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David M. Konisky

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Introduction

Comparative Risk Analysis (CRA) is a policy tool designed to help government decision-makers identify the relative risks posed by environmental problems and to subsequently determine where to direct risk reduction efforts.[1] Also known as risk ranking, or relative risk ranking, CRA debuted in 1987 with the publication by the U.S. Environmental Protection Agency (EPA) of *Unfinished Business: A Comparative Assessment of Environmental Problems* (*Unfinished Business*). This report represented the first effort by a federal agency to explicitly evaluate and compare the risks posed by a set of environmental harms. The primary objective of *Unfinished Business* was "to develop a ranking of the relative risks associated with major environmental problems that could be used as one of several important bases on which EPA could set priorities."[2]

Unfinished Business did not immediately change public perception of risk or lead to a re-allocation of resources at EPA, but environmental

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** David M. Konisky is a Research Associate in the Center for Risk Management at Resources for the Future. He received his A.B. (History and Environmental Studies) from Washington University, and a M.A. in Internationals Relations and a M.E.S. in Environmental Studies from Yale University. *E-mail: konisky@rff.org.*

1 There are two primary types of comparative risk analysis. One type consists of comparing two relatively well-defined types of risks (e.g., the cancer risk from exposure to two different pesticides). The second type of comparative risk analysis is programmatic and is used for setting priorities. This type involves comparison of a large number of risks. Unless stated otherwise, comparative risk analysis as used in this article refers to the second type. For a discussion, see J. Clarence Davies, Comparing Environmental Risks: Tools for Setting Government Priorities 5 (J. Clarence Davies ed., 1996).

2 U.S. Environmental Protection Agency (U.S. EPA), Office of Policy Analysis, Unfinished Business: A Comparative Assessment of Environmental Problems 1 (1987) (hereinafter Unfinished Business).

policymakers have recognized the utility of the CRA method for setting environmental priorities.[3] As evidence, CRA has since been widely adopted on the regional, state, and local levels as an instrument to assist governments in their efforts to identify the environmental risks of most concern in their respective jurisdictions. To date, all ten EPA regional offices and over thirty states and municipalities have completed comparative risk projects. CRA projects are currently underway in New Jersey and New York, and the process itself was the topic of a recent Congressional hearing before the Senate Committee on Environment and Public Works.[4]

Although there has been a considerable effort to summarize the approaches and methods employed to conduct CRAs,[5] little attention has been given to analyzing the risk ranking results.[6] After over a decade of experience with the method, it is useful to reflect on the ranking results of completed CRA projects. This article focuses on one type of risk endpoint — human health — and, more specifically, develops a consolidated list of the environmental problems most often selected in CRA projects as posing significant risks to human health. The purpose of this consolidated list is not to replace or undermine the legitimacy of the locally-specific rankings of individual comparative risk projects, but rather to provide a benchmark that can be used to approximate the most important environmental health risks as judged by constituencies throughout the United States.

This article first provides a brief background on CRA and describes its basic components. The article subsequently addresses the obstacles that complicate cross-project analysis. As will be illustrated, although

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3 Richard A. Minard, Jr., *CRA and the States: History, Politics, and Results*, *in* Comparing Environmental Risks: Tools for Setting Government Priorities 30 (J. Clarence Davies ed., 1996); U.S. EPA, Science Advisory Board, Reducing Risk: Setting Priorities and Strategies for Environmental Protection 16 (1990).

4 The Senate Committee on Environment and Public Works held a hearing on October 3, 2000 to discuss the "Use of comparative risk assessment in setting priorities and on the Science Advisory Board's residual risk report."

5 *See, e.g.*, David Lewis Feldman, Ralph Perhac, & Ruth Anne Hanahan, Environmental Priority-Setting in U.S. States and Communities: A Comparative Analysis (1996); Minard, *supra* note 3; Clinton Andrews, *Substance, Process, and Participation: Evaluating a Decade of Comparative Risk*, presented at the Annual Conference of the American Collegiate Schools of Planning, Pasadena, CA (1998).

6 *See* Richard D. Morgenstern, Jhih-Shyang-Shih, & Stuart L. Sessions, *Comparative Risk Assessment: An International Comparison of Methodologies and Results*, 78 J. Hazard. Mater. 19 (2000).

