# Comparing Risk Standards

## The Superiority of a Benefit-Cost Approach

**Albert L. Nichols**

Setting standards to protect health and the environment has proved to be difficult and contentious. Perhaps the single most controversial issue has been deciding how safe is safe enough. Two decades after federal regulation in these areas began to expand rapidly, no consensus has been reached as to the criteria that should be used in making the tradeoffs inherent in these decisions. Indeed, sizeable fractions of the public and Congress seem to deny that any fundamental tradeoffs are required. They argue that we should continue to strive for absolute safety.

Many laws reflect this objective. In the case of noncarcinogenic substances, at least the appearance of perfect safety can be achieved by setting standards below the levels at which adverse effects have been observed, with some margin of safety added to provide more assurance. In reality, of course, no level is completely safe, because there are likely to be some people who are unusually susceptible or there are effects that have not yet been identified. Nonetheless, the existence of thresholds is widely accepted, so that we can operate under the myth that we have achieved "safe" levels.

With carcinogens, however, policymakers are seemingly convinced that risk is a function of dose, even at low levels, so that *any* level of exposure short of zero imposes some risk. Thus, absolute safety requires zero exposure, and zero exposure generally means zero use of carcinogens. Many carcinogens, however, are unavoidable by-products of essential activities. Combustion of fuels releases carcinogenic "products of incomplete combusion," for example. Other carcinogens are themselves important inputs to the production of goods or services that are widely viewed as essential. Benzene is a proven human carcinogen, but it is also a major chemical and an unavoidable (though reducible) component of gasoline. In such cases it is impossible to avoid the problem of deciding how far to go; even the most ardent safety advocates would not shut down all processes that release carcinogenic materials.

Economists have a long-standing and deceptively precise sounding answer to the question of how much to regulate: controls should be tightened to the point where the incremental costs of further control would exceed the incremental benefits. The use of such benefit-cost analysis to guide decisions about health and the environment is extraordinarily controversial, however, with few adherents beyond the ranks of economists. Opponents of benefit-cost analysis charge that it is insensitive to ethical considerations, that technical uncertainties are inherent in such analyses, and that benefit-cost

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analysis is so expensive and time-consuming that it will delay needed protective regulation.

Any frank appraisal of the potential role of benefit-cost analysis in making decisions about regulating health and the environment must acknowledge that such analysis falls well short of perfection. Weighing the costs of control against reducing risks to health or the environment does raise a host of ethical issues that make most people uncomfortable. Frequently analyses must be based on highly uncertain, often crude science, and inevitably they are incomplete. They can also be expensive and time-consuming to conduct. In assessing the value of benefit-cost analysis, however, it is important not to judge it in isolation. We need to look at it in comparison with the alternatives. Many of the problems that plague benefit-cost analysis are common to all approaches to setting standards for health and the environment, given our limited knowledge.

**With carcinogens policymakers are seemingly convinced that risk is a function of dose, even at low levels, so that any level of exposure short of zero imposes some risk. Thus, absolute safety requires zero exposure. But many carcinogens are by-products of essential activities.**

This article examines the role that benefit-cost principles can play in helping reach decisions about risks to health and the environment. To keep the discussion concrete, I shall focus on the EPA's regulation of hazardous air pollutants under the Clean Air Act, where we have over twenty years of experience involving several different approaches. Much of the article compares benefit-cost analysis with two other common decision criteria. The first are technology-based standards subject to an affordability constraint, which have dominated much regulation, particularly affecting the environment. The second are the efforts that have been made by regulators, the courts, and others to define appropriate levels of safety in terms of risk alone, without reference to cost. Both of these approaches have been supported as being simpler and faster to apply than benefit-cost analysis. In practice, however, they have not yielded either swift or clear decisions, in part because their purely mechanical application would lead to such patently irrational outcomes. Their use has therefore been tempered by some implicit consideration of costs and benefits. Moving to a more explicit benefit-cost framework for decisionmaking would allow such consideration to take place more openly and consistently.

