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William K Graham
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To: pope.janet@epa.gov
cc:
Subject: OMC-Waukegan Coke, Comment

Ref: Hoskin, Alan F. et. al., Estimated Risk of Occupational Fatalities Associated with Hazardous Waste Site Remediation, *Risk Analysis, Vol.14, No. 6, 1994*

Before selecting a remedy, I request USEPA apply the decision tool similar to that presented in this article which proposes quantitation of risk for occupational fatalities. This has been peer reviewed and uses valid US government data on fatalities experienced by occupation. I today mailed you a copy. I believe USEPA is legally obligated under CERCLA 121(b)(1)(G) to consider the "potential threat to human health" posed by the actual remedy.

The method estimates the risk of experiencing at least one fatality for an 18 acre landfill capping remedy as 0.012, or 1.2E-02 (one in eighty). The excavation scenario in the referenced paper yielded a risk of at least one fatality of 0.149 (one in seven). The remedies studied are of a scale similar to that proposed for this site. Risks for off site traffic fatalities are added to this and estimated at about 5.0E-02 (one in twenty). **In simple terms, the probability of at least one fatality in connection with USEPA proposed remedy at about one in ten.**

In several ROD's, the USEPA has cited the risks of extensive excavation and disposal as being unreasonably high but does not quantify them. A fatality risk of one in ten dwarfs those posed by contaminants at the site. Please note that if the site is not cleaned up, the risk of a fatality is essentially zero.

The authors have prepared a second article on non fatal injuries for activities at remediation sites and is planning an article on the off site risks of transportation of materials to and from hazardous waste remediation sites. These may be available to support more detailed remedy evaluations.

These facts can be used to demonstrate to the public that the proposed remedy is technically not feasible. We suspect that the Waukegan community has not been informed of these risks, which they would find unacceptable. These real risks can be mitigated only by reducing the proposed level of activity, especially the occupational hours for laborers and truck drivers, who have the highest death rates. This means dramatically reducing the amount of material handled at the site.

In some forums it is suggested that risks differ if they are assumed or not. While this is questionable, there does not appear on the record any authority for USEPA to weigh

these risks differently. I believe it is USEPA's legal obligation to fairly communicate risks to the public. If USEPA has not explained to the Waukegan community the increased risk they bear from truck traffic accidents or on-site occupational fatalities, USEPA has not fulfilled its public notice obligations.

In conclusion, I ask USEPA to honor its obligations under CERCLA [121(b)(1)(G)] and for public disclosure, before proceeding with any remedy at this location. Lastly, the site environs may qualify under USEPA guidelines under the Environmental Justice policy. It would be wholly inappropriate to take expeditious short cuts in the decision process which clearly put at risk the members of this community.

Sincerely,

William K. Graham, P.E.

Glen Ellyn, IL 60137

Risk Analysis, Vol. 14, No. 6, 1994

Estimated Risk of Occupational Fatalities Associated with Hazardous Waste Site Remediation

Alan F. Hoskin,[1,3] J. Paul Leigh,[2] and Thomas W. Planek[1]

Received October 19, 1993; revised May 24, 1994

This study presents a method to assess short term traumatic fatality risks for workers involved in hazardous waste site remediation to provide a quantitative, rather than qualitative, basis for evaluating occupational exposures in remediation feasibility studies. Occupational employment and fatality data for the years 1979–1981 and 1983 were compiled from Bureau of Labor Statistics data for 11 states. These data were analyzed for 17 occupations associated with three common remediation alternatives: excavation and landfill, capping, and capping plus slurry wall. The two occupations with the highest death rates, truck driver and laborer, contributed most to total exposure hours in each alternative. Weighted average death rates were produced for each alternative and multiplied by respective total person-years of exposure. The resultant expected number of fatalities was converted, using the Poisson distribution, to the risk of experiencing *at least* one fatality, as follows: 0.149 for excavation and landfill, 0.012 for capping, and 0.014 for capping plus slurry wall. These risks were discussed in light of the need to obtain more reliable and comprehensive data than are currently available on the occupational safety and health risks associated with hazardous waste site remediation and the need for a more scientific, quantitative approach to remediation decisions involving risks to workers.

