
Nuclear Waste and Public Worries: Public Perceptions of the United States' Major Nuclear Weapons Legacy Sites

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Abstract

We surveyed 1351 residents who lived near six U.S. Department of Energy (DOE) former nuclear weapon sites using random digit dialing and stratified random sampling in order to determine which risks most worried them and the predictors of their worries. Respondents' greatest concerns were threats to their drinking water, transportation accidents, and worker exposures. The strongest predictors of their worries were concern about the quality of the local environment and the feeling that the federal and state governments were not doing enough to protect it. Many distrusted DOE's communications to them, and they tended to be relatively poor and African American, women, not college educated, and admitted to little knowledge about the site. The results were largely, but not completely, consistent with the risk perception and trust literatures, and they pose a challenge to the DOE to establish an effective partnership with diverse communities that will allow the DOE to manage some of these risks in perpetuity at these sites.

Keywords: worry, risk perception, nuclear waste, Department of Energy

Introduction

During the last two and half decades, a multi-disciplinary effort in Asia, Europe, North and South America has at-

tempted to understand why the public worries about some risks more than others. The psychometric paradigm has been a key product of these efforts. Created by Slovic, Fischhoff and their colleagues, and tested by many others, the paradigm countered the previous assertion that risk was the product of a rational analytical process leading to estimates with confidence limits. The psychometric paradigm, in contrast, portrays public perception of risk as the product of emotions and analytical reasoning. Using statistical methods, analysts reduce these attributes of risk to two or three, typically "dread" and the "unknown" (Bronfman and Cifuentes 2003; Cha 2000; Rohrman and Chen 1999; Slovic 1987; Xie et al. 2003; Yong-Jin 2000).

A consistent finding of this research is that nuclear war, nuclear power and nuclear waste are among the most dreaded and unknown risks. For example, Slovic (1987) found that out of 30 different risks, nuclear power ranked first among college students and members of the League of Women Voters. Cha's (2000) study of Koreans found that nuclear weapons/war, nuclear weapon tests, and nuclear reactor accidents ranked one, two, and four, respectively, among 70 risks. Radioactive waste disposal, transportation of nuclear materials and nuclear power plants ranked 11, 12, and 19, respectively. Bronfman and Cifuentes (2003) observed that nuclear weapons had the highest dread among 54 risks in Chile. Only earthquakes and landslides had higher dread than nuclear power, which ranked fourth in dread. Xie et al. (2003) found that Chinese respondents ranked nuclear war number one, but

nuclear power was only 27 out of 28 risks. The psychometric paradigm is still being used and refined (Siegrist et al. 2005), and so some of what it shows may be revised. Yet, with some interesting variations by country, it is clear that people are extremely worried about the use of nuclear technology, most obviously for war, but also to produce energy, and they are concerned about managing nuclear waste.

The reasons for this high level of public dread are found in the history of the technology. The images of the mushroom cloud, and the deaths of many thousands of Japanese during World War II are powerful images against nuclear technology (Hinman et al. 1993; Weart 1992). The accidents at Chernobyl and Three Mile Island have raised fears that a Chernobyl-like event could occur near any nuclear-technology-based electricity generating station. People remember and trust negative information about risks more than positive information (Koren and Klein 1991; Siegrist and Cvetkovich 2001; Skowronski and Carlston 1989; Slovic 1993). These powerful negative images are not going to go away, and they are frequently reinforced by media stories and movies.

Many countries have accumulated a nuclear legacy, and they need knowledge about public concerns that go much deeper than the broad labels of nuclear weapons, nuclear power, and nuclear waste. How worried are people about a transportation accident? The ability to prevent waste from leading to a leak into water supply? New nuclear-related activities? Worker exposure?

