Journal of the Air Pollution Control Association

ISSN: 0002-2470 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uawm16

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To cite this article: Noel de Nevers (1977) Air Pollution Control Philosophies, Journal of the Air Pollution Control Association, 27:3, 197-218, DOI: 10.1080/00022470.1977.10470411

To link to this article: https://doi.org/10.1080/00022470.1977.10470411

Published online: 13 Mar 2012.

AIR POLLUTION CONTROL PHILOSOPHIES

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Most air pollution control programs rest on one or more of the following four basic philosophies: emission standards, air quality standards, emission taxes, and cost benefit analysis. Frequently they rest on mixtures or combinations of these four. This paper examines each of the four separately, tries to show why each is different from the others, and compares their advantages and disadvantages.

Although air pollution control actions have a history reaching at least as far back as the 13th Century,[1] the major efforts have taken place in this century. The people who undertook these efforts tended to "control pollution" rather than philosophize. However, the magnitude of the effort now being made and the public controversies which have surrounded it indicate the need for some philosophical understanding of air pollution control.

Some of the controversies have resulted from the fact that the opposite sides in the controversies were basing their views on entirely different philosophies, and did not recognize that; and some have resulted from the fact that the philosophies have been applied in mixed forms, without clear delineation of which philosophy was truly the governing one. In this paper the philosophies are examined as if they existed in "pure form," even though in practice they often occur in mixed form.

The wish of all concerned with air pollution is that we could have a completely unpolluted environment at no cost to anyone. That is apparently only possible if we can repeal the laws of nature. Since that appears impossible, our logical goal is to have an appropriately clean environment, obtained at an appropriate cost, with this cost appropriately distributed among industry, car owners, homeowners, etc. An air pollution philosophy is a fundamental idea or set of ideas about how one would determine what constitutes an appropriately clean environment, appropriate control cost, etc. These ideas must be implemented by detailed regulations. Such regulations have been the subject of controversy in recent years. The purpose of this paper is to examine the underlying ideas on which such regulations are based. In setting forth these detailed regulations, it can be done in a strict way or a lax way (one may choose to err on the side of strict control or on the side of minimum control cost). Whether one should be strict or lax in applying the philosophy is a question separate from the questions about the underlying philosophies which this paper discusses.

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The Properties of a Good Philosophy

Considering the difficulties we have had with various kinds of air pollution control regulations and their underlying philosophies, we can formulate a list of the properties which a perfect air pollution control philosophy and its implementing regulations would have. A perfect air pollution philosophy (and its implementing regulations) would be cost-effective, simple, enforceable, flexible, and evolutionary.

A cost-effective philosophy gains the maximum possible benefits (reduced damages or discomforts) for the resources expended on pollution control. A simple philosophy with its implementing regulations is understandable to all involved in the pollution control effort and does not require legal interpretation of every word of the regulations. An enforceable philosophy with its regulations is one which makes clear who must do what, in a way which courts of law will enforce. A flexible philosophy with its regulations has a good way of dealing with emitters with special difficulties (control equipment breakdown, delays in control equipment delivery, etc.). A flexible philosophy with its regulations enables us to take into account new data on the effects of pollution and new developments in control technology without major overhauls of our legal structure or major revisions of existing industrial plants.

The Four Philosophies

The four philosophies of greatest interest are emission standards, air quality standards, emission taxes, and cost-benefit standards. The first two are in current use in the U. S. and other industrial countries and are fairly well understood. The latter two have mostly been the subject of academic publications and have not had much practical testing.

Each of these philosophies can be stated and examined in "pure form," as is done here, and could in principle be applied in pure form. As later examples will show, this is not always done.

Emission Standards Philosophy

The basic idea of the emission standards philosophy is that there is some maximum possible or practical degree of emission control. This maximum degree of control varies between various classes of emitters but presumably can be determined for each. If it is determined for each, and each member of that class of emitters is required to control his emissions to this maximum degree possible, then we will have the lowest possible emission rate. Because emission rate and air cleanliness are inversely related, it follows that if this philosophy is carried out rigorously, we will have the cleanest possible air. Thus in the pure form this might reasonably be called a "cleanest possible air" philosophy.

Apparently the first large scale application of this philosophy was in the form of the Alkali Acts in England starting in 1863.[1] These followed the introduction of the Leblanc process for manufacturing soda ash (an alkali). A byproduct of this process is hydrochloric acid, which in the original form of the process was emitted from the plant's smokestack as a vapor or mist. This emission devastated vegetation downwind and led to controversy and legislation. The legislation created the corps of "alkali inspectors" whose duty was regularly to inspect all alkali plants and to find the best techniques for minimizing the emission of harmful pollutants. Once such a technique had been shown to be effective in one plant, the inspectors forced all the other plants to adopt it. Thus, in this case, the emission limitations were steadily made more stringent as the control technology developed, and each member of the class was obliged to meet the same emission limitation as the cleanest member of the class. This kind of application is frequently called the "best technology" type of emission standard because the requirement which is placed on all the members of a class is that they employ the best technology currently available for controlling emissions and that they keep the control equipment in good operating condition. In this type of regulation there is generally no specified emission rate or emission test; the operator who installs and operates properly the "best technology" is deemed to be complying with the regulation. The English equivalent phrase for "best technology" is "best practical means." English air pollution law is very strongly oriented to best practical means.[2]

This "best technology" approach is in widespread use and is well liked by the air pollution control fraternity. For example, the Los Angeles Air Pollution Control District[3] Rule 56 requires all parties who store gasoline in quantities of 40,000 gallons or more to store it in a floating-roof tank or a tank with a vapor recovery system or some other system which can be shown to be of equal control efficiency. Many other jurisdictions have followed this procedure for controlling emissions from gasoline storage. Measuring emissions from a floating-roof tank is a difficult task; but since a well maintained one is a low emission storage system, this has been a widely approved technique.

