange system. If this is so, costs and benefits in terms of market prices or simulated market prices will be relevant from the standpoints of many individuals. There can and will exist disagreement over these measurements and valuations, especially over the evaluation of the pervasive spillover benefits and costs that must be valued subjectively by each person. But the exhibits will contain <u>some</u> information that can help numerous individuals select the course of action they prefer.

FOOTNOTES

1. Harold Demsetz, "Some Aspects of Property Rights," Journal of Law and Economics, October, 1966, pp. 67-70.

2. Marion Clawson and Jack L. Knetsch, Economics of Outdoor Recreation, Johns Hopkins Press for Resources for the Future, Baltimore, 1966.

EVALUATING PUBLIC EXPENDITURES UNDER CONDITIONS OF UNEMPLOYMENT

Robert H. Haveman[1]

Department of Economics, Grinnell College

In the post-war period, the expenditure side of the public sector has been the subject of a substantial amount of analysis. While some of this work developed and refined the theory of public expenditure analysis, other work was aimed at improving the methods for evaluating the economic gains and the costs of alternative expenditure projects. This paper reflects the latter of these two emphases. It presents the reasons why monetary costs fail to reflect real social costs when the economy is experiencing unemployment and excess capacity, and elaborates a method for adjusting monetary costs when such conditions prevail. The implementation of this method eliminates the overstatement of real costs by monetary costs when some of the resources drawn into use by a public expenditure have idleness as their alternative.

I

An essential proposition in public expenditure economics is that, in evaluating the economic worth of a public expenditure, it is the <u>social</u> costs and <u>social</u> benefits which must be evaluated and not the private (or monetary) costs and private (or monetary) benefits. A second proposition is that, while social and private values may well be identical, they are not likely to be when there is some imperfection in the operation of the market system. Clearly, the existence of unemployed resources represents market system imperfection which would cause these two values to diverge.[2]

If resources in the economy are fully employed, the monetary costs of the labor and capital purchased by a public expenditure are likely to be a good approximation of the value of the things which society would be able to enjoy if the expenditure were not undertaken.[3] This is so because the price paid to resources employed in any enterprise tends to equal the value of what these resources are producing in that use. When they are hired away from that activity, society is forced to forego the output which they would have produced.

Consider, for example, a $100 public expenditure which is used to purchase $100 worth of labor and capital. If there were full employment and if the economy were functioning ideally in other respects, these resources would have been used to produce $100 worth of goods and services of some unknown composition which would have been purchased, used, and enjoyed by members of the society. This $100 worth of goods and services, then, is the social cost necessitated by the public expenditure. Stated alternatively, because of the $100 public expenditure, resources of that value are diverted from producing $100 worth of other things and society is forced to forego the opportunity of using and enjoying these particular "other things."

However, when there is not full employment of labor, or when plant capacity is not fully used, some of the resources hired by the public expenditure may not have to be diverted from alternative uses. Some of them may be drawn from the pool of unused or idle labor or capital resources. In the case in which the public expenditure employs otherwise idle resources, society does not have to forgo the opportunity to use and enjoy other things. By definition, these unemployed resources are not producing other things. Consequently, to the extent that otherwise unemployed resources are drawn into use by the public expenditure, the social cost of the expenditure–the value of the alternative uses that would have been made of the required manpower and capital--is less than the market or monetary cost.

II

It is clear that public expenditures made during such a period would call into use some resources which would otherwise have been unemployed. Not so obvious, however, is the fact that a similar result is likely when the national unemployment rate is quite low. However, this latter proposition–that some resources called into use by the marginal public expenditure would otherwise be idle, even under conditions of relatively full employment--is a point which must not be neglected.

The reason for this effect is the substantial variation of unemployment rates by occupation, by industry, and by region around the national average unemployment rate. If the nation showed a full employment rate of 4 percent and if every occupation in every region showed that same rate of unemployment, a public expenditure could in all likelihood cause 100 percent of the resources which it required to be diverted from other uses. However, if the 4 percent national rate is composed of a 2 percent unemployment rate in some occupations (regions) offset by a 6-7 percent unemployment rate in other occupations (regions), it is not likely that all of the labor which is hired by the public expenditure would be diverted from other uses. A part of these resources would be drawm from the high unemployment occupations (regions), in which case the public expenditure would call into use some resources which would otherwise have lain idle. Indeed, in the case in which there is substantial variation of occupational, industrial, and regional unemployment around the national unemployment rate, it is conceivable that the full set of resource demands imposed by the public expenditure might be met by units of labor and capital drawn from the idle pool.

Table 1 shows that, in fact, there is a substantial amount of variation of occupational, industrial, and regional unemployment rates around the national average. The distribution of unemployment rates around the national average is presented for 1960. In that year the national unemployment rate was 5.6 percent. From the data in these distributions, it is clear that it is necessary to know the structure of demands which a public expenditure imposes on the economy in order to determine the extent to which the expenditure does or does not use resources which would otherwise be unemployed.

Table I

Variation of Occupational, Industrial, and Regional Unemployment Rates around National Average, 1960

Unemployment Rates	Occupational[1]	Industrial[2]	Regional[3]
below – 2.6	4	1	0
2.6 – 3.6	3	2	6
3.6 – 4.6	0	0	8
4.6 – 5.6	2	4	16
5.6 – 6.6	3	4	11
6.6 – 7.6	0	1	7
7.6 – 8.6	1	2	2
8.6 – or more	5	2	1

1. Data for 18 major occupational categories.

2. Data for 16 major industry categories.

3. Data for 50 states.

When this result is related to the opportunity cost logic presented in Section I, it becomes clear that much public spending in the post-war period imposed social (or opportunity or real) costs on the society which were less than the monetary costs.[4] Moreover, and more importantly given today's unemployment situation, some spending which occurs during periods of rather full employment may entail the use of resources which would otherwise have been unutilized or underutilized. This would be especially true if the pattern of resource demands imposed by a particular public expenditure emphasized the occupations, industries, and regions which had substantial unemployment even though, overall, the economy was rather fully employed. Again, the use of these resources entails zero opportunity costs.[5] Clearly, the accurate economic evaluation of the social costs of a public expenditure required a detailed estimate of the pattern of the occupational, industrial, and regional demands imposed by the expenditure and a comparison of these demands with the existing pattern of occupation, industrial, and regional unemployment, both when the economy is not fully employed and when it is.

III

The first step in evaluating the opportunity costs of a public expenditure is to estimate the pattern of the demands generated by the expenditure for labor, by occupation, for capital, by industry, and for both labor and capital, by region. While the pattern of labor and materials employed directly by the expenditure is not difficult to ascertain, the set of final labor and capital demands imposed after the material inputs are traced through the several rounds of the production process is far more difficult to estimate. Recently, this estimation task has become possible because of the national input-output matrix assembled and published by the Office of Business Economics of the U.S. Department of Commerce[6] and the industry-occupations matrix completed by the Bureau of Labor Statistics of the U.S. Department of Labor.[7] When these empirical matrices are incorporated along with basic estimates of the direct resource demands of a public expenditure into an appropriate computational model, the full catalog of direct and indirect demands placed on factor sources--by occupation, industry, and region--can be estimated.

In one particular model developed for the purpose of estimating the complete pattern of labor and capital demands imposed by a public expenditure, the sequence of computations proceeds as follows:[8] Given the basic data on the direct material, equipment and supply inputs required by an expenditure, the complete pattern of industrial demands can be calculated through use of the input-output matrix. Then, on the basis of a set of relationships which grant a preferred status to the region in which the expenditure is undertaken and the geographic location of each industry's capacity, the geographic distribution of these total industrial demands is estimated. Third, by using the industry-occupation matrix, the labor demands imposed on each region because of the industry output demands is estimated, in occupational detail. Fourth, these occupational labor demands generated by purchases of materials, equipment, and supplies (and distributed among the regions) are added to the on-site occupational pattern of labor demands by region. Finally, the pattern of demands imposed on capital are determined by industry and by region by applying appropriate capital-output ratios to the total output demands, by industry, which were estimated in the second step.

By employing this model, the pattern of resource demands can be computed for any public expenditure in 156 occupation, 80 industry, and 10 region details. Table 2 shows, in substantially consolidated form, the kind of detailed estimate furnished by this model. In that table, the pattern of occupational, industrial, and regional demands is shown when a multiple purpose (including hydro-electric power generation) water development project is constructed in the Lower Atlantic states.

In the final column of this table, it is shown that a total gross output of \$1032 is generated per \$1000 of expenditure by the direct purchases of materials, equipment, and supplies required for the project.[9] Of this total gross output demand, 29 percent of it, or \$300, is imposed on the Lower Atlantic region–the region where the project is assumed to be constructed. In addition, because of the heavy demands which this kind of installation places on durable equipment manufacturing, a substantial set of demands are imposed by the project on the mid-Atlantic and East North Central regions where these industries are concentrated. Together, these three regions account for over 70 percent of the total gross output stimulated by the expenditure. That it is the durable goods industries which account for this regionally concentrated result is also seen in the table. Of the total gross output of \$1032, durable goods production accounted for \$539, or over 50 percent. Of the \$539 of durable goods output, over \$320 or 60 percent is produced by the Mid-Atlantic and East North Central regions.

In the lower portion of Table 2 the labor demands required by the project are shown in occupational detail and by region. Because of the nature of this kind of construction installation, many of the labor demands are

TABLE 2. GROSS OUTPUT BY INDUSTRY AND TOTAL LABOR COST BY OCCUPATION IN EACH OF 10 REGIONS FOR A $1000 PUBLIC EXPENDITURE ON A MULTI-PURPOSE WATER RESOURCE PROJECT ASSUMED TO BE CONSTRUCTED IN THE LOWER ATLANTIC REGION, IN DOLLARS PER $1000 OF EXPENDITURE[a]

INDUSTRY	NEW ENGLAND	MID-ATLANTIC	EAST NORTH CENTRAL	WEST NORTH CENTRAL	SOUTH-EAST	LOWER ATLANTIC	WEST SOUTH CENTRAL	MOUNTAIN & WEST COAST	TOTAL OUTPUT***
AGRICULTURE, FORESTRY AND FISHERIES	* (5)	* (6)	1(15)	2(21)	1(16)	* (4)	1(13)	2(21)	8
MINING (INC. CRUDE PETROLEUM)	*(**)	4 (5)	4 (5)	4 (6)	2 (4)	45(58)	10(14)	7 (9)	77
CONSTRUCTION	* (2)	1(11)	1(16)	* (3)	* (3)	5(54)	* (4)	* (6)	9
NON-DURABLE GOODS MANUFACTURE	7 (7)	20(20)	24(23)	5 (5)	10(10)	11(11)	14(14)	11(10)	103
DURABLE GOODS MANUFACTURE	31 (6)	126(23)	197(37)	27 (5)	29 (6)	49 (9)	25 (5)	56(10)	539
LUMBER AND WOOD PRODUCTS	1 (5)	1 (7)	2(12)	* (4)	2(16)	1 (8)	1 (7)	6(40)	13
STONE, CLAY AND GLASS PRODUCTS	4 (5)	15(19)	19(24)	6 (8)	7(10)	13(17)	5 (6)	9(12)	78
PRIMARY METAL INDUSTRIES	6 (4)	37(28)	47(36)	4 (3)	6 (5)	14(11)	3 (3)	14(10)	129
FABRICATED METAL INDUSTRIES	6 (6)	23(23)	31(31)	6 (6)	8 (8)	12(12)	5 (5)	11(11)	100
MACHINERY (EXC. CONSTR. & ELEC.)	8(10)	22(29)	34(45)	3 (4)	2 (2)	2 (2)	1 (1)	4 (5)	75
CONSTRUCTION MACHINERY	1 (1)	4 (8)	27(52)	4 (7)	1 (3)	2 (3)	9(17)	4 (9)	52
ELECTRICAL MACHINERY	5 (8)	19(29)	26(40)	3 (5)	2 (3)	3 (5)	1 (1)	5 (8)	64
TRANSPORTATION EQUIPMENT	1 (4)	3(14)	11(52)	1 (4)	1 (5)	1 (7)	1 (3)	2(10)	20
MISCELLANEOUS MANUFACTURING	1(14)	3(45)	1(21)	* (5)	* (3)	* (2)	* (2)	* (7)	7
TRANSPORTATION AND WAREHOUSING	1 (2)	6 (8)	8(11)	2 (2)	2 (3)	49(58)	2 (3)	3 (4)	72
WHOLESALE AND RETAIL TRADE	1 (2)	6 (6)	9 (9)	1 (2)	2 (2)	70(75)	2 (2)	3 (3)	93
ERVICES	4 (3)	14(11)	21(16)	4 (3)	4 (3)	71(54)	6 (5)	7 (6)	131
TOTAL[bc]	45 (4)	177(17)	264(26)	45 (4)	52 (5)	360(29)	61 (6)	89 (8)	1032
OCCUPATION									
PROFESSIONAL, TECHNICAL, & KINDRED	2	6	9	1	1	49	2	3	72
MANAGERS, OFFICIALS, & PROPRIETORS	1	5	8	1	2	43	2	3	66
CLERICAL, AND KINDRED WORKERS	2	6	9	1	1	22	2	3	46
SALES WORKERS	*	1	1	*	1	6	*	*	10
CRAFTSMEN, FOREMEN, & KINDRED	3	11	18	3	3	274	3	5	319
CARPENTERS	*	*	*	*	*	48	*	*	49
CEMENT FINISHERS	*	*	*	*	*	4	*	*	4
IRON AND METAL WORKERS	*	*	*	*	*	22	*	*	22
CONSTRUCTION EQUIPMENT OPERATORS	*	1	1	*	*	45	*	*	48
OTHER BUILDING TRADES	*	1	1	*	*	37	*	*	41
MECHANICS	*	2	3	*	*	12	*	1	18
LABOR FOREMEN	1	2	4	1	*	48	1	1	58
OTHER CRAFTSMEN, FOREMEN & KINDRED	1	5	9	1	1	58	1	2	88
OPERATIVES AND KINDRED WORKERS	4	13	20	3	4	54	3	7	108
TRUCK AND TRACTOR DRIVERS	*	2	2	1	*	15	1	1	22
SAILORS AND DECKHANDS	*	*	*	*	*	*	*	*	*
OTHER OPERATIVES AND KINDRED	3	12	17	2	3	39	3	5	86
SERVICE WORKERS	*	1	2	*	*	3	*	*	7
LABORERS	1	3	4	1	1	77	1	1	89
FARMERS AND FARM WORKERS	*	*	*	*	*	*	*	*	2
TOTAL[bd]	12 (2)	47 (7)	12 (2)	12 (2)	14 (2)	527(73)	13 (2)	24 (4)	719

a. Percent of row totals stated in parenthesis behind the dollar values.
b. Rows may not add because of rounding.
c. Percent of total gross output stated in parenthesis behind regional total gross output figures.
d. Percent of total labor cost stated in parenthesis behind regional total labor cost figures.

* Less than $0.1 but greater than zero.
** Less than 0.5 but greater than zero.
*** Total Gross Output

required on the construction site. This accounts for the heavy concentration of labor demands in the region in which the project is assumed to be constructed. The Lower Atlantic region supplies nearly three-fourths of the total labor demand generated by the project. Consistent with the gross output estimates which demonstrated the concentration of durable goods in the highly industrialized regions, it is seen that those labor demands which the project imposes on other regions are concentrated in the Mid-Atlantic and East North Central regions and among the craftsman and operatives occupations.

Finally, although not shown in Table 2, the substantial disparity in the pattern of industrial and occupational demands generated by various project types should be noted. While all of the project types analyzed were water resource investments, the anatomy of their industrial, occupational, and regional impacts is far more diverse than is generally recognized, while some project types require very little on-site construction (dredging) others require the installation of huge capital facilities (multi-purpose projects). For 12 project types analyzed, the ratio of labor compensation (direct and indirect) to total project cost ranges from .52 to .72. The range in the ratio of on-site labor cost to total labor cost ranged from .25 to .58. The ratio of durable goods demanded to gross material demands extends from .2 to .65. When all of the project types are assumed to be constructed in the Lower Atlantic region, the percent of national gross output retained in that region ranges from 24 to 32 percent; the percent of national labor cost retained extends from 69 to 75 percent. Even more radical disparities among project types are noted as detailed industrial or occupational sectors are studied.

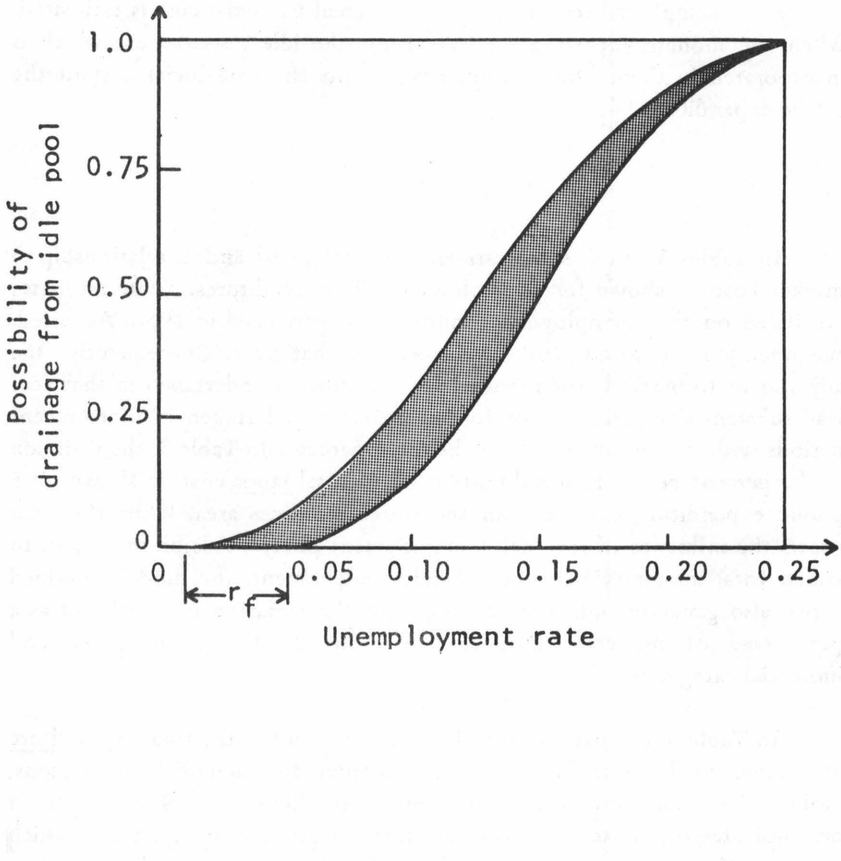
IV

Having ascertained the pattern of resource demands imposed by a public expenditure, the next step in evaluating the social costs of these demands is to compare them with the occupational and regional pattern of labor unemployment and the industrial pattern of excess plant capacity. As described above, the monetary costs of a public expenditure represent real opportunity returns forgone at the margin only if all of the resources used had alternative employs. If there is unemployment, however, some labor used is likely to be drawn from the idle pool. This labor has no comparable opportunity cost. Similarly, the opportunity rate of return on otherwise idle capital services are largely storeable, depreciation charges are a real cost properly imputed to the expenditure even when otherwise idle industrial capacity is drawn into use.

On this basis, the occupational, industrial, and regional breakdowns of monetary costs can be modified to the extent that the units of labor and capital represented would have been otherwise idle. To estimate the extent to which any labor and capital demand employs otherwise unused resources, it is necessary to trace each unit of labor and capital employed to its source and to inquire concerning its alternative use. In the absence of data necessary to implement this counsel of perfection, the model discussed here assumes that the levels of occupational unemployment (or, in the case of capital, industrial excess capacity) are significant determinants of the proportion of labor drawn from any occupation and region (capital drawn fron any industry) which would have, in the absence of the expenditure, been idle. For example, this approach treats an increase in the demand for labor at low levels of unemployment as simply shifting workers among jobs without reducing unemployment (excess capacity) rises, so too does the probability that the incremental demand will draw otherwise unemployed labor (idle capital) into use. Because accurate knowledge on the pattern of labor and capital market response does not exist, a set of synthetic response functions is employed. These functions relate the probability that a given increment in the demand for labor and capital will be drawn from otherwise unemployed resources to the level of occupational unemployment and industrial excess capacity on the basis of reasonable assumptions concerning market operation.

In Figure 1, the kind of relationships used to estimate the extent to which labor demands are supplied from otherwise unutilized resources in this model are shown.[10] The set of synthetic functions inscribed within the area between the two curves state that the higher the unemployment rate, the greater the proportion of labor from any given occupation which is hired from the idle pool. The region labled r_f describes the range of unemployment rates at which each of the major occupational categories is said to be fully employed.[11] Full unemployment for each occupation is defined by the national unemployment rate experienced by that occupation in 1953--a year with minimum unemployment without undue inflationary stress. The point labled r_n signifies the rate of unemployment at which an increment of demand would be entirely supplied from otherwise unutilized resources. For the set of relationships included in the shaded area of Figure 1, this unemployment rate is .25, which is the estimated rate of unemployment at the height of the depression of the thirties. It is assumed that under such conditions, increments to the demand for labor and capital are satisfied with no displacement of alternative outputs. The relationships incorporated into the curves which lie in the shaded area are offered as an accurate portrayal of actual labor market behavior.

Figure 1


1.0
0.75
0.50
0.25
0
Possibility of drainage from idle pool
0
0.05
0.10
0.15
0.20
0.25
r_f
Unemployment rate

These relationships (and similar ones for estimating the withdrawal of capital from the idle pool) are used with detailed data on the level of occupational unemployment by region and industrial excess capacity to provide the basis for estimating the real costs of public expenditure. By combining the labor and capital response relationships with detailed evidence on the occupational, industrial, and regional patterns of unemployment, an estimate of the proportion of the labor and capital withdrawn from the idle pool in each pertinent occupation, industry, and region is obtained. By multiplying these percentages by the dollars of monetary cost in each category, the amount of monetary cost which, because of the use of otherwise unemployed resources, is not matched by social cost is estimated. When the monetary costs are adjusted for the idle resource use which is incorporated in them, the remainder represents the true social cost of the public expenditure.[12]

V

In Tables 3 and 4, some estimates of social cost and its relationship to market cost are shown for a sample of public expenditures. These estimates are based on the unemployment conditions experienced in 1960. As noted, the unemployment rate was 5.6 percent in that year. Consequently, the adjustment to marked cost required for investments undertaken in that year was substantially greater than for investments undertaken in more recent periods with unemployment levels below 4 percent. In Table 3, the variation in the percentage which social costs form of total <u>labor</u> costs is shown for 5 public expenditure categories in the water resources area. While this data shows the influence of regional unemployment differentials on the degree to which total monetary labor cost requires adjustment, the model described above also generates tables which highlight the variation in social cost as a percentage of monetary cost for numerous detailed occupational and industrial categories.

In Table 4, estimates of social cost as a percent of the total <u>expenditure</u> are shown for the same public projects constructed in each of the ten regions, again with unemployment conditions prevailing in 1960. Table 4 demonstrates the substantial variation in the required cost adjustment which exists among project types. It also shows that the variation in adjustment for a single project type as its geographic location changes is even more significant than the variation among project types. In no case does the range for the latter variation fail to exceed 15 percentage points. The influence of geographic unemployment on required cost adjustment is clearly seen by

Table 3

Estimate of Social Labor Cost as a Percentage of Market Labor Cost for Five Representative Public Expenditutes in Ten Regions of Project Location, 1960.

Region	Large earth fill dams	Local flood protection	Medium Concrete dams	Large multiple-purpose projects	Dredging
New England	88	82	88	87	83
Mid-Atlantic	80	74	82	81	76
East North Central	90	89	92	92	89
West North Central	87	84	89	89	88
Southwest	93	92	94	94	88
Lower Atlantic	75	65	74	73	73
Kentucky -- Tennessee	81	75	81	80	77
West South Central	92	91	93	93	86
Mountain	91	92	93	93	94
West Coast	85	82	86	86	74
Range of percentages	75-93	65-92	74-94	73-94	73-94
Median percentage	87.5	83	88	88	84.5

Table 4

Estimate of Total Social Cost as a Percentage of Total Expenditure for Five Representative Project Types in Ten Regions of Project Location, 1960.

Region	Large earth fill dams	Local flood protection	Medium concrete dams	Large multiple-purpose projects	Dredging	Range of percentage	Median percentage
New England	89	84	88	87	84	84-89	86.5
Mid-Atlantic	82	77	84	82	78	77-84	80.5
East North Central	91	90	92	92	90	90-92	91.0
West North Central	88	85	90	89	89	85-92	87.5
Southwest	93	93	94	94	88	88-94	91.5
Lower Atlantic	78	69	77	76	75	69-78	73.5
Kentucky -- Tennessee	83	78	83	81	79	78-83	80.5
West South Central	92	92	93	93	87	87-93	90.0
Mountain	92	92	93	93	94	92-94	93.0
West Coast	86	84	87	87	76	76-87	81.5
Range of percentage	78-93	69-93	77-94	76-94	75-94		
Median percentage	88.5	84.5	89	88	85.5		

comparing the cost adjustments for projects constructed in the high unemployment Lower Atlantic Region with similar data for project construction in other regions. For every project type, the cost adjustment required for construction in this region is at least 10 percentage points below the median adjustment for all regions.

The results of both Tables 3 and 4 are summarized in Figure 2. The charts shown there display the percentages by which the dollar costs of the selected public expenditures undertaken under economic conditions similar to those of the 1957-1964 period (of which 1960 is taken to be typical) would overstate the social costs. The differences vary with the unemployment levels and other economic conditions in the region where a project is located, and also with the amounts, kinds, and origins of labor and materials required for each type of project.

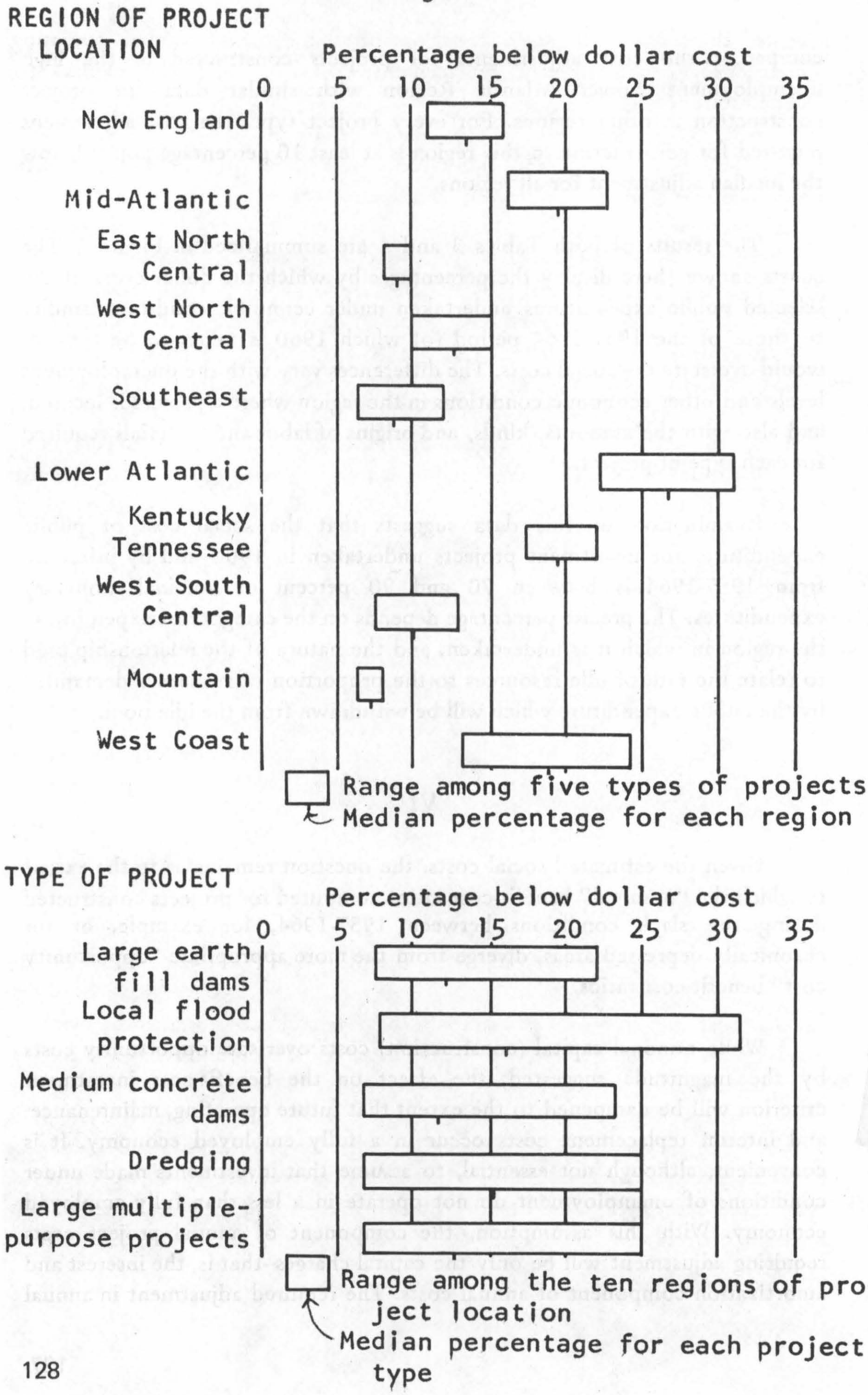
Examination of this data suggests that the social cost of public expenditures for investment projects undertaken in 1960--and by inference from 1957-1964--is between 70 and 90 percent of nominal monetary expenditures. The precise percentage depends on the category of expenditure, the region in which it is undertaken, and the nature of the relationship used to relate the rate of idle resources to the proportion of resources demanded by the public expenditure which will be withdrawn from the idle pool.