In the United States, risk perception information is critical for those who are responsible for managing the nuclear legacy wastes near former nuclear weapons sites and nuclear energy-generating stations. In the case of nuclear weapons manufactured by the United States during World War II and the Cold War, the nuclear legacy left hazardous nuclear and chemical waste in 34 states at over 100 locations (OEM 1995a,b; Rhodes 1986). In 1989, the United States Department of Energy (DOE) created an environmental management (EM) program with an annual budget averaging six to seven billion dollars to address the nuclear weapons legacy. Despite the expenditure of over \$70 billion, DOE estimates are that it will take decades, a great amount of research and technology development, and hundreds of billions more to manage this legacy. Nuclear and chemical wastes will be left at some DOE site for decades, some in perpetuity. As the primary responsible party for this waste, the DOE must build and maintain a working relationship with the residents who will live with this legacy. This requires finding out what the people who live near these sites are concerned about regarding the sites, that is, what do they fear the most.

As part of a three stage study that seeks to understand public concerns, what steps the DOE can take to reduce those worries, and what role the mass media and the local commu-

nity advisory panels who represent the DOE play in the process of risk perception, we asked people who live within 50 miles of arguably the six highest hazard DOE nuclear legacy sites to tell us about their concerns regarding DOE's site activities. More specifically, we answered three questions:

1. What DOE actions at the sites most worry the public?
2. How worried are residents about DOE's cleanup of nuclear-weapon related waste compared to other environmental risks in their areas?
3. What factors predict the public's worries about DOE's activities?

Previous Research and Expectations

Worry is a state of the mind in which someone is frequently or perpetually restless and sometimes distressed about existing or possible negative outcomes (MacGregor 1991; Fischer et al. 1991; Sjoberg 1998). With regard to the first research question (worry about DOE activities at the sites), opinion polls have shown that the public is most concerned about hazards that directly and immediately influence them, family and friends (Baldasarre and Katz 1992; Baxter 1990; Gillespie 1999). For example, in 2002, Gallup asked 1,006 Americans how much they worried about 10 environmental problems (Carroll 2002). The public's primary concern was drinking water. Fifty-seven percent said that they worried a "great deal" about pollution of drinking water. Over 50% worried a great deal about pollution of rivers, lakes and reservoirs; contamination of soil and water by toxic waste; and maintaining a supply of fresh water for households. Next, 45% worried about air pollution and 38% about damage to the earth's ozone layer. Extinction of plant and animal species was a great worry among 35% of respondents, and at the bottom of the worry list were global warming and acid rain with 29 and 25%, respectively. This ordering of concerns has been observed in other surveys. It follows from this literature that the public living near DOE sites will not be equally worried about all DOE activities. We expect that they will be more worried about activities that threaten water supplies, air quality, and worker exposure than about damage to ecological systems and archeological sites.

With regard to the second research question (worry about DOE site cleanup compared to other local environmental risks), all the respondents to this survey were selected because they live near a DOE nuclear weapons site. Logic and literature suggest they would be excessively worried about the nuclear weapons sites compared to agriculture, mining, loss of open space and other region-specific risks. Yet research shows that familiarity leads to desensitization and acceptance (Halpern-Felsher et al. 2001; Lima 2004). Some respondents have worked there or have a family member or friend who worked

there, and most, we assumed, would have driven near their local site. Our respondents might be less concerned about cleaning up the nuclear weapons legacy that has been there for all their lives than they are about other environmental problems that are new to them. Accordingly, our expectation was that fears about site cleanup would not be the major environmental concern. New threats, such as loss of open space/sprawl and terrorism were expected to be more distressing.

With regard to the third research question (correlates of public worrying about the DOE sites), research shows that worries about a specific problem typically are grounded in larger concerns about the environment and health (Baxter 1990; Gillespie 1999; Greenberg 2005; Wulfhorst 2003). We expected that worrying about DOE's on-site activities would be part of overall worry about the environmental health of the area. Our assumption was that those who were worried about DOE's on site activities would also be worried about the local environment, and they would feel that the federal and state governments were not doing enough to protect the local environment.

We anticipated the relationship between worry and local environmental health concerns would be influenced by trust of the DOE, site differences, distance from the site, and respondent demographic characteristics. With regard to trust, research shows that people distrust authority if they feel that it does not share their values, does not communicate appropriately with them and lacks technical competence (Earle and Cvetkovich 1995; Nye et al. 1997; Pew 1998; Poortinga and Pidgeon 2003; Slovic 1993). It follows that respondents who do not trust the DOE for these reasons would worry more about the DOE's ability to manage nuclear waste on the sites.