KEY WORDS: Occupations; fatalities; evaluation; exposures; hazardous waste site remediation.

1. INTRODUCTION

The U.S. Environmental Protection Agency (EPA) provides guidelines for evaluating human health risks associated with lifetime exposure to hazardous waste sites.[1,2] These guidelines, however, provide only brief mention of the potential for traumatic injury or fatality to workers due to physical hazards associated with various types of remediation processes and recommend simply "a qualitative assessment of worker risk" (Ref. 2, p. 20). While the guidelines are silent about the reasons for this recommendation, it is apparently assumed either that the risks to workers due to physical hazards are not significant compared to the health hazards or that the site safety and health plan (see 40 CFR 311 and 29 CFR 1910.120) will adequately control them. While the occupational risks may be qualitatively different from risks to the general public by virtue of (presumably informed) consent by and compensation of the workers to accept the risks, that is insufficient reason to subject those risks to a less scientific, qualitative analysis.[3]

The tendency to exclude dangers to workers from discussions of risk in hazardous waste site remediation appears in other settings as well. For example, assessment models,[4] informal risk-based screening tools,[5] and state remediation laws[6] consider only health exposures. The latter two examples use 10^{-6} as an explicit human cancer risk criterion.

The purpose of this paper is to present a method to assess short-term risks to workers based on estimates of

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the frequency of traumatic occupational fatality associated with hazardous waste site remediation processes. This method can then be incorporated into site remediation feasibility studies. While other aspects of occupational risks, such as nonfatal injuries, should also be considered, this paper focuses only on fatality risk.

To illustrate the application of this method to evaluation of remediation methods, three alternative approaches to remediation of a typical hazardous waste site were evaluated. The three alternatives—excavation and landfill, capping, and capping plus slurry wall—were selected because they are among the most common remediation techniques.

2. METHOD

An extensive review of the literature found no data on occupational injuries or fatalities involving remediation activities, involving related activities in nonremediation settings, or specific to the remediation industry. Data were found on work-related fatality rates by occupations. Weighted combinations of those work-related fatality rates were used as surrogates for remediation-specific data.[7]

Work-related death rates for the occupations involved in hazardous waste site remediation were taken from a forthcoming study.[8] The number of deaths was obtained from the U.S. Bureau of Labor Statistics (BLS) Supplementary Data System (SDS). Estimated employment was compiled from BLS data.

The SDS file contains data extracted from the first report of injury or illness that employers are required to submit to state workers' compensation (WC) agencies.[9] The "extent of disability" item was used to select cases resulting in death. Data files for the years 1979–1981 and 1983 were used for this study. No SDS file was produced for 1982. All occupation data were coded according to the 1970 U.S. Census occupation classification. Not all states participate in the SDS program each year. In total, 11 states were represented for the 4 years.[10] These states contributed roughly 15 to 18% of total U.S. employment, depending on the year.

The BLS occupational employment data comprised three digit occupation codes based on 1970 U.S. Census definitions of occupations for the years 1979–1983.[11]

An annual death rate for each occupation was based on the number of deaths divided by the estimated number of persons employed using Eq. (1):

$$Rate = \frac{\sum_{t=1979}^{1983} \sum_{i=1}^{I} D_{it}}{\sum_{t=1979}^{1983} E_t \cdot P_t} \qquad (1)$$

where t is the data years (1979, 1980, 1981, 1983), I is the number of states reported ($I = 7$ in 1979 and 1980; $I = 9$ in 1981 and 1983), and D_{it} is the number of job-related deaths in the ith state in the tth year. E_t is the number employed in the year t for the total United States. P_t is the percentage of national employment contributed by the seven or nine states in year t. The percentages of national employment were calculated for each year: 17.11% (1979), 15.09% (1980), 17.11% (1981), and 17.91% (1983).[12]

The overall incidence rate of occupational fatalities for a remediation project is a weighted average of the individual occupational fatality rates using the percentage distribution of the labor hours inputs as the weights. Multiplying the weighted fatality rates by the person-years of exposure gives the expected number of fatalities for a given project.

