Airborne Lead: A Clearcut Case of Differential Protection

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Our society imposes much less stringent measures to protect workers against technological hazards than it requires for the protection of the general public. Arguing this point in the first article in this series,¹ the authors observed that "while public protection is ordinarily set below the level of medically observed harm, worker protection is customarily set above the hazardous level, thus exposing workers to known dangers." They also concluded:

Differential protection is a problem in part because of the significant, if poorly understood, health toll that it represents and in part because of the serious questions of justice which it raises about parts of our social and economic systems.

Airborne lead appears to be a clear-cut example of such differential protection. The occupational standard provides that workers can be exposed to up to $50 \mu\text{g}/\text{m}^3$ (micrograms per cubic meter) over an 8-hour period. On the other hand, the National Ambient Air

Quality Standard for lead for the general population limits exposure to only an average of $1.5 \mu\text{g}/\text{m}^3$ —apparently more than a thirty-fold difference in protection. However, care is needed in interpreting this apparent difference. The standards apply to different time periods and different exposed populations.²

The case of lead offers a good opportunity to compare social values for worker and public protection because it is an old familiar hazard, so there has been

ample time for society to develop responses to it. Lead was first smelted 6000 years ago as a byproduct of silver smelting. It soon was used for alloying, pigments, and glazes. These uses continue, but now the largest uses are for storage batteries and as a gasoline additive. The medical effects and epidemiology are well studied, at least compared to most hazardous materials. Hippocrates described symptoms of lead poisoning in 370 BC,³ and in recent years hundreds of papers have appeared documenting

much more subtle adverse effects and relating these effects to blood-lead levels.

In the 1970s lead was recognized as a serious problem, with tens of thousands of workers and hundreds of thousands of children manifesting blood-lead levels deemed hazardous by health authorities.

Both the workplace and community standards have been the subjects of recent regulatory and court action.^{4,5} The community ambient air quality standard was adopted by the Environmental Protection Agency (EPA) in the month just before the Occupational Safety and Health (OSHA) standard and both have been recently upheld by the same court of appeals.^{6,7} Thus, the legal mandates, agency rationales, and considerations in judicial review can be directly compared.

Our ultimate goal will be to ask:

- (A) *What do the different standards imply for the health and well-being of the exposed populations?*
- (B) *How can the origins of the differences between the two standards be best explained?*
- (C) *What if any justifications for the differences appear in the agency and judicial proceedings on the two standards?*
- (D) *What long-run strategic considerations may have affected the agencies' use of discretionary authority in these cases?*

Because our purpose is to use these standards as our test of the way society views the protection of workers and the public, we have relied on the agencies' reasoning (as interpreted by the court) for assessments of health and other effects. We have made minor extensions of the agencies' analyses in some cases, but have for the most part refrained from offering our own independent judgments about the technical facts.

The body of this article is organized into four sections: (1) a survey of the

kinds of theoretical considerations that, from first principles, could lead to different treatment of a particular hazard in different situations; (2) a review of the legal mandates of the two agencies, showing how Congressional judgments embodied in law call for different treatment of scientific and technical information, and different agency actions; (3) a description of the agencies' actual regulatory decisions in the case of lead and the anticipated consequences; and (4) the answers to questions (A) through (D), based on the record.

Theoretical Considerations

Before we can compare the social value judgments implicit in the EPA and OSHA actions, we must have a common framework for understanding different kinds of risk reduction measures. The framework should help clarify: (1) What harm would occur in the absence of added preventive measures and how would it be caused? (2) How much of the harm might be prevented by alternative interventions? and (3) What additional effects would the alternative interventions have for items of social value other than health?

The Biological Impact Pathway

To answer the first question we need a systematic approach for assessing health risks. Figure 1 is a model causal pathway developed to structure risk assessment work for all kinds of chemical hazards.⁸ In general, an analyst will attempt to trace the ultimate effects of discharges on health by determining the quantitative

This is the fourth article in a series which explores the differences in protection from hazards given to workers and to the general public. Most of the research for the series has been conducted at the Center for Technology, Environment, and Development at Clark University or by individuals associated with the Center. Roger E. Kasperson and Robert W. Kates are coeditors of the series.

FIGURE 1: Biological impact pathway and associated information-gathering activities.

SOURCE: N.A. Ashford, D. Hattis, et al., *Evaluating Chemical Regulations: Trade-Off Analysis and Impact Assessment for Environmental Decision-making*, MIT Center for Policy Alternatives, Report No. CPA-80-13, NTIS Number PB81-195067, July 1980, P. ES-33.

relationships between the successive steps (boxes) in the pathway.

At the end of the pathway, health effects are characterized by the nature and severity of the harm; the extent of the populations at risk; and the likelihood of harm for individuals within the population(s) at risk. One could multiply the second and third factors (the size of the population at risk and the individual chance of harm within the at-risk group) to determine the number of people who might be expected to be harmed in the absence of further preventive action. But this simple multiplication does not capture some complex aspects of the harm that are important for judging social value.⁹

Effectiveness of Prevention Alternatives

In order to assess the health benefits of alternative controls, the analyst first attempts to decide how much difference a particular control will make in "presence" or "exposure" or some other step. Then, as before, the analyst tries to quantitatively trace the effects of the differences through the pathway to predict the changes in ultimate health damage.

The framework of Figure 1 can also be used to identify different options for prevention. Action can be taken

to interrupt or reduce the hazard process at any point in the causal chain. In the case of lead, these might include:

- Reducing discharges by reducing the lead content of gasoline or installing better containment/trapping apparatus within factories;
- Modifying the transport pattern of air lead by restricting emissions to times that favored more rapid deposition or by installing larger stacks to disperse lead emissions more quickly over a wider area;
- Changing the amount of lead "present" within the workplace by increasing local exhaust ventilation, speeding the exchange between air in the factory and external air;
- Modifying the behavior of exposed workers or community residents in ways that reduced lead intake (e.g., have workers wear respirators);
- Limiting the maximum exposure of individuals by transferring them out of high-lead areas of the plant if their blood-lead levels rise above a specific standard;
- Screening the population that is to be exposed to lead to eliminate those who might be more likely than others to suffer certain ill effects (e.g., those who intend to have children in the

immediate future in order to avoid reproductive effects);

- Providing medical treatment to those suffering toxic effects in order to reduce long-term consequences.

From this series it can be seen that interventions toward the "discharge" end of the biological impact pathway tend to place a lesser burden on the people whom we wish to protect. Clearly, relying on medical treatment to reduce health damage implies some tolerance for early stages of damage as well as any side effects of the treatment itself. Screening the population to eliminate workers who are especially sensitive to a particular type of toxicity involves changing the job opportunities of those workers. Requiring respirators involves at least some extra effort and discomfort during work.

In practice, a social intervention usually does not take the form of requiring a specific control technology. Instead, the regulation ordinarily will specify some *performance requirement* based on *information* derived from one of the stages that appear in boxes in Figure 1. For example,

- A *discharge* standard might limit emissions directly (primary smelters

could be limited to emitting no more than X lbs. of lead per day);

- A *presence* standard might require that there be no more than a particular concentration of the pollutant at a particular place over a specified time period (both ambient air quality standards and OSHA workplace air standards are "presence" limitations);

- An *exposure* standard might place a limit on the amount of the toxic agent that workers could absorb or accumulate before some action would be taken (the OSHA workplace standard for lead provides that workers whose blood-lead levels rise above a particular value must be removed from exposure at no loss of pay or benefits);

- An *effect* standard might prescribe that some action be taken when injury or harm of a defined type and severity takes place (workers' compensation systems generally provide reimbursement for medical expenses and limited compensation for lost wages for workers disabled in the course of their jobs).

It is clear that requirements toward the "discharge" end of the pathway give the regulated parties the least flexibility in meeting the standard. There is no way to comply with a discharge limitation other than by directly limiting discharges. By contrast, a "presence" limitation could be met either by reducing discharges or by altering the amount of the regulated pollutant transported to or from the point where it is to be measured (for example, by using a tall stack to reduce community ambient air concentrations or local ventilation to reduce pollutant concentrations in workplace air).

An "exposure" limitation is still more flexible in that it allows the regulated parties to comply by altering the absorption of the pollutant without necessarily changing the concentration of the pollutant in air (for example, by requiring workers to use a respirator). This flexibility makes it possible for the regulated parties to choose the control option, or combination of options, that is least expensive or most convenient for them. As will be seen, some of the disagreements between the contending parties in both the EPA and OSHA lead cases were essentially disagreements over where in the biological impact path-

way the regulations and control technology should be applied.

Other information that is helpful in assessing the effects and effectiveness of alternative prevention measures includes:

- A detailed exposure profile (how many people of various kinds are exposed to how much of the substance of concern);

- A calculation of the overall magnitude of harm and harm to specific classes of people, using the appropriate dose-response relationships and the exposure profile;

- An assessment of the likely effectiveness of the social mechanisms that are available to implement the proposed control measures. A clear analysis of the effects of any intervention must start with a description of who will do what when and how well. (Who monitors and enforces compliance? Who pays? What powers are given or taken away as a result of the parties' role in the intervention?)

- A frank analysis of the uncertainties involved and the differences that would be produced in overall conclusions if key assumptions were changed based on the limits of available knowledge.