We expected location-based differences in worrying. Savannah River and Hanford have the bulk of the high level nuclear waste. If amount of hazard leads to more concern, then these two sites should have more worried nearby residents than the other sites. Where a respondent lives relative to the site should influence perception. Studies of landfills, power generating stations, brownfields and other locally unwanted land uses (LULUs) show that people who live near a site or along a road that leads to one would be more worried than those who do not. Distance is important because sound, odor and visual contact with a site create negative perceptions (Clay and Hollister 1983; Edelstein 1988; Roddweij 2002). But, with a few exceptions (Williams et al. 1999, 2001), the literature that shows a distance influence is based on observations of people who live within a few miles of a site. The DOE sites are remote. "Close" to these DOE sites means 10-20 miles. It is debatable that someone who lives 15 miles away is more worried than his/her counterpart who lives 30 miles from a site. More likely, we assumed that knowledge of the site is more important. We expected that those who had worked on the site, had a relative who had worked on the site,

and/or in other ways were familiar with the site would be less concerned (Gonzalez 2002; Halpern-Felsher et al. 2001; Liu and Hammitt 1999). Workers probably live closer than non-workers. In short, we did not expect people who live closer to these sites to be more worried.

Demographic characteristics were expected to be associated with worry. Risk perception studies show that race/ethnicity, socioeconomic status, gender, age and other common characteristics are associated with perception (Bord and O'Connor 1997; Finucane et al. 2000; Flynn et al. 1994; Greenberg 2005; Stern et al. 1993; Vaughan and Nordenstam 1991). We expected more worrying by African and Indian Americans, women and the relatively poor. Overall, the literature guides us to the expectation that those who are generally worried about the environment, do not think that government is doing enough to protect the environment, do not trust the DOE's technical abilities nor its messages, and know little about the site would be most fearful. Much less was expected from demographic and location indicators.

Data and Methods

The bulk of military high level nuclear waste has been located at a small number of sites, six of which we chose for this study: Hanford (WA), Savannah River (SC), Idaho National Engineering Laboratory (ID), Oak Ridge (TN), Fernald (OH) and Rocky Flats (CO). In essence, Hanford, Savannah River and INL are each hundreds of square miles and are located in relatively rural settings. Fernald, Oak Ridge and especially Rocky Flats lie in more urbanized settings near Cincinnati, Knoxville, and Denver, respectively.

In order to answer the three research questions, we designed a survey instrument with 26 main questions, of which 56 specific queries are used in this study. With regard to the first question (public worries related to the DOE site), eight questions examined DOE on-site specific concerns regarding cleanup and management of the legacy, including how much they worried about worker, resident, ecological risk, and destruction of cultural/archeological attributes. Another seven asked about off-site externalities, such as seepage of contaminants off-site into drinking water, transportation accidents, terrorist attacks on DOE off-site activities, animals carrying contamination off site, and job losses if the site reduces cleanup activities (Table 2). The questions were posed as a four point scale: 1 = worried a great deal, 2 = worried some, 3 = not much, and 4 = not at all.

While not every conceivable risk was included, the breadth of questions allowed us to test our expectations about perception of each risk. The set of risks also allowed us to determine if there is a general thread of worry that runs through the set of 15 risks. Are some people worried about almost all

the risks and others not worried about them? Or are people focused on only a few of the risks?

With regard to the second question (relative concern about cleanup of the sites compared to other risks in the area), we asked respondents to rate their worries about cleanup of the site compared to natural disasters (fire, flood, etc.), disposal of toxic waste from manufacturing and mining in the area, traffic congestion and development, terrorism, loss of open space for recreation, drinking water pollution, and agricultural practices in the area (Table 3). The same four point scale was used.