CRAs generally follow a common procedural framework, differences in project design are numerous and have a profound impact on risk ranking results. The next part of the article uses a simple, two-part process, first to systematically standardize a set of completed human health risk rankings, and second to quantitatively determine a consolidated list of environmental health risks. Lastly, the article offers a couple of general conclusions.

Terminology

To avoid confusion, it is necessary to first define a couple of important concepts used throughout the article. "Risk" is an often-defined term with wide-ranging conceptualizations depending on the perspective (e.g., toxicological/epidemiological, actuarial, economic, social, etc.).[7] For the purposes of this article, risk can be broadly understood to mean the potential unwanted hazard associated with a particular activity, product, or technology. More specifically, since this article concentrates on the human health impacts posed by environmental problems, risk in this article is conceptualized as the potential for an environmental stressor to cause health problems.

"Environmental problem area" is another concept referred to throughout this article that requires clarification. A critical component of CRA project design is the delineation of what to rank. Although a CRA could conceivably rank a variety of things, most comparative risk projects have opted to consider the risks posed by environmental problems. "Environmental problem areas," thus, is a logical term to describe those items whose risk is typically assessed, compared, and ranked in CRAs. A related concept, "environmental problem category," refers specifically to the aggregated units of environmental problem areas created in the process used to formulate the consolidated list of environmental health risks.

Background

CRA processes can vary substantially. Practitioners must make important decisions regarding the specific design of CRAs, and these decisions may have significant implications for the resultant risk

7 For a detailed discussion, see Ortwin Renn, *Concepts of Risk: A Classification, in* Social Theories of Risk 53 (Sheldon Krimsky & Dominic Golding eds., 1992).

rankings. Accordingly, it is necessary to dissect the CRA process in order to establish the connection between project design and risk ranking results.

A CRA generally is comprised of three components.[8]

1. *Problem list:* Determination of the set of environmental problem areas to be analyzed and compared. This list is often wide-ranging in scope and typically consists of about two dozen problems.
2. *Criteria for evaluating problems:* A set of analytical criteria defines what the participants think is important to measure, such as pollution levels or various types of risks to human health, to ecosystems, or to quality of life. These criteria often specify what type of units analysts should use for measuring impacts under each criterion (e.g., lives lost, dollars lost, rate of change, recovery time, etc.). Some of the criteria will allow for quantitative estimates of harm or risk (e.g., water quality), but others will require qualitative descriptions of such impact (e.g., aesthetic degradation or injustice).
3. *Ranking:* Process that participants use to sort out the data and draw conclusions about the relative severity of the problems or their sub-components. The ranking inevitably involves comparing problems along several dimensions or criteria at once. The ranking most often is in the form of an ordered (e.g., 1 to 10) or categorized (e.g., high, medium, and low) list.

While it is true that all CRAs share these basic components and other common procedural attributes,[9] individual CRAs may vary significantly in methodological approach. As the next section explains, seemingly minor differences in project design can profoundly influence risk ranking results.

Important Caveats of Analyzing Risk Rankings

The more than forty comparative risk projects thus far completed have differed considerably in terms of the lists of environmental problems considered, the evaluative criteria applied to assess their respective risks, and the ranking schemes used to compile the results.

8 *See generally* Richard A. Minard, *A Focus on Risk: States Reconsider Their Environmental Priorities*, 1 Maine Pol'y Rev. 13 (1991).

9 EPA published a comparative risk guidebook in 1993, which became a common starting point for many of the comparative risk exercises performed thereafter. *See* U.S. EPA, A Guidebook to Comparing Risks and Setting Environmental Priorities (1993).

Project design varies according to the judgment of project organizers and sponsors. Not surprisingly, CRA practitioners seek to tailor the CRA process to their specific circumstances (e.g., geographic/demographic dimensions, institutional frameworks, and resource constraints). An inevitable consequence of these methodological variations is dissimilar risk ranking results. This section of the article briefly discusses some of the methodological aspects of CRAs, summarized in Figure 1, that are frequently the source of these dissimilarities.