Other Effects of Alternative Measures

Because people value other things besides health, we also need to consider such potentially relevant information as the economic effects, the distribution of risks in the affected population groups, and the relationships among

the affected parties. These can be directly related to the four moral justifications for risk allocation that were discussed in detail in the first article in this series, the terms of which are reviewed in the box below. How this information is weighed is an indication of a society's values.

Economic Effects. We need information on the costs of the proposed intervention (and of the uncertainty in the estimate), the likely impact on the industry, and the expected final distribution of the costs. To determine the impact on industry we need to know:

- The technology and organization of the industry: what processes result in discharges, in what types and sizes of plants;

- The state of competition in the relevant markets: monopolistic, oligopolistic, or competitive;

PRINCIPLES OF JUSTICE

UTILITY: *An allocation is just if, and only if, it maximizes the summed welfare of all members of the morally relevant community.*

ABILITY: *An allocation of risks is just if, and only if, it is based upon the ability of persons to bear those risks.*

COMPENSATION: *An allocation of risks is just if, and only if, those assuming the allocated risks are rewarded (compensated) accordingly.*

CONSENT: *An allocation of risks is just if, and only if, it has the consent of those upon whom the risks are imposed.*

- The financial strength of the industry members: how much of the industry can bear how much in compliance costs;

- The technical and economic potential for the industry to innovate and develop new control measures.

To determine the final disposition of costs we might wish to know:

- What portion of compliance costs the industry is likely to be able to pass forward to consumers, backward to suppliers, and/or out to government; and

- The relative costs and benefits of substitutes for the industry's products and who would bear them (costs and benefits of substitutes may include both economic and environmental/health effects).

Effects on Population Groups. There are two types of inequities to worry about. One is biological; we would like to know if there are sensitive subgroups of the exposed population. This information should appear in the analysis described in the previous section. We also need to know about social inequities—if there are characteristics of the exposed population (such as wealth, income and job security, age, sex, race, health status) that might affect their ability to mitigate or offset harm. Some types of possible interventions may interact in undesirable ways to further exacerbate these preexisting social inequities. For example, screening of exposed

worker populations to remove unusually sensitive individuals might reinforce other discriminatory patterns.

Relationships between Parties. The relationships between parties pose intricate questions of fairness. For example, it may be relevant to ask whether people have consented to their exposure to a hazard. But that begs the question: Is it consent when the person does not have adequate knowledge to evaluate the risk, or when his only choice is to suffer the major social and economic dislocation of losing his job? One might wish to specify the relative bargaining position of the parties and to identify correspondences between risks and benefits. Specifically,

- To what extent is knowledge about risks accessible to those exposed?
- What penalties would those exposed have to accept in order to opt out of the risk?
- Do they take any measures, short of opting out, to indicate objection to the exposure?
- To what extent can they bargain for risk reduction?
- Is there compensation for their exposure, identified as such?
- To what extent can they secure relief or compensation by legal or political means?

The relationships among the parties can be affected by the specific mechanism chosen for intervention. For example, in the lead case the groups can overlap. If the same party is a member of more than one group, that can affect the relationship between that party and others. For example, the affected industry suggested that instead of promulgating an air-lead standard (a "presence" limitation within the framework of Figure 1), compliance should be evaluated on the basis of measurements of worker blood-lead levels (an "exposure" limitation). OSHA determined, and the court upheld, that this would be inappropriate. OSHA feared that asking the worker/victim to also take the role of principal monitor would "be unfair, since employers might fire employees with high blood-lead levels as a means of avoiding citations, and unreliable, since such a program would depend far too much

on the contingencies of worker cooperation with medical surveillance."¹⁰

The Role of the Legal System

Law is a mechanism by which social control is exercised over science and technology. Aspects of the governmental or legal intervention in the toxic substances area include:

- (1) The funding and performance of toxicological or epidemiological research;

- (2) Laws governing access to the research results and reporting requirements;

- (3) Legal definitions of the standard of proof that is sufficient to permit governmental intervention in requiring prevention, treatment, or compensation;

- (4) The legislative mandate embodied in the various environmental/health laws for agencies and private parties to undertake various preventive activities;

- (5) Rehabilitation and compensation systems; and

- (6) Mechanisms for private citizen redress for prevention (injunctions) or compensation (product liability litigation).

Clearly, an appreciation of the social values expressed in the protection of workers and the general public from a particular hazard requires an analysis of the *net* effect of all these systems on a comparative basis, which is beyond the scope of this paper. However, in the case of lead, systems (3) and (4) are particularly important as they operate through the environmental/health regulatory laws. What we will identify are the social judgments expressed in the preventive legislation, including the extent to which the regulatory agencies OSHA and EPA can exercise discretion where there are uncertainties in the scientific information.

The Occupational Safety and Health Act of 1970 requires that, for toxic substances and harmful physical agents, the Secretary of Labor shall

*set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life.*¹¹

"The best available evidence" is the basis upon which the Secretary of Labor establishes the standard. The role of the courts in reviewing the Secretary's standard is not to repeat the same deliberations the agency has just gone through but, primarily, to see whether the Secretary's decision process and decision criteria lie within an allowable range of discretion defined by the legislation and past precedents.

The U.S. circuit courts of appeals must ascertain whether the Secretary's determination is supported by "substantial evidence on the record taken as a whole." The courts of appeal have uniformly acknowledged that the "substantial evidence" test can be satisfied even though the determination may be "on the frontiers of scientific knowledge," so long as the evidence and analysis used are the "best available." The courts also recognize the Secretary's determinations about protection needs and feasibility to be more of a (delegated) legislative judgment of social policy, rather than a factual determination in the usual sense. In the OSHA lead case the D.C. Circuit Court of Appeals stated:

*The peculiar problem of reviewing the rules of agencies like OSHA lies in applying the substantial evidence test to regulations which are essentially legislative and rooted in inferences from complex scientific and factual data, and which often necessarily involve highly speculative projections of technological development in areas wholly lacking in scientific and economic certainty. We noted in the cotton dust case that we do not pretend to have the competence or the jurisdiction to resolve technical controversies in the record, . . . or, where the rule requires setting a numerical standard, to second-guess an agency decision that falls within "a zone of reasonableness."*¹²

The requirement that "no worker suffer material impairment" (subject to feasibility limitations) is far-reaching in its mandate. Recently, however, in the benzene case,¹³ the Supreme Court effectively added the requirement that standards must be directed against the reduction of a "significant risk" in terms of the numbers of workers to be protected. This recent license taken with what would have appeared to be a stricter requirement that "no worker"

suffer material impairment is in fact the law under which the occupational lead standard was reviewed by the D.C. Circuit Court of Appeals.

The Supreme Court noted in still another recent case that "Congress itself defined the basic relationship between costs and benefits, by placing the 'benefit' of worker protection above all other considerations save those making the attainment of this 'benefit' unachievable."¹⁴ Thus, limiting occupational exposure to toxic substances is to be given especially heavy weight relative to compliance costs; but a significant health benefit in terms of the numbers of workers suffering material impairment—while it must be demonstrated to some degree of satisfaction—may indeed fall short of the usual scientific standard of proof. OSHA is expected to "err on the side of caution" when it comes to serious hazards affecting a significant number of workers.

The Clean Air Act requires that ambient air quality standards be set such that "the attainment and maintenance of which in the judgment of the administrator, . . . [allow] an adequate margin of safety, are requisite to protect the public health." The administrator of EPA is not allowed to consider economic impact or feasibility or cost in setting these air quality standards.

In order to understand the social value judgment implicit in this language, we need to examine the institutional context within which the standards are promulgated and enforced. The Clean Air Act sets forth a special procedure for controlling pollutants that both (1) have "an adverse effect on public health or welfare" and (2) are emitted by "numerous or diverse mobile or stationary sources."¹⁵ Because there are many sources, planning of permissible emissions in particular areas is required if public health protection goals are to be met.

The statutory scheme calls for the federal EPA first to list the pollutants that meet these conditions, to put out a document analyzing the scientific literature and specifying air quality "criteria" needed to protect public health, and to promulgate air quality standards based on those criteria. Then,

each state is required to develop a "State Implementation Plan" to restrict the emissions of specific sources to the extent needed to attain and maintain compliance with the national air quality standards. This is to be done "as expeditiously as practicable but . . . [subject to an additional two-year delay under some circumstances] in no case later than three years from the date of approval of such plan."¹⁶

The leading case for interpreting the standard-setting mandate under the Clean Air Act is the ambient air lead case itself. Lead is the first new ambient air quality standard to be set under the act since the original six "criteria pollutants" were regulated in 1970. EPA originally declined to regulate lead as a criteria pollutant, even though it admitted that the two conditions for listing it as such were satisfied. The Natural Resources Defense Council brought suit against EPA to force it to do so, and the judicial determination was that, under the mandatory wording of the act ("the administrator *shall* . . . publish, and *shall* from time to time thereafter revise . . ."—emphasis added), the EPA administrator did not have discretion to refrain from regulating lead through an ambient air quality standard.¹⁷

When the resulting standard came up for judicial review, the D.C. Circuit Court of Appeals indicated that it was permissible for the administrator of EPA to promulgate air quality standards for lead that were more stringent than might be strictly necessary to protect public health, since Congress directed EPA to allow "an adequate margin of safety," in part to protect against health effects which might not yet have been uncovered by medical research.¹⁸

The basis of judicial review in this case is an "arbitrary and capricious" standard, which presumes the correctness of the agency's determination unless it is clearly shown to be otherwise. The reviewing court, however, does undertake a "substantial inquiry into the facts, one that is 'searching and careful'"—a standard of review that may be so close to OSHA's "substantial evidence" test as to render the distinction meaningless.