With regard to the third question (predictors of public worry), we expected strong associations with general environmental concern. People who are “very” or “somewhat” worried about environmental problems in their county were expected to be more concerned about DOE’s activities than those who were “not too worried” or “not worried at all.” Likewise, those who think that the prognosis for the environment in their county in 25 years is that it will be “worse” were expected to be more concerned about the DOE than those who perceive that their county environment would be the “same” or “better.” Also, we expected greater worry from respondents who feel that protecting the environment should be given priority, even at the risk of curbing economic growth. The final set of three questions asked if the federal, state, and local governments were doing “too much,” “too little,” or “just about the right amount” to protect the environment of the area. Those who felt that government was doing too little were expected to be more worried about the DOE.

Five questions examined trust of the DOE. They asked if respondents “strongly agreed,” “agreed,” “disagreed” or “strongly disagreed” that the DOE will make sure that the air, water and land are not polluted outside of the site’s boundaries, and that the DOE will be able to cleanup using new and safe technology, that the Department can effectively manage legacy and new waste. The last asked if the DOE communicates honestly with the public. The first four indicators measure perception of technical and managerial competence. The last is an indicator of general trustworthiness.

With regard to location, the six study sites have been owned and operated by the DOE, or its predecessor the Atomic Energy Commission and contractors for more than a half century. Hence it was essential that we include an indicator of site-specific differences. The most obvious was to create a simple yes-no variable for each of the six sites. If actual amount of high level waste prompts concern, then INL, Savannah River, Oak Ridge and Hanford should have more worry than Fernald and Rocky Flats.

Measuring the impact of distance from the site required initial analysis of the population distribution around the sites. Many of the areas within 20 miles have had a strong eco-

nomical relationship with the DOE. If we sampled only within 20 miles, we expected to find a strong bias toward less concern about the DOE and less restrictions placed on the DOE. We chose to sample out to 50 miles and to compare the responses of those who lived up to 20 miles with those who live further than 20 miles from the site.

The last set of questions asked for demographic information and about familiarity with the site. Familiarity questions asked if the respondent had ever heard of the site, how familiar they were with it, had they visited, driven by or through the site, and had they or a family member ever worked there. These separate questions were aggregated into a single question that rated familiarity from 1 (never heard of the site) to 6 (worked there; see D6, Table 4). The demographic questions included age, race/ethnicity, educational achievement, gender, length of residence in the area, and income. Age was a continuous variable, and was recoded into four age groups; family income was coded into five categories; educational achievement into five; and each of the six locations was coded as a separate dichotomous location indicator (see Table 4).

The survey was administered over the phone using random digit dialing (RDD) using American Association for Public Opinion Research standards with a minimum target of 200 at each of six sites, or 1200 overall. This means that bad numbers (not in service, non-residential) were eliminated. Each good number was called up to seven times. Including all the good numbers who were contacted seven times, the response rate was 44%. Of those who were reached, the cooperation rate was 71%, with a low of 66% at the Rocky Flats site and a high of 82% at Fernald. With respect to methods, we used simple and multivariate statistics, as described in more detail in the results section.

Results

During the period July 14 to August 2, 2005, 1351 surveys were collected: 225 at five sites and 226 at one. Table 1 presents summary demographic data for each site. There were differences among the sites, such as the relatively large proportion of African American respondents in the Savannah River sample and a larger proportion of college-educated respondents in the Rocky Flats sample than in the Savannah River and Hanford ones. These differences reflect real differences among these areas observed by examining U.S. Bureau of Census data for the year 2000.

Question 1. Worries about the DOE Sites

On a four point scale, Table 2 shows a range of worry from 48% who worried a great deal about materials seeping into the ground and contaminating local streams and drinking water to

Table 1. Percent Distributions of Respondent Demographic Characteristics

(1,351 responses)