VI

Given the estimated social costs, the question remains as to the extent to which the "nominal" benefit-cost ratios computed for projects constructed during the slack conditions between 1957-1964, for example, or for chronically depressed areas, diverge from the more appropriate "opportunity cost" benefit-cost ratios.

While nominal capital (construction) costs overstate opportunity costs by the magnitude suggested, the effect on the benefit-cost investment criterion will be dampened to the extent that future operating, maintenance, and interim replacement costs occur in a fully employed economy. It is convenient, although not essential, to assume that investments made under conditions of unemployment do not operate in a less than fully employed economy. With this assumption, the component of annual project costs requiring adjustment will be only the capital charges--that is, the interest and amortization component of annual costs. The required adjustment in annual

Figure 2


REGION OF PROJECT LOCATION
Percentage below dollar cost
0 5 10 15 20 25 30 35
New England
Mid-Atlantic
East North Central
West North Central
Southeast
Lower Atlantic
Kentucky Tennessee
West South Central
Mountain
West Coast
Range among five types of projects
Median percentage for each region
TYPE OF PROJECT
Percentage below dollar cost
0 5 10 15 20 25 30 35
Large earth fill dams
Local flood protection
Medium concrete dams
Dredging
Large multiple-purpose projects
Range among the ten regions of project location
Median percentage for each project type

costs, therefore, will be a function of the ratio of annual operating, maintenance, and interim replacement costs (c) and the capital (or construction) costs (K).

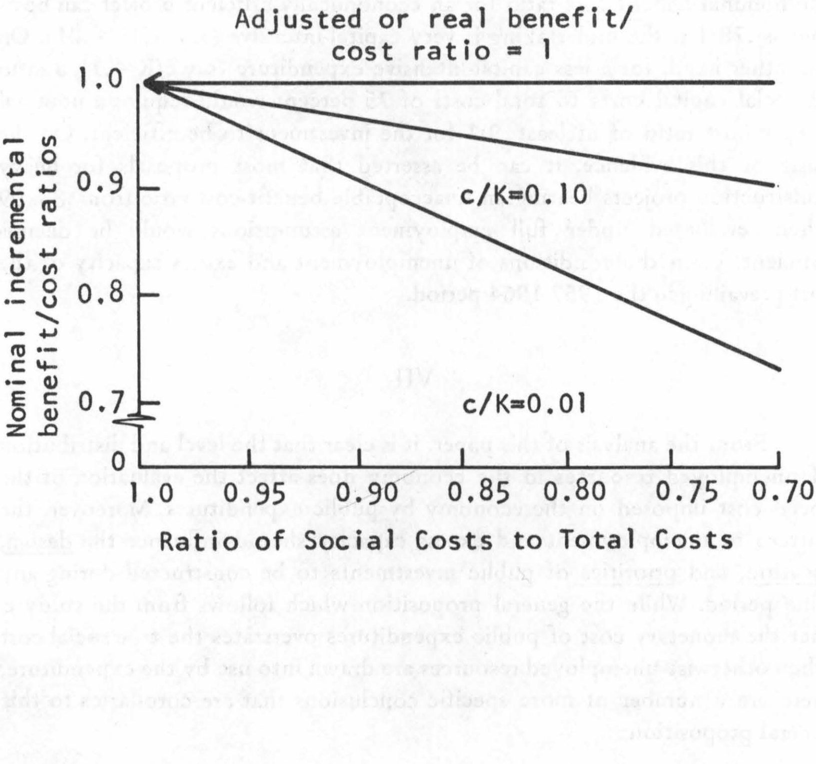
The impact of construction cost adjustment on benefit-cost ratio calculations is shown graphically in Figure 3 on the assumption that only construction costs require adjustment. Here the divergence in the nominal benefit-cost ratio from the true social benefit-cost ratio is analyzed for capital intensities (c/K) of .01 and .10. The upper curve shows the relationship of the social to the nominal benefit-cost ratio at different ratios of social capital costs to total capital costs for a public expenditure in which the annual operating costs (c) are 10 percent of initial construction costs (K). The lower curve shows the same relationship for a more capital-intensive expenditure--one in which annual operating costs are only one percent of initial capital costs. From these relationships, it is seen that when social costs for initial project construction are, say, 75 percent of total monetary costs, the nominal benefit-cost ratio for an economically efficient project can be as low as .78:1 if the undertaking is very capital-intensive (say, c/K = .01). On the other hand, for a less capital-intensive expenditure (say c/K = .1), a ratio of social capital costs to total costs of 75 percent would require a nominal benefit-cost ratio of at least .9:1 for the investment to be efficient. On the basis of this evidence, it can be asserted that most proposals for heavy construction projects bearing an unacceptable benefit-cost ratio from .85-.99 when evaluated under full employment assumptions would be deemed efficient, given the conditions of unemployment and excess capacity of the sort prevailing in the 1957-1964 period.

VII

From the analysis of this paper, it is clear that the level and distribution of unemployed resources in the economy does affect the evaluation of the social cost imposed on the economy by public expenditures. Moreover, the pattern of unemployment and excess capacity should influence the design, location, and priorities of public investments to be constructed during any time period. While the general proposition which follows from the study is that the monetary cost of public expenditures overstates the true social cost when otherwise unemployed resources are drawn into use by the expenditure, there are a number of more specific conclusions that are corollaries to this general proposition:

Figure 3

Ratio of Social Capital
Costs to Total Market Costs



If the national unemployment rate exceeds the frictional minimum or if there is variation of occupational or regional unemployment around a national full employment rate, it is likely that more of all expenditures, public and private, can be justified than would be implied by the efficiency criterion using monetary benefit and cost estimates.

If either of the idle resource conditions described above exist, the ranking of projects by the standard benefit-cost ratio using social value estimates would differ from the ranking which would occur if monetary estimates were used. Those expenditures, either public or private, which place heavy demands on occupational, industrial, and regional sectors showing idle resource rates above the frictional minimum would rise in the ranking relative to those which place predominant demands on other sectors.

If either of the idle resource conditions exist, the design of projects relying on social benefit-cost computations will differ from the design resulting from adoption of the full employment assumption. Those projects placing relatively heavy demands on occupational, industrial, and regional sectors showing high idle resource rates will be oversized relative both to their full employment design and to the scale of projects which place demands on other sectors. Moreover, all expenditures, public and private, which rely on social benefit-cost calculations for design, will make relatively heavier demands on occupations, industries, and regions showing relatively high idle resource rates than if the design criterion were based on the full employment assumption.

Because of the implications of the above propositions, the problem of unemployment, regional stagnation, and high unemployment occupations and industries would tend to be eased by use of the social benefit-cost design criterion rather than the market cost design criterion based on the full employment assumption. This is so because unused resources are evaluated at a very low cost in the social benefit-cost criterion. Use of these resources is, consequently, encouraged.

As a word of caution, it should be emphasized that the results of this study should not be taken to imply that every public expenditure project which has been rejected because of an inadequate benefit-cost ratio should be undertaken when the unemployment rate rises above 4 percent. The conclusion to be drawn is that there is an operational framework by which to re-evaluate projects in terms of their opportunity costs when regional or national unemployment rates depart from frictional minima. Moreover, to avoid biasing public expenditures in the direction of a single program, all public investments (including tax cuts) should be similarly analyzed to determine what, if any, differences exist among them. A second warning concerns the extent of adjustment required in the benefit-cost ratio when otherwise unutilized resources are a part of monetary costs. As seen in the calculations of Tables 3 and 4, the level of social costs typically falls only about 10-15 percent--at most 25 percent--even when the rate of unemployment is 8-9 percent, as it was in a number of regions in 1960. At a time when there is much expectation that the incorporation of "redevelopment benefits" or "secondary benefits" into benefit-cost analysis will lead to the justification of many projects not otherwise meeting the efficiency criterion, this conclusion should be sobering.

Only through substituting social opportunity costs for nominal monetary costs in the expenditure criterion can public decision-makers isolate expenditures which are both intrinsically economic and substantial employment generators. Through such shadow pricing efforts, more discriminating judgment can be applied to public expenditure policy in general and especially to public expenditure policy in the chronically depressed, high unemployment, and declining areas of the nation.

FOOTNOTES

1. Associate Professor of Economics (on leave), Grinnell College, and Senior Economist, Subcommittee on Economy in Government, Joint Economic Committee. The views expressed in this paper are the author's, and not necessarily those of the Joint Economic Committee.

2. William J. Baumol, Welfare Economics and the Theory of the State (Harvard University Press, 1952). In that volume, Baumol treats unemployment as an external diseconomy requiring a collective remedy outside of the market system.

3. This, of course, assumes that the market system is operating at its "efficient best" in all other respects.

4. If an unemployment rate of 5 percent is defined as full employment, 10 of the 21 years since World War II were years with idle productive capacity in excess of this minimum; 15 of the 21 years saw unemployment in excess of the frictional minimum if 4 percent is the full employment rate.

5. Implicit in this position is the proposition that involuntary leisure has zero benefit to either the unemployment worker or the society.

6. Morris R. Goldman, Martin L. Marimont, and Beatrice N. Vaccara, "The Inter-Industry Structure of the United States," A Report on the 1958 Input-Output Study, Survey of Current Business, 44 (Nov. 1964), 10-29; Norman Frumkin, "Construction Activity in the 1958 Input-Output Study," Survey of Current Business, 45 (May, 1965), 13-23; National Economics Division Staff, "The Transactions Table of the 1958 Input-Output Study and Revised Direct and Total Requirements Data," Survey of Current Business, 45 (Sept. 1965), 33-49.

7. U. S. Department of Labor Statistics, Labor Bureau, Handbook of Methods for Surveys and Studies, Bulletin No. 1458 (Washington, 1966), Chap. 7, and U. S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics, Sources, and Data, Report No. 305 (Washington, June, 1966).

8. An elaboration of the details of this model and its use can be found in Robert Haveman and John V. Krutilla, Unemployment, Idle Capacity and the Evaluation of Public Expenditures (Baltimore: Johns Hopkins Press, 1968).

9. This $1032 represents the total gross output, both direct and indirect, generated by a final expenditure. Its size and industrial breakdown was estimated by an input-output calculation. The value of final demand, representing direct purchases of materials, equipment, and supplies, was $514 (out of $1000 of total project cost). It is this final demand which, through the input-output calculation, generated the $1032 of total gross output. The portion of the $1000 of total project cost not represented by direct purchases of materials, equipment, and supplies is largely accounted for by the direct demand for on-site labor.

10. The area between the two curves is the region within which the response functions, one for every major occupational category, fall. A separate set of functions, not shown here, was used to estimate the portion of capital demands, by industry, which were satisfied by otherwise idle capacity.

11. There is a single rate for each occupational category within r_f.

12. On the basis of this formulation, it is seem that the exercise of adjusting nominal costs for the unemployed labor and idle capital which is used is an example of "shadow pricing."

AIR POLLUTION DAMAGE TO COMMERCIAL VEGETATION

Donald G. Gillette

National Air Pollution Control Administration, North Carolina

Introduction

Damage to vegetation from air pollution is not a recent phenomenon but the seriousness of this problem has increased progressively with industrial expansion and population growth. Scientists first became concerned with the effects of air pollutants on vegetation nearly 100 years ago when Stockhardt reported smoke damage to German forests.[1] By the turn of the century incidences of vegetation damage from air pollution were reported in many countries including the United States. Recent estimates of the annual crop losses suffered by farmers from air pollutants in the United States have ranged from $250 million to $500 million.

Since vegetation damage from air pollutants was first recorded in the United States, the number and variety of pollutants and the amount of each have increased. Prior to World War II, considerable expansion occurred in the aluminum, steel, and phosphate industries and fluorides, emitted by these industrial groups became an important contaminant causing vegetative damage. Also during this period highly reactive photochemical smog products such as oxidized hydrocarbons, ozone and PAN (peroxyacylnitrates) caused widespread damage to vegetation around large metropolitan areas.

According to Middleton, the principal pollutants, ranked in order of importance in causing vegetative damage, are fluorides, ozone, sulfur dioxide, PAN, and ethylene.[2] Other air pollutants that occasionally cause plant damage are chlorides, chlorine, hydrogen sulfide, ammonia, various types of hydrocarbons, sulfuric acid aerosol, sulfates, and sulfites. Most of these so-called minor pollutants are emitted from specific industrial operations.

The pollutants responsible for most of the air pollution damage to vegetation vary considerably from area to area. Fluoride damage to vegetation as well as livestock is prevalent in the southeastern United States and in the Pacific Northwest, where there are concentrations of phosphate mining operations and aluminum reduction plants. Sulfur dioxide damage to vegetation is more serious in the eastern part of the country where high sulfur coal is readily available and is used by industrial plants. On the West Coast, where the ratio of automotive sources of hydrocarbons to industrial sources of NO_x, is high, PAN injury is a serious problem. Along the East Coast, ozone injury is more common.

Basic Symptoms and Effects

The phytotoxic substances generated by air pollutants can cause plant injury from a single fumigation whenever the concentration of the pollutant exceeds the capabilities of the plants' metabolism to render the pollutant non-toxic. Growth suppression (hidden injury) may result from low concentrations of PAN, ozone, and oxides of nitrogen. Detection of this type of injury or crop loss, although it may be significant, is extremely difficult because of visible signs of necrotic lesions or markings on the plant.

Hidden injury effects from fumigations of fluorides and sulfur dioxide are believed to be negligible but further investigation is needed. Fluorides, sulfates, and chlorides are absorbed by plants and may continue to be absorbed over a series of fumigations until the accumulation of toxic compounds reaches the level at which necrotic plant tissue appears. Although fluorides may accumulate in forage without causing visible plant damage the crop may be useless for livestock feed because of its toxic effect on cattle. Despite its limited effect on plant growth, fluoride has been known to affect the quality of fruit and has been suspected of causing a reduction in fruit set and resulting crop yields.

Crops and ornamental plants differ greatly as to the injury that results from specified levels and periods of exposure to given pollutants. Different plant species, genetic differences within species, humidity, light intensity, temperature, rainfall, and the stage of development of the plant are all important factors that may alter the degree to which different plants are injured. For example, genetic differences among white pine seedlings with respect to susceptability to plant injury from air pollutants is quite marked. White pines showing symptoms of chlorotic dwarfing in areas exposed to high levels of sulfur dioxide and oxidants are often interspersed with healthy white pines showing no effects from pollutants. These genetic differences, in white pines, as well as other plant species, have encouraged researchers to develop less sensitive and more susceptible strains of these species to either reduce the impact of air pollution on plant injury or serve as indicators of prevailing air pollution levels.

Some of the plants found to be highly susceptible or resistant to three of the major pollutants are listed in Tables I and II. It should be recognized that under certain climatic, weather or growth conditions some of the susceptible varieties may be quite resistant or resistant varieties may become highly susceptible particularly when two or more pollutants are present in the atmosphere. Synergistic effects, the combined effects of two or more pollutants on plants, tend to reduce the threshold at which injury may occur. Synergistic effects of pollutants on plants may occur when sulfur dioxide is combined with high levels of either nitrogen dioxide or ozone.[3]

Vegetation exposed to different pollutants at sufficiently high concentration levels and time periods may exhibit markings which are characteristic for that pollutant. The most common marking of ozone injury is the small triple or fleck-like necrotic lesions visible on upper leaf surfaces. Very young and very old leaves are normally resistant to ozone injury while the intermediate aged leaves are most susceptible. Several varieties of lettuce and tobacco are particularly susceptible to ozone injury. Some strains of tobacco are currently being used to detect the presence of this pollutant.

Symptoms of plant injury indicating the presence of both ozone and PAN may appear simultaneously in the ambient air. PAN injury usually results in lower surface glazing or bronzing of the leaves and causes most injury to young expanding leaves while ozone causes most injury to the intermediate or expanded leaves. In instances where severe injury occurs, the resulting collapsed leaf structure will create serious identification problems. PAN injury on grasses and small grains appears as small bands of injured tissue separated by apparently healthy bands of tissue across individual leaves. In the latter case, where monocot leaves are injured, the usual symptoms of PAN injury - glazing, bronzing, and silvering of leaves - are not applicable.

Tipburn and marginal markings on leaves are some of the visible symptoms of fluoride injury. Before these visible symptoms appear a sufficient amount of fluoride accumulation may occur in the plant to cause it to be toxic to livestock. Thus, the serious consequences of fluoride may not be reflected in reduced yields or physical destruction of vegetation but in its toxic effects. It has been demonstrated by several researchers, however, that the accumulation of fluoride tends to be greater at the leaf extremities than in the base portion of the leaf. Because of this tendency it appears reasonable to expect visible injury symptoms to occur first in these extremities.

Sulfur dioxide is another pollutant which is responsible for considerable damage to agriculture. However, acute injury may result when the plant is

Table I. Susceptible Plants to Three Phytotoxic Air Pollutants

Fluoride	Sulfur Dioxide	Photochemical Smog
Gladiolus	Alfalfa	Tobacco
Pine	Barley	Alfalfa
Chinese Apricot	Cotton	Bean
Azalea	Radish	Beet
Prune	Lettuce	Celery
Tulip	Sweet Potato	Parsley
Corn	Spinach	Spinach
Sweet Potato	Bean	Swiss Chard
Peach	Broccoli	Romaine Lettuce
Crabgrass	E. White Pine	Oats
Buckwheat	Oats	Endive
Day Lilly	Sweet Clover	Onion
Chickweed	Squash	Parsnip
Pigweed	Turnip	Turnip
	Wheat	Snapdragon
	Ragweed	Annual Grass
	Tulip	Petunia
	Violet	Walnut
	Mustard	

Table II. Resistant Plants to Three Phytotoxic Air Pollutants

Fluoride	Sulfur Dioxide	Photochemical Smog
Petunia	Privet	Mustard
Carrot	Cantaloupe	Sweet Corn
Zinnia	Citrus	Wheat
Privet	Celery	Broccoli
Snapdragon	Chrysanthemum	Corn
Pepper	Cucumber	Pepper
Onion	Corn	Pea
Spinach	Lilac	Cucumber
Bean	Onion	Carrot
Celery	Honeysuckle	Cabbage
Tobacco	Maple	Canteloupe
Cotton	Rose	Cauliflower
Willow	Sweet Cherry	Barley
Ragweed	Gladiolus	Pansy
	Peach	Sweet Pea
	Cabbage	White Clover
	Apple	Bermuda Grass
	Elm	

exposed to high concentrations of sulfur dioxide over a short time. Chronic injury may result when the plant is exposed to low concentrations of sulfur dioxide over a long term period and the amount of sulfur absorbed exceeds the threshold value. Visible injury from sulfur dioxide is typified by intervenial chlorosis of the leaves and closely resembles the acute injury symptoms of nitrogen dioxide. The latter pollutant, however, has not caused an appreciable amount of plant injury.

Some of the other important pollutants known to cause some plant injury are chlorine, ethylene, acetylene, and propylene. Chlorine injury is similar in appearance to ozone type symptoms. Ethylene and associated olefins, acetylene and propylene, show similar responses on vegetation. Ethylene may cause a considerable reduction in plant growth. This pollutant is of concern to greenhouse growers and although acute symptoms of ethylene injury are seldom observed chronic symptoms are prevalent.

Estimates of Loss

The United Stated Department of Agriculture has estimated that annual losses to agricultural crops from air pollution ranged from $150 million to $500 million for the period 1951 to 1960.[4] These damage estimates are approximately 1 to 2 percent of the average annual farm value of commercially produced crops. None of these estimates, however, includes an allowance for damage to non-commercial crops or vegetation in urban areas where plants are more likely to be exposed to high pollutant levels.

The basis of most estimates of damage to vegetation are highly judgemental. In some instances, plant injury or damage not attributed to other causes are related to air pollution by observers in the field. The estimates which have been made by the U.S. Department of Agriculture are derived primarily from the information obtained from these observers and upon the extrapolation of this data to other areas where such observations are limited. However, air pollution damage to vegetation is difficult to identify or quantify even by experts particularly with respect to the impact of air pollution on yields, quality, and suppressed growth of plants.

Economic estimates of air pollution damage to vegetation from specific episodes or industrial sources have been reported in the United States since the early 1900's. Extensive damage to vegetation from sulfur dioxide has been found around most smeltering plants throughout the country. Thousands of acres of land have been completely denuded of vegetation and thousands more have suffered extensive damage to vegetation around smelter operations in California, Utah, Georgia, Alabama, Tennessee, Montana, and Canada. Extensive damage to vegetation from sulfur dioxide has also been found around large power plants in the Tennessee Valley and Central Pennsylvania. Numerous litigations have been instigated by farmers to obtain monetary compensation or injunctions against the operators of these firms. Because damages to farmers are usually settled out of court, information on the settlements is not available. A large number of the smelters have purchased the land surrounding their operations to avoid litigation. Nevertheless, the damage to vegetation from these smelting operations remains a serious problem.

Extensive damage to vegetation from fluorides has been reported in Florida, Oregon, and Washington. Crocker recently attempted to estimate the damages to agriculture from fluorides emitted by the phosphate industry in Florida.[5] He met with little success. Most of the legal actions taken by farmers against the phosphate companies were terminated by out of court settlements or the purchase of citrus groves or grazing land from the farmers. In the Pacific Northwest, where aluminum companies are important emitters of fluoride, similar settlements have occurred. Although thousands of acres of cattle land and citrus groves have been abandoned in Florida because of fluoride emissions, it has been difficult for farmers to obtain settlements because of the large number of emitters within the area.

Damage to vegetation from photochemical smog has been reported since 1945 in the United States.[6] Although smog damage was initially discovered on the west coast, additional damage from this complex pollutant was soon reported throughout the United States. Extensive damage to crops has been reported annually around the Los Angeles and San Francisco Bay Area. Major episodes of crop damage from similar pollutants have occurred in New Jersey, Pennsylvania, New York, and New England. Although photochemical or oxidant damage to vegetation has not been extensively reported in the Midwest or Central States, the extent and amount of this damage may be more widespread than these reports indicate.

Numerous estimates of air pollution damage to crops from oxidants or photochemical smog have been recorded. Most of these estimates, however, apply to limited geographical areas or crops and are crude approximations of the actual damage incurred. Since 1960, the number of estimates of damage that have been reported throughout the country has declined. Part of the reason for the hesitancy to estimate damage is undoubtedly due to the failure to substantiate past estimates and the wide variation in opinion as to the reliability of such estimates. The point that Knesse has made in a recent speech...that..."current estimates of the national cost of air pollution are indefensible"...is well recognized. We must also agree with his statement that..."A modest effort is indicated to provide more reasonable numbers."[7]

Current Research to Evaluate Damage

Over a million dollars is spent annually by NAPCA to study effects of air pollution on vegegation. In-house research on this problem is conducted by the Agricultural Branch of the Division of Economic Effects Research. Several of the members of this Branch hold joint appointments as U.S. Department of Agriculture and the U.S. Department of Health, Education and Welfare employees.

The Agricultural Branch of the Division of Economic Effects Research has been studying the effects of different types and combinations of pollutants on vegetation. Most of their work has involved carefully controlled chamber studies. In the near future field chambers will be developed to provide information on ambient levels of pollution and its effect on growth. Although basic research on synergistic effects and threshold levels needs to continue, the movement of the experiment from the laboratory to the field should provide better guides for evaluating injury to vegetation.

Most of the air pollution research effort in agriculture has been to discover the physical relationships between variables. The Effects Assessment Branch of the Division of Economic Effects Research has the responsibility of taking the physical relationships developed by the Agricultural Branch and converting these into economic terms. The Effects Assessment Branch also has the responsibility of deriving economic estimates of damage caused by air pollution throughout the United States. Several areas of investigation are now being undertaken by this Branch to improve existing estimates of damage.

One of the major impediments to obtaining reliable estimates of vegetative damage from air pollution is the lack of trained personnel to detect and identify the damage. During this past year an effort has been made to acquaint agricultural extension personnel with the symptoms of such damage. In conjunction with the Office of Manpower Development of NAPCA and Penn. State University, a course designed to train county agricultural extension agents in Pennsylvania to identify injury is under development.

Forms and instructions for reporting vegetation damage or injury will be provided to the participants of this course. Technical manuals containing descriptions of the various symptoms will be supplied to these agents and plant specialists at the University will be available when notified to check and verify incidences of air pollution damage to vegetation.

Previous efforts to obtain estimates of air pollution damage to vegetation from extension service personnel have met with limited success. Concern among these agents with other major plant disease and insect problems and the difficulty of identifying and assessing plant injury from pollutants have resulted in their neglect and apparent apathy toward the air pollution problem. It is hoped that even if a small percentage of the actual incidences is reported by county agents in Pennsylvania, a greater appreciation and awareness of the importance of this problem will be gained. It is anticipated that a similar course to that presented in Pennsylvania will be offered to agricultural leaders and extension agents in other states.

During this past year we have been working with the U.S. Forest Service to assess the oxidant injury on ponderosa pine in the San Gabriel and San Bernardino Mountains of southern California.[8] Several plots of trees were checked for injury symptoms in field surveys. The results obtained from these field surveys were then compared with results of photo interpretations of the same plots. The purpose of this study was to determine the feasibility of aerial photography, using various types of films and photographic scales, as a rapid survey technique for assessing air pollution damage. In fiscal year 1970 this project will be extended to do similar studies in northern Alabama and Tennessee.

Prospects for future use of aerial photography as a means of assessing injury appear good. Considerable difficulty still exists, however, in placing an economic value on losses, particularly when the losses involve multi-purpose uses. For example, the ponderosa pine in the San Gabriel and San Bernardino mountains are valued more for its contribution to residential and recreational facilities than for timber. Although the decline of ponderosa pine should have a depressing effect on the real estate market; other factors such as the increased population and demand for less polluted areas in the Los Angeles area have augmented this market.

Other rapid survey techniques that will be investigated shortly are multiple scanning and heat sensing devices that can distinguish different healthy and unhealthy plants. Like aerial photography, however, ground surveys are required to insure that the damage is due to air pollution and not other causes. Some of these instruments may be mounted on satellites or high flying airplanes The advance in technology in this area is fantastic and it is one of our jobs to put it to worthwhile uses.

A national survey of vegetation damage from air pollution will be initiated this year. This study is being done by Stanford Research Institute, under the sponsorship of CRC (the Coordinating Research Council) and NAPCA. The basic objective of this study will be to develop a reliable estimate of annual economic losses to agriculture in all regions of the United States resulting from damage to vegetation by air pollutants. In reaching this objective, a method will be developed for evaluating the damage. Furthermore, the principal sources or areas of incidences, major pollutants causing the damage, and the extent and type of damage and crops affected will be documented. This project will include the most extensive survey that has been conducted to evaluate these losses.

Given the state of the art, much more needs to be known before we can have much confidence in our estimates of damage. Nevertheless, such estimates are necessary to help guide policy makers concerned with air pollution problems. Action must be taken now to arrest air pollution or we might not have anything to evaluate. We must, therefore, provide the most current and reliable information for decision makers.

FOOTNOTES

1. Mukammel, E. J., et.al., Air Pollutants, Meterology and Plant Injury; Technical Note No. 96, World Meteorological Organization, Geneva, Switzerland, 1968.

2. Middleton, J. I., "Air Conservation for the Preservation of Agricultural Production," Proceedings–15th Annual Meetings – Agricultural Research Institute, National Research Council, 1964.

3. Taylor, O.C., "Effects of Oxident Air Pollutants," Journal of Occupational Medicine, Volume 10, No. 9, 1968.

4. United States Department of Agriculture, Agricultural Research Service, "Losses in Agriculture" Agricultural Handbook No. 291, Washington, D.C., U.S. Government Printing Office, 1965.

5. Crocker, Thomas D. "Some Economic Aspects of Air Pollution Control with Special Reference to Polk County, Florida" - Report submitted to the Director, Office of Research Grants, NAPCA, January 1968.

6. Middleton, J . T., "Photochemical Air Pollution Damage to Plants," Annual Review of Plant Physiology, Vol. 12, 1961.

7. Knesse, Allen V. "How Much is Air Pollution Costing Us in the United States," Proceedings - The Third National Conference on Air Pollution DHEW-PHS, 1966.

8. Larsh, Robert N., P. Robert Miller and Steven L. Wert; "Aerial Photography to Detect and Evaluate Air Pollution-Damaged-Ponderosa Pine," paper to be presented at annual meeting - Air Pollution Control Association, New York, 1969.

STUDIES TO DETERMINE THE COSTS OF SOILING DUE TO AIR POLLUTION: AN EVALUATION

A. Craig Jones

National Air Pollution Control Administration, North Carolina

Introduction

Attempts at estimating the economic cost of air pollution damage have been proceeding at two levels of inquiry - the national level and the local level. Often the national estimates of damage have been extrapolated from data collected at the local level. In most cases, however, so little confidence can be placed in these local estimates, particularly with regard to soiling damage, that the error is probably only compounded when used as a basis for national estimates.

It is obvious then that one must begin by improving the quality of the local estimates of pollution damage. In order to do so, one must first look at the research work that has been done in the area of determining the cost of air pollution. Ronald Ridker[1] has provided the framework for estimating these costs. According to his basic strategy of measurement, the effects of air pollution and their related costs can be categorized as follows:

1. Cost of direct effects of air pollution in the absence of adjustments.
2. Cost associated with individual adjustments to various levels of air pollution to reduce direct effects.
3. Costs involved in the market effects of these adjustments.

The cost of damage to vegetation, as discussed by Dr. Gillette in his paper, "Air Pollution Damage to Commercial Vegetation," is a cost of the direct effects of air pollution. Other direct costs might include damage to materials and the costs of ill health associated with air pollution.

This paper centers around the second category, the cost of individual adjustments to the effects of air pollution. For example, a homeowner might have to paint his home more often. Because studies of adjustment costs have dealt mainly with the household soiling due to particulates, I shall necessarily concentrate my remarks in this direction. There is evidence, however, that indicates that industrial, commercial, and public structures, as well as often being obvious sources of pollution, can also be receptors of the effects of air pollution that require costly adjustments.