A different kind of emission standard is the prohibitive standard; for example, the widely applied prohibition of open burning of combustible wastes. This is an emission standard because open burning is not the minimum-air-pollutant-emission way of disposing of such wastes. Land fill or closed incineration produce much lower air pollutant emissions. By forbidding open burning, we force waste disposers to use better technology.

A third kind of emission standard is a visible emission standard. This was introduced into air pollution by Ringelmann,[4] who devised a system for visually estimating the opacity of emissions from the chimneys of coal-burning furnaces. Since the opacity is related to the rate of emission of particles (not by a simple relation), limiting the opacity of the effluent limits the particle emission rate. This type of regulation has the virtue that trained smoke readers can make such readings very quickly and inexpensively without entering the plant from which the emissions come. Thus the Ringelmann test is a cheap, rapid tool for emission regulation and enforcement.

Fuel sulfur content limitations and olefin content limitations in gasoline are also emission limitations because most of the sulfur in fuels enters the atmosphere as sulfur dioxide and because olefins are more effective in causing photochemical smog than equivalent amounts of other hydrocarbons.

The final kind of emission standard is the numerical one. For example,[5] under current EPA regulations, no coal-fired electric power plant whose construction commenced after August 1971 may emit to the atmosphere more than 1.2 lb of sulfur oxides per 10^6 Btu of fuel burned as determined by stack test. Similarly, 1976 model automobiles may not emit more than 1.5 g/mile of hydrocarbons in a well-defined test procedure.[6]

All of these kinds of emission standards and their variants have the same general idea; namely, that there is some level of control of emissions which it is practical to ask all members of a well-defined class of emitters to achieve and that level of control should be achieved by all members of the class nationwide.

This philosophy has been the basis of most of the air pollution control activities in the industrial world for the period between 1863 and 1965. In current U. S. air pollution law, there are two sections which are "pure" emission standards. These are the *New Source Performance Standards,*[7] which set nationwide maximum permissible emission levels for various classes of emitters (new electric power plants, new sulfuric acid plants, new municipal incinerators, etc.) and the *Hazardous Pollutant Standards*[8] which set specific emission regulations on mercury, beryllium, and asbestos. These latter three pollutants are considered to be inappropriate to attempt to control by the air quality standards philosophy (discussed later). Although it is not clear in the Clean Air Act that ambient air concentrations should play any role in setting Hazardous Pollutant Emission Standards, EPA did in fact consider them in setting the beryllium and mercury standards.[9]

These are "pure" emission standards in the sense that the emission rates permitted were determined on the basis of "best technology" in the way described above and were not determined as a subsidiary to some other philosophy. In addition, there is a set of emission standards for motor vehicles[10] whose values were determined not by inquiring what was the best available technology but rather by deciding on the basis of the ambient air quality standard philosophy (discussed later) what emission level was permissible and then making that emission level the standard. Because the standards arrived at this way were more stringent than could be met by the then current "best technology," this is referred to as a "technology forcing" emission standard.[11] Many state and local air pollution agencies have emission standards, both "pure" emission standards based directly on their assessment of what is "best technology," and those based on an overriding application of the air quality standards philosophy.

The Advantages and Disadvantages of Emission Standards

Table I compares emission standards (and the three other philosophies to be discussed later) with the list of qualities previously given. The emission standards philosophy's cost effectiveness is very bad. If we apply the same uniform emission standards to a class of emitters including those at a remote location and those in the center of an industrial, densely populated area, then if the standard is stringent, the remote plants will make a large expenditure with a small reduction in damage to receivers and hence a small benefit. If the standard is lax, then the plants in the industrial area will not be controlled to the degree which minimizes the damages to the surrounding population. This is a natural consequence of the application of a common standard ("cleanest possible air") to densely populated and sparsely populated areas.

Because of this poor cost effectiveness, we frequently do not apply the emission standards philosophy in its "pure form," but rather apply it in modified forms which take the location of the source into account.

The simplicity of the emission standards philosophy is excellent. The entire set of regulations consists of the permitted emission rates and the description of the test methods to be used to determine if the emission standards are met.

The problem of the tradeoff between cost effectiveness and administrative simplicity of the emission standards strategy is well illustrated by the history of the emission standards for motor vehicles in the U. S. In 1967 the automobile manufacturers petitioned the Congress to write uniform motor vehicle emission standards for the whole U.S. and forbid the states from individually writing their own. They did so because they feared the complexity of having to produce a multiplicity of different vehicles to meet different state standards.[12] In 1973 they petitioned Congress to do the reverse and allow it to use a "two-car strategy" in which very stringently controlled vehicles would be sold in areas with severe air pollution problems, and much less stringently controlled vehicles would be sold in areas without severe air pollution problems.[13] They did this because they believed that the extra expenditure for stringently controlled cars in areas without severe air pollution problems was not cost-effective.

The enforceability of the emission standards philosophy is excellent. Once standards are set and test methods defined, one knows whom to monitor and for what; and violation criteria can easily be written and penalty schedules formulated.