### Regulating Hazardous Air Pollutants

The Clean Air Act of 1970 established the basic framework for regulating air pollutants in the United States. The largest and most elaborate system created by the act deals with "conventional" or "criteria" pollutants. For those pollutants the EPA sets ambient standards (which establish permissible concentrations in the air) that are supposed to protect public health with an "adequate margin of safety." The EPA and the courts have interpreted this language to mean that standards should be set below the levels at which harm occurs and that costs should play no role in making that determination. The EPA also sets new source performance standards for conventional pollutants, but emissions from existing factories and other sources are regulated by the states with EPA oversight. The system for conventional pollutants, however, applies to only a handful of the most ubiquitous air pollutants: carbon monoxide, lead, nitrogen dioxide, ground-level ozone, particulate matter, and sulfur dioxide.

The 1970 act established section 112 to deal with hazardous air pollutants, which it defined as a pollutant "to which no ambient air quality standard is applicable and which in the judgment of the Administrator causes, or contributes to, air pollution which may reasonably be anticipated to result in mortality or an increase in serious irreversible, or incapacitating reversible, illness." Once the administrator had identified such a pollutant and "listed" it, he was directed to set emission standards for sources emitting it at levels that would "provide an ample margin of safety to protect the public health."

The EPA's implementation of section 112 has focused almost exclusively on chemicals identified as carcinogens. That focus caused a collision between those scientists who believe that carcinogens pose a risk at *any* nonzero level of exposure and the EPA's mandate to protect public health with an "ample margin of safety." If "ample margin" meant "no risk," then the only acceptable standard would be zero use as well, because some release is inevitable if a chemical is used. The EPA's rule for asbestos in 1973 acknowledged that dilemma, and pointed out that banning asbestos would "result in the prohibition of many activities that are extremely important."

**Technology-Based Standards.** The EPA's solution to that problem was to require that sources install best available technology (BAT) to limit emissions of carcinogens, where the best is tempered by affordability; however, controls are not pressed so far that significant numbers of plants must close and workers lose their jobs. The EPA has a long history of defining regulations based on technology, with an alphabet soup of acronyms used to differentiate among various levels of stringency in setting standards or issuing permits. These include RACT (reasonably available control technology), BPT (best practicable technology), BDT (best demonstrated technology), BACT (best available control technology) or simply BAT, and LAER (lowest achievable emission rate). The Clean Air Act amendments of 1990 added a new, better-than-best acronym called MACT (maximum achievable control technology) as well as the more modest GACT (generally available control technology).

The EPA spelled out the BAT approach more explicitly when it issued regulations in 1976 for plants emitting vinyl chloride, another carcinogen. It interpreted section 112 to allow it to set standards for carcinogens that "require emission reduction to the lowest level achievable by the best available control technology in cases involving apparent nonthreshold pollutants, where complete emissions prohibitions would result in widespread industry closure and EPA has determined that the cost of such closure would be grossly disproportionate to the benefits of removing the risk that would remain after imposition of the best available control technology." In 1979 the EPA formalized that approach in a proposed "generic" policy for dealing with carcinogens under section 112. That policy was part of a broader effort by the Carter administration to develop a common approach across the relevant agencies—the Consumer Product Safety Commission, the Food and Drug Administration, the Occupational Health and Safety Administration as well as the EPA. Under the proposed policy, carcinogens would be regulated *at a minimum* to the level achievable with BAT. Quantitative risk assessment was not supposed to play any role in determining BAT, but it could be used (along with information on costs and other factors) to determine whether the risks remaining after BAT were "unreasonable" and necessitated even tighter controls. Benzene—which had been "listed" in 1977 but for which no regulations had been proposed by 1979—was viewed by the EPA as the prototype to demonstrate the new approach. BAT rules for several benzene categories were proposed in 1980, but action on them languished with the change of administration in 1981. During the next two years, little happened with regard to section 112, although several bills were proposed in Congress that would have forced the EPA to list certain substances and to regulate quickly.