The Poisson distribution is commonly used to model injury-producing processes because the number of "failures" (injuries) is quite small compared to the number of "trials" (opportunities for injury). The mean of a Poisson distribution (μ) is the number of successes in n trials, each with probability p of success, and is defined as $\mu = np$. If we assume that the incidence of traumatic fatalities in remediation projects follows the Poisson distribution, then the number of deaths predicted by the fatality rate is the mean of the Poisson distribution. The death rate, expressed as deaths per person-year, is p and the number of person-years required to complete the project is n. The probability, or risk, of exactly x fatalities in a project may be found by evaluating the Poisson function for various values of x.[13]

$$f(x) = (e^{-\mu} \cdot \mu^x)/x! \qquad (2)$$

Evaluating (2) with $x = 1$ gives the probability $f(1)$ of experiencing *exactly* one fatality during the course of a remediation project. The probability or risk of experiencing *at least* one fatality is $f(\geq 1) = 1 - f(0)$.

To demonstrate the application of this method to evaluation of remediation projects, three alternatives were developed. The first was excavation and landfill, the second was capping, and the third was capping and slurry wall. Labor inputs by occupation for each alternative were estimated by a contractor familiar with remediation work and are shown in Table I.[14] The

Table I. Occupational Fatality Rates by Occupation and Remediation Alternative

Occupation code	Occupational title	Death rate $\times 10^{-4}$	Alternative 1: Excavation and landfill			Alternative 2: Capping			Alternative 3: Capping and slurry wall		
			Estimated h	Percentage distribution of hours	Weighted rate $\times 10^{-4}$	Estimated h	Percentage distribution of hours	Weighted rate $\times 10^{-4}$	Estimated h	Percentage distribution of hours	Weighted rate $\times 10^{-4}$
245	Manager	0.594	4,752	0.5	0.310	1,122	1.4	0.846	1,309	1.4	0.840
452	Inspector	1.059	8,712	1.0	1.014	2,112	2.7	2.838	2,464	2.7	2.820
011	Civil engineer	0.328	9,768	1.1	0.352	2.431	3.1	1.012	2,805	3.0	0.994
085	Safety officer	—[a]	4,356	0.5	—	1,056	1.3	—	1,232	1.3	—
010	Chemical engineer	0.244	4,356	0.5	0.117	1,056	1.3	0.327	1,232	1.3	0.325
161	Surveyor	0.543	484	0.1	0.029	352	0.4	0.243	352	0.4	[illegible]
372	Secretary	0.029	4,356	0.5	0.014	1,056	1.3	0.039	1,232	1.3	[illegible]
441	Foreman	1.172	19,514	2.1	2.515	4,054	5.1	6.030	4,659	5.0	5.900
415	Carpenter	0.694	352	—[b]	0.027	110	0.1	0.097	110	0.1	0.082
751	Laborer	3.290	57,420	6.3	20.772	21,032	26.7	87.812	23,379	25.3	83.117
436	Operating engineer	2.158	31,417	3.5	7.455	7,128	9.0	19.521	9,181	9.9	21.410
481	Mechanic	0.541	493	0.1	0.029	154	0.2	0.106	—	0.0	—
522	Plumber	1.308	282	—[b]	0.041	88	0.1	0.146	88	0.1	0.124
430	Electrician	0.990	282	—[b]	0.031	88	0.1	0.111	88	0.1	0.094
412	Dozer operator	2.840	17,732	1.9	5.537	2,112	2.7	7.612	2,699	2.9	8.283
642	Oiler	3.073	9,821	1.1	3.318	1,056	1.3	4.118	1,349	1.5	4.480
715	Truck driver	3.876	735,350	80.9	313.401	33,792	42.9	166.218	40,362	43.6	169.053
Total estimated hours		—	909,447	100.0	—	78,799	100.0	—	92,541	100.0	—
Weighted death rate		—	—	—	354.962	—	—	297.076	—	—	297.768

[a] No deaths reported.
[b] Less than 0.05%.

pertinent characteristics of the example site and the remediation alternatives are shown in Fig. 1.