The flexibility of this philosophy is poor. If a plant orders pollution control equipment in good faith and the equipment fails to meet the manufacturer's predicted performance criteria (and hence the emission standards), it will generally take years to replace it. How should the control authorities deal with this plant? Under this philosophy they can close the plant, fine it, or give it a variance to operate until the equipment is fixed. Experience has shown that plant closing is politically impossible, serious fines are politically very difficult, and the variance is an invitation to infinite delays; but under this philosophy there are no other obvious alternatives.

The evolutionary ability of this philosophy is fair. If a new technology makes it possible to set a lower standard, it can be done for all sources built after a certain date. This works well for autos, whose lifetime in the economy averages 10 years, but poorly for industrial plants, whose lifetime is 30 to 50 years. Mandating a lower emission standard for plants built after a certain date will help the air quality in areas undergoing growth after that date but not those which do not have such growth.

In its early days this was an excellent philosophy. Most of the progress which has been made in air pollution since 1863 was made by the application of this philosophy. The "best technology" approach made sense for the Leblanc soda-ash plants because their pollutant could be collected and sold at a profit. It made sense for coal-burning furnaces because their black soot emissions were wasted fuel. But most of the air pollutant emissions which can be recovered and sold at a profit are now being so collected and sold. Further progress in control of air pollutants (either to get a cleaner air or to maintain current air cleanliness in a time of industrial and population growth) will be made by applying more stringent controls to sources which cannot recover a saleable product or reduce expenses by reducing emissions. For this problem, the emission standard philosophy is useless.

This uselessness is illustrated by the question of the design efficiency of electrostatic precipitators for large particulate emitters, e.g., coal-fired electric power plants. The typical percent recovery of particulates by new installations has risen steadily over the past two decades, from 90% to 99+%. There appears to be no reason why we cannot build precipitators with recovery efficiencies of 99.9% or 99.99%, etc. The most general design equation for these precipitators is the Deutsch-Anderson equation[14]

$$\text{collection efficiency} = 1 - \exp(-v_d A/Q) \qquad (1)$$

where v_d is the "drift velocity" which is an appropriate average particle movement velocity toward the collecting plates, A is the area of the collecting surface and Q is the volumetric flow rate of gas being cleaned. The cost of an electrostatic precipitator is *roughly* proportional to the area of the collecting surface (A) so that for a given installation (and hence a constant Q and v_d) we can say approximately

$$\text{collection efficiency} = 1 - \exp(-\text{some constant} \times \text{cost}) \qquad (2)$$

Thus, according to Eq. 2, if it costs N dollars to install a 90% efficient precipitator, it will cost $2N$ for 99%, $3N$ for 99.9%, 4N for 99.99%, etc. (This is only approximate because precipitators collect the big particles preferentially so that as efficiency goes up, the average value of v_d goes down.)

Given this approximate cost-efficiency relation, what is the "best technology" or "cleanest possible air" value for this kind of installation? Clearly, we can mandate any level of control efficiency we wish, and the precipitators can be built to meet them. If the level of "best technology" is deemed to be 99.5% (a typical current value) and some plant installs a 99.95% efficiency one, shall we then mandate that all future plants should install precipitators that efficient? That is the logical result in the pure form of this philosophy. At that point the effluent would contain approximately 6% as many particles per unit of heat released as the typical home oil-fired space heating furnace.[15] However, even then we could design and build more stringent control devices if we wished. Should we?

If society had infinite resources and were willing to commit them to the control of air pollution, this would not be a difficult question. But I believe society has finite resources and will probably only commit some fraction of them to air pollution control. If this is correct, then it would seem folly to commit all of them to this particular kind of pollutant. But the "best technology" philosophy or "cleanest possible air" philosophy if carried out relentlessly, would lead inevitably to that. For this reason, those who have tried to apply this philosophy have generally tempered it with some qualifier like "taking costs into account." The same idea appears in the protracted discussions of the meanings of terms such as "good technology," "best reasonable technology," "best demonstrated technology," and "reasonably available control technology," and "best available control technology."[16] These all reflect the fact that this philosophy, if pursued to its logical conclusion, leads to impossible results. Thus, although it has been useful in the past, it provides little guidance for the future.

The dilemmas of this philosophy are also illustrated by an example from the author's personal experience. In trying to prevent the relentless application of this philosophy, Congress, in the Clean Air Act of 1970[7] required that one of the emission standards should be based on "... the best system of emission reduction which (taking into account the cost of achieving such reduction) ... has been adequately demonstrated." EPA based its power-plant sulfur dioxide regulation on the demonstrated performance of the largest limestone scrubber then in operation in an investor-owned power plant in the U.S. The electric utility industry then pressured the owners of that plant to disavow it and claim that it was not functional, practical, etc. EPA pressured the owners to defend it. These conflicting pressures were so great that when the vice president of that power company was asked for a simple public relations photo of the plant to use in a magazine article[17] he refused. If the whole industry must do whatever the most advanced has done, then he who advances fastest incurs the wrath of his colleagues. Given this basis for standard setting, the electric power industry has taken action to prevent one of its members from installing advanced control equipment on its plants.[18] If that member succeeds, all must follow, whether it is a prudent use of the country's resources or not. This particular case (limestone scrubbing for sulfur control) is an issue which is under intense, current national debate. The emission standard philosophy gives no guidance at all on how that debate should be resolved.

Air Quality Standards Philosophy

If the emission standards philosophy is logically a "cleanest possible air" philosophy, the air quality standards philosophy is logically a "zero damage" philosophy. To see why, consider a dose-response curve, Figure 1.