One of the major advantages claimed for technology-based approaches is that they can be applied with greater consistency and speed, without the uncertainties that attend benefit-cost analysis or other approaches that involve consideration of risk. This certainty is more apparent than real, however. Even when the "best" technology is designated, there is rarely a clear technological basis for picking a particular limit. Whatever level of control is set, it is always possible to imagine a more stringent one. For example, the primary method for complying with radiation standards for uranium mill tailings is to cover them with dirt. The thicker the cover, the less radiation escapes. There is no technological basis for deciding how thick is "best." Similarly, if incinerators are to be used to destroy emissions from chemical plants, what percentage of the emission stream should they be designed to remove—90, 95, 99, or 99.99 percent? If a substitute is available, should its use be required? If a substitute is not available, perhaps production of the good in question should simply be banned. Technology per se has little to offer in deciding these questions.

In fact, the technology-based approaches also look at cost, although primarily in terms of potential economic impacts (particularly plant closures and job losses) rather than in terms of resources. Thus, the financial health of the industry in question becomes a key factor. Costly standards can be imposed on industries that are in robust financial condition or that can easily pass on costs. Industries that are less financially secure and less likely to withstand cost increases are generally subject to less-stringent standards. For many years, for example,

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copper smelters in the southwest faced much less stringent sulfur dioxide ($SO_2$) rules than did power plants, because the smelters faced foreign competition and would probably close if they faced high costs. In contrast, regulated utilities could simply raise rates to cover the costs of stringent controls. The result was an extraordinarily inefficient allocation of control efforts; we could have had less $SO_2$ at lower cost.

Nor do technology-based standards necessarily lead to quick, clear decisions. The EPA's handling of the benzene case is illustrative. The first standard proposed for benzene covered emissions from plants that used benzene as a feedstock to produce maleic anhydride (another industrial chemical used to produce a range of different products). The EPA identified two potential BAT candidates, 97 and 99 percent control, which could be achieved by using carbon adsorbers or incinerators. Some plants already achieved those control levels as the result of requirements under state implementation plans, and others achieved 90 percent control. Moreover, at least one plant did not emit any benzene because it used a different feedstock. Thus, it would have been hard to argue on technological grounds for anything less stringent that 99 percent control, and a plausible case could have been made for a complete ban. The EPA indicated that it intended to set a standard that effectively would require 97 percent control, however, because it feared that a tighter rule would cause at least one plant to close. Moreover, as several plants already met the 97 percent level, the incremental reductions in risk from a 99 percent requirement would have been minimal relative to the costs of installing new equipment at those plants. Similar arguments later convinced the agency to back off to a 90 percent rule, which was already met by several more plants. Thus, "best" technology proved to be considerably less crisply defined than one might imagine as the EPA responded to indications that a rigid adherence to some preconceived notion of what control device was best would impose substantial costs while generating little benefit.

**Ruckelshaus: Balancing Multiple Factors.** In 1983 William Ruckelshaus returned to the EPA as administrator. One of his first major acts was to publicly pose the dilemmas that faced him under section 112. He used the case of the Asarco copper smelter in the state of Washington. The smelter processed a copper ore that was high in arsenic, and hence it emitted unusually large amounts of arsenic, a suspected carcinogen. Even with the installation of BAT controls, the smelter would still emit enough arsenic to cause lifetime risks to some nearby residents of more than one in a hundred, an unusually high risk relative to most of those encountered by the EPA. The dilemma that Ruckelshaus posed for debate was whether more stringent rules, which might well force the smelter to close, should be imposed. A spirited debate followed, but the agency's dilemma was resolved when the smelter closed, primarily as the result of low copper prices rather than of the EPA's pending action under section 112.