3. RESULTS

As shown in Table I, the 17 occupations involved in hazardous waste site remediation tasks had widely varying average annual fatality rates. The most hazardous occupation was that of truck driver followed by laborer, oiler, and dozer operator. In contrast, secretary, with a fatality rate more than 130 times lower than truckers, was the safest occupation listed.

Alternative 1, excavation and landfill, represented the most labor intensive remediation alternative of the three with total estimated exposure of 454.7 person-years. The two occupations with the highest death rates per person-year contributed the most to total project hours in this alternative. Truck drivers accounted for more than 80% of the labor hours, while laborers were responsible for another 6%.

Alternative 2, capping only, was the least labor-intensive remediation alternative, with 39.4 person-years of exposure. The total estimated hours for this procedure was 91.3% less than the labor expenditure for excavation and landfill. Even so, the weighted death rate was only 16.7% less than that found for Alternative 1. Truck drivers and laborers were again the major contributors of labor hours in this alternative. The apportionment of the two group's contributions differed markedly in Alternative 2 from that present in Alternative 1, however. The relative percentage of laborers' exposure was more than four times higher than was the case in Alternative 1, while trucker exposure in capping was almost 50% lower than was estimated for the excavation and landfill operation. Sizable differences in the labor requirement mix for capping vs excavation and landfill were found for most of the other occupations included in this analysis. In particular, increases in the proportional contributions of foremen as well as civil and operating engineers were projected for capping, compared with the excavation and landfill procedures.

Assumptions for all alternatives

- The site was 20 acres.
- The site was assumed to be in a nonresidential area.
- The site required demolition of two 20 feet by 25 feet buildings, erection of a site security fence (4,000 linear feet), site clearing, mobilization, and demobilization.
- A mixture of Level C and Level D personal protection was used. Truck drivers and other workers that should not come into contact with the contaminated soil were in Level D. Workers doing the excavation work wore Level C protection.

Additional assumptions for Alternative 1, excavation and landfill

- The entire site was excavated to a depth of 15 feet.
- Two hazardous waste disposal sites were used for the excavated materials: one 100 miles away from the site and one 500 miles away from the site.
- The excavated areas required backfill material from off-site. The backfill material source was 50 miles from the site.
- The groundwater table was 6 feet below the ground surface. Therefore, a waste water treatment system was required to treat the contaminated groundwater that was produced during the dewatering of the contaminated soil below the water table.
- The excavated soil was a RCRA hazardous waste and required stabilization before land disposal.

Additional assumptions for Alternative 2, capping

- Of the 20 acre site, 18 acres required capping.
- A RCRA-type cap was used. This included 2 feet of clay above the contaminated soil, a geotextile fabric layer, an 80 mil synthetic membrane, 1 foot of sand, another geotextile layer, 2 feet of topsoil, and a vegetative cover.

Additional assumptions for Alternative 3, capping and slurry wall

- The same cap was used as in Alternative 2.
- The slurry wall was 4,000 feet long, 15 feet deep and 3 feet wide.

Fig. 1. Characteristics of the example site.

Alternative 3, capping and slurry wall, required about 17% more total labor than capping alone, or 46.3 person-years of exposure. Nevertheless, Alternative 3 had almost the same weighted fatality rate. As might be expected, in the capping and slurry wall operation, truck drivers and laborers were represented to the same degree as was the case for capping, with respective contributions of 43.6 and 25.3% to the project hours.

The expected number of fatalities was found by multiplying the weighted fatality rates by the person-years of exposure in each alternative. For example, multiplying 454.7 person-years of exposure by 3.55×10^{-4} deaths per person-year gave 0.161 expected deaths associated with Alternative 1. Similarly, based on total person-years of exposure, the expected fatalities associated with Alternatives 2 was 0.0117 and Alternative 3 was 0.0138.