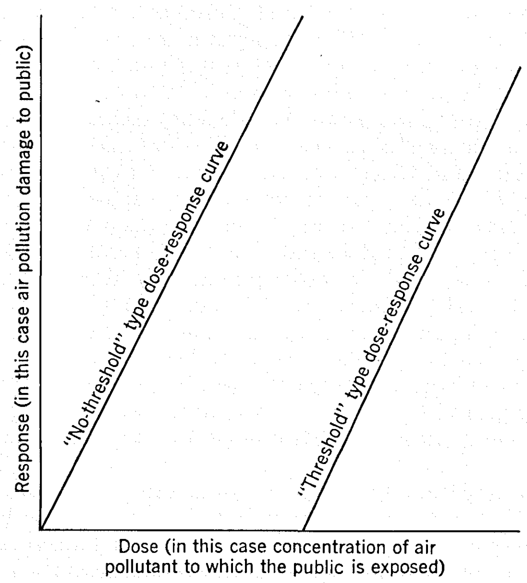

Figure 1. Dose-response curves of the threshold and no-threshold types.

We know most about dose-response curves from pharmacology where one regularly gives laboratory animals known doses of experimental pharmaceuticals and measures their response. From theory and experiment[19] we know that for pharmaceuticals the most common dose-response curve is the

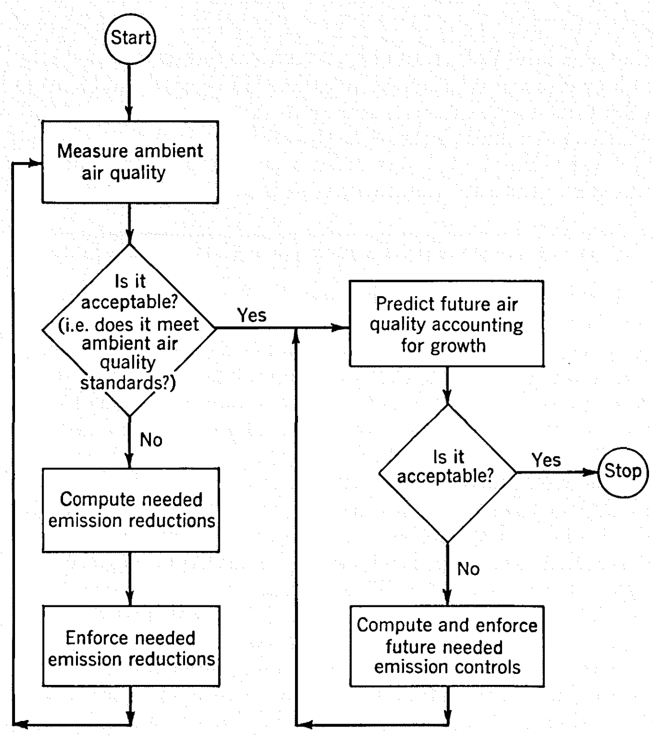

Figure 2. Flow-diagram representation of the air quality standards process.

"no-threshold" curve, which passes through the origin. A quite different view prevails in industrial hygiene. There it has been observed that for workers industrially exposed to toxic materials there is some exposure concentration, called the "threshold value," which "represent(s) conditions under which it is believed that nearly all workers may be repeatedly exposed day after day, without adverse effect."[20] These values, called "threshold limit values," are established by industrial hygiene boards; and industrial plants are expected to protect their workers from higher values.

The air quality standards philosophy is based on the *assumption*[21] that the true situation for most major air pollutants is the "threshold value" situation sketched in Figure 1. If that assumption is true, and if we can determine the concentration values (including time of exposure) which correspond to such threshold values, and if we can regulate the time, place, and amount of emissions to guarantee that these threshold values are never exceeded, then it follows as an inescapable consequence that there can be *no air pollution damage, ever, anywhere.* This is precisely what the air pollution community is trying to do now in the U. S., in carrying out the air quality standards philosophy which is the basic philosophy of the Clean Air Act of 1970.

To implement this philosophy, some body or group must study the available dose-response data and determine what are the "threshold values." In U. S. air pollution law, these are to be set "with an adequate margin of safety ... to protect human health,"[22] and are called Ambient Air Quality Standards. (Note the upbeat wording; this really means permitted levels of contamination.) The Environmental Protection Agency has established such standards for five major pollutants.[23] The states are now attempting to manage the air quality to assure that those standards will not be violated, ever, anywhere. How this is being done is illustrated, in flowchart form, in Figure 2.

The process (for some specific locality) begins with a measurement of the ambient air quality. This is then compared with the standards. If the measured value is acceptable (i.e., less than the Ambient Air Quality Standards) then the next step is to compute the predicted future air quality over some finite time period. If this is acceptable, no action is needed.

If the future emissions (taking into account population and industrial growth, etc.) are above the standards, then emission regulations must be devised to prevent this predicted future violation.

If the current values are above the permitted values, then emissions must be reduced to bring the current values into compliance with the standards. To do this, one must have some way of estimating the relation between emissions and ambient air quality. This is normally done by means of some kind of air quality model.

Based on these models, one computes a set of needed emission reductions, enacts the regulations to compel the emitters to reduce their emissions, enforces this set and, once the emissions have been so reduced, again measures the ambient air. If the standards are not met (and the emissions have indeed been reduced as required by the model) then the modeling exercise must be repeated and the entire cycle repeated until the standards are met. This process was begun in the U. S. for the first time in the spring of 1971[24] with the standards all to be met in 1975. Delays in meeting the standards were granted, as provided by law, in some cases. The states and EPA are now in the process of determining where the standards are and are not being met, and thus initiating the second trip around the loop shown in Figure 2.