The decisions that the EPA was compelled by court order to make in 1984 about sources emitting benzene posed less dramatic tradeoffs between health and jobs. The question was not so much whether the companies affected would be driven out of business, but whether the risks warranted regulation. The EPA dealt with five different categories of benzene emitters. In three cases—maleic anhydride plants, ethylbenzene/styrene plants, and benzene storage vessels—it withdrew the proposed rules after arguing that the risks to public health were too small to warrant federal action. These cases also involved relatively high costs per cancer case avoided, but the EPA did not invoke cost effectiveness as a rationale for its decision. At the same time, the EPA issued a final rule for benzene equipment leaks and proposed a standard for coke oven plants that recover benzene. Both of these source categories involved higher levels of risk, and they had much lower estimated costs per cancer case avoided. (The cost estimate for equipment leaks was actually negative, because the EPA estimated that the value to firms of avoiding leaks exceeded the cost of the rule.)

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Under Ruckelshaus, it appeared that the EPA was moving away from a technology-based approach, towards consideration of a much broader array of factors, including costs and the risk reductions achievable through controls. The agency, however,

never spelled out a clear set of criteria that it would use in making choices.

**Defining Safety in Terms of Risk Alone.** In 1987 the U.S. Court of Appeals for the District of Columbia handed down a decision *(Natural Resources Defense Council* v. *EPA)* invalidating the technology-based approach that the EPA had taken to vinyl chloride. In a unanimous decision written by Judge Robert Bork, the court directed the EPA to determine what level would be safe, independent of considerations of cost or feasibility. The court did not interpret *safe* to mean risk-free. Instead, it pointed out that society accepts the continuation of many nonzero risks, including operating motor vehicles and breathing urban air. The court did not, however, provide any clear guidelines for defining *safe* and left that to the administrator's "expert judgment." Although the court limited the EPA to health considerations in setting a safe level, it did allow the agency to consider a wide range of factors—including costs and feasibility—in determining whether a tighter limit shoult be imposed to achieve an "ample margin of safety."

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After the *Vinyl Chloride* decision, the EPA proposed new rules to deal with several source categories for its old friend, benzene. The agency put forth several different methods for determining a safe level, all of which would be based on benzene's carcinogenic risk. The EPA's assessments for carcinogens emphasize two summary measures. "Maximum individual risk" is the lifetime risk to an individual, usually one exposed for a full lifetime at the point at which concentrations of the substance are highest. "Incidence" or "population risk" measures the predicted number of cancer cases contracted per year, on the basis of all of the individuals exposed. Thus, the EPA has characterized the risk from benzene emitted from coke by-product plants as a maximum individual risk of seven in 1,000, with an annual incidence of two cancer cases. Note that the maximum individual risk is independent of the number of people exposed. It is also based on the rather peculiar assumption that a person will stand outside at the point of maximum exposure for a full seventy years. In contrast, the incidence is a function of the number of people exposed and their *average* exposure levels, although it too assumes that people spend all of their time outdoors. Thus, one can think of incidence as measuring the overall magnitude of the potential public health threat, while individual risk may be thought of as some measure of equity. Implicitly it attempts to evaluate the distribution of risk in terms of the individual in the worst position.

In its 1988 proposals for benzene the EPA offered four different methods for determining a safe or acceptable level. On a case-by-case basis the EPA would examine the full distribution of estimated risks, with individual risks under one in 10,000 preferred. In reaching a judgment about safety, however, it also would consider the incidence, strength of the evidence, and other factors related to health. Other methods included an annual incidence of less than one cancer case, a lifetime maximum individual risk of less than one in 10,000, and a lifetime maximum individual risk of less than one in a million. Under all four approaches the agency would consider a wide range of factors—including costs—in deciding whether to go beyond this initial level to determine what would constitute an ample margin of safety. In issuing its final rules for benzene sources in 1989, the EPA announced that it had selected an approach based on all four methods. In other words, it decided to do a little bit of everything.

### Dilemmas in the Risk-Based Approach

It is easy to criticize the policy that the EPA adopted in response to the *Vinyl Chloride* decision for lacking coherence or predictability. But I believe that those problems reflect the inherent irrationality of trying to define an appropriate level of safety in terms of risk alone, without reference to costs and other factors. Over the years various proposals have been made to establish risk levels that would or would not require regulation. In their most extreme versions those proposals have taken the form of rigid rules that would make decisions on risk independent of other factors. In other cases they have been presented as rough rules of thumb to help with preliminary sorting or simply as empirical regularities observed in regulatory decisions.