The third and final strategy for evaluating costs due to air pollution results from the effects of one's actions upon another - the market effects. In this category, property values, as Professor Crocker will soon attest, seem to afford a very promising strategy of measurement.

Early Studies

Surely the best known of the early studies of economic loss due to air pollution is the Mellon Institute Study of the Pittsburgh smoke nuisance in 1913.[2] The fame of this report has probably grown from its use as the basis for the $11 billion national damage estimate that has been so often quoted in recent years by both public officials and the public-at-large. The attention given to it here now is for the purpose of understanding its limitations and for the realization that the extrapolation of such local data to the national level is virtually useless.

The purpose of the Mellon Institute Study was to assess the economic cost of the smoke nuisance to the city of Pittsburgh. The cost estimates were based upon literature searches, observations and informal surveys. Included in the total yearly cost estimate were:

1.	Cost to the smoke maker for imperfect combustion	$1,520,740
2.	Cost to the individual	
	a. Laundry bills	$1,500,000
	b. Dry cleaning bills	750,000
3.	Cost to the household	
	a. Exterior painting	330,000
	b. Sheet metal work	1,008,000
	c. Cleaning and renewing wall paper	550,000
	d. Cleaning and renewing lace curtains	360,000
	e. Artificial lighting	84,000
4.	Cost to wholesale and retail stores	
	a. Damaged merchandise	1,650,000
	b. Extra precautions to avoid damage to merchandise	450,000
	c. Inside maintenance	750,000

	d. Artificial lighting	650,000
	e. Department stores for the above costs	175,000
5.	Cost to quasi public building for increased inside maintenance and artificial lighting	
	a. Office buildings	90,000
	b. Hotel	22,000
	c. Hospital	55,000
	Total	$9,944,740
		or $20 per capita in 1913.

The damage estimates obviously included some direct costs as well as some adjustment costs. However, the list of items for which estimates were made was not meant to be all inclusive. No attempt was made to measure the extra cost of cleaning public buildings and cleaning and maintaining the exteriors of buildings, nor of health, agricultural, and aesthetic effects.

Finally, only the briefest attention was given to the market effects of the Pittsburgh smoke nuisance. First, several isolated cases of possible decreases in property values were cited - some not even dealing with the city of Pittsburgh. Second, some brief evidence was presented to indicate that there was an absence of certain industries in Pittsburgh because of the smoke nuisance. However, neither of these cost areas was included in the total gross estimate of damage.

Although fine for its day, the study obviously lacked a great deal of sophistication. First, some of the damage estimates were determined by a comparison to other cities which were assumed to be less dirty than Pittsburgh. For example, houses in Pittsburgh were found to be painted every 3 years, while in other cities the houses were painted every 6 to 8 years. The additional cost to the citizens of Pittsburgh was attributed solely to air pollution. However, the level of air pollution in Pittsburgh and the comparison cities was never measured, and the effects of socio-economic variables were never considered. Second, other damage estimates were determined by the application of a certain percentage or damage factor, thought to be attributable to the smoke problem, to the specific cleaning or maintenance category. For example, it was determined that the average yearly cost of cleaning a store was $754.00. One-third ($250.00 per store) was estimated to be attributable to atmospheric conditions in Pittsburgh. Little data is available to back up these estimates of the size of the damage factors. With such shaky foundations, one is not very hard pressed to question the validity of the results.

It would seem that the author himself realized the limitations of his cost estimates. Problems have arisen when those who do not realize the simplifications and estimations inherent in the $20.00 per capita figure have extrapolated it to the $11 billion damage estimate.

To describe quickly the extrapolation, between 1913 and 1958, the consumer price index for apparel and upkeep costs increased by a factor of three. Applying this factor to the $20.00 per capita figure results in a per capita estimate of $60.00 annually. Further increases of this index in recent years have brought the per capita figure to the $70.00 range. Multiplying these figures in turn by the respective U.S. population, results in the total damage estimate of $11 to $12 billion.[3]

The most glaring problems of such an extrapolation are readily apparent. Surely, the pollution level of Pittsburgh in 1913 was not then nor is now representative of the entire nation. Thus, multiplying by the total U.S. population would only seem to compound the error involved. Of secondary concern is the fact that wasted fuel costs were included in the Mellon Study and should not be included in such an extrapolation.

The review of this pioneering work now brings our attention to the work of more contemporary researchers. As you will soon see, one could reasonably question whether any progress has been made since the Mellon Study.

Existing Studies

In recent years, several attempts have been made to identify the costs of soiling due to air pollution. They have met with only limited success. For the most part, these studies have worked with the household as the primary unit of investigation in an attempt to measure pollution related cleaning and maintenance costs in certain localities. Attempts to identify soiling costs to business and industry have been even less fruitful except to note certain one-time expenditures for particular cleaning tasks.

In the area of evaluating household costs of soiling due to air pollution, the work of Irving Michelson has received the most attention. Michelson's method of study is based upon the theory that if air pollution causes meaningful soiling, it may be reflected in a shorter time interval between successive cleaning and maintenance operations in areas with higher levels of pollution. If this relationship could be established, then using the cost of each operation studied and the damage functions relating particulate level and costs, the costs of a polluted environment could be calculated.

To test his theory, Michelson conducted a survey by mailed questionnaires in the towns of Steubenville and Uniontown in the Upper Ohio River Valley. These towns have particulate levels of 235 $\mu g/m^3$ and 115 $\mu g/m^3$ respectively. A good response rate was achieved through a large publicity campaign, and a positive relationship was found to exist between frequency of the home and personal care items and particulate level.

In the analysis phase, the cost comparisons were made within two income groups (less than $8,000 and more than $8,000), and the total costs were calculated on the basis of the number of families and persons in each income group in each city. The differences in frequencies were calculated and then converted into dollar differences by applying local market prices for the various household services used in the survey. The resulting figures showed that the economic cost of air pollution for Steubenville as compared to Uniontown was $3.1 million or $84 per capita.[4]

In an attempt to validate this study a subsequent survey was conducted in three suburban cities of the Washington, D. C. area. The Washington area was chosen for the validating study because it was thought to offer a severe test to the methodology. First, the absolute levels of suspended particulates of the paired cities was so much smaller in the Washington area as compared to the paired cities of the Upper Ohio River Valley. Finally, the character of the two areas was very different as far as industrial mix and population characteristics.[5]

As far as the results are concerned, again Michelson found a positive relationship between the frequency of performance of the cleaning and maintenance operations and the level of suspended particulates. Although the findings of the second study would seem to support the findings of the first study, there appear to be not only major differences between the two studies but also inherent problems within each that throw a great deal of doubt upon this conclusion. For example, while income level was the only controlling factor in the analysis, only the responses of the above-average income group was analyzed in the Washington study. Once the relationship was found to exist in that income group, it was assumed to exist for the below-average group. Also, within each study there are considerable problems with the sample survey design, the data, and the analysis. However, the chief complaint must be with the lack of statistically reliable techniques that allow us to have a certain degree of confidence in the results.

Since these two major studies, Michelson has applied his methodology in other sections of the country. Only recently, he completed a study of the total extra household costs resulting from air pollution in Connecticut.[6] In these studies, no household survey was performed to measure the frequency of cleaning and maintenance operations. Instead, the frequencies were taken from the Upper Ohio River Valley and Washington area studies. Because these frequencies were not alike some kind of "graphical averaging" must have been done. The local costs of the operations were investigated and with the demographic figures from census materials were used to come up with a total damage estimate for the state of Connecticut. Such a use of the methodology without adequate verification is highly questionable.

Ronald Ridker also did research into identifying the economic costs of air pollution. Part of this research has been concerned with the adjustment to the soiling effects of air pollution. In 1965, Ridker conducted a study in high, medium and low pollution zones of Philadelphia to determine whether family behavior and expenditures were affected by air pollution. Despite the apparent adequate collection of data, the results of the analysis phase were inconclusive. Although there appeared to be many detailed problems and errors in the analysis phase, the principal problem involved the use of time expended in routine household cleaning which may very well be an inappropriate estimate of these costs.[7]

Ridker also conducted a time-series analysis of a pollution episode in Syracuse. A questionnaire was developed and administered by personal interview. While the results of this household survey were much better than the cross-sectional analysis in Philadelphia, the approach was obviously limited to the episode-type of situation and could not be put to widespread use.[8]

These previous studies point out several major problem areas with regard to evaluating household soiling costs due to air pollution:

1. Isolation of costs due to air pollution from those due to other variables.
2. Sample selection and bias.

3. Development of a survey technique which will provide reliable answers.
4. Inclusion of all household tasks whose costs are influenced by soiling damage from air pollution.

The review of this past research gives direction to future studies and should improve upon and extend the methodologies already developed. In addition, these pioneering works provide a foundation for the development of other strategies for measuring the economic cost of air pollution.

Future Studies

As air quality criteria documents are issued by the Federal Government, the States will be required to adopt air quality standards to reflect these criteria. The Secretary of Health, Education, and Welfare will then determine whether these standards are "consistent with the air quality criteria and recommended control techniques.[9] Surely, the minimum standard that would be accepted is that the level of air quality not endanger the health of the citizens in the region or state. Cost-benefit analysis may prove to be a valuable tool in defining the degree to which further pollution control is economically justified.

Cost-benefit analysis of air pollution involves identifying the costs of controlling pollution and the cost of damages caused by pollution. In the present situation, one is limited to identifying the costs on both sides associated only with particulate pollution. As was discussed earlier, on the side of the cost of damage caused by particulate pollution, much attention has recently been focused upon determining the cost of household soiling. Although Michelson's studies have shown a positive relationship between the cost of soiling and particulate level, his methods do not allow one to have much confidence in the results. This is one of the reasons that the National Air Pollution Control Administration has recently contracted a study in the Philadelphia air quality region to determine the residential soiling costs of particulate air pollution.

The research of soiling costs in Philadelphia is actually part of a larger cooperative study that is being conducted in that region. As a tool to improve the air pollution control program in the Philadelphia air quality region, a computerized simulation model has been proposed. This model is designed to give the expected results of any air quality standard and/or control regulation that might be put into effect in this region. The results will include the cost of controlling particulate pollution from stationary sources and the benefits resulting from reduced household soiling costs. Of course, additional benefits or savings would result from improving the air quality of the community. For example, damage to vegetation would probably be reduced and property values would be enhanced. However, at the present time only the savings to household soiling will be used as a measure of benefits, but if Michelson's studies are an indication of the costs involved in residential soiling, the benefits of improved air quality will far exceed the costs of control.

The proposed soiling study is designed to eliminate the errors and confusion of Michelson's work and improve upon the statistical techniques in both the survey design and the analysis phases. The following steps will be taken in this study to assure success:

1. Measurements of the air pollution levels throughout the Philadelphia region will be made through a sampling network set up by the Division of Abatement of the National Air Pollution Control Administration. This network will provide more thorough and accurate air quality measurements than those available for previous studies.

2. Household maintenance and cleaning operations that are expected to be adversely affected by particulate pollution will be studied and identified during a series of group panel discussions.

3. The frequency with which these various household tasks are performed will then be measured by questionnaires through a sampling survey. The questionnaire will be administered by personal interview to a random sample of households in at least four pollution zones. Such a sampling design will allow extrapolation of the results to the rest of the region.

4. Before any relationship is established between the frequency of these cleaning operations and the level of particulate pollution, other socio-economic variables that may contribute to the frequency will be identified and the degree of their interaction established through a factor analysis. In Michelson's studies, only income was used as a controlling factor.

5. The frequency with which these cleaning operations are performed will then be set up as a function of particulate pollution. This relationship will be established by a comparison of the zones of pollution.

6. Information will be gathered concerning the costs of performing the

various cleaning and maintenance operations (including labor and supplies) by contacting businessmen in the field. An attempt also will be made to allow for do-it-yourself work.

7. Updated census material will then be obtained and used in the calculation of total community costs.

8. Finally, the study will provide recommendations for improving the methodology and applying it to other regions.

This final step may prove to be a very important one as other regions establish their air quality standards. Hopefully, each region would not have to conduct such extensive research in order to determine soiling costs. As one can see, the methodology proposed is not altogether different than the one Michelson has used. For the present, the interest is in improving the quality of the work and increasing the confidence in it through statistically reliable techniques.

As a final note, a great deal of concern remains regarding estimates of gross economic losses due to air pollution. The most recent attempts at estimating these gross losses have had to depend on very sketchy data. The basic procedure involves:

1. The identification of categories of air pollution damage.
2. An estimate of the total value of the category regardless of air pollution effects.
3. The determination of an air pollution damage factor that represents the precentage of the category damaged by air pollution.
4. The application of the damage factor to the total value of the category.

This procedure is similar to the one used by the Mellon Institute in 1913. The critical element in this approach is the determination of the damage factor in each category. The Mellon Institute had little basis for the size of the damage factors used in its study, and the basis for our most recent attempts at estimating the gross economic losses is just as questionable. Some of the damage factors are based on figures from the Beaver Report, which provided estimates of air pollution effects in England in 1954.[10] Unfortunately, the damage factors of the Beaver Report are at best very crude. As new data become available and research such as the Philadelphia soiling study discovers relationships between pollutants and damages, more precise estimates of economic losses at the national level can be introduced. In the meantime, local estimates of damage costs will be infinitely more useful and hopefully more accurate than such estimates at the national level. Eventually, the information at the base or local level may then be sufficient to allow for extrapolation to the national level.

FOOTNOTES

1. Ronald G. Ridker, Economic Costs of Air Pollution (New York, 1967), pp. 12-29.

2. John J. O'Connor, Jr., The Economic Cost of the Smoke Nuisance to Pittsburgh: Mellon Institute of Industrial Research and School of Specific Industries, Smoke Investigation, Bulletin No. 4, (University of Pittsburgh, Pittsburgh, Pa., 1913).

3. Irving Michelson and Boris Tourin, "Comparative Method for Studying Costs of Air Pollution," Public Health Reports, 81 (June 1966), 505.

4. Ibid.

5. Irving Michelson and Boris Tourin, Report on Study of Validity of Extension of Economic Effects of Air Pollution Data from Upper Ohio River Valley to Washington, D. C. Area, PHS Contract PH 27-68-22, Environmental Health and Safety Research Associates (New Rochelle, N. Y., 1967).

6. Irving Michelson and Boris Tourin, The Household Costs of Air Pollution in Connecticut, The Connecticut State Department of Health, Environmental Health and Safety Research Associates (New Rochelle, N.Y., 1968).

7. Ridker, Economic Costs of Air Pollution, pp. 73-89.

8. Ibid., pp. 90-114.

9. 81 Stat. 481 ["Air Quality Act of 1967" Section 108 (c)].

10. Committee on Air Pollution (Sir Hugh Beaver, Chairman), Report, Command Paper 9322 (London, Her Majesty's Stationery Office, 1954).

ODORS, VISIBILITY, AND ART: SOME ASPECTS OF AIR POLLUTION DAMAGE

Brian W. Peckham

National Air Pollution Control Administration, North Carolina

Air pollution disturbs people in the United States because it keeps them from getting what they want. Most people, for example want good health, but waste products from industrial and automotive combustion impair respiratory capacity and increase the risk of disease. Similarly, most people also want food, clothing, and shelter in such quantity and quality as will satisfy not only basic physical drives, but also acquired tastes. Here again, air pollution has an effect. It can injure agricultural crops and animals. It weakens and discolors textiles and nylon stockings. It brings dirt into homes, and soils furniture, clothing, and draperies. It also is responsible for peeling paint, corroding metals, cracking rubber, and decaying limestone. Air pollution, at least to this extent, can sometimes be an obstacle to the satisfaction of common wants for food, clothing and shelter.

Human wants or needs are not, however, confined to those with such strong physiological origins as the need for food. Men experience psychological, religious, esthetic, as well as basic survival needs. These are the motives in our behavior that seem to derive more from social learning than from physiological drives. Men learn to cope with the anxieties arising from death, finitude, and meaninglessness through religious institutions. Men learn to desire high status, support, and normative structure from the groups to which they belong. Men learn to value the experience of certain qualities of song, dance, painting, and natural environment; they affirm an esthetic dimension to the human condition. In all cultures they decorate their crude material existence with the creations that proceed from the distinctive human capacities for complex emotion and symbolization.[1]

This paper evaluates the extent to which air pollution interferes with the satisfaction of this last group of human wants. Men want an environment congenial to their esthetic and psychological needs. Air pollution restrains progress toward such an environment. Odors from various industrial sources deprive many of the full enjoyment of their property. Particulates and oxidants dangerously diminish visibility, impair athletic performance, cut out sunshine, bring on rain, clouds, and fog. Oxides of sulfur emitted into the air accelerate the decay of honored works of air and statuary. Emissions from automotive combustion injure the trees on the street. Air pollution in the

United States is a problem not only because it contends against elemental wants for health, food, clothing, but also because it contends against acquired wants for the refinements and pleasures of a high consumption society.

The problem of odors arises from the waste products of many industrial operations.[2] The transportation industry is responsible for large amounts of diesel fumes. Digester blow systems within kraft pulping plants release hydrogen sulfide, methyl mercaptans, and dimethyl sulfide, all offensive to most people even in quite small concentrations. Hydrogen sulfide has the distinctive smell of rotten eggs, while methyl mercaptans have the smell of decayed cabbage. The main emissions from the by-product coke ovens in steel mills include not only smoke and dust, but also hydrogen sulfide, phenols, and ammonia. Oil refineries give off mercaptans from cracking units, phenols and napthenic acid from scrubbing-solution storage tanks, and hydrogen sulfide. The smell of decomposing proteins, often associated with rendering plants, is an offensive mixture of hydrogen sulfide and putrescine, skatole, butyric acids. Kettle-cooking processes in the manufacture of paint and varnish permit the escape of malodorous hydrocarbons as do continuous processing ovens for vinyl plastic products. Other industrial processes that are often major sources of odors include acid treatment in thermal-process phosphoric acid plants, wire enameling in magnet manufacture, metal lithographing in can manufacture, and tungsten filament manufacture.

Odors from all these sources generate a high level of public concern. This is clear from opinion surveys sponsored by the Public Health Service. For example, the survey conducted as a part of the 1966 Interstate Air Pollution Study in St. Louis showed that 926 of the 1361 complaints received during 1958-1962 by the St. Louis Division of Air Pollution Control pertained to odors.[3,4] Furthermore, over 73 per cent of the subjects interviewed defined the concept "air pollution" as offensive odors. Ninety-one per cent of the respondents to an opinion survey taken in Clarkston, Washington made a similar identification of air pollution with odors.[5] In an independent study taken in the Cincinnati metropolitan area, control officials found that well over half the air pollution complaints registered in the suburbs during 1965 involved odors.[6] Once again, odor problems were most often given as a definition of "air pollution."

This concern with the olfactory effects of industrial wastes is of ancient origin. Theophrastus, a pupil of Aristotle, wrote a treatise on stones about 271 B.C. in which he called attention to the objectionable odors from the combustion of coal. The odors and soot from coal smoke have chased at least two English monarchs from London. The first to go was Queen Eleanor in

1257; William III moved out about 400 years later in 1690. Queen Elizabeth I could not abide coal smoke, and Edward I became so unhappy over the smoke from London furnaces that he threatened severe penalties for any who might substitute coal for wood. The ancient notion that diseases came from "bad airs" suggests that odors and air pollution in general have long been conspicuous problems.[7]

Although odors are frequently confined to a small area, sometimes they can span considerable distances. Public Health Service investigations of the interstate odor problem along the Vermont-New York boundary turned up evidence that a conjunction of stable atmospheric conditions and a wind speed of 5 miles per hour was sufficient to carry detectable hydrogen sulfide fumes from the International Paper Company mill in Ticonderoga, New York 31 miles downwind.[8] Similarly, mercaptans from industrial processes in New Jersey, although usually localized within a one or two mile radius, at times have carried all the way across New York City into Nassau County on Long Island.[9] In December of 1960 an accident at a chemical plant in Carteret, New Jersey, released a cloud of ethyl mercaptan gas that covered Manhattan from Hudson to the East River, from City Hall to the vicinity of 90th Street.[10]

Regardless of the area they cover, odors can deprive people of the use and enjoyment of their property. A survey of court records is a good way to confirm this. Recently, for example, 31 homeowners brought suit against the Weyerhauser Paper Company to recover for damages caused by odors emitted from the company's kraft pulp mill in Elkton, Maryland.[11] The variety and extent of injury is well illustrated by the testimony received by the court. One complainant said that the odors kept her from sleep, caused nausea, and on five occasions actually sickened her to the point that she lost breakfast on the way to get her car out of the garage. Another attributed frequent chest pains to the odors. One family complained that the odors not only interfered with sleep, but also drove away guests and forced the closing of all windows and doors. Apparently the mill odors canceled a number of outdoor barbeques, and even obliged one family to retreat to an air tight room in order to get some sleep. The argument could of course be made that these plaintiffs were exaggerating their injuries to win larger awards from the court. However, the testimony was evidently convincing enough that the court found for the plaintiffs in the amount of $18,703. An earlier New Jersey case involved an action to enjoin the emission of foul odors from a rendering plant in Saddle Brook. The trial court accepted evidence of damage as follows:

> At various times during the year, especially in the hot summer months, or when a strong wind is blowing in the direction of their homes, unbearably foul and noxious odors emanate continuously from the defendant's plant...These offensive smells permeate the atmosphere and befoul the homes and clothing of these residents, causing some of them to become ill, producing extreme discomfort, dulling their appetites, spoiling their meals, and interfering with normal social and family relations.[12]

On the basis of this evidence, the Superior Court of New Jersey, Chancery Division, held the odors to be a nuisance and granted an injunction. This judgment was affirmed upon appeal to the Appellate Division. Twenty years earlier the Supreme Court of Wisconsin upheld an award of $4000 to a home owner who had suffered frequently from offensive odors released by a municipal sewage disposal plant in Hartland, Wisconsin.[13] An award of $1000 for injuries caused by rendering plant odors was affirmed by the North Carolina Supreme Court in 1939.[14] In a 1960 case a Pennsylvania court held that $5700 was appropriate compensation for an odor nuisance created by air pollution from mine refuse dumps.[15] A North Dakota man recovered $3500 for harms suffered when the city of Bismarck erected a city dump 800 feet from his home. This judgment was later affirmed by the North Dakota Supreme Court.[16,17]

Bad smells do not affect only those who live in poor or shabby neighborhoods. For a number of years the residents of Georgetown, one of the most prestigious addresses in the District of Columbia, have complained of the obnoxious odors drifting up from the Hopfenmaier rendering plant by the Potomac River.[18] On warm days many could not sit out in their elegant gardens or leave their windows open. Influential residents such as Senator Stuart Symington (D-Mo.) have urged the city to take action. Even public agencies sometimes are troubled by odor problems. Wicomico County, Maryland recently offered an 85-acre site to the Maryland Board of Public Works for a mental retardation center. The state was just about to accept this gift when it learned that adjacent to the property was a malodorous chicken rendering plant. As a consequence, it deferred action on the matter until it could ascertain the effectiveness of odor abatement equipment to be installed at the plant.[19]

Action against odor problems begins with measurement.[20] Human monitors are used to evaluate smells in terms of their quality (fragrant, burnt, sour) and their intensity. Intensity is often expressed by the odor unit, which is simply the amount of each type of odor that will just be perceived (just reach threshold) when introduced into a cubic foot of clean, pure air. If a sample of contaminated air contains X odor units per cubic foot, it carries an odor of such intensity that when one part sample is diluted with X-1 parts clean air, the odor reaches threshold. The number of odor units in a sample is often determined in the field through the use of a scentometers or the Fair-Wells Osmoscope. Both of these devices work on a dilution principle. They allow the operator to adjust the volume of air that he inhales through charcoal filters and through orifices open to the ambient air. The mix of clean and contaminated air that is associated with the threshold level of the odor can then be determined. Unfortunately, measurement of odor is hindered by the difficulties of insuring uniform olfactory sensitivity among observers and among different time periods for the same observer.[21] Age and humidity seem to affect sensitivity, as does odor fatigue. Any observer will get used to a particular odor if he monitors it long enough:

> The problem of odor fatigue is impossible to eliminate. The Community under study (Clarkston, Washington) would be considered highly odorous by newcomers to the area. Within an hour of arrival, however, a marked reduction in odor, caused by fatigue, is noticeable.[22]

Control officials try to get around these barriers by standardization of observers through careful selection and training.[23]

Attempts at systematic measurement of community odor problems have been undertaken by the Public Health Service. During November and December of 1963, as a part of the Interstate Air Pollution Study in St. Louis,[24] firemen at 79 stations throughout the metropolitan area recorded odor pollutants five times daily. Thirty per cent of the observations recorded the presence of odors, two-thirds of which were unpleasant. The most common smells came from combustion and chemical processes (diesel, refinery, incinerator) between evening and midnight. On November 24, 1963, observers noted a 7-mile-per-hour wind blowing chemical effluents from the Illinois side of the River onto a 25-square-mile area in Missouri. During this St. Louis study the Public Health Service was also conducting a similar survey in Kansas City.[25] Here again firemen were used as monitors and samples were taken five times daily, and here also odors were identified in 30 per cent of the observations. The most frequent odors recorded were those of smoke, stockyards, and diesel exhaust. In neither of these projects was an attempt made to measure odor intensities in a precise way. Firemen were simply asked to describe any perceptible fumes in their own words. Perhaps the first Public

Health Service odor study to measure intensity as well as quality resulted from the abatement conference called in connection with interstate air pollution in the Selbyville, Delaware - Bishop, Maryland area.[26] A team of observers using the scentometer device established interstate transport of odorous pollutants and found that the intensity of these odors at times reached 30-odor units per cubic food. At such strength the emissions from the rendering plant in Bishop, Maryland constituted a serious nuisance. Subsequent to this survey, the U.S. Justice Department and the State of Maryland each brought suit against the rendering plant to enforce abatement of the odors.[27] The most recent activity of the Public Health Service in the evaluation of community odor problems is a contract awarded May 1969 to Copley International Corporation of La Jolla, California. The first phase of this project will consist of a national evaluation of the odor problem and the selection of areas for more intensive study. Phase two will be concerned with the development of methods for the measurement and evaluation of community odor problems that can be made available to local control officials.

Air pollutants offend not only the sense of smell but also the sense of sight. They create serious hazards to transportation by degrading visibility. They cloud over the countryside with haze and fog. They discolor the sky.

Aerosols such as smoke or hydrocarbon mists affect visibility by scattering and absorbing light.[28] Particles in the air can act on the energy of electromagnetic radiation in two ways. They can intercept and transform the energy into heat or chemical form--this is light absorption. Alternatively, they can reradiate the energy with the same wavelength but in different directions--this is light scattering. The nature of the effect and its magnitude are functions of the chemical composition of the particle, particle size, shape, and concentration. In either case, the perception of luminant and chromatic contrasts over the visual field is impaired. Visibility is reduced.

Air pollution exerts an indirect effect upon visibility by aggravating fogs and diminishing sunlight. Particles in the air provide condensation surfaces for water vapor, and thereby facilitate the formation of fogs.[29] Chemical pollutants dissolve in water droplets, and slow their dissipation. Kratzer[30] reports that the increase in the number of foggy days per year in London between 1871 and 1890 (from 50.8 for 1871-5 to 74.2 for 1886-90) was related to similar increases in urban population and, presumably, in air pollution. For the years 1936-37 the city experienced 40 days with fog, while the London suburbs had only 15. Several attempts have been made to measure the blocking of solar radiation by air pollution. One of the earliest used potassium iodide solutions to monitor ground light intensity in Leeds, England in 1895.[31] This test and another, 15 years later, showed that city smoke took out 40 per cent of the potential sunlight. Clark in 1926 found a difference of 55 per cent between the sunlight of Manchester and that of its suburbs.[32] Shrader and his co-workers in 1929 published data showing that rural areas 10 miles outside Baltimore received 50 per cent more ultraviolet radiation than the urban center itself.[33] Readings were taken from recorders attached to photoelectric cells. In 1945 the U.S. Public Health Service determined that Chicago smoke, together with fog and partial cloudiness, was depriving the city of approximately 44 per cent of its possible hours of sunshine.[34] Hand reported an 18 per cent difference between 4-year mean radiation levels for central and suburban Boston.[35] During October and November of 1954 Stair and Gates measured insolation through the Los Angeles smog.[36] Due to absorption of light by water, ozone, carbon monoxide, and hydrocarbons, loss of ultraviolet radiation in Los Angeles was undertaken by a Public Health Service team during October 1965.[37] Photochemical and photoelectric sensors were set up on the roof of the Los Angeles County Air Pollution Control District Laboratory downtown and on Mt. Wilson at an elevation of 5700 feet. Moderate to heavy smog attenuated insolation by a mean value of about 38 per cent, with peaks at 58 per cent.

When air pollution degrades visibility, whether through fogs, scattering or absorption, travel becomes difficult and hazardous. Representatives of the New Jersey Turnpike Authority testified before the Public Health Service Abatement Conference for New York that "air pollution contributes to visibility restrictions that endanger the safety of traffic."[38] A 1963 report of the Senate Public Works Committee reported that:

> "any smoke close to a modern highway can pose a serious threat to travelers. In at least two recent instances–one in Pennsylvania close to a smoldering culm pile, another in Los Angeles near a burning dump–the sudden application of brakes by a single motorist led to a chain reaction which involved the wrecking of a number of vehicles."[39]

The 1962 air pollution disaster in London showed how heavy smoke and fog together can disrupt all types of transport.