Conversion of the expected mean number of fatalities into a probability, or risk, was done by evaluating Eq. (2) with $\mu = 0.161$ and $x = 1$, which gave $f_1(1) = 0.137$ (the subscript on f indicates the alternative number). That is, the probability of experiencing exactly one fatality during the course of excavation and landfill is 0.137. The probability or risk of experiencing *at least* one fatality was $f_1(\geq 1) = 1 - f_1(0) = 1 - 0.851 = 0.149$. Similarly, the probabilities of experiencing *at least* one fatality were $f_2(\geq 1) = 0.012$ for capping and $f_3(\geq 1) = 0.014$ for capping and slurry wall. Thus the workers' risk of fatality due to physical hazards is of the order of 10^{-1} to 10^{-2}.

4. DISCUSSION

The fatality rate data used in this study were obtained from government sources and had certain limitations that should be discussed. Generally, these deficiencies tended to result in rates that were more likely to underestimate than overestimate the actual safety and health hazards to which remediation workers are exposed.

The occupational data used in this study were not the most current available. SDS data are available for the years 1976–1981, 1983, and 1985–1988. Data for all 11 years could not be used, however, partly because 1970 U.S. Census occupation codes were used through 1983 and 1980 Census occupation codes were used for 1985 and later years.[15] A "cross-walk" manual relating 1970 to 1980 census codes was available, but it warned that "as a result of the changes...most 1980 occupation major groups and detailed categories are not comparable to similar categories in the 1970 census."[16]

Denominator data indicating the number of persons employed in a given occupation for the 7 to 11 states over 4 years had to be estimated. Annual, state-specific, occupational employment data would have been preferred but could not be found and are not available from the BLS. Equation (1) estimates were, however, based on the most finely calibrated government data on occupational employment available to the investigators.

The numerators showing the number of fatalities associated with each occupation included in this study were obtained from workers' compensation (WC) data. Both the validity and the completeness of these data have been questioned.[17,18] Stout and Bell[19] find that WC boards discover only 57% of all fatal occupational injuries. Toscano and Windau[20] find that only about 44% of work-related deaths are identified by WC records.

State WC programs do not cover all employees.[17] Among wage and salaried workers, roughly 88% are covered. Self-employed persons may refuse coverage. Federal government employees are excluded. Most states exclude farm labor, domestic servants, casual employees, and maritime and railroad workers. A few states provide exemptions for coverage for all public employees, but the coverage is voluntary in several states.

The tendency of death rates to be understated by use of WC records may be offset to some extent by OSHA's emphasis in recent years on safety in the construction industry. That is, death rates in construction-related occupations may be lower now than they were in the years covered by the data in this study. A similar argument may be made concerning heavy truck safety.

Another potential problem concerns national representation. The numerators were taken from 11 states. Components of the denominators were taken from all states. BLS investigators have, nevertheless, expressed confidence that the SDS data are representative of the national experience.[21,9]

Finally, fatality rates calculated here did not account for certain risk factors unique to hazardous waste site remediation. For example, the rates were not adjusted for the potentially detrimental effects of the personal protective equipment (PPE) that workers are required to wear by OSHA regulation (29 CFR 1910.120). These effects include heat stress and reduced vision and hearing. Although no data were found that provided a basis for adjusting rates to account for these factors, occupational safety and health guidelines consistently emphasize the increased risks hazardous waste workers incur when wearing PPE. Compared with unequipped individuals, workers who must use PPE will be subject to a considerable risk of developing heat stress and most likely experience performance decrements as well. The magnitude of these effects is markedly influenced by both the type of PPE worn and the personal physiological and health factors that can affect a worker's ability to function.[22]

Although these limitations influence these findings, their effect should not be exaggerated. The fatality rate estimates are credible and fall within the range reported in other studies. This observation applies in particular to truck driver and laborer, the two occupations that are predominant in remediation work. Rates used here were 39 (per 100,000) for truck drivers and 33 for laborers. The CDC and Meng death rate estimates for these occupations were 60 to 70% higher.[7] The Census of Fatal Occupational Injuries (CFOI) reported 1992 rates of 25 for truck drivers and 34 for laborers and the National Traumatic Occupational Fatality (NTOF) surveillance system reported 1980–1989 annual average rates of 26 for transportation operators (including but not limited to truck drivers) and 17 for general laborers (not just construction).[7]

The overall fatality rates for these projects, as shown in Table I, were dependent primarily on just two occupations: truck driver and laborer. Not only did these two occupations have the highest death rates, but also they contributed the greatest proportion of the labor input to these projects—from 69 to 87%. Remediation alternatives that reduce dependence on these two occupations should be considered most desirable from the point of view of minimizing the risk from physical hazards.