The greatest emphasis has been on defining a de minimis risk—one so small that regulation is not warranted. The most frequently proposed figure is one in a million, which has been discussed for three decades. It has no particularly compelling rationale, however, other than repetition and the fact that it is very small and round.

Some observers and agencies have tried to define de minimis risk or, at the opposite end of the scale, significant risk by reference to background rates or detection limits. The Nuclear Regulatory Commission suggested at one point, for example, that radiation standards should be set so that the predicted risks would be less than .1 percent of the background mortality rate from cancer. There is no basis, however, for choosing .1 percent, as opposed to some other standard.

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Daniel Byrd and Lester Lave have suggested that significant risks—ones for which there would be a presumption that regulation would be required—should be defined in terms of the minimum risk that could be detected by a well-conducted epidemiological study. For increases in relatively common risks, they suggest that that criterion translates to an increased lifetime risk of roughly 2 percent, or about the same as the lifetime risk of death in a motor vehicle accident. It is hard to see, however, why a rational person would choose to make decisions on this basis. Why is it relevant whether an epidemiological study could detect the effect, particularly if the test is only applied hypothetically? (Byrd and Lave talk about a risk that could be detected, as opposed to one that has been observed.) Moreover, the risks deemed significant by their test vary, depending on the rarity of the risk. For rare diseases much smaller risks can be detected. It is difficult to see, however, why a rational individual would be less willing to accept a given level of incremental risk simply because it is associated with a risk that normally is very uncommon.

Some observers have suggested that risk-based criteria should include not just the maximum individual risk, but also the overall incidence. As discussed earlier, in the 1988 benzene proposals the EPA suggested that it would regulate if the annual incidence for a source category were greater than one. Its final policy included incidence as one of several factors to be considered.

Paul Milvy has developed a more formal approach to estimating acceptable risk as a function of the size of the population affected. He notes that society seems to be willing to accept higher levels of individual risk if the number of people affected is small. He argues that the traditional value of one in a million, or an annual incidence of slightly less than four cancer cases, is appropriate for risks involving the full U.S. population, but he suggests that higher values should be applied for small groups. Higher levels of risk for a small exposed population can, of course, still lead to a reduced incidence.

Including incidence as well as individul risk has considerable intuitive appeal. Presumably, most observers would agree that the government generally should devote more attention to risks that affect many people than to risks that harm only a few. Any particular rule, however, is largely arbitrary. Incidence-based criteria also suffer from the fact that they are extraordinarily sensitive to how sources are categorized. A given group of sources may fail if they are classified as being in the same category, but pass if they are arbitrarily divided into two categories, each of which has an incidence below the cutoff point for action.

Reliance on individual risk as the criterion for acceptability will also tend to encourage finer levels of categorization of sources. Often the maximum individual risk varies widely across sources, depending on their sizes, the distance to the nearest residence, and other factors. Typically, all sources in a category must meet the same standard. If the critical concern really is to keep risk below some level, however, it would make more sense to limit regulation to those sources that create high individual risks. Alternatively, standards could be stated in terms of acceptable concentrations in the air rather than in terms of emission limits.

### The 1990 Clean Air Act: Technology with Deadlines

The Clean Air Act amendments passed in November 1990 created a hybrid risk-technology approach reminiscent of the cancer policy proposed by the Carter administration in 1979, but in an even more extreme version. The new law solves the problem

of delay in listing chemicals: it explicitly identifies 189 different individual substances or classes of substances. The EPA is directed to develop lists of categories of sources for each substance within two years of the law's enactment and to issue regulations for those source categories over ten years. There are also intermediate deadlines. The EPA can remove one of the substances from the list only if it determines that no individual is exposed to a lifetime risk of more than one in a million for carcinogens or that no exposures for noncarcinogens are above the relevant thresholds with an ample margin of safety. Similarly, the EPA must write standards for each category of sources unless no source (or group of sources, in the case of area sources) imposes a lifetime maximum individual risk higher than one in a million. Thus, the trigger for initiating regulation of carcinogens is based on risk alone.