> Shipping was virtually at a standstill in the Port of London with 60 ships fog-bound between Gravesend and the Nore. The Clyde was also closed to shipping.[40]

As visibility fell to 30 yards in many parts of the city, all London bus service was halted; ambulances of the Royal Automobile Club rescue squad did not leave their garage.[41] London Airport was closed for more than 60 hours; two trains crashed together at Gillingham, Kent, killing one and injuring three.[42] Air pollution settled in over Manchester also. The Ford works in Dagenham closed down in the early afternoons when deliveries to the plant were suspended. Workers were forced to walk home; soccer games were postponed; 15 cars collided near Wallsend; 12 buses, petrol tankers, and cars were wrecked in two accidents near Cheshire.[43] Two years later similar conditions were present in Manchester:

> South Lancashire and North Cheshire were today in the grip of some of the worst fog experienced for two years...The worst, and most dangerous conditions, today were on the East Lancashire Road linking Manchester and Liverpool. The road is flanked by industrial and housing areas which are not subject to smoke control, and visibility at times was down to a few feet. A number of vehicles were involved in concertina accidents.[44]

In the United States the Public Health Service has conducted visibility measurements at major metropolitan airports to determine the impact of air pollution on air transportation. At Kennedy International Airport in New York City, smoke and haze during October 1964 reduced visual range for an average of 9 hours a day.[45] The Greater Pittsburgh Airport was similarly studied on the 15th and 16th of October 1963. Thirty-five consecutive hours of smoke reduced visibility to 1 mile on the 15th and 1 1/2 miles on the 16th. The conclusion was reached that "practically all the low visibility was caused by air pollution."[46] The Kansas City Municipal Airport is surrounded by large industrial establishments. Smoke plumes have been found to obscure runways and even to envelop the control tower.[47] At the Fairfax Airport in adjacent Kansas City, Kansas, smoke from burning dumps, a Phillips Petroleum Company refinery, and an Owens-Corning Fiberglass Corporation plant have often interfered with airport operations:

> Heavy smoke all directions causing a partial obscuration west, north, and east. Very hazardous conditions at north end of field (December 20, 1966, 0700)
>
> Heavy blacksmoke from dump at north end of field drifting east across airport. (December 23, 1966, 1700)[48]

Poor visibility results in accidents and disruptions of service. The Civil Aeronautics Board, in a review of 1962 aircraft accidents in the United States, found at least six to be directly due to "obstruction to vision" caused by smoke, haze, sand, and dust.[49] The FAA, along with the Airline Pilots' Association and the Air Transport Association of America, has regularly complained about the airport delays caused by air pollution in the New York City area. Went reported in 1955 that smog in Sao Paulo, Brazil forced the closing of local airports for hours every morning: airports in Bogota and Medellin, Columbia, were also shut down for long periods for the same reason.[50] Captain O. M. Cockes, an Eastern Airlines pilot, claimed that in 1965 the risk was so great of near-collisions due to smoke that "you've had a dull trip when you don't experience at least one on every trip sequence as an airline pilot."[51] On May 23 of that year he had to take evasive action to miss a light aircraft obscured by smoke. On another flight he entered smoke at ground level and did not emerge into clear sky until he climbed above 31,000 feet. Another Eastern pilot, testifying before the Virginia Air Pollution Control Board, described the many delays and cancellations caused by air pollution.[52] He further indicated air pollution as the cause of at least two mid-air collisions during 1967: one over Hendersonville, North Carolina in which 82 persons died and another near Urbana, Ohio in which 26 persons died. That Eastern Airlines and its pilots should be concerned about air pollution is not surprising. Early on the morning of January 15, 1959, an Eastern aircraft, having lost its bearing in a cloud of smoke, crashed on the runway of Moisant Airport, New Orleans. Fortunately no one was injured, but damages to the aircraft totaled $376,000. The airline contended that smoke from an American Cyanamid chemical plant adjacent to the airport was responsible and brought suit. During the trial the pilot testified that as his plane crossed the edge of the runway, dark smoke completely enclosed it and abruptly destroyed his visibility. However, the jury did not find for Eastern, this judgment was later affirmed on appeal.[53]

People want safe and dependable transport. They want to be able to travel without extraordinary risk or delay. Furthermore, most people also want access to pleasing scenery and bright, clear weather with sunshine. Air pollution can often defeat these wants by depressing visibility, blocking sunshine, and intensifying fog. This seems clear from the evidence. What is not so clear, however, is the monetary magnitude of the injuries suffered.

Another kind of injury to esthetic sensitivities occurs when air pollutants, primarily the oxides of sulfur, accelerate the decay of stonework.[54] Calcareous materials such a limestone, marbles, lime plaster walls, and frescoes are subject to chemical assault by the sulfuric acid formed from moisture and sulfur oxides. The calcium carbonate in the stone converts to calcium sulphate and its hydrated form, gypsum, both of which are water soluble. In the process the volume of the stone expands by seventy per cent. Stress and leaching result, and ultimately the stone crumbles. Granites and sandstones are not similarly affected.

This relationship between air pollution and stone deterioration has been understood for a relatively long time.[55] Richmond, in 1906, complained of air pollution damage to ancient sculpture and manuscripts housed in the British Museum.[56] Sir Frank Baines, Director of His Majesty's Office of Works, reviewed smoke damages to the House of Parliament at the Smoke Abatement Conference held in Manchester during November 1924.[57] He estimated that almost 30 tons of loose stone had crumbled from the magnesian limestone structure during its lifetime. He noted the annual expenditure of 120,000 pounds by the Office of Works to maintain and protect official buildings.

The contaminated atmospheres over modern industrial centers are shortening the lifespan of many forms of air. Frescoes, stonework, tapestries, paintings have all been subject to some kind of chemical attack. Injuries to the 14th century Giotto frescoes in the Scrovegni Chapel at Padua, Italy have been the object of special studies. These works had suffered by late 1960 such scaling of paint and such deterioration of supporting plaster that Italian authorities commissioned specialists from Brookhaven National Laboratory and New York University's Institute of Fine Arts to undertake an intensive investigation of the problem.[58] Using X-ray diffraction techniques, Sayre and Majewski found a correlation between plaster decay and gypsum content. This data, together with sulfation measurements by the University of Padua, led them to the conclusion that sulfur oxides in the air were primarily responsible for the deterioration of the frescoes.[59] Many European cathedrals need continuous attention to ward off the effects of air pollution.[60] Cologne Cathedral in Germany has a permanent repair staff of masons. The State of North Rhine-Westphalia, Federal Republic of Germany, spends $4 million annually to preserve ancient churches and stone monuments, the Italian government $10 million a year. French authorities are worried about holding together the stonework on the Strasbourg and Chartres Cathedrals, Belgian authorities the stonework of the Brussels City Hall and the Cathedral of St. Michel and St. Gudule. During his last term as prime minister, Winston Churchill inaugurated a campaign to raise the $2.8 million necessary to restore and protect the venerable Westiminister Abby from the corrosive effects of London air.[61]

Such chemical attack on antiquities and stone artwork occurs all over the industrial world. Air pollution has blemished Rodin sculptures on display outside a Tokyo museum.[62] In New York City it has helped to spoil the facade of City Hall, resulting in a $4 million expenditure for restoration,[63] and forced officials of the Metropolitan Museum of Art to coat statuary with beeswax and air condition exhibition areas.[64] J. V. Noble, Operating Administrator of the Museum, explicitly implicates air pollutants:

> The presence of various forms of sulfur in the air is particularly injurious to limestone and marble. There is an appreciable, visible etching on marble...I would say that all of the exposed stonework of ancient elements at the Cloisters has deteriorated since its erection in New York City as a direct result of air pollution...It is pointless to collect outstanding works of art, many over a thousand years of age, if one thousand years from now they are going to be so badly deteriorated as to be virtually worthless.[65]

Typical of other statements from the scientific community are the following by Professor Seymour Lewin, Department of Chemistry, New York University and Professor Erhard Winkler, Department of Geology, Notre Dame University:

> The rate of decay has increased greatly. The situation is getting more serious all the time. It's at its worst in highly industrialized cities. Many buildings have noticeably deteriorated in the last twenty years.[66]

> The firing and open venting of fossil fuels in humid and semihumid climates have caused millions of tons of corrosive substances to be blown into the air. These soon return to the ground through rain washout or dry fallout near the sources of pollution and inflict devastating damage to stone in urban areas, where the rate of stone decay is doubled or tripled under prevailing adverse atmospheric conditions.[67]

Professor Lewin has recently developed a liquid preservation compound that appears to retard decay in marble and limestone. The compound, composed of glycerine, barium hydroxide, water and urea, can be brushed on monuments and buildings like paint.[68]

Libraries, as well as art museums, have concern for the effects of air pollution. The same acid atmospheres of New York City that decompose the Egyptian statuary outside the Metropolitan Museum of Art also decompose the pages of old books stored in the City's Central Research Library on Fifth Avenue. E.G. Freehafer, Director of the New York City Public Library has estimated that about 1.8 million of the 4.8 million volumes in the Central Research Library are in an advanced state of deterioration.[69] Air pollution is a prime factor in this problem. The City Library has spent $900,000 since 1952 to microfilm decaying books.

A number of miscellaneous effects of air pollution, in addition to odors, visibility, reduction and corrosion, can tarnish the quality of urban life. Dr. P. B. Pironue of the New York City Botanical Gardens studied air pollution damage to trees along city streets in the Bronx.[70] He claimed that as soon as a bus stop was placed in front of Jacobi Hospital, trees in that area began to die. He concluded that vegetation around street intersections was being denuded by emissions from automobiles. Heggestad has reported the phytotoxic effects of common urban pollutants on many common ornamental shrubs and flowers lilacs, petunia, orchid, and gladioli.[71] Air pollution works against other forms of life as well. Good evidence exists that oxidants such as those contained in Los Angeles smog adversely affect athletic performance,[72] that scuba divers suffer some danger when they purchase compressed air obtained from urban atmospheres,[73] and that various air pollutants may injure wildlife.[74] Some social scientists have linked air pollution to urban blight. Professor Peter Gregory, for instance, of Hull University of England, reports that sulfur oxides and particulate emissions from the giant I.C.I. chemical works in Billingham County have turned a housing development built in 1920 as a model community into a slum: "...the area is regarded in Billingham as not only physically filthy, but also an area in which only rough people live."[75] Wallace Agnew, President of the Washington Board of Realtors, Inc., testified before a Senate Committee that smoke pollution was "one of the several factors that is driving people–helping to drive people from the District of Columbia into the suburbs, and especially the middle class family."[76]

American cities are oppressed by their own wastes. Many have become like Ruskin's London, "rattling, growling, smoking stinking–a ghastly heap of fermenting brickwork, pouring out poison at every pore." The fault for this lies partly in a poverty of technique, partly in the confluence of several social forces. Much is known about the technology of producing consumer goods, relatively little about the technology of their disposal after use. High birth rates, rising national output, and new machinery have expanded the volume of waste, concentrated it in compact urban centers, and made it more intractable to decomposition and removal. Innovation has brought forth the automobile, electric power generating plants, and the aluminum can. These developments, together with the growth of population and of the mass of goods consumed, have thrown up the piles of auto hulks and garbage that rise upon the cities, and manufactured the brown air that settles on the horizon.

These problems reflect a basic conflict between the technical and the biological-amenity uses of natural resources. The use of air, water, and land for industrial inputs encroaches upon the use of these resources to support that quality of life most men think desirable. There are not enough water, air, and land to satisfy all the demands made upon them. This is scarcity and it generates conflict. This conflict is certain to be drawn tighter as the costs of economic and population growth continue to overwhelm industrial society. A 1968 report of the Office of Science and Technology,[77] for instance, estimates that in the next 20 years the electric power generating capacity of the nation will triple. Most of this new capacity will likely be supplied by the installation of 250 new giant plants, each having 2 to 3 million killowatts of capacity and each capable of unprecedented levels of air and thermal pollution. In the same 20-year period, rising personal incomes will push up consumer demands for the very clean air, pure streams that they may be sacrificed so that more homes can be lighted, more appliances installed. The social purpose must be to decide how such conflicting claims on natural resources shall be resolved so that welfare shall be at a maximum.

Every social system must make such decisions. Scarcity always involves conflict. The fulfillment of others. The consequences of this conflict depend on the manner of its resolution, on whether it is resolved through bargaining transactions or through externalities.

Transactions are born of the law. Men, who exist together in relations of dependence as well as conflict, have turned to collective action to establish working rules. These systems of rights, liberties, powers, and immunities lend collective sanction to certain private control over future uses of stocks of economic goods. The private property rights thus created are acquired and conveyed through bargaining transactions.[78] This method of handling competition over scarce goods enforces consistent valuations among users and encourages the full exploitation of opportunities for mutually profitable exchange.

To the extent that goods are not held under private property, conflicts over their use may result in waste. The sacrifice required to apply ownership to some goods exceeds the consequent benefit; for other goods private ownership may be restricted by law. In either case, people use these goods without being induced through bargaining to agree on their value. Gains from trade are likely overlooked, and social welfare is not at a maximum. The level of waste depends on the cost of the information, negotiation, and enforcement incident to private bargains external to property systems. This is conflict resolution through externality.

Air pollution is the classical case of externality. Air is a good which, under present legal and engineering technologies, resists administration within private property systems. Consequently, it is not the subject of regular bargaining transactions, and no social agreement on its value exists. When rendering plants, power stations, and people adopt discrepant valuations for the use of the air resource, such deteriorations of environmental quality as this paper has described become matters of concern. The problems of air pollution, including those of esthetic importance, result from externality and legal technology, between air pollution and these elements of the law of torts and property, of the rules of civil procedure that presently maintain the divorce between the air resource and ownership systems.

FOOTNOTES

1. Walter Goldschmidt, Exploring the Ways of Mankind (New York: Holt, Rinehart, Winston, 1960), p. 580.

2. Pertinent references include:

Paul Kenline and J. M. Hales, Air Pollution and the Kraft Pulping Industry (Cincinnati: Taft Center, PHS Publ. No. 999-AP-4, 1963), pp. 4-6;

Ralph Kittle, "Pulp Mill Air Pollution Control," in Proceedings, The Third National Conference on Air Pollution (Washington: PHS Publ. No. 1649, 1966): "...the odorous compounds in the kraft process, which include methyl mecaptans, are detectable by human beings in proportions as small as one part to one billion parts of air." (pp. 233-34);

Jean Schueneman, et.al., Air Pollution Aspects of the Iron and Steel Industry (Cincinnati: Taft-Center, PHS Publ. No. 999-AP-1, 1963), pp. 35-36;

APCA Petroleum Committee TI-3, "The Petroleum Refining Industry - Air Pollution Problems and Control Methods," 14 Journal of the Air Pollution Control Assn. 51, 52 (January 1964);

Atmospheric Emissions from Petroleum Refineries (Washington: PHS Publ. No. 763, 1960), pp. 15-17;

Atmospheric Emissions from Thermal - Process Phosphoric Acid Manufacture (Durham, N.C.: NAPCA Publ. AP-48, October 1968), p. 15;

Melvin Weisbrud, ed., Air Pollution Control Field Operations Manual (Washington: PHS Publ. 937, 1962), pp. 199-200;

G.A. Field, "Science Solves Air Pollution Problem" 71 Paint Industry Magazine 88 (October 1956);

M. W. First, "Control of Haze and Odours from Curing of Plastics," Paper VI/II, Proceedings: International Clean Air Congress, Part I

(London: National Society for Clean Air, 1966), p. 188;

Gerald Brewer, "Fume Incineration," 75 Chemical Engineering 160 (October 14, 1968), pp. 160-161.

3. Norman Edmisten, et.al., 1 Interstate Air Pollution Study, Phase II Project Report : Introduction (Cincinnati: USPHS, Taft Center, 1966), p. 28.

4. Public Administration and Metropolitan Affairs Program, S. Illinois University - Edwardsville, Public Awarness and Concern with Air Pollution in the St. Louis Metropolitan Area (Washington: USPHS, May 1965), pp. 24-5.

5. N. Medalia, and A. L. Finker, Community Perception of Air Quality: An Opinion Survey in Clarkston, Washington (Cincinnati: PHS Publ. No. 99-AP-10, June 1965), p. 13.

6. Southwestern Ohio - Northern Kentucky Air Pollution Survey, Air Resource Management Program for Southwestern Ohio - Northern Kentucky (Cincinnati: March 1967), p. 32.

7. On these historical points, consult Howard Eavenson, Coal Through the Ages (American Institute of Min. and Met. Engr. Serials, 1939); G. Ichok, Le Probleme de la Fumee - une Revue," 51 Rev. D' Hyg. Med. Prev. 493 (1929).

8. Report on Interstate Air Pollution in the Shoreham, Vt. - Ticonderoga, N.Y. Area (USPHS, Div. Air Pollution, November 1965), p. 17.

9. Technical Report: New York - New Jersey Air Pollution Abatement Activity: Sulfur Compounds and Carbon Monoxides (Cincinnati: NCAPC, 1967), p. 35.

10. "Unpleasant Odor Blows Over City," New York Times, December 7, 1960, p. 45.

11. Phillips, et.al., v. Elk Paper Manufacturing Co., Equity No. 1577B, Circuit Court, Cecil County, Maryland (April 17, 1969).

12. State ex. rel. Board of Health v. Sommers Rendering Co., 66 N. J. Super. 334, 169 A. 2d 165, 167 (1961).

13. Hasslinger v. Village of Hartland, 234 Wis. 201, 290 N.W. 647 (1940).

14. H.T. Aydlett v. Carolina By-Products Co., 215 N.C. 700, 2 S.E. 2d 881 (1939).

15. Evans v. Moffat, 192 pa. Super. 204, 160 A. 2d 465 (1960).

16. Donaldson v. City of Bismark, 71 N.D. 592, 3 N.W. 2d 808 (1942).

17. See also Sarrailon v. Stevenson, 153 Nebr. 182, 43 N.W. 2d 509 (1950) (slaughterhouse); Ryan v. City of Emmetsburg, 232 Iowa 600, 4 N.W. 2d 435 (1942) (municipal sewage treatment plant); Steifer v. City of Kansas City, 175 Kan. 794, 267 P. 2d 474 (1954) (municipal dump); Additional case law discussed in Annotations, 54 ALR 2d 764 (Escape, Without Negligence, of Harmful Gases of Fumes), 17 ALR 2d 1269 (rendering plant), 27 ALR 329 (slaughterhouse), 18 ALR 2d 1177 (stockyard), and 40 ALR 2d 1177 (sewage disposal plant).

18. "City's Plans to Sweeten Air Rendered Useless," Washington Post, April 10, 1969, Bl; "Scentometer Sniffs Air in Georgetown," Washington Post, May 8, 1969, Bl; "Smells of Spring (editorial)," Washington Post, April 28, 1969.

19. "Odor Problems Delay Mental Health Center," Washington Post, January 29, 1969.

20. Valuable references on this topic include R. A. Duffee, "Appraisal of Odor - Measurement Techniques," 18 J. Air Poll. Control Assn. 472 (July 1968); H. C. Wohlers, "Recommended Procedures for Measuring Odorous Contaminants in the Field," 17 J. Air Poll. Control Assn. 609 (September 1967); J. F. Byrd and Austin Phelps, Jr. "Odor and Its Measurement," A. C. Stern, ed., II Air Pollution 305, 2nd. ed., (New York: Academic, 1968).

21. Weisbrud, Field Operations Manual, p. 199; Medalia and Finkner, Community Perception, p. 96.

22. Ibid., p. 96.

23. See Amos Turk, Selection and Training of Judges for Sensory Evaluation of the Intensity and Character of Diesel Exhaust Odors (Cincinnati; NCAPC, PHS, Publ. No. 999-AP-32, 1967).

24. H. Neff Jenkins and T.O. Harris, 4 Interstate Air Pollution Study: Phase II Project Report: Odors - Results of Surveys (Cincinnati: USPHS, Taft Center, 1966).

25. Earl V. Porter, An Odor Survey of the Two Kansas Citys (City of Kansas City, Kan., Kansas City, Mo., and USPHS, July 1965).

26. Report on Interstate Air Pollution in the Selbyville, Delaware - Bishop, Maryland, Area (Washington: PHS, Abatement Branch, November 1965).

27. U.S. v. Biship Processing Co., 287 F. Supp. 624 (D. Md., 1968). This is the first litigation steming from the abatement provisions of the Clean Air Act of 1963, 42 USCA section 1857 d.

28. Visibility is the maximum range within which unaided vision can distinguish either a dark object against the daytime sky or a light source at night. References on the subject of air pollution and visibility include Carsten Steffans, "Visibility and Air Pollution," in Paul Magill, et.al., Air Pollution Handbook (New York: McGraw-Hill, 1956); H. Neuberger, et.al., "Physics of the Atmosphere," ibid.; Elmer Robinson, "Effects on the Physical Properties of the Atmosphere" in A. C. Stern ed., I Air Pollution, 2nd ed., (New York Academic, 1968), pp. 349-400; W.E.K. Middleton, Vision Through the Atmosphere (Toronto: Univ. of Toronto, 1952).

29. Ibid., p. 379 f; C.A. Gasoline, et. al., "Evaluation of Weather Effects" in P. Magill, et. al., op. cit.; P. Albert Kratzer, The Climate of Cities (Friedr. Vieweg and Sohn Brauschweig, trans. Amer. Meteorol. Society, 1956); H.B. Meller and L.B. Sisson "Air Pollution," 75 Architectural Record 277 (1934).

30. Kratzer, op. cit., p. 130, 132.

31. "The Nature and Extent of Air Pollution by Smoke," 81 Nature 468 (1909); also reported in Julius Cohen and Arthur Ruston, Smoke: A Study of Town Air (London: Arnold, 1925), pp. 35-36.

32. R. V. Clark, "Atmospheric Pollution and Health," 38 Medical Officer 93 (1927).

33. J. H. Shreader, M. H. Coblentz, and F. A. Korff, "Effects of Atmospheric Pollution Upon the Incidence of Solar Ultraviolet Light," 19 Amer. J. Public Health 717 (1929); see also J. E. Ives, "Loss of Light Due to Smoke in Baltimore, Md. From October 1929 to September 1930," 48 Public Health Reports 1 13 (1933).

34. "Report on Sunshine, Smoke, and Dust," 133 J. Amer. Med. Assn. 334 (1947).

35. I.F. Hand, "Atmospheric Contamination Over Boston, Mass.," 30 Bull. Amer. Meteorol Soc. 252 (1949).

36. R. Stair and D. M. Gates, "Special Radiant Energy From the Sun Through Varying Degrees of Smog at Los Angeles," Paper Presented at the 3rd National Air Pollution Symp., Pasadena, 18-30 April 1955, abstracted, 27 Analytical Chemistry 1034 (1955 June); see also R. Stair, 10 International J. Air Water Pollution 665 (1966).

37. John Nader, ed., Pilot Study of Ultraviolet Radiation in Los Angeles October 1965 (Cincinnati: NCAPC, PHS, Publ. No. 999-AP-38, 1967).

38. Summary of Conference and Conclusions and Recommendation on Interstate Air Pollution, New York - New Jersey Metropolitan Area (Washington, DHEW, January 1967), p. 12.

39. A Study of Pollution - Air: Staff Report, Comm. on Public Works, U. S. Senate, 88 Cong. 1 sess., September 1963, p. 21.

40. "Fog Menace to Lungs," The Times (London), December 6, 1962.

41. "Fog Raises Demand for Hospital Beds," The Times (London), December 7, 1962, p. 12.

42. "More Smog Deaths," Manchester Guardian, December 7, 1962, p. 1.

43. "60 Sudden Deaths Caused by Fog," Manchester Guardian, December 6, 1962, p. 1.

44. "Clean Air Measures Ease Fog Dangers in the North," The Times (London), November 6, 1964, p. 6 (emphasis added).

45. Melvin Nolan, A Survey of Air Pollution in Communities Around the John F. Kennedy International Airport (Cincinnati: PHS-Taft Center, 1966), p. 44.

46. S. Hochheiser, et.al., Air Pollution Measurements in Duquesne, Pennsylvania: September-October 1963 (Cincinnati: PHS and Allegheny County Health Department, Oct. 1964), p. 20.

47. Kansas City, Kansas-Kansas City, Missouri Air Pollution Abatement Activity: Visibility at Municipal and Fairfax Airports. Technical report. (Washington: PHS, NCAPC, January 1967), pp. 47-51.

48. Hourly observations from Fairfax Airport Control Tower, ibid., p. 49.

49. A Study of Pollution - Air: Staff Report, Comm. on Public Works, U.S. Senate, 88 Cong. 1 sess., September 1963, p. 21.

50. Frits Went, "Air Pollution," 192 Scientific American 63, 65, 66, (May 1955).

51. "Pilot Reports Smoke Poses Daily Collision Peril," New York Times, December 7, 1965, p. 92.

52. "Two Air Crashes Laid to Pollution," Washington Post, April 15, 1969.

53. Eastern Airlines, Inc. v. American Cyanamid Co., 321 F. 2d 683 (CA 5, La., 1963)

54. John Yocom and Roy McCaldin, "Effects of Air Pollution on Materials and the Economy," in I Air Pollution 617, A. C. Stern, ed., (New York: Academic, 1968); see also Cohen and Ruston, Smoke, 51.

55. See, for example, Augustus Volesker, "On the Injurious Effects of Smoke on Certain Building Stones and on Vegetation," 12 Journal of the Royal Society of Arts 145 (1864); Samuel Rideal, "The Acid of

Smoke," 27 J. Roy. San. Inst., Trans. 74 (1906-7).

56. William B. Richmond, "Conference on Smoke Abatement: Administration, Legislation, and Necessary Reforms," 27 J. Roy. San. Inst. 211 (1906-7).

57. Cohen and Ruston, Smoke, 52. See also "The Smoke Nuisance: A Suggested Fallacy," 153 Colliery Guardian 679 (1963).

58. Leonetto Tintori, "The State of Conservation of the Frescoes and the Principal Technical Restoration Problems," 8 Studies in Conservation 37 (May 1963).

59. Edward V. Sayre and Lawrence J. Majewski, "Technical Investigation of the Deterioration of the Paintings: Studies for the Preservation of Frescoes by Giotto in the Scrovegni Chapel at Padua," 8 Studies in Conservation 42 (May 1963). See also "Frescoes' Decay Laid to Pollution," New York Times, October 28, 1962, p. 83.

60. "Air Pollution is Eroding World's Stone Art," New York Times, April 13, 1964, p. 1. See also the papers presented at the 1967 London Conference on Museum Climatology (London, International Institute for Conservation of Historic and Artistic Works, May 1968), especially S. Delbourgo, "Atmosphoric Pollution in Parris" and T. Stambolov, "Effects of Sulfur Pollution on Building Materials."

61. Trevor Christie, Antiquities in Peril, (Philadelphia: Lippincott, 1967), p. 30.

62. R. Trumbull, "World Problems: Tokyo," Freedom to Breathe: Report of the Mayor's Task Force on Air Pollution in the City of New York (New York, June 1966), pp. 158-9.

63. Special Committee to Investigate Air Pollution, Council of City of New York, Air Pollution in New York City: Interim Technical Report M-970 (New York, June 22, 1965), p. 29.

64. "Expert Disputes Dirty Air Report," New York Times, June 26, 1965, p. 1.

65. Special Committee to Investigate Air Pollution, Council of the City of New York, Blueprint for Clean Air: Final Report M-10 (New York, December 1965), p. 24.

66. "Air Pollution is Eroding World's Stone Art," New York Times, April 13, 1964, p. 24.

67. Erhard Winkler, "Air Pollution and the Decay of Monuments," 147 Science 459 (29 January 1965).

68. "Liquid to Save Stone Monuments From Erosion Effects Developed" New York Times, February 24, 1966; "Tombstone Gets Erosion Shield," New York Times, August 3, 1968. The standard reference in this area is Harold J. Plenderleith, The Conservation of Antiquities and Works of Art (London: Oxford, 1956).

69. "Library Battles Decay of Books," New York Times, February 20, 1967, p. 37. See also Plenderleith, op. cit., p. 12: "The rotting of paper and textiles can often be traced to the action of sulfuric acid, and it is this acid...that is often responsible for the powdery and decayed condition of old leather bookbindings."

70. "Death of Tree Laid to Fumes from Cars, Trucks, and Buses," New York Times, July 17, 1964, p. 29.

71. H. E. Heggested, "Disease of Crops and Ornamental Plants Incited by Air Pollution," 58 Phytopathology 1089 (August 1968); See also Rauh and Sons Fertilizer Co., v. Shreffler, 139 F. 2d 38 (CA 6, Ohio, 1943) for case involving air pollution injury to commercial greenhouse.

72. Walborg S. Wayne, Paul F. White, Robert Carrol, "Oxidant Air Pollution and Athletic Performance," 199 J. Amer. Med. Assn. 901 (March 20, 1967); Louis Jaffe, "Photochemical Air Pollutants and their Effects on Men and Animals," 16 Arch. Environ. Health 241 (February 1968).

73. Special Committee to Investigate Air Pollution, Council of the City of New York, *Air Pollution in New York City*: Interim Technical Report M-970 (N.Y.: June 22, 1965), p. 25; see also, *New York Times*, January 23, 1965, p. 30.

74. See testimony of Louis Clapper, National Wildlife Federation, *Air Pollution* - 1967: Hearings, Subcommittee of Air and Water Pollution, Committee on Public Works, U. S. Senate, 90 Cong. 1 sess., Part 3, pp. 1751-1756; for litigation involving fluoride damage to an Idaho fish hatchery, see Food Machinery and Chemical Corp. v. Meader, 294 F 2d 377 (CA 9, 1961). Court awarded $57,295.80 damages.

75. "Air Pollution in a Garden Setting," *The Times* (London), September 25, 1965, p. 6.

76. Statement of Wallace Agnew, President, Washington Board of Realtors, Inc., *Problems of Air Pollution in the District of Columbia*: Hearings, Comm. on the District of Columbia, U.S. Senate, 90 Cong. 1 sess. pp. 686-689.

77. Energy Policy Staff, Office of Science and Technology, *Considerations Affecting Steam Power Plant Site Selection* (Washington, December 1968); see also "Power Report Warns of Peril to Air, Water," *Washington Post*, January 5, 1969. On thermal pollution dangers of the proposed 1.6 million kilowatt power plant in Calvert County, Maryland, see "Power Needs Bring Risk of Radiation," Washington Post, May 1, 1969.