Figure 1
Taxonomy of Selected Potential Methodological Variations, by Stage of Process

Stage of Process	*Methodological Variations*
Problem List	Environmental problem areas included Environmental problem area definitions
Criteria for Evaluating Problems	Types of risk analyzed—human health, ecosystem, quality of life Scope of risk considered—inherent vs. residual Participants conducting the ranking—public vs. expert
Ranking	Scheme used to compile rankings—numerical vs. categorical

Environmental Problem Areas

An important initial decision for those undertaking a CRA is the determination of what is going to be ranked. Among the options are a broad range of categories, including environmental problems, agency programs, geographical areas, specific problem sites, proposed actions or risk reduction solutions, economic sectors or sources, and affected populations.[10] To date, most completed CRAs have focused on environmental problems, yet the variability of those selected for comparison is considerable. Though most lists of environmental problem areas generally resemble the one used in *Unfinished Business*, no two CRAs have utilized the exact same list for their ranking exercises.

Two elements in particular contribute to the differences in environmental problem area lists: local conditions and definitional dissimilarities. With respect to the former, each list will, in part, be

10 Davies, *supra* note 1, at 13.

area-specific in that it will reflect issues of particular local salience. Since, of course, these issues will vary by project, it is not surprising that many CRAs analyze one or more environmental problems not considered by other CRAs (e.g., feedlots by the State of Minnesota, allergens and valley fever by the State of Arizona).

An additional source of variation is how environmental problem areas are defined. There are several different ways to classify environmental problems. Among the more common are by pollutants (e.g., particulate matter, radon), by sources (e.g., motor vehicles, power plants), by pathways (e.g., air, water), or by receptors (e.g., people, forests).[11] In *Unfinished Business*, the EPA chose a slightly different approach and decided to define environmental problem areas in terms of how laws were written and how environmental programs were organized. Other CRAs have chosen to define environmental problem areas broadly. For example, whereas *Unfinished Business* considered three groups of outdoor air pollutants — "criteria air pollutants," "hazardous/toxic air pollutants," and "other air pollutants" — the State of Vermont and Clinton County, Ohio, decided instead to consider outdoor air pollution for ranking purposes as a single environmental problem area.

Each approach has advantages and disadvantages, and differences in environmental problem area lists should be expected, either due to location-specific or definitional issues. As long as each environmental problem area is clearly defined and understood by those conducting the CRA, any approach can be useful. For the purposes of this analysis, dissimilarities in environmental problem area definitions complicate the development of a consolidated ranking of environmental health risks. Varying conceptualizations of environmental problem areas mean that risk ranking results cannot easily be compared without considerable aggregation or disaggregation.

Types of Risk

Another key component of CRA project design is the determination of what types of risks should be considered (e.g., cancer, non-cancer health, ecological, socio-economic, etc.). Choices regarding which risks to include and how they should be grouped together are

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11 *See* Unfinished Business, *supra* note 2, at 8.

critical to CRAs.[12] Some CRAs have elected not to divide risks into specific types. Instead, these projects have simply considered the total risk posed by environmental problem areas irrespective of the endpoint, and ranked these problem areas in a single, overall category. The State of New Hampshire and Athens County, Ohio, for example, chose this approach. To date, however, the majority of completed CRAs have assessed risks in terms of three endpoints: human health, ecosystems, and quality of life. Many CRAs have taken the additional step of combining the resulting rankings from the three separate endpoints into a single, integrated ranking. However, since the endpoints for the three categories are largely incommensurable, this has proven to be a difficult process.[13]

Since this article is primarily concerned with environmental health risks, of particular relevance is how the human health endpoint has been defined. Risk in terms of potential effects to human health is typically defined through risk assessment, which generally includes the toxicity of an environmental stressor (e.g., pollutant), the extent of exposure (e.g., the number of people imperiled), and the size and duration of each exposure (e.g., acute vs. chronic).[14] Due to data constraints and the imperfect science of risk assessment, measuring risks to human health from environmental stressors is encumbered by considerable uncertainty. In *Unfinished Business*, the EPA divided risk rankings for human health into cancer risk and non-cancer risk categories. This approach, however, has not been the norm for most CRAs which have instead generally considered human health as a single endpoint. That said, it would be incorrect to assume that CRAs have used a single set of criteria for evaluating human health risks. CRAs generally consider a broad set of health effects when determining the overall impact of an environmental problem on human health.