Once regulation is triggered, the basis for decision switches from risk to technology. The standard for each source category "shall require the maximum degree of reduction in emissions of the hazardous air pollutants subject to this section (including a prohibition on such emissions, where achievable)... that the Administrator determines is achievable." The act goes on to define *achievable* in terms of controls already in use by sources. Standards for existing sources are not to be less stringent than the level achieved by the best-controlled 12 percent of sources (or, for categories with fewer than thirty sources, the best five sources), and standards for new sources are to be at least as tight as the most stringently controlled plant (the so-called MACT criterion). For area sources—small sources that are widely dispersed—the administrator is allowed to use a less stringent standard, GACT.

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Note that risk plays no role in determining MACT or GACT. The standards are to be based only on technological considerations, with cost playing a minor role in the form of affordability. After six years, however, the EPA is directed to review the source categories again, to determine whether any still pose risks above one in a million. If they do, the agency is to recommend action to Congress. If Congress takes no action within two years of that report, the EPA is to set limits that will reduce all risks below the magic one in a million level.


**What Will the 1990 Amendments Accomplish?** The recent amendments to section 112 clearly reflect Congress's impatience with the slow pace at which the EPA has proceeded on hazardous air pollutants generally and carcinogens in particular. During the first twenty years section 112 was in effect, the EPA listed and regulated only seven pollutants. Congress has now directed the EPA to deal with 189 pollutants over the next decade. Moreover, Congress has established a very tight, risk-based criterion that will make it difficult for the EPA to conclude that large categories of sources can be excluded from regulation. This emphasis on speed strongly suggests that Congress viewed hazardous air pollutants as a major threat to public health.

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3,000 cancer cases per year for the country as a whole. The most recent estimate is from 1,734 to 2,697 cases per year. These figures seem rather modest—hardly a major menace to public health. Even the high end of the range is only a little more than 5 percent of the number of people who die in automobile accidents each year. Moreover, those estimates almost certainly exaggerate the real risk, because they are based on the EPA's inflated estimates for carcinogenic risks. A more plausible estimate would be fewer than 800 cases per year, after adjusting for only some of the sources of estimation bias in the EPA's procedures.

A closer look at the EPA's estimates also indicates that most of the cases are associated with emissions from widely scattered sources that will be difficult to control effectively. If we use the high estimate, almost 42 percent of the estimated cancer cases result from "products of incomplete combustion," a rather ill-defined collection of different substances that are emitted primarily from motor vehicles, with wood stoves following at a distant second. Only six other substances on the list studied have estimated national incidences above 100 cases per year, and four of them are emitted by vast numbers of sources; benzene and 1,3-butadiene both come primarily from motor vehicles. Motor vehicles are also the major known source of formaldehyde emissions, although most formaldehyde results from atmospheric reactions involving precursors of unknown origin. Similarly, the origin of most chloroform in the atmosphere is unknown. Thus, stringent controls on "major" stationary sources—the primary focus of the 1990 legislation—are unlikely to make much difference.

**Applying the New Approach to Benzene.** To gain a better understanding of the kinds of decisions that the new approach could force, it is useful to look at the series of decisions that the EPA made in 1989 and 1990 about regulating benzene source categories. It is particularly appropriate to do so, as benzene has been a prototype for new approaches to section 112 on at least three earlier occasions.