78. For the origins of this argument, see John R. Commons, *Legal Foundations of Capitalism* (New York: Macmillan, 1924) and *Institutional Economics* (New York: Macmillan, 1934).

THE MEASUREMENT OF ECONOMIC LOSSES FROM UNCOMPENSATED EXTERNALITIES

Thomas D. Crocker

Department of Economics, University of Wisconsin

Introduction

One of the more intractable and frustrating problems in economics has long been the generation of information about relative user valuation necessary to the implementation of decision rules for commodities that are to some degree indivisible or non-priced in consumption. Environmental quality problems are strongly characterized by such absences of information, particularly for the damages induced by reductions in environmental quality (and, pari passu, for the benefits created by improvements in environmental quality). Sometimes this information can be developed by restructuring conditions within which use occurs, e.g., by reassignments of liabilities where transactions costs are substantial or by the imposition of standards serving to reduce uncertainty about future uses and availabilities. Such restructuring can cause exchanges to take place which before would not have occurred. Since the relative values for the resource of the parties participating in these exchanges are conveyed by the exchange price, the restructuring generates information about user technical comsumption and production opportunities directly observable to all users as well as to whatever public control agency may be concerned. To the extent that the outcome under the restructuring resembles that under a system of costlessly transferable, secure, and divisible property rights in the resource, the information generated about user technical consumption and production opportunities then has more usefulness for descriptive rather than control purposes. Attempts to simulate relative user valuations would serve little apparent nonacademic purpose because they are already being registered in a market for all to observe and act upon. Furthermore, the manner in which they are being registered stimulates an economically optimal outcome in which the sum of sufferer damage costs and perpetrator waste disposal costs is being minimized.

More frequently, however, knowledge is lacking about the effects of the resource's users upon each other under nearly all structural alternatives where the commodity is to be jointly used. Most importantly, it is often the case that there is no known restructuring which will maximize economic efficiency within the operation of an uninhibited market. The more typical response therefore to problems of environmental quality is some more or less permanent restructuring which will generate some desired user adjustments along with the establishment of a collective agency charged with the responsibility of tinkering with the basic system in accordance with changes in parameters impinging upon the system and changes in the objectives of the agency's constituents. Both these functions require information on relative user valuations. Though extremely interesting problems are to be found in the question of the amounts and types of information that will be directly generated under various structures, our interest is solely in establishing the point that regardless of structure--except for the perfectly functioning uninhibited market--an incompletely omniscient and clairvoyant collective agency will have to infer relative valuations of users for the resource in question from something other than directly observable market prices for the resource. Without knowledge of such relative valuations, the agency is likely to find that its actions have unintended consequences which reduce the extent to which it is able to attain and to maintain its objectives. The advantages and disadvantages of the various means by which these relative valuations can be inferred is therefore a question of some substantial and substantive interest.

Two general modes are open to the control agency for the determination of these relative valuations. With the first mode, the agency can try to gage political expressions, representations, and exhortations in the hope that their intensity somehow corresponds to intensity of preference for one outcome over another. But for reasons which have only recently been widely recognized--the ability of the individual user to alter the relative prices and therefore the alternatives he has facing him, and the uncertainties introduced for the individual by both the dependence of his optimal strategies upon the difficult to predict actions of other participants and the difficulty of translating accurately alternative collective outcomes into personal benefits and costs--for these reasons the results of following this political mode are unlikely to bear much resemblance to the economically efficient results of a perfectly functioning market for costlessly transferable, secure, and divisible property rights in particular resource. In at least some contrast, the essence of the second approach is the effort to infer the relative valuations of the resource of concern by observing the prices of the goods that contribute to its value and/or to which it contributes value. Of course, the drawing of such inferences is not costless and it is therefore not universally true that the use of this second mode will describe the economically efficient results of a hypothetically perfect market in the resource any better than will the political mode. Nevertheless, there can be little doubt that there are some circumstances where the second mode will provide more information or the same information at lesser cost about the relative valuations of users than will the political mode. It is therefore to an examination of and the provision of some examples for a facet of this second or (narrowly) economic mode to which the attention of the rest of this paper will be devoted.

The plan of the paper is as follows. The next section describes three general ways associated with the second mode of measuring relative valuations for a resource which, though scarce, is unpriced or underpriced. An attempt is made in the next section to specify the sets of circumstances in which each of the three ways would seem particularly applicable. The representative resource employed is the air resource and the users to which nearly all attention is given are the sufferers from, not the perpetrators of, air pollution. Finally, a summary of the results of two attempts in which the writer has been directly involved to measure air pollution damages by means of land values will be presented. The first of these examples concerns a recently completed study where differential urban residential property values have been employed simply to determine the air pollution damages present over relatively short time intervals, apart from the determinants of air pollution concentrations. The second example describes the results of a study where differential agricultural land values were employed to assess the impact of a specific publicly imposed control policy upon air pollution damages. In the concluding section, some of the omissions of the preceding two studies are pointed out and the framework of a soon to be initiated study intended to do away with some of these omissions is described.

Alternative Means of Measuring Air Pollution Damages

The three not altogether arbitrary groups into which one might classify the alternative means of measuring air pollution damages are: (1) the direct use of technical coefficients of production and consumption; (2) the use of property values; and (3) the use of interviews with air pollution sufferers.

A copious literature exists about the physical effects of various air pollutants upon artifacts and organisms. For example, it is fairly well documented that undifferentiated particulate matter reduces the life of electrical contracts, that sulfur oxides negatively influence the respiratory abilities of animals, and that fluorides harm the photosynthetic processes of certain plants. In some cases, the magnitudes of these physical damages can be predicted with some accuracy because the forms under restricted conditions of the damage functions are known. Less successful however have been the attempts to translate these physical damages into meaningful relationships. Or, speaking in a more positive vein, success in establishing meaningful economic relations by these means has been obtained only within quite narrowly circumscribed limits. The reasons are essentially two. First, when the attempt is made to establish these relations under controlled laboratory conditions, the controlled conditions usually have little semblance to field conditions. That is, because of the understandable desire not to confound responses, nothing less than biologically and/or chemically ideal input mixes and magnitudes are usually employed. But economic reality is rarely such that ideal amounts of everything which contributes to the production or consumption of a particular entity can be obtained. It is therefore quite possible that many attempts to extrapolate laboratory results to real air pollution problems provide estimates of damages that constitute no discernable improvement in accuracy over outright guesses.

The second way of obtaining physical damage measures to translate into economic magnitudes is the field study where an attempt is made to determine the impact of a pollutant upon some resource in an environment uncontrolled by the investigator. If the processes by which the pollutants affect the entity's economically relevant attributes are understood, e.g., if the relationship between the concentration of fluorides in the leaves of citrus trees and the ultimate yield of the trees' fruit is known, this way of measuring damages can yield meaningful damage estimates fairly readily for a single property. However, extrapolation of the results for a single property to a collection of properties is likely to be a meaningless exercise. Though it is conceptually possible to take into account differences between properties in managerial efficiencies, in the qualities, ages, and types of specialized factors of production which have not been fully depreciated, differences in expectations about optimal factor mixes and magnitudes, and the possible interactions of these differences, it would be no easy task. In order to obtain anything vaguely resembling a market estimate of collective damages, some means of making individual properties commensurate must be found and then the investigator must aggregate-only rarely will this aggregation process involve a straightforward arithmetic summation-over all individual properties.

It is the necessity of discovering and accounting for the near infinitude of the aforementioned temporal and physical substitution possibilities that most inhibits the economic meaning and usefulness of the field or the laboratory aspects of the technical approach. This is easily seen when it is realized that every input or consumption good available to the pollution sufferer has several temporal dimensions each of which can be adjusted in accordance with expectations about changing pollution concentrations and durations. For example, the quantity of an input used or an output consumed can be varied according to

$$Q = \int_{t_o + H}^{H + u} r(t)\, dt,$$

where Q is quantity, H is the point in time at which the input or output is expected to be used initially, u is the length of the time interval over which use is expected to occur, r is the rate of use, and t is time. In effect, therefore, a sufferer from air pollution can reduce his suffering by employing the same inputs or consuming the same goods as he originally intended and changing the rate, time interval, or starting time with which he uses or consumes them. The specific adjustment he selects will depend upon the relative prices of the alternative adjustments. To further complicate the matter, the pollution sufferer also has the option available of substituting these inputs, each of which has the aforementioned temporal adjustment possibilities, for each other. If there are several combinations of pollutant levels and durations for each pollutant, if each input or consumption good has numerous temporal adjustment possibilities for each such combination, and if there are even only a few substitutable inputs or consumption goods, it is clear that the number of possibilities the laboratory or field investigator must account for rapidly approaches the astronomical.

Of course, the investigator can drastically reduce the number of possibilities he must consider if he uses the same criteria the sufferer employs to select among these possibilities. One criterion for selection to which any sufferer will attach substantial weight is the existing and expected prices of the various adjustment possibilities. Though this exclusion of possibilities cannot be carried out with any exactitude without prior knowledge of the technical coefficients themselves, even only a highly qualitative prior knowledge of the coefficients when combined with a knowledge of relative adjustment prices will often make obvious a great many adjustment possibilities having no economic relevance. However, this writer knows of no cases in air pollution damage investigations where any attention was explicitly given to the relative prices of adjustment possibilities before undertaking a study whose purpose it was to ascertain technical coefficients.

In summary then, the problems in employing the technical coefficients approach to the measurement of air pollution damages stem from difficulties in accounting for the adjustment possibilities on a single property and the differences in the adjustment possibilities selected between and among properties. The latter problem is caused by the same phenomenon which necessitates the calculation rather than the direct observation of uneconomic sufferer damages. That is, uneconomic damages arise because the provision of a market in rights to the use of the air resource is too costly. The result is that the standard marginal equalities are not fulfilled. Similarly, the standard marginal equalities are unlikely to be fulfilled as between and among sufferers because the provision of a market in adjustment possibilities, many of which are specific to location, is too costly. Most adjustments thus take place with those resources the producer or consumer has under his immediate control and there is incomplete opportunity for mutual adjustments between and among sufferers. The presence of these marginal inequalities therefore means that the damage calculations for one property cannot readily be extrapolated to any other property.

Faced with these obstacles, any attempt to construct economically meaningful damage functions from the fundamental technical coefficients must be a terribly slow, tedious, and expensive process. Nevertheless, given that such functions are of immediate and valuable use for decision-making, a more rapid and less complex means of determining them would seem desirable. Such a means is available in the analysis of differential site values and the immobile and durable improvements upon them.

One of the essential features of air pollution is its locational nature. That is, air pollution differs across space as well as across time. It follows therefore that air pollution will differ from location to location, and, given that individuals dislike air pollution, locations will differ in value. Thus, given that people are willing to pay to avoid air pollution and its effects, property values and air pollution concentrations must vary inversely. This is rather easily shown intuitively. Suppose that willingness to pay for property declines with increased pollutant concentrations but that the price of other goods and land prices are everywhere the same. Under these conditions, the total welfare of individuals would vary inversely with the magnitude of pollutant concentrations. It would then be in the interest of individuals subjected to high pollutant concentrations to offer a higher rent for sites subject to relatively low pollutant concentrations. Hence the value of the more favorably situated land would rise and the total welfare of individuals using these sites would fall relative to those on less favorably situated sites. This process would continue so long as individual marginal welfare tended to differ. In equilibrium, each individual occupies the highest priced property he is willing to pay for, and each property is occupied by that individual willing to pay the highest price.

The advantage that the use of site values provides now becomes a bit clearer. To be specific, the investigator does not have to discover and evaluate the pollution sufferers' adjustment possibilities, nor does he have to worry about how to make individual properties commensurate so that he can aggregate them. The market in land and landed improvements does it for him through directly observable market prices. All the investigator need do is describe the characteristics of each site and its improvements so that the separate influence of each characteristic, including air pollution, upon property value can be discerned by well-known statistical techniques.

In spite of the obvious comparative advantages of the property value approach, the technical coefficients approach is not without its potential contributions. First, though it can be shown that in a completely interdependent economic system all air pollution damages will be capitalized into land values, nobody believes that the system really is completely interdependent. If there do exist items for which land and its immobile and durable improvements are not substitutes or complements and if the value of these items is affected by air pollution, then differential property values will not register all damages. If these damages are to be ascertained, the investigator will either have to do so by means of the technical coefficients approach or by measuring the differential capitalized value of the item and the contribution of air pollution to this differential. Furthermore, the property value approach provides little insight into the fundamental processes of adjustment whereby air pollution has its impact. All it does is describe the results of these processes of adjustment and it therefore has limited predictive content. The only way to acquire substantial knowledge of these fundamentals remains the technical coefficients approach. Nevertheless, since the property value approach provides knowledge of the form of the relationship between damages and air pollution, certain inferences can be made about the processes of adjustment which would yield this form. Since this set of adjustments is likely to be smaller than the set of all possible adjustments, a certain economy of research effort can be achieved in investigations of technical coefficients. In effect therefore, the two approaches–the property value approach and the technical coefficients approach–are complementary rather than competitive. Both, if properly employed, are equally accurate. The former has the advantage of ease and simplicity whereas the latter has the advantage of providing more insight into fundamental processes.

Even if the property value approach and the technical coefficients approach are properly employed, the damages obtained by the former could be less than those obtained by the latter for all levels and durations of air pollution. This is because sufferers may not be fully cognizant of some of air pollution's effects, e.g., the gradual deterioration of respiratory systems. In this case, a third approach, the interviewing approach, becomes useful. With this approach an attempt is made to ascertain what people do and do not perceive as air pollution's effects, apart from whether they know the cause of the effects. This distinction is important, for, contrary to the confusion on the subject, it matters not in order to determine air pollution effects whether people recognize the cause of these effects. The notion of cause and effect need only be present in the mind of the investigator, for the sufferer's actions will reflect the impact of recognized effects whether or not he knows the cause.

Though the question of whether the sufferer recognizes cause and effect is of no importance in determining damage functions,[1] the question of the extent to which he recognizes effects is of obvious importance. If there are pollutants whose deleterious effects are extremely subtle so that they go completely unrecognized or are only recognized very slowly, the damage function can be changed by generating recognition or by reducing the time interval required before full recognition is achieved. In effect, these interviewing techniques provide the investigator with knowledge of sufferer information about air pollution's effects. To the extent that this knowledge is used as a basis to improve sufferer information so that they will make more complete adjustments, the air pollution damage function whether determined by the property value or the technical coefficients approach will be changed.

Examples of the Property Value Approach – Urban Residential Property Damages

The essential point of the preceding section was that differential site values provide a relatively easy means of determining actual air pollution damages because they register those air pollution effects which take place after sufferer adjustments to the presence of air pollution have occurred. To the extent that all air pollution effects are weighed in site selection, the value of all air pollution damages will, everything else being equal, be registered in the differences in site values. An economy of research effort is thus suggested since only one market--the market for sites subject to varying levels and durations of air pollution--need be studied. Since the number of parameters to be estimated with this approach is smaller, fewer assumptions are needed, less information is required, and the risk of cumulative error is reduced. In other words, the property value approach involves less danger of making the "scientific objectivity" implicit in the direct estimation of all the relevant parameters for the basic structural relations in a system synonymous with an utter lack of economic objectivity about the allocation of research effort.

That little empirical work which has been done to test the hypothesis of a negative relationship between property values and air pollution concentrations substantiates the hypothesis. Economic theory suggests that property values might be statistically explained by regressing property, neighborhood and occupant characteristics upon the property's market price. The first published study to do this was the Ridker-Henning study of St. Louis.[2] They found the expected inverse relation. In order to extend and we think substantially improve upon the Ridker-Henning study, R. J. Anderson, Jr. and I in an as yet unpublished study have made more explicit the theoretic rationale for these procedures and applied them separately to renter-occupied and owner-occupied residential properties in three standard metropolitan statistical areas: St. Louis, Kansas City, and Washington. Except for air pollution, observations on all property, occupant, and neighborhood characteristics were taken from the 1960 Census of Housing. The air pollution data, which consist of observations on annual arithmetic mean sulfation and annual arithmetic mean suspended particlates at various locations in each city, were obtained from National Air Pollution Control Administration studies conducted in the middle 1960's. Thus the air pollution observations are clearly "out of phase" with the rest of our data and we therefore must and do proceed on the rather questionable assumption that air pollution levels in the middle 1960's for the three cities were similar to those of 1959, the year in which the census data was gathered. However, as can be shown under certain plausible assumptions, this discrepancy will cause the impact of air pollution upon property values to be understated rather than overstated.

In addition to the air pollution measures, the variables we employed in our final equations to explain variations separately in renter-occupied and owner-occupied property values among census tracts were median family income, proportion of housing units classed as dilapidated, proportion of housing units more than twenty years old in 1959, proportion of occupied units inhabited by non-whites, and distance from the central city. A multiplicative equation form gave the best statistical resolution in all three cities for both classes of properties. Without exception, the coefficients for all explanatory variables, including the air pollution variables, were in accord with a priori expectations. All the air pollution variables were highly statistically significant where the oral tradition of air pollution control says they should be. For example, apart from hydrocarbons and oxidants, it is thought that the District of Columbia's air pollution problems are due to sulfur oxides. The results tend to confirm this for they show that property values in the District are highly responsive to variations in arithmetic mean sulfation levels, but don't appear sensitive to variations in arithmetic mean suspended particulates. In the Maryland suburbs of the Washington SMSA, the opposite appears to be the case, however: property values are highly sensitive to variations in suspended particulates, but unresponsive to sulfur oxide variations. Similar results are obtained for Kansas City where it is commonly thought that suspended particulates are the problem. In St. Louis substantial damages are usually attributed to both sulfation and suspended particulates. Our results for St. Louis confirm this impression.

With the functional forms that were employed, when the coefficients for the pollution variables are evaluated at their means and at the means of the property values, a figure corresponding to marginal capitalized property values is obtained. The highest marginal capitalized damage figure obtained for suspended particulates was for predominantly single-family home census tracts in the Washington SMSA, where the addition of ten u g/m^3/day to a relatively low average level of suspended particulates caused, on the average, a reduction of $700 in the market value of owner-occupied homes. The comparable figures for the same set of census tracts in Kansas City and St. Louis were $126 and $119 respectively; however, the concentrations in these latter two cities were substantially larger than in Washington. For sulfation, the highest marginal capitalized damage was $912 for each additional tenth of a mg of $SO_3/100cm^2$/day. This figure was obtained for owner-occupied homes for that portion of the Kansas City SMSA lying in Kansas, an area where average sulfation concentrations are extremely low. In the St. Louis SMSA, where average sulfation concentrations are quite high, the comparable damage figure was $158.

Though it is recognized that a comparison of results between and among the three cities is perhaps specious, such a comparison does yield an interesting pattern. Over the ranges we were able to observe for both sulfation and suspended particulates, marginal capitalized damages and the responsiveness of damages to pollution appear to decline with increases in arithmetic mean pollutant concentrations. That is, total damages seem to increase at a decreasing rate and the proportionate change in damages relative to the proportionate change in pollution concentrations appears to decline with increasing arithmetic mean pollution concentrations. Realizing that in a formal sense dissimilar entities cannot be compared and having no easy way to make the three heterogeneous cities homogeneous, the individual cities were partitioned into areas and separate regressions were run for each area. When the results for areas within an individual city were compared, the pattern obtained was no different from that obtained for comparisons among cities. In a study soon to be started an attempt will be made with new data to reproduce these patterns and to provide some conceptual grounds for their existence.

Agricultural Damages

The following example shows that the land value approach is useful for assessing the impact of air pollution control policies. It also shows that the approach is as applicable to agricultural as to urban areas. In fact, the approach may capture a greater proportion of the damages in the former sort of area since health-related costs are likely to be somewhat less important.

In the Polk County, Florida, area, atmospheric fluorides evolved in the processing of phosphate rock for fertilizers are alleged to have damaged the local citrus and beef cattle industries over a four hundred square mile area. In order to ascertain the validity of this allegation, information on over six hundred Polk County sales of agricultural land from 1947 to 1965 was collected. The earlier date corresponds to a year just two years before phosphate plants started to enter the county in force while the latter coincides with the approximate time at which it generally became recognized that the State of Florida was about to impose rather stringent emission standards upon the atmospheric fluoride generating sources. In the intervening period, a number of events occurred. A number of fluoride generating sources subject to no direct externally imposed emission controls were constructed. Fluoride air pollution damages or at least damages attributed to fluoride air pollution were widely observed. Court actions were initiated and in some cases carried through to a fairly lucrative conclusion by the plaintiffs. More often, under the threat of court action, the would-be plaintiffs were able to carry out equally lucrative negotiations with the phosphate companies. In response to all this, publicly enforced controls were started in 1957 and were gradually increased in complexity, precision, and enforcibility. The anticipated impact of all these factors upon the abilities of the owners of the agricultural lands surrounding the phosphate plants to collect rents from the production of crops and from the provision of dumping grounds for air pollutants was reflected in the mutually satisfying prices buyers were willing to pay and sellers were willing to accept for these lands. Similarly, changes in these anticipations were reflected in changes in these market prices.

The market prices of these lands over two and three year partitions of the 1947-1964 time interval were explained by common single equation multiple regression techniques. No sales to phosphate companies or known phosphate land speculators were employed. So as to obtain greater homogeneity of buyer and seller expectations and to distinguish between submarkets separate analyses of the cattle and citrus industries were performed. The most satisfactory estimating equations for citrus was multiplicative while that for pasture lands was linear in the original variables. In addition to explanatory variables intended to account for most other factors capable of influencing the site prices, a measure of air pollution was employed based upon the frequency with which a specific cumulative monthly concentration of fluorides in pasture grasses was exceeded.

For each partition, the explanatory variables in the citrus equation were statistically significant and possessed a sign in accordance with that expected from economic theory. The regression coefficient for the air pollution variable in the citrus equation became statistically significant and negative about two years after intensive construction of phosphate plants were started. This negative coefficient regularly increased in absolute magnitude with an approximate two year lag as the volume of fluoride emissions increased. By 1961-1962, the average reduction in sale price for citrus sites in the area subject to air pollution was about $150 per acre. But by 1964, when it began to be recognized that the phosphate plants were voluntarily and/or being forced to reduce drastically their fluoride emissions, the differential sale prices attributable to the presence of air pollution has disappeared.

The temporal pattern of the coefficient for the pollution variable in the pasture equation was less smooth and consistent. This variable assumed a statistically significant coefficient and the correct negative sign at about the same time as did the pollution variable in the citrus equation. However, with the formation in 1957 by the State of an air pollution control district and victory by pasture owners in several court suits, the coefficients for the pasture equation's pollution variable remained statistically significant but became positive. The simple fact that some pasture lands were subject to air pollution in 1961-1962 made them worth on the average four dollars an acre more than pasture lands not subject to pollution. At the same time the coefficient for the pollution variable in the citrus equation assumed its greatest negative magnitude; that for the pasture equation assumed its greatest positive magnitude. Similarly, when the citrus equation's pollution variable became no longer significant the pasture equations's pollution variable was no longer significant.

The explanations for these phenomena are to be found in the cost of air pollution control for the phosphate plants relative to the market values of polluted citrus and cattle sites. From nearly the inception of the air pollution control district, the publicly unstated policy of its officials was to give the phosphate plants the option of reducing their emissions to what were terned "minimum technologically feasible levels: or buying up those lands subject to damaging air pollutant concentrations." The phosphate plants appear to have attempted to select something approximating the least cost mix of these two alternatives. This least cost mix involved the reduction of emissions rather than the purchase of citrus lands because, polluted or unpolluted, the market price of most citrus lands was greater than the cost of somewhat reducing emissions. However, pasture lands when used for pasture were less valuable than when used as dumping grounds for air pollutants. Recognizing this, the owners of the pasture lands were able to capture a substantial portion of those capitalized values of the air's waste disposal abilities which formerly had accrued only to the phosphate plants. And even though the individual citrus grower was perhaps not fully compensated for his losses, the reduction in emissions forced upon the phosphate plants reduced the absolute magnitude of these losses below that which they would have been without the imposition of the option. However, rather ironically, the imposition of emission standards by the State in the middle 1960's of course meant that the phosphate plants' and land purchase efforts were all to little avail.

Conclusions

The preceding two studies provide evidence that the site value approach is a relatively easy way of determining a substantial proportion of air pollution damages. After all, only a search of some records, a compilation of the records, and a bit of computer time are all that is required to perform the mechanical party of the analysis. A moderately competent economist or econometrician can readily establish whatever adjustments might be required in special situations.

Nevertheless, the particular applications of the property value approach in the preceding examples leave some questions unanswered which are nevertheless quite capable of being answered within the approach's confines. In the previous two examples, it was assumed that the urban and suburban residents and the Polk County citrus growers and cattlemen at any short interval of time had always completed all adjustments to existing and expected air pollution levels that would ever be economically worthy of completion. To use the jargon of the economist, the previous two studies implicitly assumed that the air suffer was perpetually in long-run equilibrium.

That is, we assumed that he was in a more or less uninterrupted state of euphoria where he recognized that any conceivable move would be to his disadvantage. The realism of this assumption is rather questionable. It precludes the possibility that the air pollution damages observed over one rather short time interval may differ from the air pollution damages observed over another rather short time interval, even though the level of air pollution and the individuals who suffer from air pollution have not changed in the least.

A more realistic view would recognize that many adjustments to air pollution concentrations require substantial time intervals to complete. Over relatively short time intervals there therefore may be discrepencies between actual and desired adjustments. Thus studies using data which do not permit time for these longer-term adjustments to take place may overestimate air pollution damages.

Another factor which has not fully been accounted for in the previous studies is the quite reasonable hypothesis that it is expectations about future pollutant levels as a function of experiences with past and present pollution levels which determine the actual and the desired adjustments selected by the sufferers from air pollution. That is, only by considering pollution levels over more than one or two fairly short intervals of time can one explain why one mode of adjustments rather than another was or is being selected or is considered desirable by potential and existing property owners and renters. In effect, this hypothesis states that the present behavior of air pollution sufferers is directly related to their expectations about future pollutant levels. The expectations of air pollution sufferers about future pollutant levels are in turn governed by some of the (statistical) moments of past and present pollution levels and the past and present behavior of the perpetrators of air pollution as well as the authorities responsible for controlling air pollution. By relating past and present air pollution events to present sufferer adjustments, one is thereby explaining the means by which those sufferer expectations which govern present magnitudes of damages are formed.

An effort will be made to take the preceding factors into account in a soon to be initiated study of the impact of air pollution upon Chicago area residential property values. In this study, detailed information on air pollution concentrations and individual sales of residential properties will be combined in a manner permitting a much more thorough analysis of air pollution damages and adjustments to these damages than has been possible in previous work.

FOOTNOTES

1. However, in the longer term it might be of some importance since an inability of sufferers to identify cause and therefore perpetrators means that some adjustment possibilities are closed to sufferers. The closing of these possibilities will be reflected in the damage function.

2. Ridker, Ronald G., and John A. Henning, "The Determinants of Residential Property Values with Special Reference to Air Pollution," Review of Economic Statistics 49 (May, 1967), pp. 246-257.

CASE STUDIES OF COSTS
(Quality Air--Luxury or Inexpensive Necessity)

Benjamin Linsky

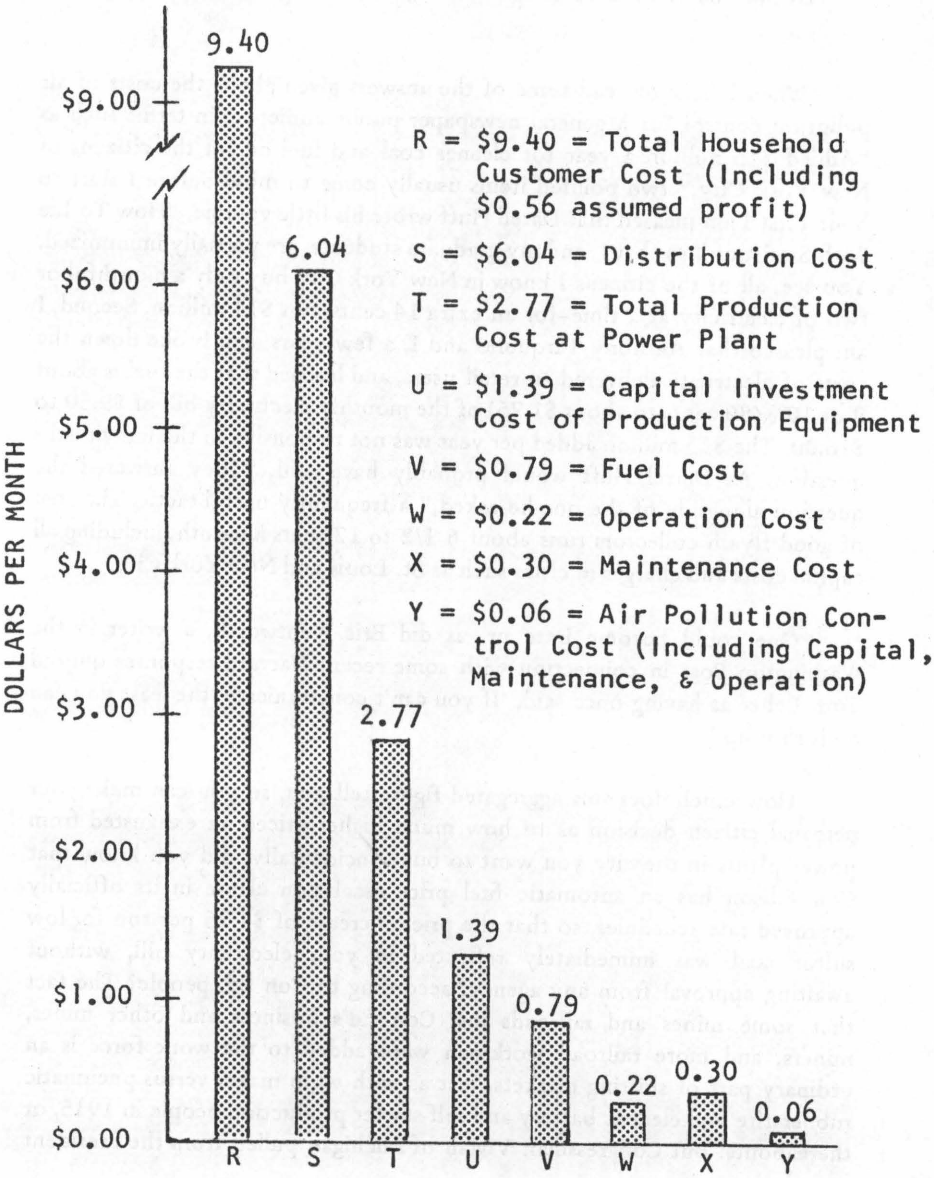
Department of Civil Engineering, West Virginia University

When I hear or read some of the answers given about the costs of air pollution control for a general newspaper public audience, in terms such as "Added $15 million a year for cleaner coal and fuel oil for the citizens of New York City," two pointed items usually come to mind before I start to boil: First I am pleased that Darell Huff wrote his little volume, "How To Lie With Statistics," so that I, and my graduate students, are partially immunized. You see, all of the citizens I know in New York City buy only a mouthful or two of electricity at a time--for an extra 14 cents, not $14 million. Second, I am pleased that Anthony Tarquinio and I, a few years ago, broke down the costs of electricity delivered to retail users, and learned that the fuel is about 8 or 10% (80 cents to about $1.25) of the monthly electricity bill of $9.50 to $16.00. The $15 million added per year was not responsive to the individual's question. As Darrel Huff would probably have said, "They answered the question alongside of the one he asked," a frequently useful tactic. The cost of good flyash collectors runs about 6 1/2 to 12 cents a month, including all capital costs and charges in cities such as St. Louis and New York City.