Despite these differences in approach and the inherent limitations of risk assessment, the CRA method can produce a credible and useful analysis of human health risks that can be used to inform priority-setting efforts. While the precise reasoning for assigning a ranking to a particular environmental problem area will vary depending on the

12 Davies, *supra* note 1, at 15.

13 Feldman et al., *supra* note 5, at 52.

14 Minard, *supra* note 8, at 23.

specifics of an individual CRA, if two projects both rank indoor air pollution as the most severe risk to human health, one can conclude that those involved in these two projects had relatively similar perceptions of this risk. In other words, it is reasonable to presume that the human health endpoint used in CRAs is similar enough to allow for cross-project comparisons and analysis.

Inherent versus Residual Risk

An additional element of CRAs that potentially complicates analysis of risk ranking results is whether inherent risk or residual risk was considered. Inherent risk refers to that risk which would exist without current control programs, whereas residual risk refers to the current level of risk, assuming full compliance with present environmental laws and regulations. In *Unfinished Business,* the EPA based its analysis on residual risk and chose to focus its attention on the prospective actions it could take to mitigate the risks not yet addressed.[15] To date, nearly all comparative risk projects have utilized this approach and have elected to base their ranking exercises on residual risk. Since residual risk has been the norm, this potentially confounding factor is of lesser significance for this analysis although it remains important to bear in mind if evaluating other endpoints.

Public versus Expert Ranking

In addition to the issue of what is being ranked, an equally important consideration is who is doing the ranking. Studies indicate that risk perceptions vary extensively between the public and experts. The reasons for the variance are complicated and based on a fundamental difference in the criteria used by the public and experts to define risk. Experts tend to base their rankings of human health risks on a narrow set of quantitative attributes, the most common being expected morbidity and mortality. The public, by contrast, uses a wider variety of attributes to rank risks. These include both quantitative features (e.g., morbidity, mortality, and catastrophe potential) and qualitative features (e.g., controllability, whether or not the risk is well understood by science).[16]

15 Unfinished Business, *supra* note 2, at 13.

16 For more detailed discussion, see Paul Slovic, *Perception of Risk: Reflections on the Psychometric Paradigm, in* Social Theories of Risk 117 (Sheldon Krimsky & Dominic

The differences in public and expert risk perception, however, do not resolve the normative issue of who should be involved in the ranking of environmental problems. A discussion of this issue is beyond the scope of this article and is available elsewhere,[17] but recent reports have emphasized that public input is an integral component of managing environmental risks.[18] Incorporation of public input in comparative risk projects is particularly important since both the risk ranking and priority-setting process are inherently value-laden endeavors. The uncertainty associated with quantitative risk data is too substantial to methodically determine a risk ranking. These types of decisions inevitably involve subjective public values that go beyond simple mathematical calculations.[19] The issues that may be neglected in a narrowly technical approach include: (1) the desire for equity; (2) aesthetic quality; and (3) intergenerational equity.[20] Additionally, it should not be assumed that experts are basing their judgments on perfect information; often there is a high level of uncertainty in the scientific analysis underlying comparative risk assessment (e.g., level of exposure, toxicity, dose-response relationships, variations in susceptibility, cumulative exposure).

Numerical versus Categorical Ranking

Another methodological difference in the way environmental problems are ranked in CRAs is with respect to how the results are compiled. To date, completed comparative risk projects have arranged risk ranking results in one of two ways—numerically (e.g., 1 to 20) or categorically (e.g., high, medium, low). This has been the case irrespective of the endpoint of concern. This issue is of relatively lesser importance than the others described above but nonetheless can hinder cross-project analysis of risk ranking results.

Golding eds., 1992).

17 *See, e.g.,* Daniel J. Fiorino, *Technical and Democratic Values in Risk Analysis,* 9 Risk Analysis 293 (1989); Ralph M. Perhac, Jr., *Comparative Risk Assessment: Where Does the Public Fit In?,* 23 Sci. Tech. Hum. Val. 221 (1998).

18 National Research Council, Understanding Risk: Informing Decisions in a Democratic Society (1996); Presidential/Congressional Commission on Risk Assessment and Risk Management, Framework for Environmental Health Risk Management Final Report (1997).