Comparing the air quality management philosophy with the list of desirable qualities described above (See Table I), we see that its cost effectiveness is good but not excellent. It has the virtue of concentrating pollution control expenditures in the areas with the worst pollution problems and allowing higher emission rates (and lower pollution control expenditures) in areas with less serious problems. However, once a set of nationwide air quality standards has been set, they must be met everywhere, even in areas seldom or never visited by people. Thus, it will require some control expenditures for which the damage reduction benefits will be small.

To date no one has found a way to write a simple set of regulations based on this philosophy. EPA's best efforts to write a simple set of regulations to enforce the air quality standards philosophy in the Clean Air Act of 1970 have resulted in a very complex set of regulations which have been the subject of a seemingly unending set of legal challenges. Some critics have referred to the Clean Air Act of 1970 as the "Lawyers' Full Employment Act of 1970." The reason for this complexity is that we are attempting to control the concentration of pollutants in the ambient air. Those concentrations are influenced by a wide variety of emitters, some nearby, some far away. The connection between their emissions and air quality at a given point depends on the meteorological transport and dispersion of the pollutants[25] and atmospheric reactions of the pollutants.[26] Neither of these subjects is well enough understood to allow exact and unequivocal calculations of the contributions of individual emitters to specific location concentrations in urban areas. Given this uncertainty, regulations attempting to deal with local and long-distance polluters have been promulgated, and contested in court, with resulting modifications and complexities.

The enforcement difficulty of this philosophy results from the same cause as its complexity; namely, that one is trying to enforce air quality. When the air quality standard is not met, it is not generally obvious who is responsible. Furthermore, some industries have proposed "intermittent control plans" in which they would reduce emissions at times of poor atmospheric dispersion, and thereby meet the standards with higher annual emissions than would result if they controlled emissions constantly at a level which led to meeting the standards at all times. If the philosophy of air quality standards were enforced in an absolutely "pure" way, this would seem to be a sensible way to meet them. However, there are some objections concerning long-range transport of pollutants[27] and in addition an enforcement problem. If we are dependent on daily monitoring and daily management of emissions both done by industry to meet the standards, how are we enforcing the law? This latter has led to EPA rejection of one plan involving such intermittent control;[28] that rejection will almost certainly be litigated.

The flexibility of the air quality standard philosophy is fair. Because of the multiple ways air quality standards can be met, those administering it have some flexibility, and each local agency can choose the detailed regulations it considers best, within limits. Special cases and emergencies can be handled locally.

Its evolutionary ability is fair. As new data require it, standards can be changed; but that will then probably require complete new emission regulations, which will be expensive and time consuming. Improvements in control technology will increase the options open to those regulating emissions.

One clear difficulty with the air quality standards philosophy, which had led to court action in the U. S. concerns "non-degradation" or "non-deterioration." If it were *absolutely true* that there was no damage at all of any kind at concentrations below the "threshold values," then there could be no logical objections to polluting up to those concentrations. In effect the EPA guidelines to the states for developing their "State Implementation Plans"[28] took this view. In contesting those regulations, a consortium of environmental groups showed that this was not apparently the intent of Congress nor even completely consistent with EPA's own regulations issuing the standards.[29] Aside from these purely legal questions, the logical bases for opposing this view are 1) that the setting of threshold values is bound to be based on limited data and that, therefore, one cannot be certain that we will not harm pure-air areas by polluting them up to the levels of the standards and 2) that visibility (the ability to see distant vistas) is inherently not a threshold value property but rather[30] is clearly a no-threshold property. Hence, if we were to pollute up to the standards, most of the scenic areas of the arid southwest and the Rocky Mountain states would experience a marked and significant deterioration of their traditionally high visibility and clear skies.

Table I. Comparison of strategies.

	Emission standards	Air quality standards	Emission taxes	Cost-benefit analysis
Cost effectiveness	Very bad	Good	Fair	Excellent
Simplicity	Excellent	Poor	Excellent	Terrible
Enforceability	Excellent	Fair	Excellent	Unknown
Flexibility	Poor	Fair	Unnecessary	Unknown
Evolutionary ability	Fair	Fair	Good	Good

This controversy has been considered by the U. S. Supreme Court once, with the conservation groups winning (on a tie vote) and has been the subject of several sets of proposed and final EPA regulations.[31] It seems certain to be the subject of future litigation. It clearly reveals the most basic difficulty with the air quality standards or zero damage philosophy; namely, that this philosophy is totally and completely dependent on the *assumption* that there are threshold values below which there is zero damage. For visibility this assumption is demonstrably false. Thus the strongest intellectual basis for the non-deterioration or non-degradation doctrine is this attack on the false premise in the air quality standards philosophy. However, as more and more data accumulate on air pollution effects on humans, it becomes harder and harder to believe that the threshold value idea truly applies to human populations.[32] If it becomes clear that it does not apply, then it will be equally clear that the ambient air quality standard or zero-damage philosophy is without intellectual foundation. If that is the case, we will still be able to use ambient air quality standards if we wish; but we will have to choose the values on some philosophical basis entirely different from that used to date. As an example of the setting of an ambient air quality standard at some value other than the "zero damage" value, an ambient air quality standard for asbestos has been proposed[33] whose proponents indicate that this standard would correspond to a mortality rate of 150 lives/year nationally due to ambient asbestos exposure. If one decides to permit a finite amount of human health damage, he must then decide how much. The cited article does not discuss how it was decided that 150 deaths/year was the desirable level. Clearly that is not arrived at by a "zero damage" assumption.