It is especially important to note the

frequent references to the OSHA cases made by the court itself in the EPA ambient air quality standard decision. The court cites the "frontiers of scientific knowledge" character and social policy nature of the determination of an appropriate standard, wherein the administrator clearly has fairly broad discretion. However, economic and technical factors are not to be considered in promulgating the EPA standard, while "feasibility" remains a constraint with the OSHA standard.

In sum, there are two broad differences between the OSHA and EPA legal frameworks. First, OSHA must consider feasibility in setting its standard. Second, whereas OSHA is required to set its standard to prevent "material impairment" in all workers (subject to the feasibility limitation) based on the "best available evidence," EPA is directed to "protect public health" with "a margin of safety" that will give some assurance of preventing even those types of health damage that may not have even been discovered yet. To "protect public health" seems at least as stringent a goal as to prevent "material impairment." The addition of a "margin of safety" to the requirement to protect public health further strengthens the protective goal for community ambient air quality, while the feasibility constraint somewhat weakens the protection mandated for workers. In addition, the requirement that OSHA regulate only "significant risks" might be viewed as a further weakening of the Occupational Safety and Health Act's protective posture.

Applying the Theories

Earlier we sketched out the kinds of information one would ideally like to have in order to allow clear value choices of preventive measures. In this section we will see what portions of this ideal set of information/analysis were assembled by EPA and OSHA in the deliberations for their respective standards, and what the agencies did on the basis of the assembled information.

Specifying Blood-Lead Levels

Both agencies extensively reviewed and interpreted the scientific literature

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Table 1
SUMMARY OF EPA AND OSHA JUDGMENTS ON LEAD HEALTH EFFECTS^a

NATURE OF EFFECT	BLOOD-LEAD LEVEL RANGE WHERE EFFECT HAS BEEN MEASURED	
	Adults	Children
<i>Red blood cells and their precursors</i>		
Inhibition of an enzyme important in heme synthesis (ALAD)	Some inhibition below 20 $\mu\text{g}/100\text{g}$; at a blood level of 40 $\mu\text{g}/100\text{g}$ more than 20 % of people have over 70% inhibition of this enzyme	10 $\mu\text{g}/100\text{ ml}$ (regarded as "adverse to health" at 40 $\mu\text{g}/100\text{ ml}$)
Buildup of free erythrocyte protoporphyrin (FEP)—a precursor of heme	15-20 $\mu\text{g}/100\text{ ml}$ (women) 20-25 $\mu\text{g}/100\text{ ml}$ (men)	15-20 $\mu\text{g}/100\text{ ml}$
Anemia (Reduced hemoglobin in circulation)	About 50 $\mu\text{g}/100\text{ ml}$	40 $\mu\text{g}/100\text{ ml}$
<i>Nervous system</i>		
Cognitive deficits		50-60 $\mu\text{g}/100\text{ ml}$ ^b
Fatigue, nervousness, sleep disturbance	Observed in 56% of a group of workers averaging 60 $\mu\text{g}/100\text{g}$; "protective threshold" set at 40 $\mu\text{g}/100\text{g}$	
Peripheral neuropathies (abdominal pain, weakness in extremities)		50-60 $\mu\text{g}/100\text{ ml}$
Slowing of nerve conduction	50-59 $\mu\text{g}/100\text{g}$	
Encephalopathic symptoms (delirium, mania, convulsions, coma, death)	100-200 $\mu\text{g}/100\text{ ml}$	80-100 $\mu\text{g}/100\text{ ml}$
<i>Kidneys</i>		
Progressive loss of function not detectable by ordinary medical screening tests until about 2/3 of kidney function is destroyed; 85% loss of kidney function requires dialysis, lesser loss produces increased risk of hypertension and resulting cardiovascular disease	Long-term exposure to levels over 40 $\mu\text{g}/100\text{ ml}$ but well below 80 $\mu\text{g}/100\text{ ml}$; it was estimated that 10% of lead workers have appreciable lead nephropathy (One study shows a small group of workers so classified had 30-50% loss of function)	
<i>Reproductive system</i>		
Decreased quantity and quality of sperm, leading to diminished fertility	Found in a group of workers with mean blood level of 41 $\mu\text{g}/100\text{ ml}$; many in this group were at 30-40 $\mu\text{g}/100\text{ ml}$	
Excess risk of abortions, from mutations carried in sperm, excess risk of fetal damage from direct exposure of pregnant women	Blood-lead levels should be maintained below 30 $\mu\text{g}/100\text{ ml}$ in both prospective parents for protection against these effects	

^aSOURCE: 43 *Federal Register*, notes 19 and 20.

^bA recent study by Needleman et al. (see note 21) found that a group of second-grade students with relatively higher lead levels in teeth (used as an index of long-term exposure to lead) had lower IQ scores and a greater incidence of undesirable classroom behaviors ("distractable," "impulsive," "does not follow a sequence of directions") than classmates with lower tooth lead levels. Single blood-lead levels done several years before in some of the students with the highest tooth lead group averaged 35 $\mu\text{g}/100\text{ ml}$, with a high value of 54 $\mu\text{g}/100\text{ ml}$. The comparison group with low tooth lead averaged 23.8 $\mu\text{g}/100\text{ ml}$.

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on the health implications of different blood-lead levels and, as far as we can determine, their technical judgments are consistent with one another.^{19,20,21} (Table 1 summarizes these judgments, as recorded in the Federal Register notices accompanying the two standards.)

Based on these judgments, EPA concluded that the highest safe individual blood-lead level for children in the most sensitive age range (1-5 years) was 30 $\mu\text{g}/100\text{ ml}^*$ (micrograms per 100 milliliters), and that the Clean Air Act's mandate of protecting health with "an adequate margin of safety" would be accomplished if 99.5 percent of children's blood-lead levels were kept below this value. Based on the same information, OSHA concluded that it should try to keep as many workers as feasible from exceeding 40 $\mu\text{g}/100\text{g}$ in order to protect against "material impairment" of health in adults. OSHA considered that there was some residual risk of reproductive effects at this level, but it provided other means (to be discussed below) to supplement the protection offered by air-lead reductions for reproductively active workers.

Extent of the Populations at Risk

Within the framework developed earlier, Table 1 represents the *nature* and *severity* of anticipated harm, with some incomplete information about the *likelihood* of some types of harm for people at different blood-lead levels. In order to assess the significance of these effects in the absence of the preventive measures taken by EPA and OSHA, we need to know something about the *extent* of the populations at risk. How many lead workers had what blood-lead levels prior to the OSHA action? How many children in cities and near stationary sources of air lead experienced blood-lead levels in various ranges?

Here, some of the differences between the kinds of analysis done by the two

*Blood-lead levels are measured either in micrograms per 100 milliliters of blood or in micrograms per 100 grams of blood. The two units are essentially equivalent ($1\mu/100\text{ ml} = .951\mu/100\text{ g}$). In this article the authors have chosen to follow the convention originally used by each source in presenting their data.

Table 2
AIR-LEAD EXPOSURES IN SELECTED INDUSTRIES BEFORE THE NEW OSHA LEAD STANDARD^{a,b}

INDUSTRY	TOTAL NO. EXPOSED	ESTIMATED PERCENTAGES OF EXPOSED WORKERS IN VARIOUS AIR-LEAD RANGES		
		under 100 ^c	100-200	over 200
Primary lead smelting	2,200	18	21	61
Secondary lead smelting	3,200	21	12	67
Storage battery manufacture	16,700	57	23	21

^aSOURCE: Based on information in N. A. Ashford, R. D. Gecht et al., *Effects of OSHA Medical Removal*, note 22.

^bUnder the pre-existing standard worker exposures were to be limited to an average of 200 $\mu\text{g}/\text{m}^3$ over an eight-hour day. (This standard was adopted at OSHA's inception in 1970 from prior voluntary industry consensus standards.)

^cAll air-lead levels are in micrograms per cubic meter.

Table 3
BLOOD-LEAD LEVELS AMONG EXPOSED WORKERS IN SELECTED INDUSTRIES BEFORE THE NEW OSHA LEAD STANDARD^a

INDUSTRY	ESTIMATED PERCENTAGES OF EXPOSED WORKERS IN VARIOUS BLOOD-LEAD RANGES			
	under 40 ^b	40-59	60-80	over 80
Primary lead smelting	27	45	26	2
Secondary lead smelting	29	30	25	16
Storage battery manufacture	20	49	25	6

^aSOURCE: 43 *Federal Register* 54453-6, November 21, 1978.