19 Jonathan Lash, *Integrating Science, Values, and Democracy Through Comparative Risk Assessment, in* Worst Things First? The Debate Over Risk-Based National Environmental Priorities 74 (Adam M. Finkel and Dominic Golding eds., 1994).

20 Minard, *supra* note 8, at 18.

Consolidated Ranking of Human Health Risks

A two-part process is used to formulate a consolidated ranking of the environmental problems most often judged in completed CRAs as posing significant risks to human health. The first part of the process involves the standardization of individual human health risk ranking results to make them more amenable to analysis. A methodology developed in a previous paper[21] is used to systematically organize the risk rankings in a way that allows for the next step, a calculation of the frequency in which each environmental problem category was identified as posing a risk to human health. From this two-part process, the most often cited environmental health risks can be determined. Though this type of analysis is problematic due to the methodological variations explained in the last section of this article, the purpose of such a list is to provide a benchmark that can be thought of as an approximate synthesis of the environmental problems most frequently judged by those conducting CRAs as posing the severest risks to human health.

The data come from the results of completed comparative risk projects that have ranked environmental problems based on their risks to human health.[22] Thirty-nine human health CRAs were included in the analysis: two national; ten regional; twenty state; two territorial; and five local.[23] (See Table 1 for a list of the comparative risk projects.) The analysis described below could also be used to compare risk ranking results of other endpoints considered in CRAs (e.g., ecosystem health, quality of life), but since this article is focused on health risks, only data from existing human health risk rankings are included.

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21 David M. Konisky, *Comparative Risk Projects: A Methodology for Cross-Project Analysis of Human Health Risk Rankings*, RFF Discussion Paper 99-46 (Resources for the Future, Washington, D.C. 1999).

22 When all endpoints are considered, the total number of comparative risk projects completed is 142 (1 national, 10 regional, 24 state and territorial, and 107 local including 82 Mississippi counties). *See* Environmental Defense Fund, Setting Priorities: Main Page *at* http://www.scorecard.org/comp-risk/.

23 *Unfinished Business*, the Wisconsin Tribes Comparative Risk Project, and the Guam Comparative Risk Analysis were each counted as two separate cases since each conducted human health rankings for both cancer risk and non-cancer risk. CRAs that covered multiple jurisdictions were counted as single CRAs since only one ranking was done for the greater area (e.g., the Northeast Ohio Regional Environmental Priorities Project was counted as one CRA though it covered the counties of Cuyahoga, Lake, Lorain, Summit, Geauga, Medina and Portage). The Mississippi CRA, Comparative Environmental Risks in Mississippi, did include individual human health rankings for 82 counties, but these were not included in the data set analyzed.

Table 1
List of Comparative Risk Projects Included in Analysis

Level of Government	*Project*
National	U.S. EPA, *Unfinished Business**
Regional	EPA Regions 1-10
State	Alabama, Arizona, Arkansas, California, Colorado, Florida, Hawaii, Iowa, Louisiana, Maryland, Minnesota, Mississippi, North Dakota, Ohio, Texas, Utah, Vermont, Washington, and Wisconsin*
Territory	Guam*
Local	Northeast Ohio, Clinton County (OH), Columbus (OH), Denver (CO), and Washington, DC

*Counted as two separate cases since each conducted human health CRA for both cancer risk and non-cancer risk.

Standardization of Risk Ranking Results

Before the human health risk ranking results can be quantitatively analyzed in any meaningful manner, it is necessary to standardize them so that they are more uniform. The first step of the standardization process is to aggregate the environmental problem areas considered in each CRA into new environmental problem categories as a means to address definitional inconsistencies. The key issue with respect to this component of standardization is the identification of the correct level of aggregation, or in other words, the determination of the appropriate scope of the new environmental problem categories. As a general rule, the aggregation of environmental problem areas should only be done to the level required to allow comparison. Adherence to this standard will best guarantee that the environmental problem categories will accurately reflect the original risk rankings. The environmental problem areas comprising risk rankings of some CRAs will be sufficiently similar as to not require much aggregation, whereas others may be so disparate that substantial aggregation is necessary.