Emission Tax Philosophy

The two previously discussed philosophies are in current active use in the U. S. We know a great deal about them, their advantages, and their drawbacks. The two philosophies discussed next are not to any significant extent in use anywhere in the world but rather are ideas which have had theoretical discussion in academic journals. They represent possible future alternatives.

An emission tax philosophy would tax each emitter of major pollutants according to some published scale related to its emission rate; *e.g.*, x¢ per pound of a pollutant for all emitters. This tax rate would be set so that most major polluters would find it economical to install pollution control equipment rather than pay the taxes. In its "pure form" there would be no legal nor moral sanction against an emitter who elected to pay the tax and not control his emissions at all. Because regulated public utilities could probably pass such taxes on to consumers, the tax would have to be set high enough that it would cost them less to control than to emit, and hence public utility commissions would base the allowable rates on the lower cost of control than on the higher cost of paying the tax. In the pure form, it is clearly quite a different philosophy from the air quality standard or emission standard philosophy.

Emission taxes have also been proposed in combination with the air quality management philosophy; in this combination, emission taxes would act as an added incentive to reduce emissions to lower levels than those required to meet air quality standards.[34] In this case the two philosophies would work in parallel. An alternative form would have the tax rate steadily increased until some predetermined ambient air quality was reached. In this version emission taxes are not an independent philosophy but a tactic being used to implement the air quality standard philosophy.

Emission taxes can be considered as one member of a larger class of philosophies called "economic incentives." The other members of this class are tax rebates and public loans for the installation of air pollution control equipment and direct public subsidies for pollution control. These latter seem in most cases not to have been proposed as separate and complete philosophies (*i.e.*, they have no "pure form") but rather have mostly been proposed and applied as ways of distributing the costs of implementing air quality standards or emission standards philosophies.

The emission tax philosophy assumes that the environment has natural removal mechanisms for pollutants (with chloro-fluorocarbons as a possible exception[35]) and that hence at any particular contaminant level, the environment has a finite absorptive or dispersive capability. If this is so and that capability is seen as public property, then it should logically be rented to private users to return maximum benefits to the public treasury, and it should not be overutilized; the analogy with publicly-owned forest or grazing land seems obvious. For this reason one might think of the emission tax philosophy as a "market allocation of public resources" philosophy, as compared to the "cleanest possible air" and "zero damage" bases of the two previous philosophies.

If we (the government) take that view and apply the "pure form" of emission taxes, then we accomplish two desirable results. First, we make the level of pollution control by the individual firm an internal economic decision. In either of the two previously discussed philosophies if the individual firm can persuade (or litigate) the control authorities into a less restrictive regulation, that firm saves money and possibly gains an advantage over its competitors who are not able to do so. If we use the emission tax philosophy, each firm must make the individual decision as to which level of control efficiency will minimize its sum of control costs and emission taxes. This sort of minimization is something American industry is demonstrably good at.

The second desirable result is that the emission tax philosophy should minimize the misallocation of pollution control resources. If we use it, small emitters will presumably find it economical to pay the taxes rather than put economically wasteful control devices on their plants. Large emitters, on the other hand, will find the taxes on their emissions prohibitive and install very high quality control equipment. Overall, this should allocate resources well.

Many versions of emission taxes have been proposed and discussed, but none has reached the state of legislation. Comparison of this philosophy with the list of qualities must be based on impressions of how the legislation would work.

The cost effectiveness should be fair because it would allow each emitter the choice of controlling emissions or paying the taxes (or controlling to some economic level and paying for the rest.) Making the decision whether or not to control and the level of control desired a matter of the internal economics of major emitters would probably result in a better overall level of cost effectiveness than is possible with uniform emission standards. However, if we enact a uniform national set of emission taxes, it may result in some remote plants installing control equipment at large cost to minimize taxes without much corresponding reduction in damages. This is the principal limitation on its cost effectiveness.

Most schemes proposed so far only envisage taxes on large sources. Such schemes are simple. For large sources, the tax rates and emission test methods comprise the whole of the regulations. If an attempt were made to extend the tax to all emitters (e.g., autos, household fireplaces, small industries), then the problem would become much more complex.[36] For sulfur oxides, for example, motor vehicle and home-heating fuels based on sulfur content could be taxed at a rate comparable to the rate for sulfur emissions from large industrial sources. This would be simple. But no comparably simple scheme for particulate emissions from home-heating sources, autos, etc., is yet apparent.

If the tax schemes are limited to large sources, then enforceability should be excellent. The emission testing industry would have to be expanded and certification of testers (like the current certification of weights and measures) instituted; but once a certified body of independent emission testers was available, their test values would be readily accepted as the basis for tax payments. Recording emission meters in exhaust stacks would also be most useful.

Flexibility to deal with the kinds of problems previously discussed would be unnecessary. Flexibility is needed in the other philosophies to deal with the problem of an emitter who cannot economically meet an area-wide standard or who cannot meet it by a statutory deadline. In an emission tax system, he simply pays the tax.