Variable	Fernald	Hanford	Idaho Nat. Lab	Oak Ridge	Rocky Flats	Savannah River	Total
Age:							
18-29	11.8	15.2	13.8	10.3	7.6	10.7	11.6
30-49	36.2	37.2	38.7	35.5	40.7	37.6	37.6
50-64	33.0	30.5	27.1	31.9	34.0	36.7	32.1
65+	19.0	17.0	20.4	22.4	17.7	15.7	18.7
Education:							
College graduate	20.2	19.3	21.5	20.1	27.4	14.7	20.6
Race/ethnicity:							
Latino	0.5	7.2	3.6	0.4	8.1	1.8	3.6
White	86.5	87.2	94.6	91.9	83.3	68.9	85.4
Black	10.7	1.8	0.0	3.1	5.0	27.4	8.0
Asian	0.9	0.5	0.0	0.9	0.5	0.5	0.5
Indian	1.9	3.7	1.8	3.6	3.6	1.8	2.7
Family income, 2005, \$, 1000s:							
<25	18.6	19.8	20.0	25.9	16.8	18.3	19.9
25-49.9	33.7	22.2	38.6	31.1	24.5	32.2	30.4
50-74.9	20.6	22.7	23.8	24.1	22.1	25.5	23.2
75-100	9.0	17.9	10.5	8.0	18.8	10.6	12.5
100+	16.1	14.5	5.2	9.9	16.3	10.6	12.1
No answer	2.0	2.9	1.9	0.9	1.4	2.9	2.0
Sex:							
male	47.6	48.0	48.0	48.0	48.2	48.0	48.0

only 19% who worried a great deal about damage to buried or archeological sites. At the top of the list are concerns about water, disturbing buried waste, worker exposures, and transportation accidents. At the bottom, in addition to archeological sites, were risk of fires and explosions, animals carrying hazards off site, new activities and area residents losing jobs.

The relatively low worry about fires and explosions (25% worry a great deal and 26% worry not at all) is fascinating because it stands in contrast to previous perception studies that have found fires and explosions to be at the top of the public list of fears about hazardous waste sites (see discussion section).

Table 2. Worries about DOE-related Activities: Fifteen Indicators

Indicator (1=worry a great deal, ... 4=worry not at all)	Mean (Std. Dev.)	Worry a great deal, %	Worry not at all, %	Factor Loading, r value*
Materials at site will seep into the ground and contaminate local streams and drinking water	1.87 (1.03)	47.9	12.1	0.816
Disturbing corroding or leaking storage containers will cause more damage to the environment than leaving them in place	2.03 (1.02)	37.0	13.7	0.799
Workers involved in the cleanup will be exposed to hazards	2.06 (1.04)	37.1	14.3	0.766
There may be accidents when hazardous waste materials are transported to and from the site	2.07 (1.03)	35.8	13.6	0.803
Cleanup of chemicals or radioactive materials will expose residents to hazards	2.11 (1.08)	36.6	16.5	0.856
Opening the site to public access could expose people to hazards	2.14 (1.10)	35.8	18.1	0.749
The site might be a target for a terrorist attack	2.18 (1.11)	35.0	18.9	0.635
People may get sick from eating fish and wildlife from the site	2.21 (1.15)	36.5	20.9	0.848
Some waste materials will need to remain buried or contained on the site	2.27 (1.08)	29.3	19.5	0.762
Fish, bird and animal habitats will be destroyed during the cleanup of the site	2.29 (1.12)	31.1	21.2	0.804
Area residents will lose jobs if the site reduces its cleanup efforts and other activities	2.32 (1.03)	23.7	18.3	0.407
About new activities at the site that involve the use of nuclear materials	2.37 (1.11)	27.5	22.0	0.792
Animals such as deer and raccoons will carry contamination off the site	2.38 (1.13)	28.3	20.9	0.815
High risk of explosions and fires related to the cleanup	2.49 (1.13)	25.2	26.1	0.795
Some burial or archeological sites may be destroyed	2.63 (1.10)	18.5	30.1	0.670

*Eigenvalue for factor was 9.1, or 61% in a principle axis factor analysis.

The second part of the first question was directed at determining if there was a pattern of high worry and low worry respondents, that is, some respondents worried about all 15 risks and some about none or only a few. This was measured with two statistics. The first was Cronbach's Alpha, which tests for the internal consistency of a scale. A Cronbach's of ≥ 0.8 is normally considered excellent evidence of a consistent scale. Cronbach's for the 15 measures was 0.952. In other words, there is a thread of high and low worry running through these responses to all 15 worry questions.