In this analysis, determining the most appropriate level of aggregation was relatively simple in that the environmental problem categories could only be as specific as the CRA with the single most general set of environmental problem areas. In other words, since many of the CRAs defined their environmental problem areas broadly (e.g., hazardous waste, surface water pollution, outdoor air pollution), the environmental problem categories also could be defined broadly. The aggregation process, however, represents only the first component of the standardization of dissimilar environmental problem areas. The second component is the normalization of ranking schemes.

The newly established environmental problem categories must be assigned a value of risk that accurately reflects those of the aggregated environmental problem areas that comprise the category. A preliminary step in this determination is the creation of a uniform ranking scheme to normalize the disparate ways in which CRAs have arranged their rankings. Normalization is possible through the reorganization of the risk ranking data, both numerical and categorical, into three categories: High, Medium, and Low.

The decision rule applied to the CRAs with numerical rankings was the following: the top third of the environmental problem areas ranked were reassigned a value of "High," the middle third a value of "Medium," and the bottom third a value of "Low."[24] With respect to categorical rankings, the original rankings were converted simply by assigning the top risk category a value of High, the middle risk categories a value of Medium, and the bottom risk category a value of Low. This uniform ranking scheme provides a reasonably accurate representation of the original rankings.

A clear drawback of reducing the original risk rankings into only three categories is the inevitable loss of precision that results. Ideally, it would enhance the comparative analysis if a ranking scheme could be devised that either incorporates more categories or creates an ordered list (e.g., 1 to 10). However, the uniform ranking scheme can only be as precise as the least precise original ranking system. Since many CRAs rely upon a categorized scheme with only three levels of risk and do not rank environmental problems areas within each of the levels, a reasonable general rule is to convert risk rankings into this three-level framework. The primary advantage of the High-Medium-Low format is that it is applicable to all completed CRAs.

24 To test the sensitivity of the results to this assumption, the numerical rankings were also reorganized by assigning the top 25% a value of "High," the middle 50% a value of "Medium," and the low 25% a value of "Low." The impact on the results was minimal and did not impact the final consolidated rankings. In large measure, this was because only 6 of the 39 human health CRAs in the data set relied solely on numerical rankings to summarize their results.

The final component of the standardization process is the determination of the appropriate value of risk to assign the newly created environmental problem categories. To the extent possible, the value of risk should match that of the original environmental problem areas that comprise the category. There are two sensible ways of assigning a value of risk to the new environmental problem categories. First, the entire category can be given the risk value of the environmental problem area in the category with the single highest risk value. The logic underlying this "highest" rule is that no category should have a lower risk value than any single environmental problem area of the category. Alternatively, the new category could be given the average risk value of the individual environmental problem areas that comprise the new category.[25] The reasoning underpinning this "average" rule is that the most representative value of risk for the new category would be the average of the individual environmental problem areas that it encompasses. As is explained below, both of these approaches were used.

Quantitative Analysis

Once the human health rankings have been reorganized so they are commensurate, it is possible to determine how often each environmental problem category was identified as posing a risk to human health. This was accomplished through a calculation of the frequency in which each environmental problem category was ranked. Each environmental problem category was tabulated in terms of the number of total times and percentage it was ranked in all the human health rankings, and the number of times and percentage each environmental problem category was ranked in a particular risk category — High, Medium, or Low.

As an additional measure, an index scoring system was devised to further characterize the data: assigning High a value of three; Medium a value of two; Low a value of one; and Not Ranked a value of zero. A raw score was calculated for each environmental problem category. Using this raw score, a weighted average score was calculated (raw score/total number of times ranked). The primary reason for

[25] The values used to calculate the average are High=3, Medium=2, and Low=1. Values with a decimal point greater than or equal to 0.5 were rounded up.

computing the weighted average score was to account for a potential outcome, for instance, in which two environmental problem categories both had a raw score of six, but one was ranked high twice and the other was ranked low six times.