The evolutionary ability should be good because the tax rate could be changed as the need arose. This would have to be done with some caution because industry has complained about their difficulties with changing standards. (They speak of the difficulty of "shooting at a moving target.") However, raising a tax rate for existing plants causes much less economic disruption than lowering an emission standard. In the case of the tax rate increase, the existing plant would probably elect

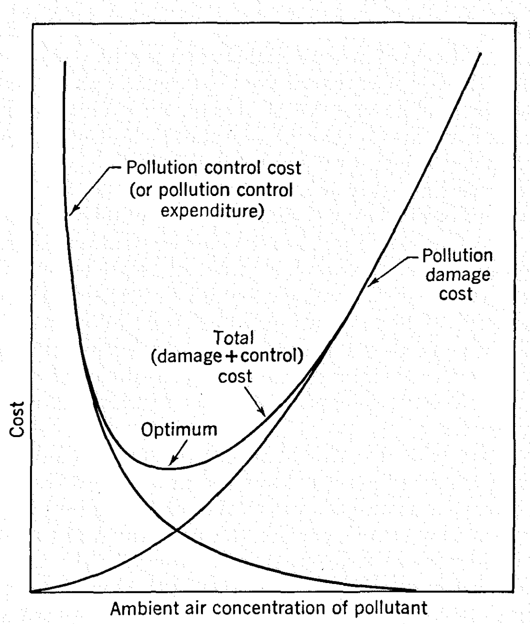

Figure 3. Schematic representation of relation between damage, control, and total costs.

to pay the higher tax, while for the lowered emission standard, it would probably have to replace its existing pollution control equipment with more effective equipment.

Although the emission tax philosophy is widely favored by economists in pure or mixed form and was once proposed in one of President Nixon's messages to Congress,[34] it has generally been anathema to American industry. One industrial group states,[37] "As a matter of principle, the right to pollute the environment should never be 'for sale.'" If we compare this view to the view of the holders of grazing rights on the public domain, we see that it is the same. Those who enjoy the free or subsidized use of the public domain are reluctant to pay the fair market price for that use.

An inherent difficulty with emission taxes as a pure philosophy is that there is no obvious answer to the question of how high the taxes should be. Generally it is suggested that we will raise the tax rates on a previously announced schedule, continuing until the air is "clean enough," and then hold the rates constant. How will we decide that the air is "clean enough"? If we decide on the basis of assumed threshold values, then emission taxes become merely a novel way (possibly a very good one) of implementing the air quality standards philosophy and not a pure philosophy at all. If, as discussed previously, the basic assumption of the air quality standards philosophy proves incorrect, then using it as a basis for determining "clean enough" in the emission tax philosophy has the same drawbacks as discussed previously.

We could opt not to consider air quality at all in deciding on our tax rates and use some purely economic criteria; *e.g.*, maximum tax revenue or marginal cost of pollution control equal to some current "best technology" value. Such an approach would presumably ignore the question of air pollution damage to the public.

Cost Benefit Philosophy

The previous discussion has shown that only the ambient air quality standards philosophy gives any guidance on how clean the air should be and that this guidance is based on the assumption that there are true threshold values. If that proves false, then that philosophy gives no guidance. If the assumption turns out to be true, it may still turn out that the true thresholds are so low that the cost of maintaining "zero damage" air quality is more than we can bear.

The cost-benefit approach assumes that either there are no thresholds, or if there are, they are low enough that we cannot afford to have air that clean. If this is so, then it follows that we must accept some amount of air pollution damage to someone, somewhere. In this situation this philosophy suggests that we face this fact and attempt to decide, in as rational a manner as possible, how much damage we should accept and correspondingly how much we should be willing to spend to reduce damages to this level.

The idea is illustrated in its simplest form in Figure 3. This figure, which is only conceptual and does not represent any particular situation, shows that if we make zero air pollution control expenditures, we will have some large ambient concentration of pollutants. As we increase the control expenditure, the concentration of pollutants will fall with the costs going up very steeply as we approach zero concentration. The damage cost curve is shown starting at some low value at a small or zero concentration and increasing rapidly at high concentrations. The sum of the two is shown to have a minimum value at some intermediate concentrations. This minimum is the optimum; expenditures above or below it are wasteful.

Figure 3 is but one example of the classic "minimization of the sum of two costs" problem which appears in economics and engineering texts. The minimum occurs when the slopes of the two cost curves are equal and opposite, or

$$\frac{d(\text{pollution damage} + \text{pollution control cost})}{d(\text{concentration of pollutant in the atmosphere})} = 0. \quad (3)$$

Figure 3 is a great simplification of reality because it shows one control cost curve, one damage curve, and one atmospheric concentration. In the real problem there is a damage curve for each individual exposed to air pollution, a control curve for each emitter (including autos, household space-heating plants, etc.), and a concentration dimension for each pollutant at each location. Thus instead of having a one-dimensional optimization, we have a multi-dimensional optimization with the number of dimensions being at least as large as the number of people in the world. One can in principle solve such multi-dimensional optimization problems; the solution of this one—in principle—is:

$$\left[\frac{\partial\,(\text{pollution control} + \text{damage cost for whole nation})}{\partial\,(\text{pollution control} + \text{damage cost for each individual})}\right]_{\text{all others constant}} = 0. \quad (4)$$

Eq. 4 indicates that at the true global optimum for each person and each pollutant, we are at a minimum of the form sketched in Figure 3. Although this is clearly the right place to be, getting there may be difficult, and Equation 4 should be considered as only a philosophical guide until we know much more about its detailed application.

This approach is frequently criticized by those who say, "You can't reduce . . . to monetary terms," where . . . maybe human health, human life, or the quality of a clear sky, or air pollution damage to the cathedrals of Europe, or something else is at stake.