It is clear that occupational risks associated with alternative hazardous waste site remediation methods can be quantified and given the same scientific evaluation as health risks. Those making decisions about site remediation should undertake such evaluations so as to minimize the physical (safety) risks to workers as well as the health risks to the public.

Evaluation of worker risks should play an important role in selecting the method by which a hazardous waste site is cleaned up. As noted by Pease, technical and economic considerations generally determine the level of health risk reduction (within the target range of 10^{-4} to 10^{-7}) at CERCLA sites.[23] Worker injury risks are an important aspect of technical feasibility.

Because of the disagreement among epidemiologists and economists with regard to the degree to which workers understand the risks they accept or receive compensating wage differentials, the qualitative differences between worker injury risks and public health risks may not be as great as is generally assumed. The fatality risks to workers engaged in remediation, 10^{-1} to 10^{-2} as found here, are orders of magnitude greater than the 10^{-6} human cancer risk criterion often used in association with remediation risk discussions[5,6] and actual cancer risks to the general public. While no data are available on either the average or the range of cancer risks associated with hazardous waste sites, Travis and Hester found that the lifetime cancer risk to individuals due to local exposure to large point sources of pollutants "typically have maximum individual risks on the 10^{-3} to 10^{-4} range, but because risk drops off rapidly with distance from the source, risk to the average individual is typically in the 10^{-5} to 10^{-7} range."[24]

The evaluation method used here can be extended to other remediation methods such as excavation and on-site incineration, steam removal, groundwater pumping, air stripping, etc. One needs to know only the kinds of occupations that will be used and the estimated number of employee-hours required of each occupation. Fatality rates for occupations not used in this paper are available.[8]

A number of directions for future research are suggested by these results. The extensive use of trucks to transport both contaminated and backfill materials involved in remediation projects suggests that there may be considerable crash-related risks to other highway users. Estimation of the rate of occurrence of such consequent fatalities involving the public would also improve the evaluation of alternative remediation processes.

It would be desirable to produce incidence rates for *nonfatal* injuries by occupation to provide a more balanced analysis of the potential for injury associated with hazardous waste site remediation.[25]

Future analyses of job-related deaths would be greatly improved if the federal government would regularly publish annual average U.S. employment for all three-digit occupations and periodically publish employment within three-digit occupations for each state.

This study should be replicated with more recent fatality and employment data. OSHA's emphasis on construction safety and other developments in occupational safety and health may have reduced the level of risk in construction occupations. As noted before, however, the current CFOI and NTOF data indicate the same general level of fatality rates as found here.

ACKNOWLEDGMENTS

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2. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, *Risk Assessment Guidance for Superfund, Vol. I. Human Health Evaluation Manual*, Part C, Risk Evaluation of Remedial Alternatives, Interim, EPA/540/R-92/004 (EPA, Washington, DC, 1991).
3. The issue of compensating wage differentials for risky jobs is still under debate. W. K. Viscusi, *Fatal Tradeoffs: Public and Private Responsibility for Risk* (Oxford University Press, New York, 1992); J. P. Leigh, "No Evidence of Compensating Wages for Occupational Fatalities," *Industr. Relat.* 30(3), 382–395 (1991).