^bAll blood-lead levels are in micrograms per 100g.

agencies begin to emerge. OSHA collected a considerable amount of data on air lead and accompanying blood-lead levels in various kinds of industries. Tables 2 and 3 show this information for three of the industries with the highest exposures.²² It can be seen that, prior to OSHA's action, there was widespread violation of the then-existing 200 $\mu\text{g}/\text{m}^3$ occupational standard. It is also clear that a large percentage of workers in these industries had blood-lead levels posing risks of adverse health effects, despite the use of respirators by many exposed workers. Considering all the industries subject to the air-lead standard, OSHA estimated that about 42,000 workers were exposed to air-lead levels above 100 $\mu\text{g}/\text{m}^3$ and that an additional 56,000 were exposed to between 50 and 100 $\mu\text{g}/\text{m}^3$. Given the variability of

individual response to various air-lead levels, and available data about air-lead/blood-lead relationships, this air-lead exposure would be expected to produce blood-lead levels over 60 $\mu\text{g}/100\text{g}$ in more than 30,000 workers and over 40 $\mu\text{g}/100\text{g}$ in about 80,000 workers.

This problem addressed by OSHA, therefore, is one of relatively intense exposure in a limited number of industries that significantly affects an appreciable, though not massive, number of people. In the case of the ambient air-lead exposure dealt with by EPA, the target of action appears at first glance to be a much smaller individual absorption of lead by a much larger general population—the approximately five million children under five years of age who live in inner-city areas (based on 1970 census date).²³

Figure 2 and Table 4 show some information on blood-lead levels found in screening programs in New York in the early and mid-1970s. It is clear from this and much other data assembled in the EPA's criteria document²⁴ that very substantial numbers of inner city children have blood-lead levels judged to be dangerous by the criteria listed in Table 1. Unlike OSHA, however, EPA did not attempt to make estimates of the benefits to be achieved—that is, how many children were at specific blood-lead levels prior to the standard,²⁵ or how those blood-lead levels would be expected to change in response to EPA's previously promulgated requirements for the phased reduction of lead in gasoline.²⁶ In this case, therefore, we do not have an appropriate baseline that could be compared against an expected post-regulation blood-lead distribution to judge the incremental health benefits of the ambient air quality standard.

Preventive Actions and Consequences

Another conclusion to be drawn from the data in Figure 2 is that within narrowly defined populations, blood-lead levels are distributed in a relatively orderly and predictable way; the logarithms of blood-lead levels fall into a standard normal curve. EPA used this property (and several other assumptions, including the relationship between air-lead levels and blood-lead levels) to estimate how many children would be expected to be at specific blood-lead levels given alternative air exposure levels. From this they determined the air quality goal required by their interpretation of the Clean Air Act's mandate to "protect public health" with "an adequate margin of safety."

The derivation of EPA's ambient air quality standard for lead is summarized in Table 5. The agency rejected an alternative proposed standard of $5 \mu\text{g}/\text{m}^3$ (proposed by many of the affected industries) as not sufficiently protective. Another proposal, by the St. Joe Minerals Company, to protect health by monitoring blood-lead levels in community residents near major point sources was also rejected as beyond the scope of controls available to EPA and impermissibly intrusive on the population to be protected.

FIGURE 2: Distribution of blood-lead levels for blacks aged 25-36 months, with July-September sampling date.

The axes of this figure are constructed in a special way depicting a population distribution—such that if logarithms of the blood-lead levels in the population are distributed according to a normal bell-shaped curve, the lines will be straight. The curve is read as follows: The fraction of the population shown on the horizontal "x" axis is observed to have blood-lead levels less than or equal to the height of the line as read on the vertical "y" axis. For example, in 1971 only about 40% of the readings in this age and ethnic group were under $30 \mu\text{g}/100 \text{ ml}$ and 90% were under $50 \mu\text{g}/100 \text{ ml}$. By contrast, somewhat more than 80% of the readings were under $30 \mu\text{g}/100 \text{ ml}$ in the 1976 data.

SOURCE: I. H. Billick, S. Curran, and D. R. Shier, "Analysis of Pediatric Blood Lead Levels in New York City for 1970-1976," *Environmental Health Perspectives* 31 (1979): 183-190.

Table 4
GEOMETRIC MEAN BLOOD-LEAD LEVELS ($\mu\text{g}/100 \text{ ml}$) AMONG 2-3 YEAR-OLDS SCREENED IN LEAD POISONING PREVENTION PROGRAMS IN NEW YORK CITY^{a,b}

ETHNIC GROUP	YEAR ^c			
	1970	1972	1974	1976
Black	30.4	26.7	25.6	21.2
Hispanic	24.9	22.2	23.1	19.2
White	26.6	21.9	22.0	19.3

^aSOURCE: I. H. Billick, A. S. Curran, and D. R. Shier, "Analysis of Pediatric Blood-Lead Levels in New York City for 1970-1976," *Environmental Health Perspectives* 31 (1979): 183-190.

^bData were taken from a study of over 170,000 blood levels in children of all ages. The peak age group for lead absorption appeared to be 2-3 years, and blacks appeared to have consistently higher lead levels than hispanics or whites.

^cThe decline in blood-lead levels between 1970 and 1976 seen in these data occurred at a time when air-lead levels were declining as a result of reductions in lead in gasoline (see the Billick et al. study), although it is also possible, of course, that publicity about the lead poisoning screening program itself contributed to the decline by stimulating the cleanup of peeling lead-based paint.

Table 5
EPA'S DERIVATION OF THE AMBIENT AIR QUALITY STANDARD FOR LEAD^a

1. Sensitive population: Children, ages 1-5.
2. Health basis: Maximum safe blood-lead level for individual children is $30 \mu\text{g Pb (lead)}/100 \text{ ml}$; margin of safety for anemia is above $40 \mu\text{g Pb}/100 \text{ ml}$ and nervous system deficits above $50 \mu\text{g Pb}/100 \text{ ml}$.
3. Maximum safe geometric mean blood lead for children based on placing 99.5 percent of the sensitive population below the $30 \mu\text{g Pb}/100 \text{ ml}$ level of concern: $15 \mu\text{g Pb}/100 \text{ ml}$.
4. Estimate of blood-lead level attributed to non-air sources: $12 \mu\text{g Pb}/100 \text{ ml}$.
5. Allowable contribution to blood lead from air sources after achieving the standard: $(15 \mu\text{g Pb}/100 \text{ ml}) - (12 \mu\text{g Pb}/100 \text{ ml}) = 3 \mu\text{g Pb}/100 \text{ ml}$.
6. Air-lead concentration consistent with blood-lead contribution from air sources: $(3 \mu\text{g Pb}/100 \text{ ml}) \times (1 \mu\text{g Pb}/\text{m}^3 \text{ of air}/2 \mu\text{g Pb}/100 \text{ ml blood}) = 1.5 \mu\text{g Pb}/\text{m}^3 \text{ of air}$.

^aSOURCE: 43 *Federal Register* 46256, October 5, 1978.

Table 6
CUMULATIVE FREQUENCY DISTRIBUTIONS OF QUARTERLY LEAD MEASUREMENTS ($\mu\text{g}/\text{m}^3$)
AT URBAN STATIONS BY YEAR, 1970 THROUGH 1974^a

YEAR	NO. QUARTERLY COMPOSITES	MIN.	PERCENTILE							MAX.	ARITHMETIC		GEOMETRIC	
			10	30	50	70	90	95	99		MEAN	S.D.	MEAN	S.D.
1970	797	LD ^b	0.47	0.75	1.05	1.37	2.01	2.59	4.14	5.83	1.19	0.80	0.99	1.84
1971	717	LD	0.42	0.71	1.01	1.42	2.21	2.86	4.38	6.31	1.23	0.87	1.00	1.89
1972	708	LD	0.46	0.72	0.97	1.25	1.93	2.57	3.69	6.88	1.13	0.78	0.93	1.87
1973	559	LD	0.35	0.58	0.77	1.05	1.62	2.08	3.03	5.83	0.92	0.64	0.76	1.87
1974	594	0.08	0.36	0.57	0.75	1.00	1.61	1.97	3.16	4.09	0.89	0.57	0.75	1.80

^aSOURCE: EPA Criteria Document, note 24, p. 7-2.

^bLD = Limit of detection.

The reasoning shown in Table 5 was deemed adequate by the court to sustain EPA's standard against a challenge from industry that the margin of safety provided was *excessive* on the basis of the evidence. We cannot know whether the court would also have sustained EPA had it been challenged from the other side—had the Natural Resources Defense Council, for example, contended that leaving .5 percent of exposed children with "unsafe" individual blood-lead levels above 30 $\mu\text{g}/100$ ml provided too little "margin of safety" for the health of that not insubstantial portion of the public. It seems likely that the same type of reasoning used by EPA could have been used to support either a more stringent standard or a less stringent standard simply by adjusting the percentages of the sensitive population which the EPA deemed sufficient to protect. However, EPA was not challenged as to why it did not devise greater protection. That challenge may have forced EPA to go further in order to meet the strict mandate of the Clean Air Act.

We can gain some insights into why EPA and the environmental groups may have chosen not to press the lead standard to a lower level than they did by pursuing the kind of analysis outlined earlier in this article somewhat to the degree that would have been possible based on the evidence in the record. Table 6 places the proposed air standard in the context of the general urban air-lead levels observed in the National Air Surveillance Network during the early 1970s. As can be seen from the Table 6

data, there was a trend toward progressively lower air-lead levels so that by 1974 only somewhat over 10 percent of the quarterly samples collected at urban stations exceeded the 1.5 $\mu\text{g}/\text{m}^3$ level.