Summary of Results

Through the quantitative analysis of the human health risk rankings, it is possible to generate a list of the environmental problem categories ranked in terms of the risks they pose to human health, as judged by the participants in the 39 CRAs considered. This consolidated ranking could be formulated in several different ways: total times ranked, total times ranked high, raw score, or weighted average score. Among these options, two are seemingly the best proxies for determining which environmental problem categories were most often associated with high risks to human health—the number of times ranked high and the weighted average score. Figure 2 displays these results.[26]

The number of times each environmental problem category was ranked high represents the frequency in which each problem was placed in the highest risk category of a CRA, whereas the weighted average score takes not only this factor into account but also the frequency in which each environmental problem category was ranked. For each case, it is necessary to consider the results in two sets ("highest" or "average") to illustrate the slight differences that emerge due to the choice of the decision rule used to assign risk values to the environmental problem categories.

An examination of the results suggest that, regardless of whether the total times ranked high or the weighted average score was used, in large measure, the same set of environmental problem categories comprise the consolidated lists. The most robust finding is that indoor air pollution and outdoor air pollution repeatedly emerge as the environmental problem categories most frequently cited as presenting the most significant risks to human health. The second group of environmental problem categories is more dependent on the tabulation method, but generally includes lead, food quality, pesticides, and stratospheric ozone depletion. Interestingly, the results are quite similar to those of the cancer risk rankings of *Unfinished Business,* in which

26 The complete results are summarized in Konisky, *supra* note 21, at 19-20.

the environmental problem areas placed in the highest risk category included worker exposure to chemicals, indoor air radon, pesticide residues on food, indoor air pollutants other than radon, consumer exposure to chemicals, and hazardous/toxic air pollutants. All are components of the aggregated environmental problem categories determined in this analysis to be most frequently judged as presenting serious human health risks.[27]

Figure 2
Consolidated Lists and Final Ranking

	Total Times Ranked High		*Weighted Average Score*		*Total*	*Final Ranking*
Environmental Problem Category	*Highest Rule*	*Average Rule*	*Highest Rule*	*Average Rule*		
Indoor air pollution	1	1	1	1	4	1
Outdoor air pollution	2	2	2	4	10	2
Lead	3	3	3	2	11	3
Pesticides	4	4	5	5	18	5
Food quality	5	5	4	3	17	4
Stratospheric ozone depletion	5	5	6	6	22	6
Toxics	5	5	7	7	24	7
Drinking water pollution	8	8	8	8	32	8
Accidental releases	9	9	11	11	40	9
Hazardous waste	10	10	10	10	40	9
Radiation exposure (other than indoor radon)	10	12	13	14	49	13
Surface water pollution	10	13	12	12	47	12
Groundwater pollution	13	11	9	9	42	11

The most significant discrepancy in the order of the environmental problem categories occurs with respect to outdoor air pollution. When the "highest" rule was applied, outdoor air pollution emerged as the second most frequently ranked environmental health risk, both when measured in terms of its total times ranked high and its weighted average score. In contrast, when the "average" rule was employed, outdoor air pollution dropped down to the fourth position when measured in terms of its weighted average score. The explanation for this divergent outcome is that, more often than any other type of environmental problem category, outdoor air was separated into distinct components for risk ranking purposes. While typically at least

27 Unfinished Business, *supra* note 2, at 28-29.

one of these individual components was judged as posing a high risk to human health, overall there was a wide range of risk values associated with outdoor air pollutants. This is not a surprising result considering the location-specific nature of outdoor air pollution. Thus, when aggregating and assigning a risk value based on the "highest" rule, outdoor air pollution frequently was ranked as posing a higher risk than when the risk value was assigned using the "average" rule.

A simple approach to reconcile the effect of the decision rules is to sum the ranking results horizontally to generate a "final" ranking. The lower the resulting total, the higher rank the environmental problem category. Not surprisingly, the results closely correspond with the previous lists. As displayed in Figure 2, indoor air pollution, outdoor air pollution, and lead comprise the top three positions.

Overall, the consolidated lists of environmental health risks are quite similar, irrespective of the tabulated data used and the decision rule employed for assigning risk values. These results should not be interpreted, however, as representing a definitive list of environmental problems presenting the greatest risks to human health. Clearly, as is the case with respect to all environmental problems, there are considerable local variations in the extent of the risk, which is the main reason state and local governments choose to conduct their own CRAs. Ideally, it would be helpful to compare the results found here with the results of other methods used to compare risk ranking results to judge the robustness of the findings. Until other such methods are devised, the consolidated risk rankings presented in this article, at minimum, provide a benchmark and a credible representation of the environmental problem areas repeatedly determined in CRAs as posing significant risks to human health. That said, there are some important shortcomings of these synthesized risk rankings, as are noted below.