> To press non-economic values into the framework of the economic calculus, economists use the method of cost/benefit analysis. This is generally thought to be an enlightened and progressive development, as it is at least an attempt to take account of costs and benefits which might otherwise be disregarded altogether. In fact, however, it is a procedure by which the higher is reduced to the level of the lower and the priceless is given a price. It can therefore never serve to clarify the situation and lead to an enlightened decision. All it can do is lead to self-deception or the deception of others; for to undertake to measure the immeasurable is

absurd and constitutes but an elaborate method of moving from preconceived notions to foregone conclusions; all one has to do to obtain the desired results is to impute suitable values to the immeasurable costs and benefits. The logical absurdity, however, is not the greatest fault of the undertaking: what is worse, and destructive of civilisation, is the pretence that everything has a price or, in other words, that money is the highest of all values.[38]

It is hard to believe that a distinguished economist could write this, and clearly ignore what all economists teach: that money is an indicator of value, and not a value itself.

It is hard to assign monetary values to non-material things, but society obviously does. The value we place on health is indicated by how much we are individually willing to spend to safeguard or improve our own personal health and by how much society is willing to spend to improve community health. The value society places on human life is indicated by how much society will spend to prevent one accidental death. Juries set financial values on loss of life and health every day.[39] The value we place on clear skies is indicated by how much people will give up to live in areas with such clear skies. Frequently, the person making this criticism disagrees with society's evaluation. I disagree with some of society's evaluations, but that is not ground for saying that society cannot and does not evaluate these things.

A paradox which continually puzzles me is that many well-educated people express such strong chagrin and distaste at the idea that society places dollar values on such things as human life, human health, the quality of the clear sky, etc. Frequently, the people who assert that setting such dollar value is immoral simultaneously reject as too expensive such life- and health-saving measures as mandatory seat belts, mandatory safety measures in auto construction, more comprehensive and thorough drug testing, safer highway design, improved public health facilities, improved occupational health standards, etc. In so doing they show that, at least subconsciously, they have placed dollar values on human health and human life. It appears that setting such dollar values is for our society like sex was for the Victorians; everyone does it, everyone knows that we all do it, but it is considered awful and disgusting to talk about it in public or admit that one does it.

Comparing the cost-benefit philosophy with the list of desirable properties, we see that its cost effectiveness is excellent. Since the whole idea of this philosophy is to solve the cost-benefit minimization problem, if it is done properly, it must have the best possible cost effectiveness.

Its simplicity should be terrible. Given the problem of solving Eq. 4 with as many variables as there are people and enacting regulations to enforce that, one can see the magnitude of the problem. Clearly, some simplified version of the solution to Eq. 4 must be used. Even so, the complexity should be fearsome.

Because of this complexity, it seems very unlikely that we will even have air pollution regulations based directly on cost-benefit analysis or on the direct application of Eq. 4; *i.e.*, a "pure" cost-benefit philosophy. More likely, greatly simplified approaches will be used. Two probable approaches are the use of cost-benefit analysis to set emission standards or to set air quality standards. Most likely this has been going on, informally, for many years. Most applications of the emission standard philosophy have included some wording in the laws suggesting that the standards be set . . . "taking into account the cost . . . "[7] or analogous words about "reasonableness" or "practicality." In deciding what is reasonable or practical, those writing the regulations have consciously or unconsciously attempted to decide what the benefits of a given control measure would be and balanced these benefits against the cost. I know of no conscious example where this has been done with air quality standards; but when and if it becomes clear that one or more of the major air pollutants is a no-threshold pollutant, this will probably be the way used to decide what the air quality standard will be.

Because Table I is written for "pure" philosophies, I have listed "unknown" for the enforceability and flexibility of the cost-benefit philosophy. No one has, to my knowledge, published any clear idea of how a set of regulations based on "pure" cost benefit analysis would be written. Hence this uncertainty. One may estimate that the evolutionary ability would be good. As we discover new air pollution damage data or new control technology, we can introduce these into our cost-benefit equation and modify the regulations to take this into account.

If, as stated above, this philosophy will most likely be used, not as a "pure" philosophy, but as a guide for setting emission or air quality standards (and this has been going on, informally, for a long time), why list this as a philosophy at all? The major purpose of this paper is to elucidate the true philosophical bases on which we are currently acting. If, as I suggest, we have been applying this philosophy in an informal, non-public way while using emission standards and air quality standards as our public philosophies, then I believe we ought to admit it. If we really are using emission standards and/or air quality standards not as basic philosophies but as enforcement tools for an overall cost-benefit strategy, then we ought to devote the thought and effort necessary to putting our cost-benefit decisions on as sound a basis as possible. To do so will require public exposure of the assumptions and value judgments which are needed to do cost-benefit calculations involving human health damage, aesthetic damage, etc.[40] I predict that exposing such value judgments will be painful and controversial, but the alternative is to continue making air pollution control decisions in ways where the true bases are hidden from public view and public debate.

Conclusions

From 1863 to 1965 air pollution control efforts were largely based on the emission standards or "cleanest possible air" philosophy. From 1965 to the present, the air quality standards or "zero damage" philosophy has found increasing application and become the dominant philosophy in U. S. air pollution law. The emission tax or "market allocation of public resources" philosophy has been proposed and discussed as an alternative to these two philosophies.

The air quality standards philosophy answers the question, "How clean should the air be?" but bases the answer on an unproven assumption. The other two philosophies do not answer it at all. If the basic assumption of the air quality standards philosophy proves false, then none of these philosophies will answer that question.

Informally, or unconsciously, pollution control agencies have answered the question by some kind of estimates of costs and benefits. In the future, the author suggests that this kind of analysis should be removed from the guesswork and "engineering judgment" of pollution control officers and become a formal, publicly debated part of our air pollution regulation-setting procedure.

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