This result was confirmed by a principal axis factor analysis, which measures if there are multiple meaningful dimensions in a data set. The first statistical factor accounted for 61% of the variance (eigenvalue of 9.1), and all of the 15 peace of mind options had a correlation of less than 0.4 with this composite "worry" statistical factor (see last column of table 2 for factor loadings). The other 14 factors created by the method had eigenvalues less than one, a sign of a dominant single dimension. The signature worry (activity that had the highest factor loading (correlation) with this worry factor was cleanup of chemicals or radioactive materials will expose residents to hazards. The only activity with a factor loading of less than 0.63 was area residents will lose jobs if the site reduces its cleanup efforts and other activities ($r = 0.407$). This was the only non-health and environmental risk activity question.

Given consistency in response to the measures of worry, we created a single DOE-worry scale by adding the 15 scores of each respondent. Then to return the scale back to the original four point question (1=worry a great deal,...4=worry not at all), we divided the summed score by 15. The mean score for the DOE-worry scale was 2.2, and the median was 2.1. This compares to means that range from 1.9 to 2.6 for the 15 individual fear questions (Table 2).

Question 2. DOE-Cleanup and other Local Risks

Table 3 compares seven other environmental issues in these regions and worry about nuclear weapon-related waste cleanup. Table 3 shows that nuclear waste cleanup ranks fifth in the proportion of respondents who reported worrying "a great deal." Respondents, as a whole, were more concerned about traffic congestion and development, and about losing open space for hunting, fishing, and other recreation. These observations are consistent with a growing national concern about the affects of sprawl. Residents were also slightly more concerned about drinking polluted water and the disposal of toxic wastes for manufacturing and mining in the area, which have been national concerns for three decades (Baxter 1990; Gillespie 1999; Saad 2003, 2004). Traffic congestion/loss of open space was a significantly higher worry than the on-site nuclear weapons legacy ($p < 0.05$).

Table 3. Comparison of Nuclear Weapons-Related and Seven Other Environmental Issues

Environmental issue	% worried a great deal	% worried not at all	Average value*
Traffic congestion and development of area	25.3	20.9	2.39**
Losing open space for hunting, fishing, hiking, and other recreation	24.8	27.2	2.50
Drinking water is polluted	24.1	29.2	2.52
Disposal of toxic wastes from manufacturing and mining	22.3	25.9	2.51
Cleanup of nuclear-weapons related waste will lead to environmental contamination in the area	22.1	28.4	2.56
Agricultural chemical, fertilizer use, dust generation, and open-burning	16.1	24.6	2.57
Terrorism will hit your area	13.2	31.5	2.78**
Natural disaster, such as fire, flood, tornado, hurricane, and earthquake	9.3	31.8	2.88**

*Lower value means more worry: (1=a great deal; 2=some; 3=not much; 4=not at all).

**Cleanup of nuclear-related waste is significantly different from other worry at $p < 0.05$.

Not surprisingly, there was variation among the six sites. At Hanford, Savannah River, and Oak Ridge, nuclear weapon-related waste ranked two, three, and four, respectively among the eight environmental concerns. At Rocky Flats, and Fernald, the nuclear legacy ranked seven and eight, respectively. It also ranked relatively low at INL despite the fact that INL has a good deal of high level waste.

Question 3. Predictors of DOE-Related Worry

The associations between the aggregate "worry" scale and the multiple predictors were tested with both simple (one way analysis of variance, rank correlation) and more complex regression methods. First, we present one-way-analysis-of-variance (ANOVA) results for 15 of the predictors and Kendall's tau-B ordinal correlation coefficient. Then, we present the results of a regression analysis. The variables in Table 4 were selected to represent general environmental concerns, trust, region, distance, age, race/ethnicity, income, sex, education, and respondent familiarity with the site. The ANOVAs present the average values for subgroups (e.g., respondent region), which helps interpret the results. Please note that a lower average value translates to more worry (1 = worried a great deal; 4 = worried not at all).

The overall mean of the peace of mind scale was 2.21 (standard deviation 0.83). The first five variables in Table 4 are environmental predictors (E1-E5). They show that those who are worried about the environment today and are not optimistic about the environment also were more worried about

the DOE's activities. These respondents also did not think the U.S. government or their state government was making the appropriate effort (these were the two highest rank correlations), and they felt that protection of the environment should be given precedence over economic growth. The difference between the worry score for those who are very worried (mean 1.66) about environmental problems in the local

county and those who were not at all worried (mean 2.76) was the largest observed difference (E1).