In view of the preeminent importance of gasoline lead for urban air-lead emissions and the then-ongoing program to further reduce this source by over two-thirds by the end of the 1970s, few general urban locations were expected to exceed the proposed ambient air-lead standard by the time State Implementation Plans could be formulated and enforced (about 1982). In public statements accompanying the standard, then-EPA administrator, Douglas Costle, reportedly said that the gasoline lead reductions would handle the problem for most urban areas.²⁷ However, given the tortuous history of delays in gasoline lead limitations, it may well be that the ambient air quality standard was seen in part as a bulwark to make sure that limitations on lead in gasoline were pursued as quickly as possible.

Using EPA's reasoning as set forth in Table 5 and the data in Table 6 to lead to the assumption that the gasoline lead regulations would eventually cut urban air-lead levels to a third of their 1974 values, one might then expect that the gasoline lead regulations would produce the changes in blood-lead levels among urban children as shown in Table 7. (The fact that the "base case" blood-lead distribution in the first column of Table 7 indicates many fewer children at high blood-lead levels than lead poi-

soning screening programs give us reason to believe²⁸ and other population data²⁹ suggest that EPA's reasoning rather badly *underestimates* the extent of the lead exposure problem from "non-air" sources among urban children. If this is true, then the last column of Table 7 would also seriously understate the incremental benefits of reducing air-lead exposures from gasoline lead.)

Other than this possible effect by way of gasoline lead reduction, it is clear that the major foreseeable effects of the ambient air-lead standard were on large point-sources of lead emissions; primary and secondary lead smelters, large battery plants, makers of gasoline lead additives, etc. (Under the statutory scheme of the Clean Air Act, the ambient air quality standards issued by the federal EPA are used to derive emission limitations for individual sources within their jurisdictions—"discharge" controls within the framework of Figure 1.) Although making up only a small fraction of total air emissions, serious lead exposure problems had been detected in communities around at least two smelters during the 1970s.³⁰

There is no EPA analysis of the total population at risk in this way or the blood-lead reductions that would result from the controls on stationary sources. But from our own very crude back-of-envelope calculations (using EPA's methods and assumptions as much as possible), it seems likely that point-source controls would be likely to move on the order of five to twenty thousand children from the 30-40 $\mu\text{g}/100$ ml

Table 7
HYPOTHETICAL CALCULATIONS OF CHANGES IN BLOOD-LEAD LEVELS
AMONG URBAN CHILDREN LIKELY TO RESULT FROM THE REDUCTION OF
LEAD IN GASOLINE TO .5 $\mu\text{g}/\text{GALLON}$ (assumed to produce a three-fold reduction
of lead in urban air)^a

BLOOD-LEAD RANGE ($\mu\text{g}/$ 100 ml)	EXPECTED BLOOD-LEAD DISTRIBUTIONS AMONG URBAN CHILDREN GIVEN:		EXPECTED CHANGES FROM AIR-LEAD REDUCTION
	1974 air-lead levels ^b	Reduction to 1/3 of 1974 air-lead levels	
Under 20	10,937 ^c	11,515	+578
20-30	1,030	479	-551
30-40	32	6	-26
Over 40	.98	.08	-.9
<i>Total</i>	<i>12,000</i>	<i>12,000</i>	<i>0</i>

^aGiven the EPA assumptions listed in Table 5.

^bFrom Table 6.

^cNumbers are in thousands of children, age 1-5, based on a total urban population in this age group of 12,000,000 (see note 24).

blood-level range to below $30\mu\text{g}/100$ ml, leaving perhaps one thousand or so over that level after compliance.³¹ Comments of the EPA administrator at the time indicate that the severity of required controls to achieve these benefits was a major concern to EPA. They and the environmental groups may well have feared that further tightening of the lead standard would have entailed too large a political risk of Congressional weakening of the act, and the consequent loss of future opportunities to protect public health.

In contrast to the rather theoretical reasoning underlying the EPA standard (Table 5), OSHA made at least some attempt to project the effects of its workplace regulation on blood-lead distributions in the real world. Figure 2 indicates how OSHA believed the number of workers at various blood-lead levels would eventually change under different suggested air-lead standards, based on its physiological model of air-lead/blood-lead relationships, and neglecting any supplemental use of respirators. The "a" section of the figure shows the situation in the absence of further action, and the lower sections show the changes under alternative standards. The left-hand side of the figure shows how many workers would remain at various

blood-lead levels, and the right-hand side shows the reduction from the baseline "a" compliance level.

It can be seen from Figure 2 that full compliance with the $200\mu\text{g}/\text{m}^3$ air standard was expected to reduce to about half the numbers of workers with blood levels over $60\mu\text{g}/100\text{g}$, but would have left the numbers of workers over $40\mu\text{g}/100\text{g}$ essentially unchanged. Compliance with OSHA's original $100\mu\text{g}/\text{m}^3$ proposal would have reduced the number of workers over $60\mu\text{g}/100\text{g}$ very substantially (from nearly 33,000 to about 2,500) and begun to reduce the number of workers in the $50\text{--}60\mu\text{g}/100\text{g}$ range. However nearly 50,000 would still be expected to exceed $40\mu\text{g}/100\text{g}$. Full compliance with OSHA's ultimate standard ("d") was expected to further reduce the number of workers over $60\mu\text{g}/100\text{g}$ (to about 500) and cut the number over $40\mu\text{g}/100\text{g}$ to below 30,000. OSHA judged that although it would have liked to make further reductions in the numbers of workers over $40\mu\text{g}/100\text{g}$, it had reached the limit of feasibility with the $50\mu\text{g}/\text{m}^3$ standard.

These are long-run calculations. According to the model of lead transport and distribution in the body used by OSHA,³² lead levels build up slowly in bone and some other body compart-

ments and are re-released slowly into the blood from these storage places. Long-exposed workers thus have a relatively high "floor" of blood-lead levels and show only a limited response in the short term to reductions in air-lead exposure. In practice it would take many years after full compliance for actual blood-lead levels to reach the distributions shown in Figure 3, as workers with high body burdens from previous exposure were replaced by new workers without high past exposure.

Moreover, compliance through OSHA's preferred method of engineering controls was by no means expected immediately. In recognition that extensive modification (perhaps in some cases, rebuilding of facilities) was necessary in the industries with greatest exposure, OSHA provided for a ten-year transition period in the case of the primary lead smelting industry, five-year periods for secondary lead smelting, battery manufacture, nonferrous foundries, and lead pigment production, and a one-year compliance period for all the rest.

Because it was determined to be unfeasible to achieve all the protection it deemed appropriate for workers using limits on the "presence" of lead in air (see Figure 1), OSHA designed into its standard some backup measures based on "exposure" information. It provided that workers in places with air-lead levels over an "action level" of $30\mu\text{g}/\text{m}^3$ have the benefit of a continuing medical surveillance program, including periodic sampling of blood-lead levels and removal from exposure above the action level after finding of blood-lead levels in an individual worker above a series of phased-in "trigger" levels.³³

Removal could also be triggered by other medical conditions deemed to create an unusual risk for lead exposure (for example, pregnancy). Representatives of workers testified during OSHA hearings that many workers would not participate in such programs if it jeopardized their pay or seniority. Therefore, in accordance with the allocation of responsibility to employers for worker health embodied in the Occupational Safety and Health Act,³⁴ OSHA provided that workers' pay and seniority be maintained by the employer during any periods of medical removal (up to

FIGURE 3: Best point estimate of ultimate equilibrium benefits of reducing air-lead exposures under different blood-lead level variability assumptions* (blood-lead standard deviation = $\mu\text{g}/100\text{g}$).

* Computations based on air lead-blood relationships predicted by Bernard Model and Assumption C and DBA's best point estimates of exposure.

** All blood-lead levels are in micrograms per 100 grams.

18 months), even if such removal entailed sending the worker home.

The Lead Industries Association proposed during the OSHA hearings and in later court challenges that blood-lead levels be the primary measure of industry compliance with the lead standard. That is, instead of taking air samples, as OSHA industrial hygienists usually do, blood samples would be drawn and violations assessed if workers were found to have levels over a specific cut-off—an action which would have converted the stan-

dard entirely to an "exposure" limitation within the framework in Figure 1. For the employers it would have meant the flexibility to comply with the lead standard either by (a) requiring workers to wear personal protective equipment (imposing a barrier between "presence" and "exposure"), or by (b) discharging workers who for one reason or another developed high body burdens of lead, in addition to (c) imposing the same controls on air-lead levels as those required for compliance with an ambient air stan-

dard. (LIA's fallback position was that the OSHA air-lead standard be maintained at $200 \mu\text{g}/\text{m}^3$.) OSHA rejected the biological monitoring approach for a number of reasons:

- Evaluating the air environment helps locate the source of air contamination and leads naturally to control of lead emissions at the source—the preferred method of control.

- Because of the broad variability of worker blood levels in response to a given air-lead level, it would be impossible to pick an appropriate discrete blood-lead value that could be the basis of an OSHA citation. A dangerously high blood-lead level could result either from particularly high air-lead levels in a specific location or from moderate air-lead levels and individual variability.

- A biological standard would provide inadequate protection for workers, because excessive exposure would not be expected to be immediately reflected in the full blood-lead levels that would eventually ensue after a period of years. Air monitoring provides much more timely information for taking preventive action.

- "Worker groups uniformly and vehemently oppose biological monitoring for compliance purposes. OSHA views this opposition seriously since workers would be the subjects of a compliance program based upon biological monitoring and their voluntary participation in such an invasive process would be crucial to its success."