One could become irate or, as did Eric Wentworth, a writer in the Washington Post in connection with some recent Harvard responses quoted Tom Leher as having once said, 'If you can't communicate, the least you can do is shut up.'

How much does this aggregated figure tell you, so you can make your personal citizen decision as to how much higher priced air exhausted from power plants in the city you want to buy? Incidentally, did you know that Con Edison has an automatic fuel price escalation clause in its officially approved rate schedules, so that the price increase of $1.25 per ton for low sulfur coal was immediately reflected in your electricity bill, without awaiting approval from any agency, according to Con Ed. people? The fact that some mines and railroads lost Con Ed's business and other mines, miners, and more railroad workmen were added to the work force is an ordinary part of shifting markets, just as with whip maker versus pneumatic rubber tire and electric battery and self-starter production people in 1915, or thereabouts. But Congressman Vivian of Michigan pulled from the President

AVERAGE HOUSEHOLD CUSTOMER'S MONTHLY PRICE
OF ELECTRICITY AT 375 Kw-Hr. PER MONTH



of the Manufacturing Chemist Association a statement that site selection almost never considered the cost of AP & WP. He also heard a comment about obsolete, badly located plants that might have to shut down. Wes Vivian pointed out that a number of businesses had already shut down because of the water pollution-lake and beach resorts. They were downstream from the Monroe, Michigan, and River Raisin paper Plants-that were not now considered well located.

By the way, the Linsky-Tarquinio chart display was reviewed and–shall we say "not disapproved"–by key Con Ed. and Union Electric people on two or three occasions.

This leads to another piece of case history regarding the 6 cents a month for good air pollution control equipment, especially highly effective flyash collectors. This figure is probably a little low for Consolidated Edison because I learned from an excellent control equipment engineer, who would be in a position to know, that the Consolidated Edison people buy electrostatic percipitators whose hardware capital costs about twice as much (over $5 per KW rating) as do most other utility plants because they insist on more dependable, continuing efficiency through more rugged hardware, circuitory, and back-up units (for redundancy or safety factor).

Another small sidelight about malinformation in specific case histories is the added price per ton of coal for Consolidated Edison due to lower sulfur used in the 1968 Office of Science and Technology U.S. Presidential report on power plant site selection factors. A figure is available that is correct from the New York Company because of the fuel escalation clause, etc. I had used my above figures in the 1966 National Air Pollution Control Conference in Washington, published in the proceedings.

Nevertheless, the OST quoted a loosely phrased article of the Wall Street Journal as its source of information for a much higher fuel price. Some readers including some of my students, are of the unverified opinion that the largest number available in print was chosen for use. It will also be noted that the OST report did not translate the price into retail consumer terms - 14 or 15 or 25 or 50 cents per household per month.

I don't usually like to confuse community air pollution control programs with community water pollution control programs for reasons I spelled out in a paper in 1958, "Some Air Pollution Aspects of Liquid and Solid Waste Disposal," although I would not dream of exploring a design selection for a given air pollution control installation without assessing its liquid waste pollution design factors as well as the solid waste disposal factors, and community noise, vibration, and glare control factors. But the subjects of thermal pollution and the use of wet cooling towers or spray ponds have raised important questions about unnatural fogs, which I just recently named "sooner fogs." I chose the name for obvious caused-temporal reasons as well as to convey the notion of Oklahoma Territory homestead opening land rush day cheaters.

In the OST report will be found another of those accurate but misleading reports that rejects a dry cooling tower in the main body of the report so it doesn't even appear in the "up-front" summations. It says that the cost of dry cooling towers would add 10 to 20 percent to the cost of the consumer. On exploration, I gathered from a difficult-to-follow letter from the study director that this meant the totality of industrial consumers and other purchasers from the power plant, not the "consumer" as we all use the term, I believe.

Fortunately the concurrent issue of Scientific American told its story about dry cooling towers - appraising them at 1% to 2% added to the retail household electricity cost to get the utilities out of the thermal water pollution business while at the same time avoiding some algicides, etc. It is hard for laymen to understand why utilities don't want a larger share of the GNP. But perhaps the fact that the dry cooling tower, while adding several (25, 30, 35) dollars per kilowatt of capital cost, would use up some of the scarce electricity they are so short in supply of - is a deterring factor, short range. However, even in the winter when presumably less electricity, proportionately, might be needed to do such dry cooling, the installation would be providing a legal base for added protected utility profits, would't it?

This brings to mind the present force-feeding of power plants, including high cost, obsolescent ones, that pollute the air because the power industry is overselling its production capacity. In non-regulated industries, my rule of thumb still seems to stand - as my Sixth Theorem of Semi-Social Physics: For each year that industrial pollution control is deferred, for $1,000,000 of Control equipment, the owner can keep $250.00 in his pocket, before taxes, minus technical studies about the pollution, lobbying, and consulting costs. The April 21, 1969 issue of Chemical Engineering cites some industry round-up figures which tend to affirm this sixth theorem. These indicate that operating expenses are about 11% to 15% of the air pollution control equipment investments. To this would be added value of the capital and depreciation reserve less interest, etc. to total 25% to 39% annual cost of the investment. But this is not in all cases, only the most highly polluting processes.

At this point the discussion will follow three paths. First it will present my system of concepts so that there may be better understanding of my discussion.

IS CLEAN AIR GOOD BUSINESS AND BETTER HEALTH

Concepts and Phrases Used in Considering Air Pollution

Air Pollution - Smog

Undesirable Effects:

On people,
On the things that people own, and
On the things that people like to do.

1. Annoyance to senses
2. Soiling
3. Interference with visibility
4. Sky darkening
5. Damage to vegetation
6. Damage to other property
7. Interference with production or services
8. Impairment of health

Types of Pollutants:

Local

Large Dust
Droplets (See Fig. 2)

Area Wide and Local:

Very small dusts
Very small droplets
Gases

Primary polluting gases, directly
Secondary polluting gases, and
Double-acting gases, after sunshine or in fog (See Fig. 3)

Single Sources: Nearby small source; further large source

Multiple Sources:

Coal and heavy oil burning
Rubbish burning - industrial - commercial - multiple dwelling
Industrial processes
Residential rubbish burning
Motor vehicle exhausts
Etc.

The Weather and the Hills:

Don't create the pollutants
Sometimes hold man-made pollutants in an area:

Sunny days,
Foggy days and nights,
Other

Practical Controllability: - without economic ruin, for

Almost all types of Pollutants, now
Almost all types of sources,
The few remaining are now subjects of enough or too little engineering research and development.

Application of Practical Controls: - when

People learn they have been applied elsewhere.
People decide they want cleaner air–and insist on it, vigorously, with legislation resulting.

Growth not overcome by present control cut-backs. (See Fig. 4)

Growth not overcome by present control cut-backs.

More automated and precision industries want cleaner air for

Figure 2. Large Dust and Droplets

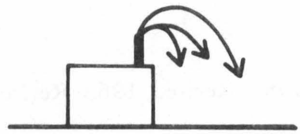


Figure 3. Area Wide and Local Pollutants

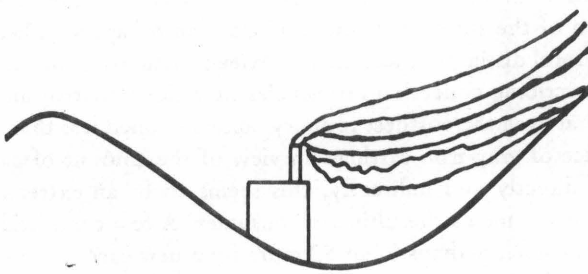
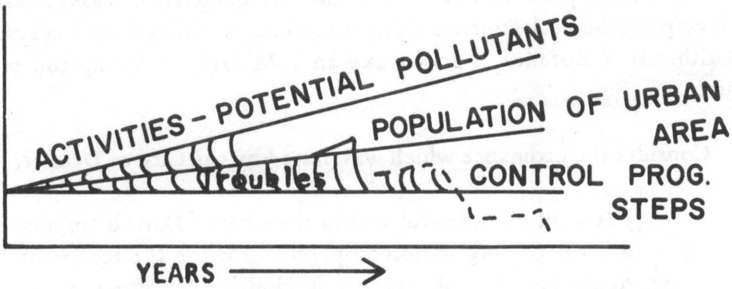


Figure 4. Growth Not Overcome by Present Control Cut-Backs



their new plants and new employees' homes.

Need for Presenting Specialized Technical Information in Non-Technical Language:

More existing information is needed by non-specialists in air pollution.

Revised, 1956; Revised, 1957; Revised, 1963; Revised, 1964.

Next let us look at some other case histories and their rationales.

The figures labled Table 1, 2, and 3 are from the well known (then) Blue Report, "A Technical Report" of air pollution in the San Francisco Bay Area Air Pollution Control District, written as a basis for the major 1960 Regulation Two of the six county, city-regional control agency I headed and started. The careful distinction was made between particulates of small versus larger size in describing collection efficiencies of various control methods. It will be noted that even the costliest foundry controls added less than 1.25 per cent to the price of gray iron castings. In view of the amount of cast iron I buy each year directly and indirectly, this seems to be an extremely small added yearly cost to me as the ultimate consumer. A few cents added to an auto price?Or, for steel, perhaps $2 or $3 more for a new car?

Third, a discussion of profits case histories brings up some bedfellow situations - such as shown in the 1915 Chicago Association of Commerce Report on Smoke Abatement and Electrification of Railway Terminals in Chicago. This proposal had the support of a large printer who disliked the soot and grit on his printing and the side support of electrical supply people. The 1912 license plate mobile air pollution sampling truck is as interesting as the Electromechanical Punched Card (round holes) data processing system of Hollerith. At a distance it looks like an IBM card, including the cropped corner.

Consider the ordinance which was passed by the City of Detroit:

> "It shall be unlawful within the City of Detroit for any person, firm or corporation to permit or cause the escape of such quantities of soot, cinders, noxious acids, fumes, gases, fly ash or industrial dust, in such place or manner as to be detrimental to any person or the public or to endanger the

Table 1. Estimated Cost of Air Pollution Control for Gray Iron Foundry Cupola.

<u>Size of operation</u>: 48" I. D. Melting rate - 8 tons per hour, 4000 scfm tuyere air, 4000 tons net castings per year

Estimated Plant Investment = $500,000 - Castings are worth $350 per ton

Control Equipment or Method	Air Pollution Emission Pounds/hour				Collection efficiency or Recovery %		COST OF AIR POLLUTION ABATEMENT FACILITIES					
	Particulates & droplets		Gases		Particles 0-5 Microns	Gases	Capital Investment $			Operat. Cost $/yr	% of Plant Invest.	% Cost Incr. of Prod.
	0-5 Microns	> 5 Microns	Org.	Others			Major Equip.	Aux. Equip.	Total			
No control	40	160	30	1325	0	0	0	0	0	0	0	
After burner	35	140	3	30	0	0	1000	1000	2000	200	0.4	0.05
Wet cap (a)	35	90	2	25	0	98	10000	10000	(b) 20000	2200	4	0.5
Scrubber (a)	25	15	2	25	30	98	17500	12500	(c)(b) 30000	4500	6	0.6
Scrubber (d)	10	0.4	1.8	25	65	98	10000	20000	30000	4500	6	0.6
Baghouse (a)	3	0	3	30	92	97	30000	20000	(c)(b) 50000	5000	10	1.0
Electrical (a) Percipitator	3	0	3	30	92	97	45000	30000	(c) 75000	6500	15	1.2

(a) Includes afterburners
(b) Estimated installation costs published by American Foundrymen's Society
(c) Estimates from similar installations on West Coast
(d) Estimate prepared by Bay Area Foundry Industry

January 16, 1959

Table 2. Estimated Cost of Air Pollution Control for a Steel Plant

Size of Operation: 5-60 Ton Open Hearths, 4 Furnace Operation
Melt Department Value - $2,500,000
Total Plant Value - $25,000,000

Control Equip. or Method	Air Pollution Emissions Pounds/hour				Collection Efficiency, or Recovery, Percent		ESTIMATED COST OF AIR POLLUTION ABATEMENT FACILITIES					
	Particulates and droplets		Gases		Particulates 0-5 Microns	Organics and Gases	Capital Investment $			Oper. Cost/yr	% Plant Invest.	
	0-5 Micron	>5 Micron	Organic	Others			Major Equip.	Minor Equip.	Total		(a)	(b)
Present	95	10	5	5	0	0	0	0	0	0	0	0
Scrubber	60	5	5	3	40	20	65000	135000	200000	30000	8.0	0.8
Baghouse	9	0	5	5	92	0	200000	225000	425000	40000	17.0	1.7
Electrical Percipitator	9	0	5	5	92	0	500000	300000	800000	50000	320	3.2

(a) For Melt Department Only

(b) On Total Plant Value

Table 3. Estimated Cost of Air Pollution Control on a Chemical Drying Operation

Size of Operation: 50,000 Tons/yr. Sodium Phosphate (137 Ton/day)

Estimated Plant Investment: $2,000,000.00

Control Equip. or Method	Air Pollution Emissions Pounds/hour				Collection Efficiency or Recovery, Percent		COST OF AIR POLLUTION ABATEMENT FACILITIES				
	Particulates & Droplets		Gases		Particles 0-5 Microns	Organics & Gases	Capital Invest., $			Operat. Cost $/yr	% Plant Invest.
	0-5 Micron	>5 Micron	Organic	Others			Major Equip.	Aux. Equip.	Total		
No Control	400	13000									
Primary Cyclone	160	390			60		15000	5000	20000	2000	1
Secondary Multitube Cyclones	100	39			75		35000	5000	40000	4000	2
Secondary Wet Scrubber	8	4			95		40000	30000	70000	8000	3.5
Baghouse	4	0			99		50000	40000	90000	9500	4.5

health, comfort and safety of any such person or of the public, or in such manner as to cause or have a tendency to cause injury or damage to property or business."

If there had been a provision such as this in a law in their area, San Carlos, California, it would have been unnecessary for Varian Associates to have moved to another city because of air pollutants from an uncontrolled non-ferrous foundry next door. The Varian employee and executive complained about dirtied cars and spoiled sunny back-of-plant lunch periods. These were fully and effectively reinforced when the foundry was closed for a vacation or a strike or something. The number of quality rejections of high-powered, costly vacuum tubes dropped sharply. The rejections shot back up when the foundry plant re-started. (All of this was prior to the establishment of the Bay Area Air Pollution Control District regulations and program). The relocation lost business for San Carlos businessmen and led many Varian employees to leave friendly neighborhoods to move to the new city–rather than face long commute travel. It was, one can imagine, disturbing to Varian's activities as well.

The San Carlos business people asked the Bay Area Air Pollution Control District to establish control over this foundry early in the control agency's program.

Another case history group involves the brass foundry industry, where melting cupolas using coke and electrically driven blowers were replaced by electric induction furnaces using relatively clean scrap and ingot metal. The savings in lost zinc alone were reported to pay out fully in 3 years. In addition, faster melting and better quality control made the sales manager happier.

But–the melting foreman had to learn new "signals" to guide additives, etc., because the molten pool looked different and the varying colors and density of visible plume had disappeared. The supplier of high frequency heating electronic and furnace equipment and maintenance services was happier. The coke supplier was unhappy, as were the suppliers of repair materials for the cupola.

Arrangements had to be made to handle the brass scrap from the brass foundry's customers' plants, mostly machine tool turnings and borings, giving him credit for the scrap's value. This oily scrap that used to be melted in the foundry's own cupolas was still to be collected by the foundry company as a customer service, even though the brass foundry would now pass the greasy, oily scrap on to a secondary smelter in exchange for credit to itself applied against the clean ingots and slabs for electric induction melting.

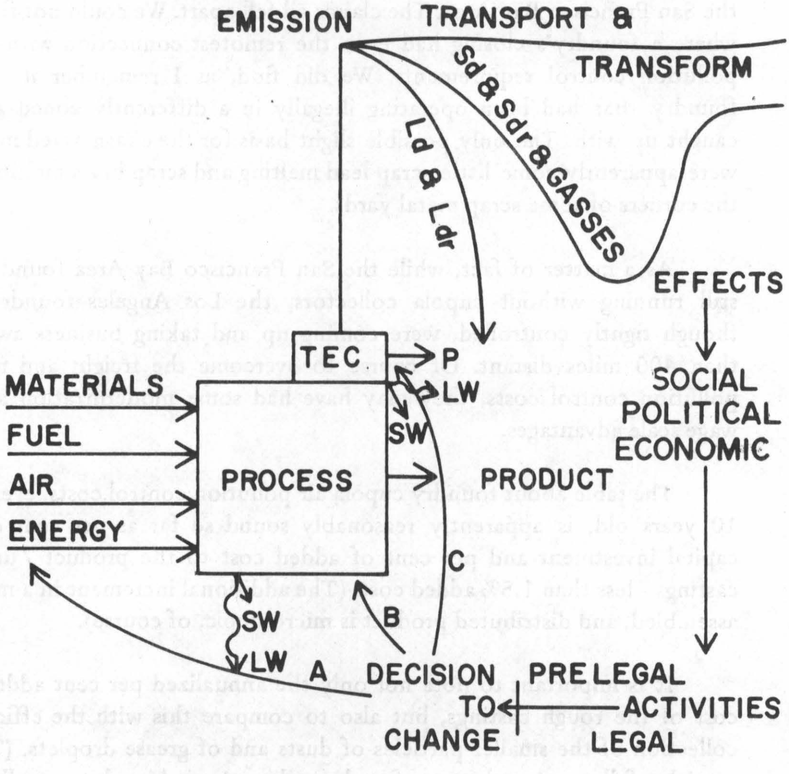
I had to puncture, 10 years ago, an often-repeated legend about the supposed number of iron foundries that were supposed to have been forced out of business or into relocation by the Los Angeles County Air Pollution Control District law and tight regulations. My specialist metals industry engineer and staff searched out every lead we could obtain, including manufacturing industry groups who were opposing similar tight controls in the San Francisco Bay Area. The claims all fell apart. We could not find a case where a foundry's closing had even the remotest connection with these air pollution control requirements. We did find, as I remember it, that one foundry that had been operating illegally in a differently zoned area, was caught up with. The only possible slight basis for the exaggerated methology were apparently some little scrap lead melting and scrap brass melting pots in the corners of some scrap metal yards.

As a matter of fact, while the San Francisco Bay Area foundries were still running without cupola collectors, the Los Angeles foundries, even though tightly controlled, were coming up and taking business away more than 400 miles distant. Of course to overcome the freight and minor air pollution control costs, they may have had some modernization and labor wage scale advantages.

The table about foundry cupola air pollution control costs, even though 10 years old, is apparently reasonably sound so far as per cent of added capital investment and per cent of added cost to the product - unfinished castings - less than 1.5% added cost. (The additional increment in a machined, assembled, and distributed product is microscopic, of course).

It is important to note not only the annualized per cent added to the cost of the rough castings, but also to compare this with the efficiency of collection of the smaller particles of dusts and of grease droplets. (The large particles fall on the plant roof and employee's parking lot, usually). Roof cleaning, car refinishing insurance claims, and even an occasional roof collapse rarely move management to collect even the large particles without pre-legal or legalistic pressures.

Figure 5. Schematic Diagram of Operational Processes and Methods for Pollution Abatement.



TEC - "TAIL END CHARLIE" COLLECTOR
SW - SOLID WASTE
LW - LIQUID WASTE
Sd - SMALL DUST
Sdr - SMALL DROPLETS
LD - LARGE DUST
LDr - LARGE DROPLETS

MULTIPLE SOURCE ANALYSIS OF AIR POLLUTION ABATEMENT STRATEGIES

Ellison S. Burton and William Sanjour

Ernst and Ernst Consulting Engineers, Washington, D. C.

Introduction and Summary

In attacking the problem of air pollution, the Federal Air Quality Act of 1967 mandates a decentralized approach to abatement. State and local air pollution control agencies must develop abatement programs to achieve Federally-approved "air quality standards" for each pollutant posing a threat to people and property.

While abatement programs could be expected to contain detailed procedures for collecting information on the character of local pollution and to provide legal procedures for hearings, appeals, and penalties, at the heart of an abatement program is the requirement for specified source-by-source reductions in pollutant emissions. Who should abate, by how much, and who should pay for it will depend on the abatement philosophy or strategy of the control agency. For example, a strategy of issuing ordinances setting industry emission standards has legal, economic, and air quality implications which can be far different from strategy banning the use of certain fuels in a region. Since there may be hundreds, or even thousands, of controllable sources of the more common pollutants in large urban areas, with several ways of controlling the emissions of each source, the choice of an abatement strategy for each pollutant requires careful study to ensure that the choice can produce the goals sought. Five factors in particular affect the feasibility of an abatement strategy:

1. The phasing of mandated emission reductions

2. The source-by-source costs of emission control options and their economic burden on the sources required to reduce emissions

3. The effect of individual emission controls on local and regional air quality

4. The control agency resources required to enforce an abatement program

5. The political acceptability of the controls mandated.

While factor 5 cannot be quantitated to the extent of the other four, it is reasonable to assume that economic self-interest plays an important role in motivating acceptance or rejection of an abatement program.

This paper discusses an approach to air pollution abatement planning which can provide most of the detailed cost-effectiveness estimates needed to evaluate the five factors listed above for any quantifiable abatement strategy. The primary basis for evaluating a candidate strategy is the least-cost strategy for achieving stated air quality goals, defined in terms of emissions or concentrations of the pollutant of interest. The least-cost strategy permits the economic efficiency of a candidate strategy to be assessed. Some results of applying this approach to Kansas City, Kansas-Missouri and to Washington, D.C. are examined in terms of the five factors above.

Analytical Approach

The analytical approach developed uses interrelated computer programs, data files, and special techniques to simulate the source-by-source control of air pollution in a geographic area so that any number of prospective abatement strategies can be compared for cost and effectiveness.

There are four major parts to the approach:

Inputs

Abatement analysis

Meterological analysis

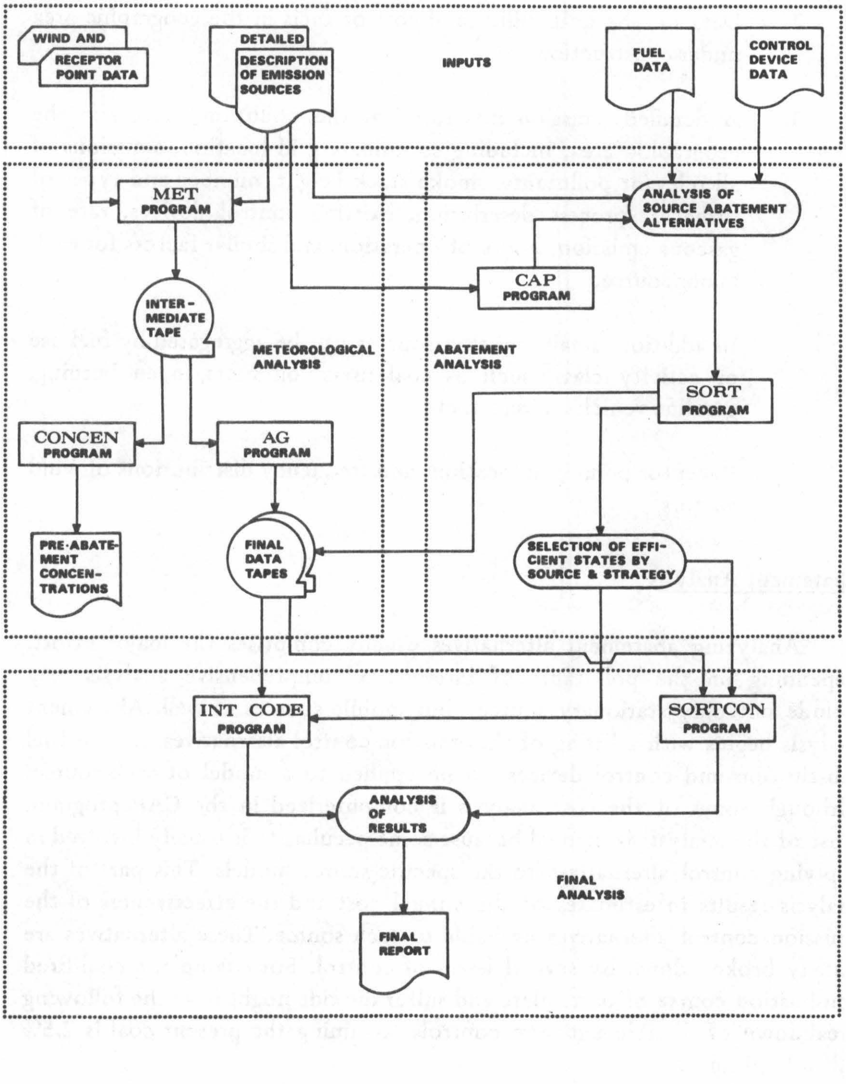
Final analysis.

In the following explanation of these parts below, refer to the Analytical Flow Diagram.

<u>Inputs</u>

There are four types of inputs:

ANALYTICAL FLOW DIAGRAM



1. Data on emission control alternatives for each pollutant considered: types, sizes, applicability, effectiveness, and capital and operating costs.

2. Data on the availability and cost of fuels in the geographic area under construction

3. A detailed emission inventory of the pollution sources in the geographic area, including coordinate grid location, emissions of all relevant pollutants, smoke stack height, number and types of furnaces, process description, existing control devices, rate of gaseous emission, hours of operation, and similar factors for each major source.

   In addition, small emission sources can be aggregated by fuel use or activity class, such as coal users, oil users, open burning, gasoline vehicles, aircraft, etc.

4. Receptor point grid locations and frequency distributions of wind vectors.

Abatement Analysis

Analyzing abatement alternatives usually comprises the major effort. Depending on the pollutants of interest, a comprehensive analysis may include not only stationary sources, but mobile sources as well. Abatement analysis begins with a listing of the emission control alternatives, such as fuel substitution and control devices, to be applied to a model of each source. Although some of the cost analysis is computerized in the CAP program, most of the analysis is manual because some peculiarity is usually involved in applying control alternatives to the specific source models. This part of the analysis results in estimates of the annual cost and the effectiveness of the emission control alternatives available to each source. These alternatives are usually broken down by several levels of control. For example, a coal-fired combustion course of particulate and sulfur dioxide might have the following breakdown of feasible emission controls, assuming the present coal is 2.5% sulfur by weight:

Control Alternative	Control Level
1. Substitute low sulfur coal (reduces SO_2 emissions)	1. 2% sulfur 2. 1.5% sulfur 3. 1.0% sulfur
2. Install precipitator (reduces particulate emissions)	1. Low efficiency 2. Medium efficiency 3. High efficiency
3. Switch to oil (reduces SO_2 and particulate)	1. 2% sulfur 2. 1.5% sulfur 3. 1.0% sulfur
4. Switch to natural gas (reduces SO_2 and particulate)	1. Interruptible (95%, gas, 5% light oil) 2. Firm (100% gas)

In this example, while there are 11 discrete levels among the four alternatives, there are actually 17 distinct control combinations available because alternatives 1 and 2 can be used together. Listing all the possible combinations with their corresponding emissions and cost variances is done in the SORT program. The most efficient states are selected from the SORT output to be used in the final analysis.

Meteorological Analysis

The MET program is a computerized meteorological diffusion model developed by personnel of the Environmental Sciences Administration and the Public Health Service for determining the concentration of a pollutant at any arbitrary receptor point per unit emission from each source point. The output of the MET program can be used by the CONCEN program to determine pre-abatement concentrations at all receptor points. MET output can also be used in the AG program for totaling the pollution contribution of small sources by user type. For example, in the Washington, D. C. study 1,000 area sources were aggregated into 12 fuel use and activity classes, such as distillate oil burners, diesel trains, open burning, etc. These classes can then be treated in the same fashion as point sources in detailing control alternatives and states.