The EPA announced decisions for twelve source categories, all in response to the *Vinyl Chloride* decision described earlier. In the case of maleic anhydride plants benzene emission standards had become irrelevant because all plants had either closed or switched to a different feedstock. In the eleven remaining categories, the EPA imposed new standards in four cases and left the others at existing levels. Table 1 briefly summarizes those eleven cases in terms of the baseline risk measures and the cost of potential rules per case of cancer avoided. The top half of the table shows the four categories on which the EPA imposed new standards, while the bottom half shows the seven for which the EPA rejected new controls. All but one of the regulated categories involved maximum individual risks in

**Table 1: Risks and Cost Effectiveness for Source Categories in 1989 Benzene Decisions**

| Category | Risk Measures without New Controls: Maximum Individual Risk | Risk Measures without New Controls: Annual Incidence | Cost Effectiveness of Least-Stringent Controls ($ millions/cancer case avoided)[a] |
|---|---|---|---|
| New Controls Required | | | |
| Transfer Operations | 6/1,000 | 1.0 | 34 |
| Waste Operations | 2/1,000 | .6 | 180 |
| Storage Vessels[b] | 2/10,000 | .08 | 3.8 |
| Coke By-Product | 7/1,000 | 2.0 | 10 |
| No New Controls Required | | | |
| Gasoline Bulk Terminals | 5/100,000 | .1 | 2,900 |
| Gasoline Bulk Plants | 1/100,000 | .05 | 1,300 |
| Gasoline Service Stations | 5/1,000,000 | .1 | 1,500 |
| Industrial Solvents | 3/100,000 | .02 | 980 |
| Chemical Process Vents | 4/100,000 | .01 | 850 |
| Ethylbenzene/Styrene | 2/100,000 | .003 | 132 |
| Equipment Leaks | 6/10,000 | .2 | 880 |

[a] Based on EPA cost estimates updated to 1990 dollars using GNP deflator.
[b] EPA reported range of baseline risks for this category; estimates used are midpoints of ranges.

excess of one in 1,000, and two also involved incidences of more than one case per year. Interestingly, the only one with cost-per-case-avoided under $10 million—storage vessels—was also the one with the lowest incidence and the lowest individual risk among the regulated categories.

Note than under the amendments just passed, the EPA presumably would have been required to regulate all eleven categories, because all had maximum individual risks above the one in a million cutoff level embodied in the law. Regulating the seven categories that the EPA rejected, however, would do virtually nothing for public health. The estimated incidence for all seven categories combined is less than one case every two years in the nation as a whole. The three gasoline distribution categories all have estimated costs per cancer case avoided well in excess of $1 billion, and three other categories have cost-effectiveness ratios approaching that level. Even the most cost-effective category (ethylbenzene/styrene) is over $100 million per case avoided. Moreover, it is not clear that the controls reflected in these high cost-effectiveness estimates would satisfy the new MACT criterion; something even tighter might be required. It is clear, however, that with the exception of the gasoline distribution categories, none of the controls would meet the ultimate one in a million criterion. According to the EPA's estimates, the postcontrol risks would range from one in 100,000 to over one in 10,000. Thus, all of those categories presumably would be on the list that the EPA is to send to Congress after six years, and all would be subject to additional regulation—if not absolute prohibition—unless Congress explicitly decided otherwise.

**Stringent controls on "major" stationary sources of carcinogenic emissions—the primary focus of the 1990 amendments to the Clean Air Act—are unlikely to make much difference.**

### The Benefit-Cost Perspective

Under a more explicit benefit-cost framework the basic and rather straightforward question is: What are we getting and how much will it cost? On the cost side the EPA already has estimated annualized costs in dollar terms. On the benefit side the primary rationale for the standards is to reduce the incidence of cancer. Thus, we need to know how many cases will be eliminated and how we want to value those reductions. As a first approximation, let us accept the risk estimates made by the EPA as being reasonably accurate and complete. Let us also accept the usual assumption that each of the predicted cancer cases results in a premature death. The question then collapses essentially to how much we are willing to spend to reduce the risk of death. Placing a limit on how much we shall spend to save a statistical life makes most people uncomfortable. It is not a question that usually has to be faced explicitly, although all of us face it implicitly in our daily decisions when we trade off mortality risks against cost or convenience. We also routinely make such decisions collectively, not only in regulatory decisions, but also in determining expenditures for such items as highway safety.