- "OSHA is concerned that a biological standard could impact negatively on workers with high blood leads and extended job tenure. Employers might terminate employment of these individuals to avoid citations for over-exposure to lead. . . ."³⁵

On appeal, the court endorsed these policy conclusions, particularly the last point.

The Social and Economic Effects

Referring back to the series of consequences other than health that might enter into social choices of protective measures, we can now assess which of these considerations seemed to play some role in the actual choices for the lead standards, and how they were used.

Economic Effects. Both agencies performed some analysis of the economic effects of compliance with their regulations, but their respective statutory mandates place different constraints on the use of these analyses. EPA is not allowed to use economic information at all in setting its standards, while OSHA is required to show that compliance with its regulations is "feasible." OSHA is not, however, permitted to use cost/benefit criteria (that is, it need not assess the "value" of the health benefits in economic terms and prove that the benefits exceed the cost) but is directed to protect health to the degree possible without economically crippling the affected industries.

It is not easy to make a direct comparison of the economic calculations of the agencies since EPA's cost estimates are for information only, while OSHA's estimates are subject to judicial scrutiny, a test which some failed to survive. Furthermore, OSHA's estimates were set forth only for its initial proposed $100 \mu\text{g}/\text{m}^3$ standard; in promulgating the stricter $50 \mu\text{g}/\text{m}^3$ standard, OSHA merely asserted that the difference would involve such a sufficiently "small increment" of cost as to remain within the bounds of feasibility based on their earlier study. However, public statements by EPA at the time the ambient air standard was finalized indicated considerable concern, based on initial generalized model calculations, about the magnitude of possible compliance costs. After promulgating the standard, EPA instituted a detailed plant-by-plant assessment of technical feasibility and compliance costs—a report which, to our knowledge, has not been published.

EPA estimated that compliance with their ambient air quality standard would involve \$530 million in capital cost for the six industries EPA determined would be affected by control requirements from the standard: primary and secondary lead smelters, primary copper smelters, gray iron foundries, gasoline lead additive manufacturers, and lead storage battery manufacturers. EPA further concluded that "some primary and secondary lead smelters and copper smelters may be severely strained economically in achieving emission reduc-

FIGURE 4: Flow of lead in the United States (1973), in metric tons per year^a.

^a All figures supplied by the U.S. Bureau of Mines 1974 Mineral Industry Surveys.

SOURCE: D.R. Tierney et al., *Status Assessment of Toxic Chemicals in Lead*, (EPA-600/2-79-210h), 1979.

tions that may be required in implementing the proposed air quality standard."³⁶

OSHA estimates amounted to about \$600 million in capital costs for forty-odd industries employing more than 800,000 workers exposed to lead. The highest costs per employee were in the primary and secondary smelting industries, in battery manufacturing, and in nonferrous foundries. OSHA concluded that the standard was economically feasible for all of these industries, a view which was upheld by the court except for the nonferrous foundries, for which the evidence was considered insufficient. The OSHA/EPA comparison is particularly interesting for the two industries most severely affected by both standards, primary and secondary smelting. Perhaps the most telling observation is one noted by OSHA, as cited in the appellate decision, which argued that the primary smelting industry could absorb compliance costs of .5 to 1 cent per pound:

*... that ASARCO, which had claimed to be in financial jeopardy, had recently committed itself to spending nearly \$90 million to install environmental controls at two smelters, resulting in a cost increase of 6.2 cents/pound, almost one third of the market price of lead at the time.*³⁷

A second question considered by the agencies is the extent to which industries might be affected by the standards. Figure 4, representing the flow of lead in the American economy, indicates the basic structure of the industry, while Table 8 gives the estimated atmospheric lead emissions for the United States in 1975. High emissions and occupational exposures occur in smelting, in battery manufacture, in miscellaneous metal foundries and pigment plants, and in gasoline additive production—although the latter has been sharply curtailed by EPA requirements. According to the OSHA economic analysis, the primary lead smelting market is oligopolistic: four companies own the seven smelters. There are a large number of secondary smelting firms; however, this market is a complicated one, with prices partly set by the primaries and partly set by purchasing industries which own many of the secondary smelters. Battery manufacture is tending toward oligopoly: there are many firms, but a few large firms dominate the market and set prices. The gasoline additive industry is oligopolistic; most of the other lead industries are competitive.³⁸

OSHA concluded that the standard was economically feasible for all these industries, although some marginal

Table 8

ESTIMATED ATMOSPHERIC LEAD EMISSIONS FOR THE UNITED STATES, 1975^{a,b}

SOURCE CATEGORY	ANNUAL EMISSIONS ^c	EMISSIONS AS PERCENTAGE OF	
		Subtotal	Total
<i>Mobile subtotal</i>	142,000	100	—
Gasoline combustion	142,000	100	88.1
<i>Stationary subtotal</i>	19,225	100	—
Waste oil combustion	10,430	54.3	6.5
Solid waste incineration	1,630	8.5	1.0
Coal combustion	400	2.1	0.2
Oil combustion	100	0.5	0.1
Gray iron production	1,079	5.6	0.7
Iron and steel production	844	4.4	0.5
Secondary lead smelting	755	3.9	0.4
Primary copper smelting	619	3.2	0.4
Ore crushing and grinding	493	2.5	0.3
Primary lead smelting	400	2.1	0.2
Other metallurgical	272	1.4	0.2
Lead alkyl manufacture	1,014	5.3	0.6
Type metal	436	2.3	0.3
Portland cement production	313	1.6	0.2
Pigments	112	0.6	0.1
Miscellaneous	328	1.7	0.2
<i>Total</i>	<i>161,225</i>	—	<i>100</i>

^aSOURCE: EPA Criteria Document, note 24, p. 5-3.

^bInventory does not include emissions from exhausting workroom air, burning of lead-painted surfaces, welding of lead-painted steel structures, or weathering of painted surfaces.

^cIn metric tons per year.

under the Clean Air Act do not contain a *legal* requirement of economic feasibility, they do carry with them a calculation of a *political* requirement of economic feasibility.

The remaining question is who will ultimately pay the costs of compliance. OSHA concluded that part of the costs for the primary smelting industry would be passed backward to suppliers, but most costs would be passed forward since demand for lead is comparatively inelastic. The secondary smelting industry was considered to have much more limited opportunities to pass costs either forward or backward since its prices follow the market for lead from the primary smelting industry, while battery manufacturing was expected to pass most costs on to consumers. OSHA finally concluded that the overall effects will be to decrease the national unemployment rate .08 percent (about 5000 jobs) and to increase consumer prices .02 percent.⁴²

Effects on Population Groups. As discussed in the previous section, the EPA standard was specifically set to protect the most sensitive population groups, small children and pregnant women. OSHA also considered another sensitive subgroup—reproductively active employees—but determined that it was not feasible to set levels low enough to protect them against harmful effects. They considered and rejected arguments that fertile or pregnant women should be excluded from jobs involving lead exposure because they had concluded that there were adverse effects of similar concern for males at equivalent exposure levels. They further observed that the new standards (including the medical removal provision) would provide considerably more protection to this subgroup than the previous standard.

The special vulnerability of certain exposed groups as a result of their social position was considered by EPA and used to help justify their protective posture. EPA noted that inner-city children living in dilapidated housing not only have other sources of lead exposure but, because of the quality of their diet and limited access to medical care, they are likely to have special sensitivity to the adverse effects of lead. There is no evidence that OSHA

secondary smelters, foundries, and battery manufacturers might be forced to close. EPA concluded that

*some primary and secondary lead smelters and copper smelters may be severely strained economically in achieving emission reductions that may be required in implementing the proposed air quality standard.*³⁹

Amid industry complaints, repeated by Senator Randolph, that "the standard, if enforced in 1982, would lead to the closing of all the country's primary lead plants and 40 of 50 recycling plants,"⁴⁰ EPA expressed its commitment to do everything possible to avoid plant closings short of compromising the long-run protective mandate of the act. In a statement made at the same time the lead standard was enacted, the EPA administrator was quoted as saying

We intend to pursue a reasonable and responsible course in finding ways for this industry to comply with the law's health protection objectives. . . . We do not believe that a major disruption of

this industry is an acceptable consequence. . . . [We promise] to explore every avenue to avoid such an impact while still protecting public health.

*[W]e will work closely with the states and the affected industry to develop a plant-by-plant analysis of how serious the problems are, and of what would be a reasonable compliance program for each smelter. If our study of these impacts over the next 18 months indicates economic effects unwarranted by the degree of health protection involved, we will consider a wide range of remedial action, including the possibility of seeking revisions to the Clean Air Act.*⁴¹

Congress has in fact intervened in the past to postpone Clean Air Act requirements where serious economic difficulties threatened as a consequence of the requirements of primary air quality standards. Section 119 of the act, passed in 1977, gave primary nonferrous smelters up to an additional ten years to achieve compliance with the sulfur dioxide standard. Thus, the impression emerges that while air quality standards

considered income, age, or other demographic variables in setting the workplace standard. However, they did consider previous patterns of exposure (a preexisting burden of lead exposure can lengthen, perhaps indefinitely, the time it takes for blood lead to decline to safe levels after removal from exposure), and they did include in the medical removal provisions some supplemental procedures for medical examinations of workers whose blood levels did not decline sufficiently in the 18-month period to allow return to their original high-exposure jobs.