Shortcomings of Consolidated Ranking

An important factor that complicates the interpretation of the consolidated rankings is the determination of the level of aggregation for the environmental problem categories. Aggregation of the environmental problem areas to different levels would produce markedly different results. The judgment made in this article is that concentration on the broadest level of aggregation provides the clearest picture of what environmental problem areas participants in CRAs most often identified as posing the most severe risks to human health. Additionally, it was the most expedient approach considering the breadth of human health CRAs considered in the analysis. In choosing to include such a large number of CRAs, a certain level of precision was inevitably sacrificed.

A clear weakness of this approach is that aggregation to this broad level obscures the individual components of the environmental problem categories that are presenting the severest risk. For example, although indoor air pollution was most often cited as posing the most significant risk to human health, focusing on indoor air pollution as a single environmental problem category conceals which indoor air pollutants should be given the most attention (e.g., indoor radon, environmental tobacco smoke, etc.). The alternative would be to base the consolidated list on a different level of aggregation. However, since many CRAs elected to define environmental problem areas broadly, it would be necessary to disaggregate to properly account for the significance of individual pollutants (e.g., carbon monoxide) or pollutant categories (e.g., criteria air pollutants). Unfortunately, while the outcome may be preferable, disaggregation is clearly not an option. The conclusion reached in this article is that, while aggregation may be problematic, it represents a feasible and useful approach.

These aggregation issues point to a locus of active debate among CRA practitioners and methodologists who are continually working on ways to best categorize environmental problems for ranking in CRAs.[28] As Graham and Hammitt indicate, there is no right answer to the question of how risks should be aggregated and listed for ranking purposes.[29] Unfortunately, the lack of consistency that results requires the type of aggregation employed in this analysis and the corresponding over-simplifications that must be made.

An additional weakness of the methodology employed in this analysis is that it relies upon a perhaps faulty assumption that the

28 *See, e.g.*, M. Granger Morgan et al., *Categorizing Risks for Risk Ranking*, 20 Risk Analysis 49 (2000).

29 John D. Graham & James K. Hammitt, *Refining the CRA Framework*, *in* Comparing Environmental Risks: Tools for Setting Government Priorities 98 (J. Clarence Davies ed., 1996).

exclusion of an environmental problem area from a problem list means that participants in the CRA considered it to pose minimal, if not zero risk. In actuality, a problem may be included or omitted for reasons unrelated to its risk. A specific problem, for instance, may be included due to its political salience at the time of the CRA, irrespective of its human health effect. In contrast, a problem may be excluded because the organizers of the CRA are uninterested in a problem because it falls outside their sphere of governmental responsibility.[30]

Another important shortcoming of this type of cross-project analysis is the inevitable blurring of human health endpoints. Of the 39 CRAs included in this analysis, most (33) of the final risk rankings reflect human health impacts as a single endpoint. In the other six final risk rankings included in the analysis, three are based on cancer-risk as the human health endpoint and three are based on non-cancer risk as the human health endpoint. For the purposes of this article, and to allow for comparability and aggregation, cancer-risk and non-cancer risk were weighted equally and commensurate with the general human health endpoint. Though the nature of the endpoint considered is a critical component of CRAs, this type of obfuscation is an unavoidable drawback of cross-project analysis.

Conclusion

This article has taken a targeted look at completed comparative risk projects — specifically, those that have considered risks to human health — to better understand which environmental problem areas most often have been cited as posing the severest risks to human health. The consolidated ranking should not be interpreted as a definitive synthesis of the environmental health risks facing the nation. Moreover, it is important not to confuse risk rankings with priority rankings. Decisions about which problems to address and how to address them must take into account a broader set of factors such as cost and feasibility of implementation. Notwithstanding these issues, the consolidated ranking formulated in this analysis provides a summary of past CRA efforts and a benchmark for future efforts.

30 Morgenstern et al., *supra* note 6.