   On balance, the worker probably has a better idea of accident risks than the public has of cancer risks due to chemicals. But worker knowledge is far from perfect. V. J. Behrens and R. M. Brackbill, "Worker Awareness of Exposure: Industries and Occupations with Low Awareness," *Am. J. Industr. Med.* 23, 695–701 (1993); J. G. Dunn, "Subjective and Objective Risk Distribution: A Comparison and Its Implications for Accident Prevention," *Occupat. Psychol.* 46, 183–187 (1972); S. Shilling and R. M. Brackbill, "Occupational Health and Safety Risks and Potential Health Consequences Perceived by U.S Workers, 1985," *Public Health Rep.* 102, 36–46 (1987).

   This lack of knowledge is likely to be especially acute for traffic accidents. The public typically does not regard traffic accidents as job-related, but vehicle crash deaths are the most frequent cause of on-the-job deaths. G. Toscano and J. Windau, "Fatal Work Injuries: Results from the 1992 National Census," *Month. Labor Rev.* 113(9), 3–8 (1993).

   It is generally agreed that exposure to involuntary risks should

be reduced but voluntary risk exposure should not be limited. Sandman noted that unfamiliar risks are less acceptable than voluntary risks and that risks controlled by others are less acceptable than risks controlled by the exposed individual. P. M. Sandman, "Getting to Maybe: Some Communication Aspects of Siting Hazardous Waste Facilities," *Seton Hall Legis. J.* 9, 442–465 (1985).

4. G. M. Marsh and R. Day, "A Model Standardized Risk Assessment Protocol for Use with Hazardous Waste Sites," *Environ. Health Perspect.* 90, 199–208 (1991).
5. R. L. Smith, *Risk-Based Concentration Table, First Quarter 1994.* (available from EPA Region III, Philadelphia, PA.)
6. New Jersey P.L. 1993 c. 139 (Industrial Site Recovery Act).
7. A dozen bibliographic databases were searched using strategies specific to remediation activities and general activities applicable to other work situations. No data were found. Industry data were also considered, such as incidence rates from the Bureau of Labor Statistics Annual Survey of Occupational Injuries and Illnesses. The data were not appropriate for this study. The Standard Industrial Classification (SIC) codes by which the data are reported, especially for the construction industries, are so broad as to encompass too wide a variety of activities, most of which are not relevant to site remediation methods. Bureau of Labor Statistics, *Occupational Injuries and Illnesses in the United States by Industry, 1991* (U.S. Government Printing Office, Washington, DC, 1993).

   Moreover, the fatality data from the BLS annual surveys of 250,000 establishments are unreliable (ibid., p.7). The BLS does not publish death rates beyond the one-digit SIC level and will politely deny researchers' requests for two- and three-digit level data. J. J. Kniesner, and J. D. Leeth, "Compensating Wage Differentials for Fatal Injury Risk in Australia, Japan, and the U.S.," *J. Risk Uncert.* 4(1), 75–90 (1991).

   In view of the lack of relevant data by activity or industry, we examined occupation data. Three studies were found that reported occupational fatality rates by detailed occupations. None reported nonfatal injury rates. The Centers for Disease Control reported death rates for the 10 occupations with the highest risk using Texas death certificates for 1982. Meng reported Canadian death rates for 482 occupations. Leigh published death rates for 347 occupations in the U.S. Centers for Disease Control, "Fatal Occupational Injuries—Texas, 1982," *Morbid. Mortal. Week. Rep.* 34(10), 130–134; 139 (1985); R. Meng, "How Dangerous Is Work in Canada? Estimates of Job-Related Fatalities in 482 Occupations," *J. Occupat. Med.* 33(10), 1084–1090 (1991); J. P. Leigh, "Estimates of the Probability of Job-Related Death in 347 Occupations," *J. Occupat. Med.* 29(6), 510–519 (1987).

   Two other more recent sources of fatality rates by occupation are available—the Census of Fatal Occupational Injuries (CFOI) and the National Traumatic Occupational Fatality (NTOF) surveillance system—but neither publishes rates at the necessary level of occupational detail. G. Toscano and J. Windau, "Fatal Work Injuries: Results from the 1992 National Census," *Month. Labor Rev.* 113(9), 3–8 (1993); National Institute for Occupational Safety and Health, *Fatal Injuries to Workers in the United States, 1980-1989: A Decade of Surveillance,* DHHS (NIOSH) No. 93-108 (NIOSH, Cincinnati, OH, 1993).