Effects on the Relationships between the Parties. As noted previously, the issue of consent involves two major questions: to what extent does the affected person have knowledge enough to consent, and to what extent is he free to opt out?

The information provided to a worker by the employer as specified by OSHA—and by his union, if any—does tell of the hazards of lead, but the information is geared primarily toward encouraging the worker to develop good work practices, such as using respirators when required and cooperating with blood screening. There is no question of providing information so that he might decide whether or not to quit his job; indeed, he is usually assured that if he does his part, he will be safe.⁴³

Drawing the Conclusions

Based on the record, we can now present answers to the four questions we posed at the beginning of this article:

(A) *There is, in fact, a difference between the level of protection provided to workers and the general public by the two standards.* We have shown (see Figure 3 and Table 7) that, using the respective assumptions and calculation procedures of EPA and OSHA, in the long run one should expect many more workers than members of the general public to suffer identifiable harm from air-lead exposures if both standards were fully implemented. OSHA predicts that, in the long run, compliance with the occupational standard will lead to a population of about 10,000 workers with blood-lead levels above 50 $\mu\text{g}/100$ ml (levels associated with neurological

effects, kidney problems, and mild anemia). Another 20,000 or so would be expected to remain between 40 and 50 $\mu\text{g}/100$ ml (at which there are indications of harm in the form of substantial inhibition of enzymes important in heme synthesis), and an unspecified number of reproductively active workers would be expected to remain above 30 $\mu\text{g}/100$ ml (the level presumed to pose some risk to this special subpopulation). By contrast, predictions made from the EPA assumptions suggest that compliance with the general community air standard will leave about 100 children with blood-lead levels over 40 $\mu\text{g}/100$ ml (consistent with anemia in children) and less than 10,000 children with levels of between 30 and 40 $\mu\text{g}/100$ ml out of a much larger population potentially at risk.⁴⁴

(B) *The discrepancy in protection does not derive from differences in the way the agencies used their discretionary authority.* It comes from the differences in the Congressionally determined mandates of the two agencies, as described earlier. OSHA appears to have exercised its statutory authority much further than did EPA in this case. The OSHA lead standard rather narrowly survived a challenge on the basis, among other issues, that the standard was infeasible (the reviewing court split 2 to 1, and the majority decision indicates a close call at some points). On the other hand, the same court unanimously and firmly rejected the challenge to the EPA ambient air quality standard. Thus, had the agencies exercised their mandates to an "equal" extent, the difference in protection between workers and the public would have been even more pronounced (see item D below).

(C) *In the agency action and the court review, we do not find an explanation of this discrepancy in terms of any of the four proposed moral principles described in the box on page 17.*

Utility. OSHA appears to be willing to impose less costs per unit of health benefit (at the margin) than EPA. This difference results not from a different valuation (utility) of the benefits conferred but from a difference in how far each agency can go in protecting the populations at risk.

Ability (Sensitivity). Both agencies

took seriously the requirement to address the problems of specific sensitive subpopulations. Inner-city children were prominently featured in the justification for the EPA standard. Reproductively active workers were identified by OSHA, but providing adequate protection for this group in setting the workplace standard was not considered feasible.

Compensation. The possibility that either workers or the public might be directly compensated for their exposure to lead did not appear in either agency's proceedings or in the court records.

Consent. It was never argued that workers had consented to assume health burdens from lead exposure; rather, OSHA sought, and the court upheld, ways of providing workers with sufficient job security so that they would be willing to cooperate with surveillance that might detect dangerous blood-lead levels. It was explicitly recognized by both the agency and the court that unequal bargaining power cannot give rise to conscionable consent.

(D) *Possible threats to EPA's protective legislative mandate may have influenced the selection of the air-lead standard and may have led to an accommodative posture in implementation.* By contrast, OSHA appears to have exercised its authority to protect workers to very near the limits of its discretion. OSHA appeared to have been less concerned with possible Congressional redefinition of its mandate, probably because its authority to set protective standards had already survived a number of judicial challenges without Congressional reaction. In the lead case, the workplace standard seems to have survived judicial scrutiny by a relatively narrow margin.

There is an interesting contrast in the court challenges to the two standards. The OSHA standard was challenged both by labor (calling for a more stringent standard) and by industry (calling for a less stringent standard). OSHA satisfied the substantial evidence test and provided sufficient data to convince the court that a significant risk was being addressed and that the standard, while not protecting all workers, nonetheless achieved what was feasible.

The EPA standard was only challenged from the industry side. The court held that EPA is permitted to go as low as $1.5 \mu\text{g}/\text{m}^3$ in establishing its standards even though industry claimed that EPA could not demonstrate health benefits at this level. Without deciding the question, the court sustained EPA's standard on the grounds that the requirement to protect health with an adequate margin of safety permitted EPA to go farther than the hard evidence might support.

We do not know how the court would have responded to a challenge that the standard was insufficiently protective. But since EPA explicitly noted that it was leaving unprotected a portion of the population with unsafe blood-lead levels, it seems that EPA did not go as far as the mandate of the Clean Air Act requires and certainly could have provided a more protective standard if it had taken seriously the mandate to provide an adequate safety margin. At first blush, EPA appears not to have met its mandate, and to have been soft on the implementation of the Clean Air Act.

However, had EPA gone as far as it legally could have, it might well have engendered a Congressional reaction to amend the act (which is now being suggested by the Broyhill bill)⁴⁵ to soften the public health mandate. In effect, it appears that EPA implicitly read a feasibility limitation into the Clean Air Act. But, unlike the technological or economic feasibility limitations explicitly required of OSHA, EPA's reading here went, rather, to the limitation of *political* feasibility regarding the general mandate. It thus appears to us that EPA made concessions in the battle over air lead (its first standard for a new criteria pollutant) in order to avoid losing the war on the Clean Air Act itself.

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NOTES

1. P. Derr, R. Goble, R. E. Kasperson, and R. W. Kates, "The Double Standard," *Environment*, September 1981.

2. The workplace air standard applies to exposure over only eight hours a day, five days a week, while the general community standard governs twenty-four hour a day, seven day per week exposure. Further, because the workplace standard is based on a single day's exposure and because air concentrations vary considerably from day to day, effective compliance with the workplace standard requires the employer to maintain average air levels considerably below the single-day limit. By contrast, the ambient community standard is set on a quarter-year basis, and compliance can be assured by maintaining long term average air levels relatively close to the quarterly limit. Finally, the populations at risk are also different. The general community air standard governs exposures to inner city children, who both are likely to take in considerable amounts of lead from other sources and are more sensitive to the long term effects of lead exposure.

3. Donald R. Lynam, "Lead Industries Association Position," *J. Occup. Medicine*, 17 (1975): 84.

4. 43 *Federal Register* 52952, November 14, 1978.

5. 43 *Federal Register* 46246, October 5, 1978.

6. *United Steelworkers of America v. Marshall*, 8 *Occupational Safety and Health Cases* (1981): 1810-1916. See also, *Lead Industries Association, Inc., et al. v. Donovan* (Nos. 80-1134, 80-1155 and 80-1170), *Denial of Certiorari*, July 29, 1981.

7. *Lead Industries Association v. EPA*, 2nd Circuit Court of Appeals decision on June 27, 1980, 14 *Environmental Reporter Cases* (1980): 1906.

8. N. A. Ashford, D. Hattis, et al., *Evaluating Chemical Regulations: Trade-Off Analysis and Impact Assessment for Environmental Decision-Making*, MIT Center for Policy Alternatives Report No. CPA-80-13, NTIS Number PB81-195067, July 1980, p. ES-33. A similar pathway was presented in Robert Harris, Christoph Hohenemser, and Robert W. Kates, "Our Hazardous Environment," *Environment*, September 1979.

9. On the one hand, a high likelihood of harm for a small, well-defined group at risk implies a special burden on those people. On the other hand, a hazard that creates even a small danger for a large number of people may cause widespread anxiety or feelings of being unfairly treated. Moreover, the uncertainty of any estimate of aggregate harm increases in significance with the size of the population at risk. If the likelihood of harm is badly underestimated for a small large risk, the worst that can happen is that all the people at risk are affected. In the opposite case, if a large number of people are exposed to what is thought to be a small risk, but the risk in fact turns out to be large, the total magnitude of the harm that actually occurs clearly has the potential to be very much greater than in the situation of the small population at risk.

10. *United Steelworkers of America v. Marshall*, note 6 above, p. 1859.

11. *Occupational Safety and Health Act*, § 6(b) (5).

12. *AF-L-CIO v. Marshall*, F.2d (D.C. Cir. No. 78-1562, decided October 24, 1979).

13. *American Petroleum Institute v. OSHA*, 581 F.2d 493 (5th Cir. 1978).

14. *Cotton Warehouse Association v. Marshall*, 9 *Occupational Safety and Health Cases* (1981): 1920, decided June 17, 1981.

15. 42 *United States Code* (U.S.C.) § 108.

16. 42 U.S.C. § 110.

17. *Natural Resources Defense Council v. Train*, 9 *Environmental Reporter Cases* (1977): 1425-1433.

18. *Lead Industries Ass'n., Inc. v. EPA*, 14 *Environmental Reporter Cases* (1980): 1906-1954.

19. 43 *Federal Register* 54354 et seq., November 21, 1978.