Final Analysis

In the SORTCON program, one emission control state is selected for each source in conformance with the abatement strategy being simulated. The program then computes the resulting concentrations and costs to answer such questions as "What reduced emissions and concentrations of SO_2 result if all sources use fuels of no more than 1% sulfur content by weight?" or "What would be the cost and effectiveness of having all power plants burn natural gas?"

The INTCODE program is a zero-one integer program which can answer maximization or minimization questions such as "What is the cheapest overall way to reduce pollution at every receptor point to at least 0.015 parts of sulfur dioxide per million parts of ambient air and 75 micrograms of particulate per cubic meter of air?" or "What is the greatest sulfur dioxide reduction that can be achieved at a cost of $10 million per year?" INTCODE allows an abatement problem to be bounded on many sides: least total cost to the community to meet a goal, most ambitious goal which can be achieved for a given total cost, most ambitious goal which can be achieved for any total cost, and so on. Sets of solutions can be computed for any combination of cost and emission constraints on individual sources and for a great variety of constraints on costs, emissions, and pollutant concentrations. The ability to compute the optimum abatement strategy under any set of constraints provides the basis for assessing the economic efficiency of any candidate strategy.

Some Applied Results

The approach described has been applied to an analysis of some prospective strategies for abating sulfur dioxide and suspended particulate (airborne soot, flyash, and other respirable solid particles) in Kansas City, Kansas-Missouri, and Washington, D. C. The discussion below concerns mainly the Kansas City analysis, but some comparison with Washington results is given.

Inputs

The kinds of input data required were described on page 51 and, for the Kansas City and Washington, D. C. studies, came from agencies of the

Federal, state, and local governments, manufacturers of emission control equipment, public utilities, process industries, trade associations fuel suppliers, consultants, and others. The U.S. Public Health Service in particular provided for study purposes detailed data on surveyed emission sources and all meteorological inputs.

Meteorological Analysis

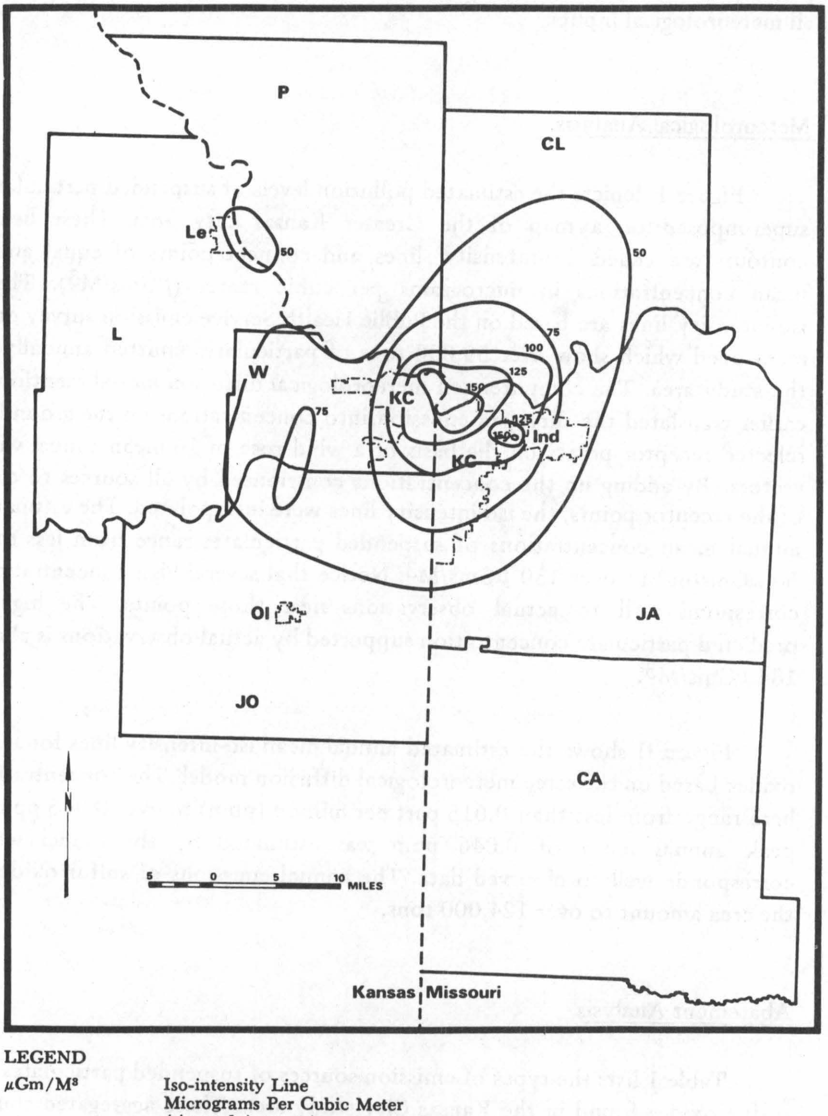
Figure I depicts the estimated pollution levels of suspended particulates superimposed on a map of the Greater Kansas City area. These heavy contours are called iso-intensity lines and connect points of equal annual mean concentrations in micrograms per cubic meter (μGms/M^3). These iso-intensity lines are based on the Public Health Service emission survey data mentioned which show over 59,000 tons of particulates emitted annually in the study area. The computerized meteorological diffusion model mentioned earlier translated the surveyed emission into concentrations on the ground at selected receptor points on the basis of a wind rose of 16 mean annual wind vectors. By adding up the concentrations contributed by all sources to each of the receptor points, the iso-intensity lines were interpolated. The estimated annual mean concentrations of suspended particulates range from less than 50 μGms/m^3 to over 150 μGms/M^3. Notice that several high concentrations correspond well to actual observations near those points. The highest predicted particulate concentration supported by actual observations is about 184 μGms/M^3.

Figure II shows the estimated annual mean iso-intensity lines for sulfur oxides based on the same meteorological diffusion model. The concentrations here range from less than 0.015 part per million (ppm) to over 0.045 ppm. A peak annual mean of 0.046 ppm was estimated by the model which corresponds well to observed data. The annual emissions of sulfur oxides in the area amount to over 124,000 tons.

Abatement Analysis

Table I lists the types of emission sources of suspended particulates and sulfur oxides found in the Kansas City study area. These aggregated sources account for the percentages shown of the total annual tonnages of the two pollutants. These emissions come from combustion of fossil fuels for space heating and power generation, from open burning and incineration of solid and liquid waste, from industrial processes, and from miscellaneous small

Figure 1 –Pre-Abatement Concentrations of Suspended Particulates (μGm/M^3)



LEGEND

μGm/M^3	Iso-intensity Line Micrograms Per Cubic Meter (Annual Average)

KANSAS CITY STUDY AREA

CA	Cass County	L	Leavenworth County
CL	Clay County	Le	Leavenworth
Ind	Independence	Ol	Olathe
JA	Jackson County	P	Platte County
JO	Johnson County	W	Wyandotte County
KC	Kansas City		

sources. Stationary sources account for over 86 percent of the particulates and over 96 percent of the sulfur oxides emitted in this area according to the Public Health Service emission survey.

Table 1
EMISSION SOURCES OF
PARTICULATES (P) AND SULFUR OXIDES (SO_x)
IN THE GREATER KANSAS CITY AREA

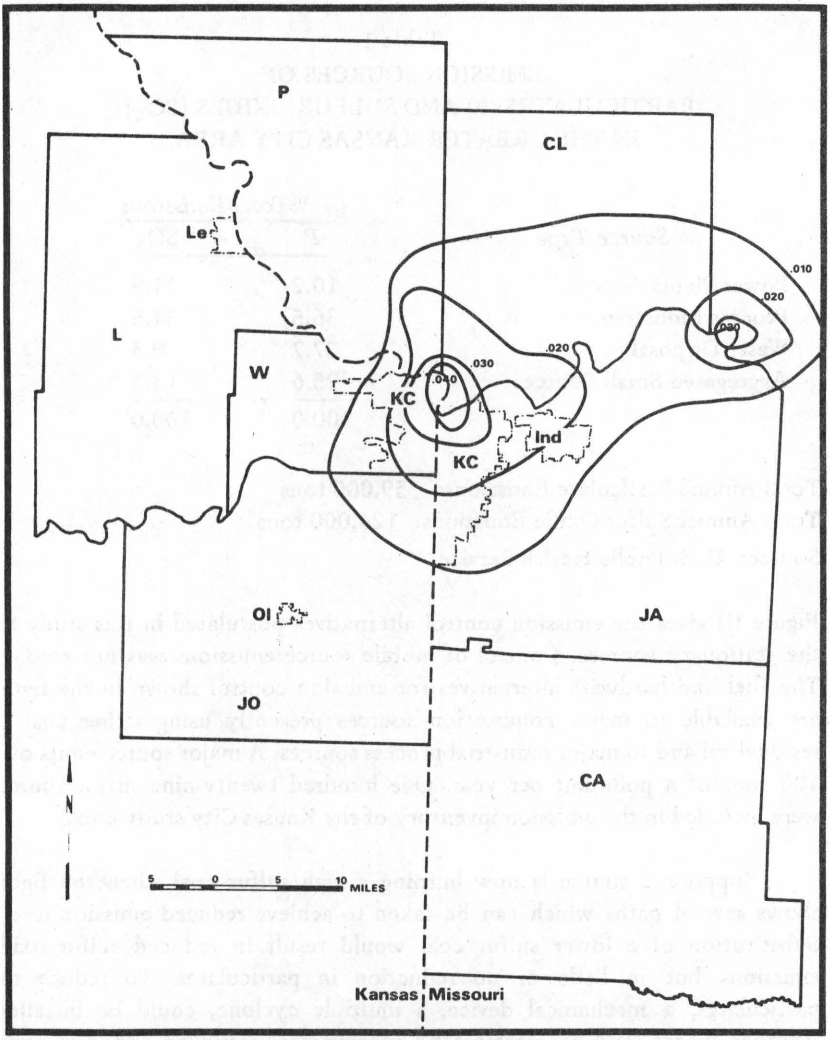
Source Type	*%Total Emissions* P	SO_x
Power Plants	10.2	51.9
Process Industries	36.5	34.5
Waste Disposal	27.7	0.3
Aggregated Small Sources	25.6	13.3
	100.0	100.0

Total Annual Particulate Emissions: 59,000 tons
Total Annual Sulfur Oxide Emissions: 124,000 tons
Source: U. S. Public Health Service

Figure III gives the emission control alternatives postulated in this study for the stationary sources. Control of mobile source emissions was not studied. The fuel and hardware alternatives for emission control shown in the figure are available to major combustion sources presently using either coal or residual oil and to major industrial process sources. A major source emits over 100 tons of a pollutant per year. One hundred twenty-nine major sources were included in the emission inventory of the Kansas City study area.

Suppose a source is now burning a high sulfur coal, then the figure shows several paths which can be taken to achieve reduced emission levels. Substitution of a lower sulfur coal would result in reduced sulfur oxide emissions but in little or no reduction in particulates. To reduce the particulatés, a mechanical device, a multiple cyclone, could be installed. Another device, and an electrostatic precipitator, could be added in series with the collector to increase particulate reduction to as much as 99.5 percent of the uncontrolled emissions of a coal-fired source. Other alternatives were also postulated. For example, a possibility for one power plant in the Kansas City area is to retain the present high sulfur, high ash coal but to install a stack gas cleaning system. Another possibility is for a coal or residual oil user to switch to natural gas. Some alternatives were not

Figure 2—Pre-Abatement Concentrations of Sulfur Oxides (PPM)



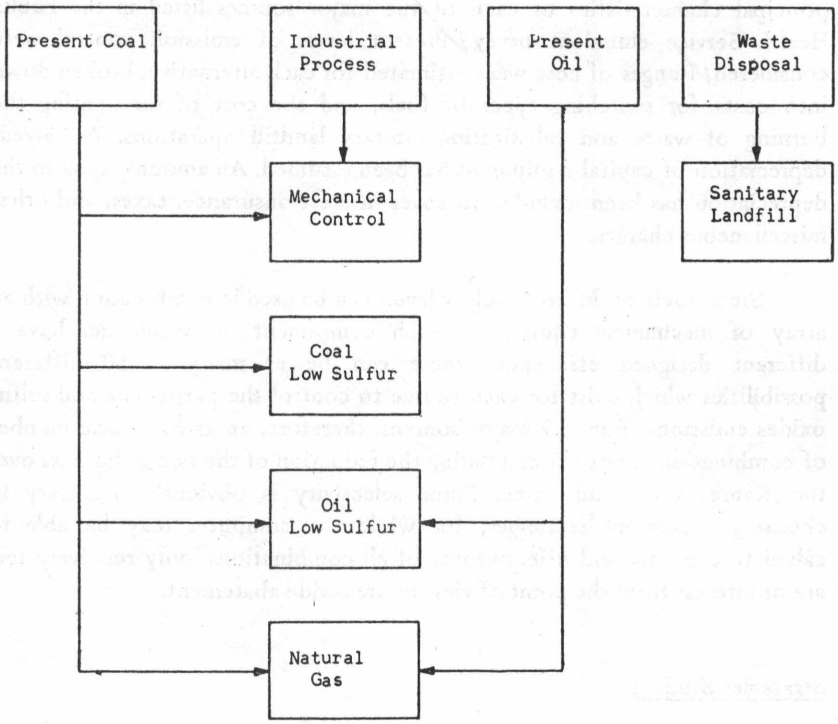
LEGEND

PPM	**Iso-intensity Line Parts Per Million (Annual Average)**

KANSAS CITY STUDY AREA

CA	**Cass County**	**L**	**Leavenworth County**
CL	**Clay County**	**Le**	**Leavenworth**
Ind	**Independence**	**Ol**	**Olathe**
JA	**Jackson County**	**P**	**Platte County**
JO	**Johnson County**	**W**	**Wyandotte County**
KC	**Kansas City**		

Figure 3—Alternatives for Particulate and Sulphur Oxides Emission Control (Stationary Sources)



considered, such as relocation of a source, switching to atomic energy, or building a high smoke stack. for the thousands of small fuel sources in the model, the only alternative stipulated was for coal users to substitute a coal with as low as 1 percent sulfur by weight. No mechanical controls were allowed for small sources because of prohibitive costs. It was assumed that the sulfur content of the coal presently used ran as high as 4 percent, and the sulfur content of the residual oil presently used as high as 2.5 percent.

In reality, no two emission sources are identical, and seemingly small differences in physical plant can imply, for some control alternatives, significantly different problems of technical and economic feasibility. For this reason, control alternatives were selected to be compatible with the principal characteristics of each of the major sources listed in the Public Health Service emission survey. Present levels of emission control were considered. Ranges of cost were estimated for each alternative, broken down into costs for switching types of fuels, and the cost of terminating the burning of waste and substituting sanitary landfill operations. A 15-year depreciation of capital equipment has been assumed. An amount equal to the depreciation has been included to cover interest, insurance, taxes, and other miscellaneous charges.

Since fuels of different sulfur levels can be used in combination with an array of mechanical equipment, each component of which can have a different designed efficiency, there can be as many as 50 different possibilities which exist for each source to control the particulate and sulfur oxides emissions. For 129 major sources, therefore, an astronomical number of combinations exist for simulating the reduction of the two pollutants over the Kansas City study area. Some selectivity is obviously necessary in choosing abatement strategies, for while the computer may be able to calculate the cost and effectiveness of all combinations, only relatively few are of interest from the point of view of area-wide abatement.

Strategies Studied

The following abatement strategies were selected for analysis and comparison:

1. Maximum control of particulate and sulfur oxides emissions

2. Maximum control of particulate emissions alone

3. Equi-proportional (EP) reductions of all major sources of particulate to at least 20, 40, 60, and 80 percent of each source's uncontrolled emissions

4. Prohibit the use of fossil fuels of greater than 2 percent sulfur content by weight.

The basis of comparison in each case is the least-cost combination of emission controls which achieves the same measure of effectiveness as the selected strategy. The primary measure of effectiveness computed for each strategy is the highest concentration of each of pollutants after application of the emission controls compatible with the strategy. A concomitant measure of effectiveness is the percentage reduction in total area-wide emissions of each of the pollutants. Thus, we are interested not only in how much the peak concentration of the mountain of pollution is reduced compared to the pre-abatement situation (Figures I and II), but also how much the whole mountain of emissions is reduced.

The estimated annual cost of a strategy is defined as the annual capitalized purchase and installation cost of equipment plus the estimated annual maintenance and operating cost of emission controls to all the appropriate emission sources of a pollutant. Control agency costs to implement a strategy are not included in these estimates.

Because the maximum control strategy bounds the problems at the top, it is interesting to study a picture of its effect, at least for particulate, which is the pollutant of major concern in Kansas City.

It will be recalled from Figure I that the present maximum annual mean concentration of suspended particulates was estimated to be 184 $\mu Gms/M^3$. The maximum control strategy reduces the maximum concentration to 85 $\mu Gms/M^3$. Figure IV shows the resulting iso-intensity lines. To achieve this, the total annual emissions of particulates are reduced 69 percent from 59,000 tons to less than 19,000 tons. This strategy simultaneously reduces the peak sulfur oxides concentration 69 percent from 0.046 ppm to 0.015 ppm. The associated total annual emissions of sulfur oxides are reduced 81 percent from 124,000 tons to less than 24,000 tons. The estimated least cost to achieve this maximum abatement strategy is $26,400,000 annually. As it happens, this is also the highest cost for any of the abatement strategies studied. Since there is only one way to achieve maximum emission control, other than closing everything down, the least-cost strategy and the maximum control strategy are the same. We shall see shortly, however, that in terms of air quality other least-cost strategies achieve approximately the same results at greatly reduced cost.

The Efficiency of Selected Strategies

For comparison purposes we have plotted in Figure V all of the principal strategies simulated in this study and a summary of their effectiveness.

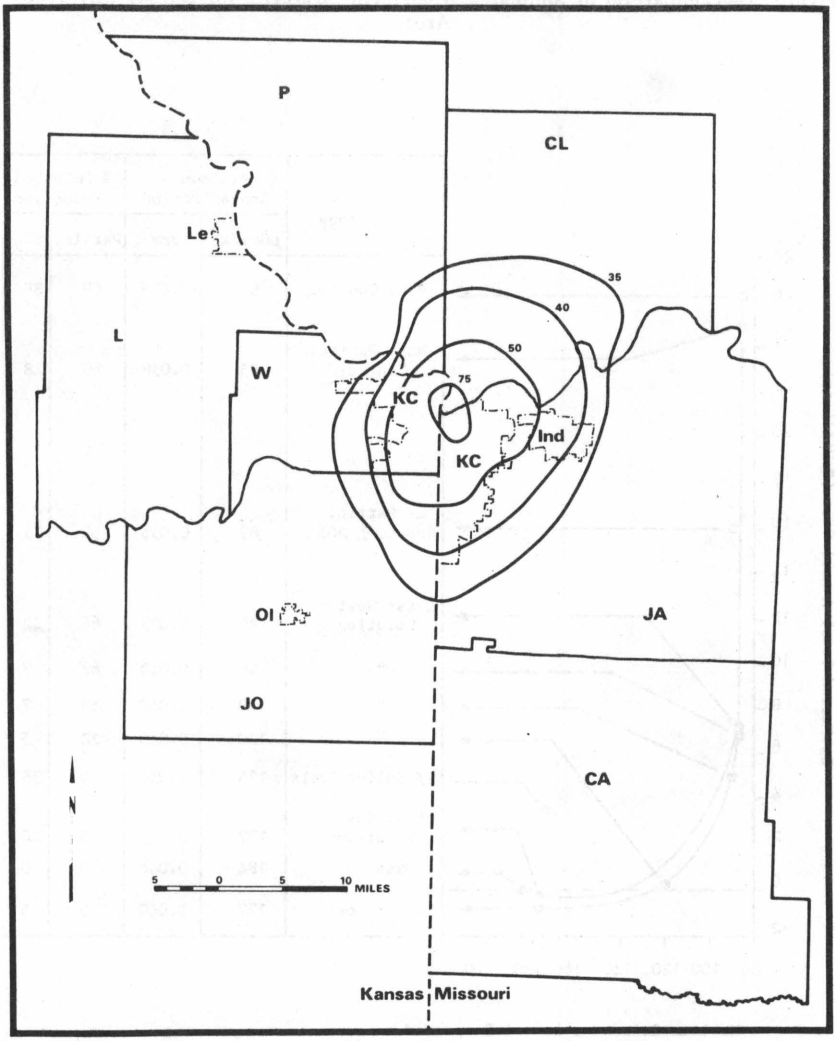
The vertical axis is estimated annual cost in millions of dollars; the horizontal axis is the predicted maximum annual average concentration of suspended particulates at any point in the Kansas City study area. The topmost point in this figure locates the maximum control strategy already discussed. The bottommost point located the lowest cost strategy. The lowest cost strategy results in an estimated total cost reduction of over $700,000 from the base conditions but without changing the pollution values significantly. While this may be surprising, it is explained by the fact that based on present fuel costs some sources can apparently effect operating cost reductions by buying fuels which are cheaper than those now being used.

The individual controls comprising any simulated strategy represent only possibilities, not certainties, unless, of course, the means of control itself is mandated–an unlikely event. A number of factors may dictate against the actual implementation of any particulate control action in practice. For example, because of cost-versus-savings trade-offs a fuel user may not elect to interrupt his operations while converting a boiler to take advantage of a cheaper fuel alternative.

The curve connecting the cost of the maximum control strategy to the lowest cost contains all of the least-cost solutions for reducing the maximum concentration of suspended particulates without deliberately controlling sulfur oxides. The curve which merges with it connects all the least cost strategies for reducing the maximum concentration of suspended particulates while requiring that the initial maximum concentration of sulfur oxides, 0.046 ppm, be reduced by half to 0.023 ppm. We show these least-cost curves as smooth curves for convenience; they are actually made up of a large number of discrete steps, since there are only a finite number of possible strategies.

A least-cost solution is defined more exactly as that combination of emission controls which achieves a stated objective for the least total annual cost to the set of emission sources. For example, with no deliberate sulfur

Figure 4—Maximum Suspended Particulate Reduction ($\mu Gm/M^3$)



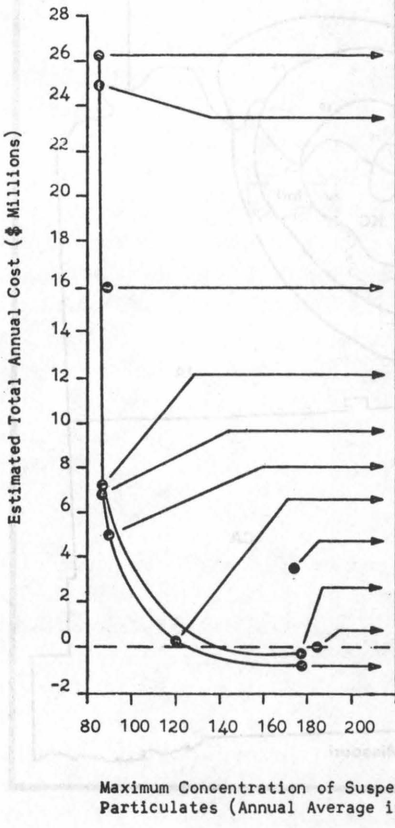
LEGEND

$\mu Gm/M^3$	Iso-intensity Line Micrograms Per Cubic Meter (Annual Average)

KANSAS CITY STUDY AREA

CA	Cass County	L	Leavenworth County
CL	Clay County	Le	Leavenworth
Ind	Independence	Ol	Olathe
JA	Jackson County	P	Platte County
JO	Johnson County	W	Wyandotte County
KC	Kansas City		

Figure 5—Comparison of Simulated Abatement Strategies for Kansas City Study Area.



Strategy	Maximum Concentration		% Emission Reduction	
	µGms/M³	ppm	Partic.	SO_x
Max. Control	85	0.015	69	81
Max. Partic. Control	85	0.038	69	48
EP Partic. Reduc. ≥ 20%	89	0.035	59	13
Least Cost Solution	86	0.023	66	42
"	86	0.040	68	7
"	89	0.040	59	7
"	120	0.040	22	5
2% Sulfur Fuels	175	0.035	10	38
Least Cost Solution	177	0.023	5	40
Base	184	0.046	0	0
Lowest Cost	177	0.040	5	5

oxides control a simulated reduction of the initial maximum concentration of suspended particulates from 184 μGms/M^3 to 120 μGms/M^3 can be achieved with 22 percent reduction in particulate emission for no net increase in the estimated annual cost. Reduction to 89 μGms/M^3 can be achieved for an estimated cost of $5,000,000 annually with 59 percent reduction in emissions. Reduction to 86 μGms/M^3 can be achieved, with 68 percent reduction in emissions for an estimated $7,000,000 annually with a bonus reduction of the maximum concentration of sulfur oxides to 0.040 ppm. For another $500,000 annually the maximum sulfur oxides concentration can be reduced to 0.023 ppm with a 42 percent reduction in emissions.

Comparing these least cost solutions first to the maximum control strategy provides a rather dramatic example of the law of diminishing returns in terms of reductions both in maximum concentrations and in total emissions. Since no real distinction can be made between an annual average of 85 μGms/M^3 and an annual average of 86 μGms/M^3 we see that the practical efficiency of either the maximum control strategy or the maximum particulate control strategy as a basis for particulate control (without considering sulfur oxides control) is only about one-fourth that of the least-cost strategy for 86 μGms/M^3. Since the present levels of sulfur oxides in Kansas City are not presently considered to pose a significant hazard, the maximum control strategy is not competitive with the $7,500,000 least-cost strategy for achieving a peak concentration 0.023 ppm for sulfur oxides in addition to the 86 μGms/M^3 peak concentration for particulate: neither the extra reduction of the peak to 0.015 ppm nor the doubling of sulfur oxides emissions reduced to 81 percent would justify the extra cost ($18,900,000) at the present level of hazard.

It is true, of course, that a least-cost solution selects those emission sources which can get the most abatement per dollar, so that some sources may not be affected. Is there, then, a more equitable, if perhaps more costly, strategy? Suppose that every source is required to reduce its particulate emissions in concert with all other sources successively by at least 20, 40, 60, 80, and maximum percent of its base emissions. The results of at least a 20 percent reduction show that the maximum concentration of suspended particulates is reduced to 89 μGms/M^3 with 59 percent reduction in total annual particulate emissions for an estimated cost of over $16,000,000 annually. The corresponding least-cost solution has an estimated annual cost only one third of that and, therefore, three times the efficiency. (The reduction in sulfur oxides obtained under both strategies is a bonus resulting from controls affecting both pollutants, e.g., switching from oil to natural gas). Table II compares the simulated emission reductions obtained by the major types of sources under the two strategies. This table shows what percentage of emission reduction is obtained by each of the major emission source types for each strategy and the associated costs. It is apparent that while the least-cost strategy is more highly selective, the so-called

TABLE II

COMPARISON OF PARTICULATE REDUCTIONS FOR EACH SOURCE TYPE UNDER EQUI-PROPORTIONAL (EP) AND LEAST COST (LC) STRATEGIES

	Source Emissions *% Reduction and Cost ($ Millions)*			
	LC		EP	
Source Type	*%*	*$*	*%*	*$*
Power Plants	68	0.2	53	0.2
Process Industries	81	0.7	71	8.6
Waste Disposal	81	4.1	100	6.4
All Other	-0-	-0-	1	0.8
Total Emissions	59	5.0	59	16.0

equi-proportional strategy has the more disproportionate impact on the emission sources in terms of both emission reduction and cost. The reason for this is that it costs no more for many sources to control their particulate emissions to the maximum than it does to control precisely 20 percent. Except for process changes or improved process operation, which were not considered, most mechanical equipment for particulate control has collection efficiencies in excess of 80 percent. Thus, the first step in control for many sources takes them to maximum control. This is demonstrated further by Figure V. Note that for an additional $9,000,000 annually the maximum particulate control strategy effects only a 16 percent increase in particulate emission reduction over the first equi-proportional step. This implies that on a cost-effectiveness basis many sources in the simulation went to maximum control in that first step. The simulated equi-proportional emission reductions of 40, 60, or 80 percent do not generate further significant reductions either in concentrations or in total emissions; the only significant change is increased cost.

A strategy of current interest in several cities for controlling the emissions of sulfur oxides is to ban the use of high sulfur fuels. In the Kansas City study, a restriction of the sulfur content of fuels to 2 percent by weight or less was evaluated. The estimated cost is $3,500,000 annually in increased fuel costs. This strategy reduces the sulfur oxides peak concentration to 0.035 ppm and effects a 38 percent reduction in the total tonnage of sulfur oxides emitted, while providing a bonus reduction of 10 percent in particulate emissions. In contrast, we note a least-cost solution which halves the peak concentration to 0.023 and reduces sulfur oxides emissions by 40 percent with an apparent net reduction in cost over the base conditions. This can be explained by some sources in the simulation changing to fuels which are both cleaner and cheaper than their present fuels.

A one percent sulfur fuel restriction strategy was simulated in the Washington study with similar results. In that case, the fuel restriction reduced the peak from 0.06 to 0.035 ppm at a cost of $5,000,000 annually. The corresponding least-cost solution also involves an apparent reduction in annual cost over the base conditions. These results strongly suggest that restrictions on the sulfur content of fuels have limited ability to reduce urban pollution levels and are very inefficient relative to the least-cost strategy achieving the same air quality.

Sulfur fuel restrictions are probably cheaper for a control agency to enforce than abatement strategies involving selective sulfur oxides emission standards, since in the former case, controls are, in effect, applied to a few fuel suppliers instead of the many fuel users. But in view of the limited pollution reduction obtained, the relatively high cost to the users of low sulfur fuels, and the adverse impact on high sulfur coal producing areas and the railroads servicing them, sulfur fuel restrictions do not appear to be economically attractive as abatement strategies.