   The Leigh death rate data were judged to be most appropriate for the purpose of this research because they represented a broader geographical base and more occupations than the CDC study, were specific to the United States, and reported results in greater occupational detail than CFOI or NTOF. Further, the original 1987 study was updated.
8. J. P. Leigh, *Causes of Death in the Workplace* (Quorum Books, Westport, CT, 1995), in press.
9. U.S. Bureau of Labor Statistics, *Supplementary Data Systems, Data Files User's Guide, 1980 Edition* (National Technical Information Service, Springfield, VA, 1982). Three files were produced each year. "File 3," which contains data on closed cases only, was used for this study.
10. States and years included in this study were as follows: Arkansas, 1981 and 1983; Colorado, 1979–1981 and 1983; Delaware, 1979–1981 and 1983; Idaho, 1980 and 1981; Iowa, 1981 and 1983; Montana, 1979–1981 and 1983; New York, 1979–1981 and 1983; North Carolina, 1979–1981 and 1983; Oregon, 1983; Virginia, 1979; and Wisconsin, 1979–1981 and 1983.
11. A change to 1980 Census occupation definitions took effect with 1983 employment data. Accordingly, employment by occupation for 1983 was estimated by multiplying the 1982 employment figures by a growth factor of 1.0064. Employment in the United States grew by 0.64% from 1982 to 1983.
12. The figure was the same in 1979 and 1981 despite the fact that information was not gathered from all of the same states in both years.
13. G. W. Snedecor and W. G. Cochran, *Statistical Methods* (Iowa State University Press, Ames, 1980).
14. CH2M HILL developed the labor estimates using an in-house cost-estimating software package.
15. Data coded under the 1980 Census system were not available to the investigators.
16. U.S. Bureau of the Census, *The Relationship Between the 1970 and 1980 Industry and Occupation Classification Systems* (Technical Paper 59) (U.S. Government Printing Office, Washington, DC, 1989).
17. G. E. Rejda, *Social Insurance and Economic Security* (Prentice-Hall, Englewood Cliffs, NJ, 1984), Chap. 12.
18. The death rates presented in this analysis generally reflect physical (safety) rather than health hazards. Some 93% of all deaths in the forthcoming study were associated with injuries, while only 7% were associated with occupational diseases. Among truck driver and laborer deaths, however, injuries accounted for over 96% of all deaths. J. P. Leigh, *Causes of Death in the Workplace* (Quorum Books, Westport, CT, 1995), in press.
19. N. Stout and C. Bell, "Effectiveness of Source Documents for Identifying Fatal Occupational Injuries: A Synthesis of Studies," *Am. J. Public Health* 81(6), 727–728 (1991).
20. G. Toscano and J. Windau, "Fatal Work Injuries: Census for 31 States," *Month. Labor Rev.* 113(9), 3–8 (1992).
21. N. Root and D. Sebastian, "BLS Develops Measure of Job Risk by Occupation," *Month. Labor Rev.* 104(10), 26–30 (1981).
22. National Institute for Occupational Safety and Health, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities* (U.S. Government Printing Office, Washington, DC, 1985).
23. W. S. Pease, "The Role of Cancer Risk in the Regulation of Industrial Pollution," *Risk Anal.* 12(2), 253–265 (1992).
24. C. C. Travis and S. T. Hester, "Background Exposure to Chemicals: What Is the Risk?" *Risk Anal.* 10(4), 463–465 (1990).
25. Although the SDS tapes contained information on temporary and permanent disabilities, only information on fatalities was analyzed. A fatality, as a category, is less ambiguous than either a temporary or permanent disability. The definition of disability varies across states as noted by Campany and Personick. Investigators will need to consider carefully these definitional differences in order to make the rates internally consistent and generalizable to the entire United States. S. O. Campany and M. E. Personick, "Profiles in Safety and Health: Retail Stores," *Month. Labor Rev.* 115(9), 9–16 (1992).