20. 43 *Federal Register* 46246 et seq., October 5, 1978.

21. H. L. Needleman et al., "Deficits in Psychologic and Classroom Performance of Children with Elevated Dentine Lead Levels," *New England J. Med.* 300 (1979): 689-695.

22. N. A. Ashford, R. D. Gecht, et al., *The Effects of OSHA Medical Removal Protection on Labor Costs of Selected Lead Industries*, M.I.T. Center for Policy Alternatives, Report No. CPA-77/11, December 1977, pp. 6-3 and 6-4; 43 *Federal Register* 54453-6, November 21, 1978.

23. 43 *Federal Register*, note 20 above.

24. *Environmental Protection Agency, Air Quality Criteria for Lead*, EPA-600/8-77-017, U.S. Government Printing Office, Washington, D.C. 20402, December 1977.

25. Some such estimates had been made earlier in the 1970s (from the results of lead poisoning screening programs) by the National Bureau of Standards, based on a total urban population at risk of ten million:

Blood Lead Level ($\mu\text{g}/100 \text{ g}$)	No. Children (under age 6)
0-20	3,250,000
20-40	6,067,500
40-60	650,000
60+	32,500

J. F. Gilsinn, "Estimates of the Nature and Extent of Lead Paint Poisoning in the United States," *National Bureau of Standards Technical Note* 746, (1972), quoted by K. Bridbord, in *Human Exposure to Lead from Motor Vehicle Emissions*, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-145 (January 1977), p. 66.

26. As of 1975, gasoline lead directly accounted for about 88 percent of air-lead emissions, and indirectly accounted for somewhat more through its contribution to the second largest source—combustion of waste oil (6.5 percent of all air-lead emissions); see note 24 above. In the mid-1970s, gasoline lead emissions were entering a long period of decline as new cars equipped with catalytic converters requiring unleaded gasoline made up an increasing share of cars on the road, and additional EPA limitations on the lead content of gasoline began to take effect. Stimulated by another suit by the Natural Resources Defense Council, on November 28, 1973, EPA ordered the following phased reduction of the average lead content of gasoline sold by refiners:

1.7 g/gal after Jan. 1, 1975
1.4 g/gal after Jan. 1, 1976

1.0 g/gal after Jan. 1, 1977
.8 g/gal after Jan. 1, 1978
.5 g/gal after Jan. 1, 1979

(This compares with an average of about 2.3 g/gallon at the peak of premium gas use in 1970.)

These limitations were initially struck down on judicial review [7 *Environmental Review Cases* (1975): 1353], but in March 1976 were restored in the landmark case, *Ethyl Corporation v. EPA* [8 *Environmental Review Cases* (1976): 1785]. Five months later, however, in order to avert "serious gasoline shortages" during the summers of 1977 and 1978, EPA eliminated the requirements prior to the .8 g/gallon limit for 1978, moved the .5 g/gallon limit to October 1979, and installed provisions to provide some flexibility in the lead reduction schedule for specific refiners [Environmental Reporter 7 (1976): 787-788]. This was the schedule when the lead ambient air quality standard was promulgated. Eventually, compliance dates were postponed another year to avoid gasoline supply difficulties [Environmental Reporter 9 (1979): 2323], and attainment of the .5 g/gallon limit was finally required in October 1980 [Environmental Reporter 11 (1980): 824].

27. "EPA Sets Final Lead Standard, Cites Possible Need for Remedial Action," *Environmental Reporter* 9 (1978): 1091-1092.

28. J. F. Gilsinn, note 25 above.

29. Air Quality Criteria for Lead, note 24 above.

30. The more severe of these resulted from an unusual incident. When the particle-trapping baghouse of the Bunker Hill Smelter in Kellogg, Idaho, broke down in September 1973, continued operation of the smelter during the following year resulted in lead emissions of about 35 metric tons per month. Geometric mean blood levels in 170 children living within a mile of the smelter were 65.9 $\mu\text{g}/100\text{ ml}$ (air levels were measured at about 18 $\mu\text{g}/\text{m}^3$) (Air Quality Criteria for Lead, note 24 above, pp. 12-15). A few children who developed blood-lead levels well over 100 $\mu\text{g}/100\text{ ml}$ and have lasting neurological problems have recently received a multi-million dollar settlement for damages from the company (United Press International, "Lethal Lead Is Turned into Children's Gold," *Boston Globe*, November 3, 1981, p. 3).

Another prominent example of excessive community lead absorption occurred near the ASARCO lead smelter in El Paso, Texas. There, emissions from the stack of 20-40 metric tons a month led to blood-lead levels of over 40 $\mu\text{g}/100\text{ ml}$ in 69 percent of the children living in the immediate area of the smelter (14 percent of the children had blood-lead levels over 60 $\mu\text{g}/100\text{ ml}$). Air concentrations on 86 days ranged from .49 to 75 $\mu\text{g}/\text{m}^3$, but averaged only 6.6 $\mu\text{g}/\text{m}^3$ (Air Quality Criteria for Lead, note 24 above, pp. 12-14).

31. Table 8 data show that the industries EPA deems significant as stationary sources emit about 4000 tons/year of lead into the air. For our crude calculation we have assumed that: (a) most of these emissions are from large sources averaging about 50 tons/year (this may overestimate the impact of the EPA regulations since the effect is greater on emissions from large sources); (b) most of the sources are located in areas with urban population densities of 2000 people/sq. mi.; (c) the fall-off in air concentrations is like that observed for large smelters (this is a tradeoff between number of people assumed to be affected and the significance of effect; we have varied the assumed concentrations

by a factor of two, giving a range in our estimate); (d) the background air-lead concentration is the 1974 urban average of .9 $\mu\text{g}/\text{m}^3$; and (e) we can use EPA's geometric standard deviation and estimate of lead absorption from other sources.

32. N.A. Ashford et al., note 22 above.

33. The trigger levels for removal and return following removal were:

Date	Removal	Return
March 1, 1979	80 $\mu\text{g}/100\text{g}$	60 $\mu\text{g}/100\text{g}$
March 1, 1980	70 $\mu\text{g}/100\text{g}$	50 $\mu\text{g}/100\text{g}$
March 1, 1981	60 $\mu\text{g}/100\text{g}$	40 $\mu\text{g}/100\text{g}$
March 1, 1983	50 $\mu\text{g}/100\text{g}$ (avg. over six months)	40 $\mu\text{g}/100\text{g}$

34. Section 5(a)(1) of the Occupational Safety and Health Act reads: "Each employer . . . shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees."

35. Cotton Warehouse Assn. v. Marshall, note 14 above.

36. 43 Federal Register 46256, October 5, 1978.

37. United Steelworkers of America v. Marshall, note 6 above, p. 1878.

38. 43 Federal Register, note 19 above.

39. 43 Federal Register, note 20 above.

40. *Environment Reporter* 9 (1978): 1092.

41. *Ibid*

42. 43 Federal Register, note 19 above.

43. Mary Melville, "Risks on the Job: The Worker's Right to Know," *Environment*, November 1981.

44. It should be noted that we believe these EPA assumptions substantially understate the risk of excessive lead absorption in urban children, principally from sources other than air. See text and notes 25 and 26 above.

45. United Steelworkers of America v. Marshall, note 6 above, p. 1908.

OVERVIEW— NATURAL RESOURCES

(continued from page 5)

hook-and-ladder trucks and fire-fighting helicopters remained parked at their fire stations. They had no intention of dousing the fire. After all, they had set it.

In national parks and U.S. forests, fires are being set by on-site professionals with increasing frequency. And fires caused by lightning bolts are being allowed to run their course.

Summer vacationers arriving at government-owned wilderness spots sometimes find the anticipated scenic wonders hidden behind a smokey curtain. They may wonder whether Smokey

the Bear has retired or gone into permanent hibernation.

Over the past half decade, prescribed (purposely set) and management (lightning fires allowed to continue) burning have become common practices in national parks, forests, and on industrial timber plantations. And the pace of this little-noticed trend is expected to increase.

Dick Montague, U.S. Forest Service assistant director for fire suppression, says fire will be a more frequently used management tool in the nation's 117 federally owned forests, particularly for the clearing of underbrush. Tighter federal pesticide restrictions and growing soil erosion problems stemming from use of bulldozers are prompting heavier reliance on fire management.

"Except for the black marks it leaves," explains Montague, "fire is pretty gentle on the environment."

Steve Botti, a resource management specialist at Yosemite, states that park has expanded its fire management program over the last three years as resource professionals learned how to effectively manage large-tract burns. Six blazes have been scheduled this summer and fall; another three are listed as optional. Botti guesses an additional 30 management burns will be allowed to smolder, although he emphasizes that fires caused by careless campers will be extinguished.

Commercial timber companies such as Weyerhaeuser and Georgia Pacific are also using prescribed fires. "Fire is widely accepted as a valid management tool," reports Mark Rey, manager of water quality programs for the Washington-based National Forest Products Association.

Forest products companies, national parks, and forests use fire for different reasons. But for all of them there is one common consideration. Since the beginning of this century, an aggressive firefighting ethic has led to a dangerous build-up of flammable forest masses, composed of dead trees, branches, bushes, clover patches, and the like. Rather than risk the timber devastation that can result from the sudden ignition of these volatile masses, fire management professionals are burning them away under carefully controlled conditions.