Many different methods for estimating the value of reducing risks have been suggested over the years. The most widely employed approaches to estimating willingness-to-pay have relied upon occupational data to see the implicit tradeoffs that workers make between wages and the risk of death on the job. The answers range widely, depending on the data set and the specific statistical model, but virtually all of them yield answers well below $10 million per life saved. That is sufficient to rule out all but one of the benzene rules in Table 1. The exception is the rule for benzene storage vessels, which has a cost per life saved of $3.8 million. The others have costs per case avoided ranging from $10 million to almost $3 *billion*, well outside any reasonable range.

**Uncertainty and Information Requirements.** These calculations assume that the EPA's risk estimates are accurate. One of the frequent objections raised to applying benefit-cost techniques, however, is that the risk assessments upon which they rely are highly uncertain, with many potential sources of error. Thus, the answer may depend on which estimate one believes. In dealing with carcinogens, however, it is widely agreed that the risk estimates of the EPA and other regulatory agencies are highly inflated and are thus likely to overstate, rather than understate, the risks (hence the risk reduction that controls will yield). As a result, consideration of uncertainties in cancer risk assessment is likely to drive risk estimates down, not up, and would simply reinforce the conclusion that at least seven of the eight categories do not warrant more stringent controls.

The risk and benefit estimates for the benzene examples may also be criticized on the grounds

that they deal only with cancer and omit other benefits that may be reaped by reducing exposures to benzene and other hazardous air pollutants. For the other toxic effects, however, thresholds are generally accepted and are likely to be orders of magnitude higher than the levels experienced in the ambient air. A stronger case can be made for benefits from reduced ground-level ozone because benzene is a volatile organic compound and thus a precursor of ozone. A quick inspection of Table 1, however, suggests that the ozone benefits would have to be many times higher than the cancer-reduction benefits to warrant control of six of the eight categories. Furthermore, if the primary rationale for controls is ozone-related benefits, it makes little sense to regulate through section 112, rather than through the elaborate system already in place for dealing with "conventional" pollutants, which allows better targeting of controls where ozone is a problem.

**In dealing with carcinogens it is widely agreed that the risk estimates of the EPA and other regulatory agencies are highly inflated and thus likely to overstate, rather than understate, the risks and hence the risk reduction that controls will yield.**

In addition to uncertainty in the underlying risk estimates, benefit-cost analysis is often criticized for being too time-consuming and expensive to perform on a routine basis. Even Executive Order 12291 requires that benefit-cost analyses be submitted only for "major rules"—those that cost more than $100 million per year (or meet other criteria). That implies that such analyses are not worth the effort for smaller issues. Benefit-cost analysis, however, need not be elaborate in many cases, as the brief discussion of the benzene decisions illustrates. Often the information already gathered by regulators is more than sufficient to make a reasonable decision. Moreover, if the benefit-cost framework were integrated into the regulatory process—rather than treated as an external test to be applied after decisions have been made—it could help *reduce* information needs by screening out some possibilities early. The EPA's experience with section 112 illustrates the delays and wasted effort that can result from *not* having such a decision framework. The agency continued for years to spend resources on rules that clearly were not going to yield significant health benefits.

In many cases, of course, benefit-cost analysis is substantially more difficult to apply than in the benzene regulations examined above. The science often is more ambiguous, with the decision depending more critically on which evidence one believes. The estimated net benefits of reducing concentrations of fine particulates, for example, depend largely on the weight one gives to a series of controversial statistical studies that find a link between fine particulates and mortality rates. Benefit-cost analysis cannot resolve these issues, but neither can other decision criteria. With both technology-based and pure risk-based approaches, one must decide whether the evidence passes some threshold of proof that requires action. One of the reasons that benefit-cost analysis is so controversial when applied to health and environmental issues is that it forces decisionmakers to be much more explicit about what they do and do not know, how they evaluate competing evidence, and, most painfully of all, what tradeoffs they are making between protection and other concerns. Only by dealing with these issues openly, however, can we hope to make progress in efforts to use our limited resources more effectively.

**Selected Readings**

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