We have used least-cost solutions to evaluate the economic efficiency of proposed abatement strategies, but are least-cost strategies themselves impractical? The question really involves the enforcement cost and the political acceptability of a strategy. Referring again to Table II, note that the cost of control for each source type is less than the corresponding costs for the equi-proportional strategy. If the politically important sources, as a class, pay less under a least-cost, or near-least-cost, strategy than under any other, then at least the economic motivations affecting political acceptability can be stimulated. As to enforcement costs, it may be feasible to write a few ordinances controlling the emissions of all sources of a certain type and channel enforcement through quasi-official industry abatement groups staffed partly by abatement agency personnel and partly by industry personnel. Cooperation and conformance with the spirit of the abatement ordinances would reduce enforcement costs for both industry and government. In any case, least-cost, or near-least-cost, strategies, should not be written off as academic.

Conclusions

The kind of comprehensive analytical approach presented can supply most of the detailed cost-effectiveness data needed to evaluate the economic impact of urban air pollution abatement strategies. The impact of a strategy on urban air quality permits rapid determination of the feasibility of attaining certain air quality standards. By providing estimates of the emission reductions and costs incurred source-by-source, an abatement agency also has a detailed basis for assessing the enforcement costs and the political acceptability of an abatement strategy.

The cost estimates presented here do not take into account future price fluctuations, deterioration of equipment, availability of low sulfur fuels, and several other factors which would have to be reckoned with in a precise determination of costs. It should also be emphasized that the results would have to be modified for conditions other than those assumed and for different geographic definitions. The approach has great flexibility as a systems analysis tool, however, and can be applied to other geographies and other pollution conditions.

FOOTNOTES

1. Mr. Sanjour is an operations research project manager for Ernst & Ernst in Washington, D. C.

2. Under Contract No. Ph 86-68-37 the U.S. Public Health Service, Department of Health, Education, and Welfare.

AIR POLLUTION CONTROL COST STUDIES

Norman G. Edminsten

National Air Pollution Control Administration, North Carolina

There is an old saying "Free as the Air" which we are beginning to recognize as being inconsistent with urban living conditions. Clean air in most urban areas can not be achieved unless considerable sums of money are spent for control efforts designed to meet air quality needs. This increasing concern with the deteriorating air quality of our Nation has generated a similar concern for the cost required to reduce source emissions to desirable levels. As a result, emphasis has been placed on air pollution economics in the Air Quality Act of 1967. This Act created the need for the Division of Economic Effects Research (DEER) within NAPCA, charged with the specific responsibility of conducting detailed research and in-depth investigation in this important area.

As a part of this responsibility, the Control Economics Branch within DEER is planning and implementing broad areas of intensive study that will establish the cost and effectiveness of emission reduction strategies. In our search for information we have found that published literature on such costs is not only scarce but is further complicated by inadequate descriptions and inconsistency in reporting. Our efforts have been directed toward determining sources of reliable information and structuring systematic procedures for assembling and analyzing data from these sources.

We have found that basic cost information for our needs can be generated from several sources as follows:

1. Literature
2. Manufacturers of control equipment
3. Engineering estimates
4. Engineering and construction firms
5. Records of tax offices and control agencies with permit and plant review
6. Users of control equipment

Each of these source areas presents data assembly problems that affect consistency in reported information. Our efforts have been directed toward the assembly of information from each source and the merging of this informatiom into reasonable estimates of the costs of controlling air pollutant emissions.

Control Cost Categories

Development of consistent and meaningful cost information requires a firm understanding of cost segments or accounting items. For purposes of understanding we have listed these cost areas in Table I.

There are several procedures available for estimating the cost of an air pollution control system. The accuracy of the estimate depends on the amount of work done on source evaluation and system design, and the degree of component accounting undertaken. Usually, the more laborious the procedure, the more accurate the estimate. Estimates prepared for competitive bidding, which define in detail each of the accounting components indicated, are usually considered to be of poor quality if they deviate by more than 5 to 8 percent from actual costs. If such detailed estimates are not required procedures are available for making reasonable cost estimates (±50 percent) of installed and operating control costs. (1,2) Such procedures account for the more definable and less variable cost items that are marked by an asterisk (*) in Table I. These estimating procedures can be further refined to give greater accuracy with specific engineering and process data for a given source.

After years of research and practical experience, the technology and art of applying gas cleaning devices for many pollutants, especially particulates, are well defined. Historically, most control efforts have been directed toward nuisance abatement and visible plume reduction. The advent of air quality standards and increasingly stringent emission standards will require many users and operators of control devices to install more efficient gas cleaning devices. Achievement of higher efficiencies within reasonable cost limits demands that attention be directed toward the integration of control equipment into the industrial process and plant layout. Figure 1 illustrates this concept in the selection of gas cleaning equipment for removing

Table 1. Accounting Items of Air Pollution Control

Capital Investment	Operation and Maintenance	Capital Charges
Engineering studies	Utilities*	Taxes*
Land	Labor*	Insurance*
Site preparation		
Control hardware*	Supplies and materials*	Interest*
Operating supply inventory	Treatment and disposal	
Auxiliary equipment*		
Installation*		
Startup		
Structure modification		

*Items contained in reported control cost data.

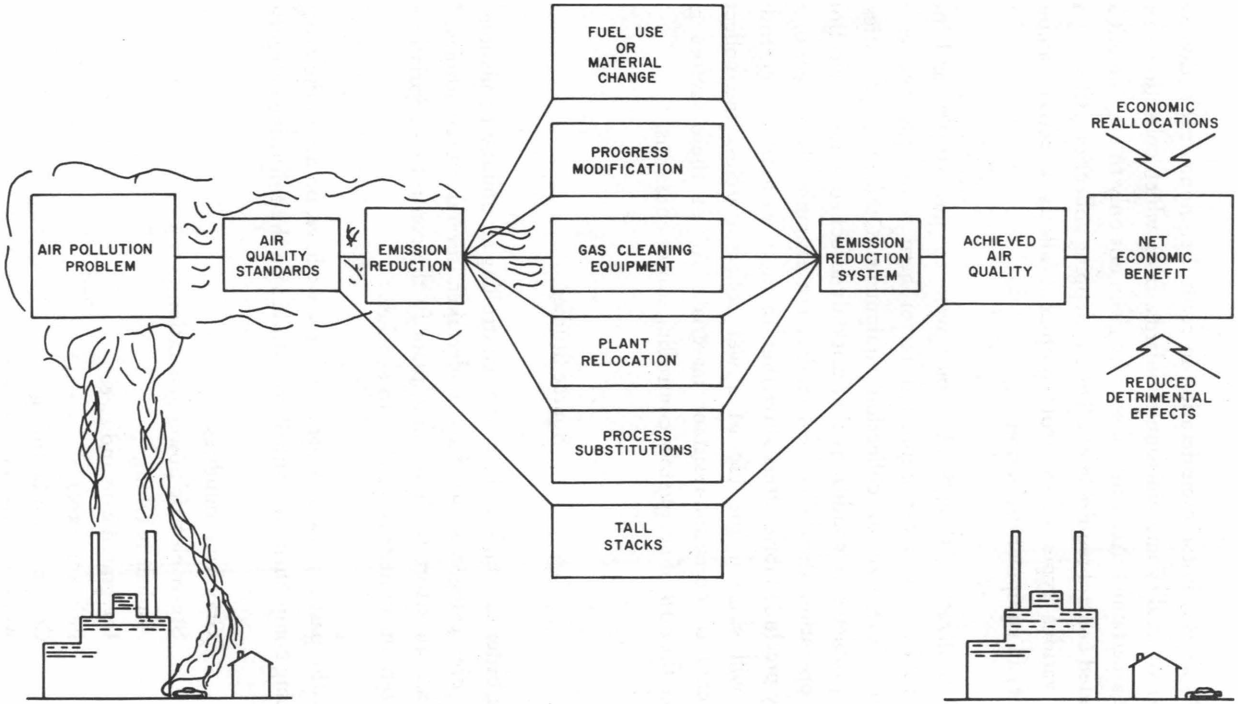


Figure 1. A Systematic Approach to Cleaner Air.

particulate matter (dust, flume, mist, aerosol) from gas streams of industrial processes.

As shown, initial consideration in control equipment selection must be given to air quality and emission standards, from which collection efficiency may be ascertained. Attention should be given not only to existing but also to anticipated control requirements. The overlapping collection efficiency ranges among various types of control equipment allows a certain amount of flexibility in equipment selection.

Consideration should also be given to gas stream and particle characteristics. The most important factor here is the gas volume, which determines the size of collection equipment. Other characteristics may present problems or conditions that not only affect equipment selection, but also its operation, durability, and service. For example, the danger of a flash fire may preclude fabric filters altogether. In another situation, a corrosive gas stream will shorten the life of a wet collector unless the collector is constructed of corrosion-resistant materials. All of these factors greatly influence the cost of adequately controlling source emissions.

Source Studies

In order to establish the cost of controlling air pollutant emissions from specific user categories, we have undertaken several source studies. These studies are an effort to define and quantify the control cost variations that exists from one industrial segment to another.

In the past 2 years of program efforts, we have, or, are in the process of conducting comprehensive control cost studies on the following categories:

1. Gray iron foundries
2. Steam electric power generation
3. Asphalt batching
4. Integrated iron and steel
5. Pulp and paper
6. Cement manufacturing
7. Aluminum ore reduction
8. Sulphuric acid mamufacturing
9. Petroleum refining

In addition, we are conducting studies to determine the control cost by generic types of equipment and to relate this cost to control efficiency or effectiveness. In this activity, we are attempting to define procedures to evaluate the net cost associated with the application of control systems to achieve a reduction in more than one pollutant. Definition of the true net cost for multiple pollutant control systems becomes increasingly important as gaseous control regulations are implemented.

Prior to investigating the cost of controlling air pollutant emissions in a given industrial source area, a preliminary review of the process segments is completed to assist in evaluating the air pollution problem. This review defines the pollutant sources and the types and quantities of pollutants emitted. It also indicates specific problems that must be considered in basic equipment design and operation. For example, the high temperatures from pyro metallurgical processes requires reducing gas stream temperature from as high as 3000°F to less than 500°F before the gases enter the collection device. In the case of fabric filters on wet cement processes, care must be exercised in basic design, installation and operation to maintain the gas stream temperature above the dew point to prevent fabric blinding. In each instance there is considerable expense that must be considered in data acquisition, analysis, and the final reporting of control costs.

This preliminary review should sufficiently guide the study design to optimize resource utilization and information acquisition. For example, in the Gray Iron Foundry Industry Study a cooperative effort was undertaken by the Department of Commerce and the National Air Pollution Control Administration. In this study, two types of questionnaires were used in data acquisition. An IBM card type questionnaire was designed to determine the number of foundries in existence, the number and types of furnaces, an indication of firm size by value of shipments, and the control systems in operation. From this information an industry sample was constructed to assure reasonable adherence to statistical principals with consideration given to source size distribution and types of control equipment in use.

A survey team consisting of an economist and an engineer visited each plant in the sample. This team made a site evaluation and assisted plant management in completing an eight page questionnaire. Information obtained included detailed financial, process, engineering, and cost data. This information is currently being evaluated for the preparation of a final technical report.

A study of the Steam-Electric Power Generation Industry was conducted in a similar fashion. This study was undertaken in cooperation with the Federal Power Commission. However, only those installations with control equipment installed since 1958 were included in the survey. Such a time constraint was considered important to obtain information consistent with present control technology and size of boilers. Also the constraint would reduce difficulties in updating cost information to present dollar values.

In the iron and steel and pulp and paper industries, the control cost studies are being conducted as part of an in-depth research investigation into the total process engineering and air pollution technology setting. These studies are being conducted by capable consultant type organizations in accordance with pre-designed plans. In each of these studies an Industry Liaison Review Committee was formed to review project reports and to supplement information gaps wherever possible.

In these two studies, the lack of control cost information on individual plant installations has been a serious problem. The lack of such information has resulted from difficulties in reconstructing cost from individual firm accounting systems and corporate policies against releasing such information. Consequently, we have resorted primarily to cost estimates prepared by cost engineering to compliment the limited amount of source data that has been obtained.

Control Cost Data

Anyone that has had occasion to review the literature on control costs has probably found cost tables listing generic types of control equipment designed for a gas volume of 60,000 acfm (actual cubic feet per minute). Such tables are generally traceable to work performed by Dr. C. J. Stairmand in the early 1950's. These data have served many useful purposes, but are becoming outdated and do not represent the cost of recent technological developments such as modular components type construction.

In the preparation of the Control Techniques for Particulate Air Pollutants(2) that was recently published as a companion document for the particulate criteria document, control costs of basic control equipment for

1968 were assembled. This cost data, as well as a systematic procedure for determining the installed and annualized control costs, are described in this document. The basic costs of "flange-to-flange" hardware for the high collection efficiency equipment are shown in Figure 2.

The total installed cost can be estimated by multiplying the purchase cost from Figure 2 by using the respective installed cost factors listed in Table II. This procedure gives an installed cost which varies from as low as $0.45 per acfm for centrifugal collectors to as high as $3.00 per acfm for an electrostatic precipitator.

This technique of developing control estimates must be tempered by knowledge about source conditions in order to reflect greater or lower cost resulting from extreme gas temperature, corrosiveness, particle resistance, moisture content, explosive conditions, pollutant concentrations, etc. Thus, a thorough understanding of the problem - solution setting is required to meaningfully apply such general cost information.

As may be observed in the basic cost curve, Figure 2, there is a condition commonly referred to as economy of scale or a gradual reduction in cost per cfm with increasing gas volume. While such economy of scale exists in the basic equipment cost, our studies actually indicate little if any economies of scale in the total installed cost. In fact, there may be some diseconomy with size due to more complex installations especially when a device must be "shoe-horned" into an existing plant installation.

The results of our intensive industrial studies are just beginning to bear fruit. We are assemblying a considerable amount of cost information but have not had adequate time to thoroughly analyze the findings for reporting purposes.

Table III list examples of cost from these studies for specific sources of particulate emissions from several major industrial categories. These estimates are the expected total cost that would be incurred and include the cost of hooding, ductwork, gas stream conditioning, and waste disposal.

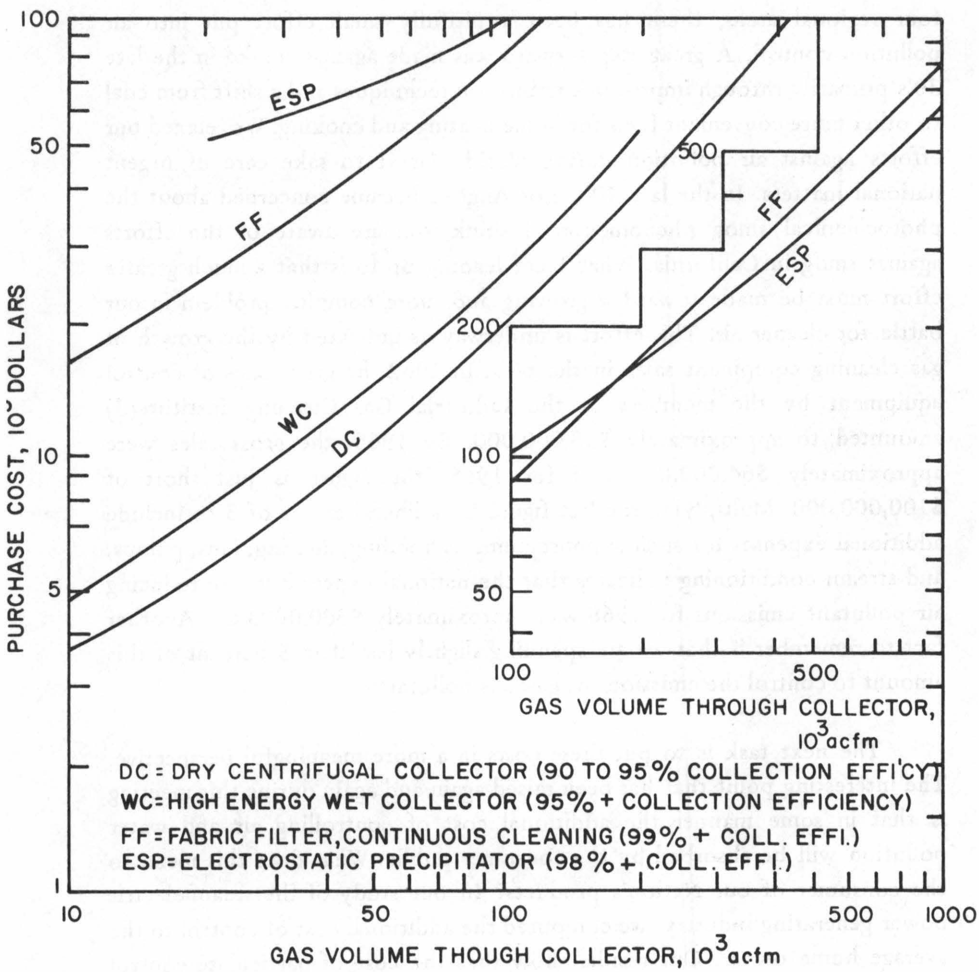
In conducting these studies, several stepping stones have been placed that are leading to a better understanding of the cost incurred and the need for such knowledge as a prerequisite to better decision making in our efforts for cleaner air.

Table 2. Installed Cost Expressed as a Percentage of Purchase Cost for All Generic Types of Control Devices

	Cost range, percent			
Generic Type	Low	Typical	High	Extreme High
Dry centrifugal	135	150	200	500
Wet scrubber				
Low, medium energy	150	200	300	500
High energy (a)	200	300	500	600
Electrostatic precipitators	140	170	200	500
Fabric filters	150	175	200	500
Afterburners	110	125	200	500

(a) High-energy scrubbers usually require more expensive fans and motors.

Figure 2. Purchase Cost of Collector Equipment



Our studies are substantiating what was already known. The cost of reducing air pollutant emissions to desirable levels is expensive. We also know that by proper planning, proper design and engineering, proper operation and maintenance and by taking advantage of collected material utilization, we can minimize these costs.

The unfortunate situation that confronts us is that we all too often wait until the eleventh hour before taking action. With the exception of three or four regional areas, there has been a pitifully small effort put into air pollution control. A great step forward was made against smoke in the late 30's primarily through improved combustion techniques and a shift from coal to other more convenient fuels for home heating and cooking. We relaxed our efforts against air pollution during World War II to take care of urgent national matters. In the late 40's, Los Angeles became concerned about the photochemical smog phenomenon. I think you are aware of the efforts against smog in California. What I am leading up to is that a much greater effort must be made toward a growing and more complex problem in our battle for cleaner air. This effort is underway as indicated by the growth of gas cleaning equipment sales in the 60's. In 1962 the gross sales of control equipment by the members of the Industrial Gas Cleaning Institute(3) amounted to approximately $38,000,000. By 1965, the gross sales were approximately $64,000,000 and for 1968, the figure is just short of $100,000,000. Multiplying the last figure by a liberal factor of 3 to include additional expenses for such support items as hooding, ducting, fans, pumps, and stream conditioning indicates that the national expenditure for reducing air pollutant emissions for 1968 was approximately $300,000,000. Another fact to remember is that we are spending slightly less than 5 percent of this amount to control the emissions of gaseous pollutants.

The next task is to put these costs in a more meaningful perspective. The interesting point that has been raised again and again during this meeting is that in some manner the additional cost of controlling air and water pollution will be absorbed by the consumer public. What does this mean to the consumer of our Nation's products? In our study of the steam-electric power generating industry, we computed the additional cost of control to the average home owner. Our results show that the cost of particulate control amounts to approximately 0.5 percent of the present cost of electricity to the consumer. This amounts to about 60 cents per year for the average home owners. This is the cost of reducing particulate emissions from coal burning

Table 3. Typical Control Cost Data by Source Category
(99% + Collection Efficiency)

Industrial Source	Control Equip.	Gas Volume (acfm)	Capital Invest.	Deprec.[1]	Capital[2] Charges	Electric Power	Maint.	Operating Labor	Annualized Control Costs
B.O.F. 100 ton furn.	Electrostatic Precipitator	375,000	$1,660,000	$166,000	$166,000	$ 90,000	$66,000	$20,000	$508,000
B.O.F. 100 ton furn.	High energy wet scrubber	220,000	$1,710,000	$171,000	$171,000	$207,000	$68,000	$40,000	$657,000
Electric arc Furnace 150 ton	Fabric filter (Med. temp. fabric)	230,000	$ 825,000	$ 82,500	$ 82,500	$ 40,000	$33,000	$30,000	$267,000
Gray iron cupola 20TPH	Fabric filter	73,000	$ 443,000	$ 44,300	$ 44,300	$ 10,200	$22,000	--	$120,800
Kraft mill 2-recovery furnaces 750 ton per day mill	99+% Electrostatic percipitator	1-Furn. @ 200,000 1-Furn. @ 130,000	$1,200,000	$120,000	$120,000	$ 15,000	$24,000	--	$279,000

[1] Depreciation at 10 percent per year of capital investment.

[2] Capital charges assumed as 10 percent per year of capital investment.

steam-electric generating plants by more than 98 percent. As efforts are being expanded to reduce sulfur oxides and other gaseous emissions, we realize these will result in additional expenses. However, these expenses may be offset by re-use of the material removed by gas cleaning equipment such as the production of a salable sulfur product.

In conclusion, an increasing effort to improve our deteriorated air quality, especially in urban areas, will cost considerable sums of money. Progress has been made toward reduction of particulate air pollutants. Greater emphasis will have to be placed on controlling gaseous pollutants. In addition, capital for air pollution control will have to compete with other heavy demands on limited resources. The challenge is before us, however with the proper information and available analytical tools we can evaluate alternative control strategies for technological as well as economic feasibility. This provides for more effective utilization of resources in our efforts for cleaner air.

REFERENCES

1. Edminsten, N. G. and Bunyard, F. L., A Systematic Procedure for Determining the Cost of Controlling Particulate Emissions from Industrial Sources, Air Pollution Control Association, June 22-26, 1969.

2. Control Techniques for Particulate Air Pollutants, U. S. Department of Health, Education and Welfare, Public Health Service, Consumer Protection and Environmental Health Service, National Air Pollution Control Administration, January 1969.

3. Industrial Gas Cleaning Institute, Private Communication, Rye, New York, March 1969.

APPENDIX A

Biographical Information

David J. Allee

Education:

Cornell University - B.S. Agricultural Economics
Oxford University - Diploma Agricultural Economics
Cornell University - Ph.D. Land Economics

Experience:

Mr. Allee has been employed in his present position, Associate Director of the Water Resources and Marine Science Center at Cornell University, since 1964. He previously has taught Agricultural Economics with the Giannini Foundation and at Cornell University. Allee is the author of many publications dealing with Agricultural Economics.

Ellison Burton

Education:

Amherst College - B.S. Mathematics
Trinity College, Cambridge University - Diploma Mathematical Statistics

Experience:

Mr. Burton is manager in charge of analytical studies for Ernst & Ernst in Washington, D. C. He has been engaged in operations research activities for over 17 years. For the past two years he has directed projects concerned with the costs and effectiveness of air pollution abatement. Approaches developed were also applied to problems of assessing the impact of tax incentives on the choice of abatement alternatives for the President's Council of Economic Advisors.

Thomas D. Crocker

Education:

Bowdoin College - A.B. Economics
University of Missouri - Ph.D. Economics

Experience:

Now teaching in the Department of Economics at the University of Wisconsin, Crocker is also a consultant to Limnetics, Inc. and to the Economic and Social Studies Section, Office of Legislature and Public Affairs, NAPCA, U.S. Public Health Service, and is an occasional member of the Research Grants Visiting Committee, USPHS. Crocker has been a Project Assistant in the Department of Agricultural Economics at the University of Missouri, a Principal Investigator, National Institute of Health, and a consultant for the Illinois Institute of Technology. He is the author of a number of publications on the economics of air pollution.

Norman G. Edminsten

Education:

San Jose State College - B.S. Environmental Science
University of Michigan - MPH (I.H.)

Experience:

Now Acting Chief of the Control Economics Branch Division of Economics Effect Research, NAPCA, Edminsten has worked with the California Local Health Department as an Environmental Engineer, with the San Francisco Bay Area Air Pollution Control District, and as a Technical Assistant for the Activities Division Air Pollution Control, DHEW.

Donald G. Gillette

Education:

Michigan State University - B.S. Agricultural Education - M.S. Agricultural Economics
University of Maryland - Ph.D. Agricultural Economics

Experience:

Previously a Marketing Specialist for the Michigan Department of Agriculture, an Economist for M.E.D., E.R.S., U.S.D.A., and an Economic Consultant for the Parson Engineering Company of Tunisia, Gillette is now Chief of the Effects Assessment Branch, DEER, of NAPCA.

Charles J. Goetz

Education:

Providence College - A.B. Economics
University of Virginia - Ph.D. Economics
University of Pavia, Italy - Post Doctorate

Experience:

After receiving his doctoral degree in 1965, Goetz studied at the University of Pavia in Italy as a NATO Postdoctoral Fellow. He then became Assistant Professor at the University of Illinois and later joined V.P.I. and is now Associate Professor of Economics. He has authored more than 20 publications on economics.

Robert H. Haveman

Education:

Calvin College - A.B. Economics
Vanderbilt University - Ph.D. Economics

Experience:

Haveman has taught at Grinnell College since 1962 and is chairman of the Department of Economics there. He is currently on leave of absence from Grinnell College as an Economist for the Joint Economic Committee of the United States Congress. Haveman has authored many publications dealing with economics.

Allen C. Jones

Education:

Pennsylvania State University - B.A. Political Science - M.R.P. Regional Planning

Experience:

Jones is currently an Urban Planner for the Effects Assessment Branch, DEER, of NAPCA.

Morton I. Kamien

Education:

City College of New York - A.B. Economics
Purdue University - Ph.D. Economics

Experience:

Kamien was a Teaching Assistant while working on his doctorate at Purdue University. Since that time he has taught in the Graduate School of Industrial Administration at Carnegie-Mellon Institute and is now Associate Professor there and the author of numerous publications on economics.

Benjamin Linsky

Education:

Wayne State University - B.S.M.E.
University of Michigan - M.S.E.

Experience:

Linsky has served as a part-time teacher for Wayne State University, University of California, Berkeley, and Stanford University. He has worked for the City of Detroit, Air Pollution Control Agency, and the San Francisco Bay Area Air Pollution Control District. Now a Consultant to the U.S. Department of Health, Education, and Welfare and Professor of Sanitary Engineering at West Virginia University, he is the author of many articles on air pollution.

Hugh H. Macaulay, Jr.

Education:

University of Alabama - B.S. Business - M.S. Business
Columbia University - Ph.D. Economics

Experience:

Macaulay has been a Graduate Teaching Assistant for the University of Alabama, a salesman for the Lipscomb-Russell Co., a Lecturer in Economics at Columbia University, a Fiscal Economist for the Treasury Department, Tax Analysis Staff, and has gone from Instructor to Professor of Economics at Clemson University. He is now Alumni Professor of Economics at Clemson and has recently coauthored a book with J. M. Stepp entitled The Pollution Problem.

Roland N. McKean

Education:

University of Chicago - Ph.D. Economics

Experience:

Now a Professor of Economics and a member of the Center for Advanced Studies at the University of Virginia, McKean has been with U.C.L.A. and the RAND Corporation, has been a Visiting Professor of Economics and of Education at Harvard and has also taught at Vanderbilt University. McKean has written Efficiency in Government through Systems Analysis; Public Spending; Teacher Shortages and Salary Schedules (with Joseph A. Kershaw); Economics of Defense in the Nuclear Age (with Charles J. Hitch); and numerous articles and chapters in books.

Ronald M. North

Education:

Clemson University - B.S.
Cornell University - M.S. Marketing
Clemson University - Ph.D. Agricultural Economics

Experience:

North has been a Research Assistant at Clemson University. He is currently Associate Professor at the University of Georgia, where he has taught since 1963.

Brian Peckham

Education:

Stanford University - A.B. Economics

Experience:

Peckham is a Graduate Student in the Department of Economics, University of Wisconsin, on leave for active duty as Assistant Health Services Officer, Division of Economic Effects Research, National Air Pollution Control Administration, U.S. Public Health Service.

Clifford S. Russell

Education:

Dartmouth College - B.A. Mathematics
Harvard University - Ph.D. Economics

Experience:

Russell is currently a Professional Staff Member for Resources for the Future, Inc. Prior to this appointment Russell had served as an Assistant Lecturer in Economics at Makerere University College in Kampala, Uganda; an Economics Statistician for the Social Security Administration; and an Instructor in Economics at Wayne State University. Russell also assisted in writing Accounting and Economic Planning by B. Van Arkadie and C. Frank.

A. Allen Schmid

Education:

University of Wisconsin - Ph.D.

Experience:

Schmid was Associate Professor in the departments of Resource Development and Agricultural Economics at Michigan State University and was a Visiting Scholor for Resources for the Future in 1964-65. The author of Rural to Urban Land Conversion, Schmid has also published other journal articles on water resources. He is currently with the Systems Analysis Group, U. S. Department of the Army (Civil Works), Office of the Secretary.

Gordon Tullock

Education:

University of Chicago Law School - D.J.

University of Virginia; Thomas Jefferson Center for Political Economy - Post Doctorate

Experience:

Presently Professor of Economics at V.P.I., Tullock has been a member of the Foreign Service Institute, serving in China, Hong Kong, Korea, and Washington, D.C. After his resignation from the Foreign Service, he spent most of his time writing but had several jobs during this time, one of which was as Research Director of a small subsidiary of the Gallup organization in Princeton. Tullock spent the 1958-59 academic year as a Post Doctoral Fellow at the Thomas Jefferson Center for Political Economy at the University of Virginia. He has taught in the Departments of International Studies at the University of South Carolina, Economics at the University of Virginia, and Economics and Political Science at Rice University. Tullock is the author of many books, articles, and other publications dealing with economics.

WATER RESOURCES RESEARCH CENTER
VIRGINIA POLYTECHNIC INSTITUTE BLACKSBURG, VIRGINIA 24061