With regard to DOE-trust, two of the five predictors are presented. The most striking is the difference with regard to communicates honestly (DOE2). Those who strongly agreed that the DOE communicated honestly had much less worry (mean 2.31) than those who strongly disagreed (mean 1.70).

Table 4. Public Fears and Predictor Variables

Variable	Groupings (number of cases in each group)	Mean	F-value	Kendall's Tau rank correlation
All respondents	(1256)	2.21 (std. dev. 0.83)		
E1: Worried about environmental problems in local county	Very worried (115) Somewhat worried (447) Not too worried (425) Not at all worried (212)	1.66 1.99 2.31 2.76	F=70.65*	0.289*
E2: Think about the environment in the county in 25 years	Better (226) Same (327) Worse (620)	2.35 2.52 1.98	F=54.42*	-0.195*
E3: U.S. government is doing too much, too little, or about the right amount in terms of protecting the environment in your area?	Too much (53) Too little (499) About the right amount (606)	2.82 2.53 1.87	F=125.76*	-0.342*
E4: State government is doing too much, too little, or about the right amount in terms of protecting the environment in your area?	Too much (51) Too little (540) About the right amount (580)	2.81 2.49 1.88	F=106.93*	-0.319*
E5: Protection of the environment should be given priority over economic growth	Yes (747) No (427)	2.03 2.48	F=44.82*	0.204*
DOE1: DOE will be able to clean up radioactive and chemical contamination at the sites using new and safe technology	Strongly agree (255) Agree (759) Disagree (138) Strongly disagree (24)	2.32 2.23 1.89 1.93	F=9.67*	-0.095*
DOE2: DOE communicates honestly with the people in this area	Strongly agree (170) Agree (641) Disagree (280) Strongly disagree (78)	2.31 2.35 1.93 1.70	F=29.50*	-0.174*
L1: Respondent is in the following region	Fernald (200) Hanford (200) Idaho National Lab (197) Oak Ridge (204) Rocky Flats (201) Savannah River (204)	2.04 2.34 2.56 2.00 2.20 2.10	F=13.74*	-0.072* 0.066* 0.156* -0.091* -0.001 -0.056*
L2: Respondent distance from the site	Less than 20 miles (660) 20 to 50 miles (547)	2.27 2.10	F=11.53*	-0.086*
D1: Respondent age	18-29 (147) 30-49 (467) 50-64 (380) 65+ (205)	2.13 2.14 2.21 2.37	F=4.30*	0.095*
D2: Respondent race/ethnicity	Non-Hispanic White (1008) Non-Hispanic Black (99) Native American (33) Hispanic American (40)	2.29 1.72 1.76 1.75	F=17.91*	0.199* -0.151* -0.078* -0.099*

Continued on next page

Table 4. Public Fears and Predictor Variables (continued)

Variable	Groupings (number of cases in each group)	Mean	F-value	Kendall's Tau rank correlation
All respondents	(1256)	2.21	(std. dev. 0.83)	
D3: Family income, 2005, \$	Under 25,000 (218) 25,000-49,999 (345) 50,000-74,999 (260) 75,000-99,999 (145) 100,000+ (139)	1.90 2.16 2.23 2.35 2.55	F=15.74*	0.179*
D4: Respondent sex	Male (577) Female (629)	2.42 2.01	F=77.36*	-0.201*
D5: Respondent education	Less than high school (87) High school graduate (373) Post college (327) Four year college (250) Graduate work (173)	1.89 2.01 2.29 2.34 2.43	F=8.25*	0.162*
D6: Respondent familiarity with the site	Worked there (125) Visited there >5 times (107) Visited 1-5 times (173) Driven by (402) Never seen site (249) Never heard of site (150)	2.80 2.36 2.35 2.17 2.02 1.84	F=25.08*	-0.219*

* Statistically significant with one way analysis of variance test or with rank correlation at $p < .01$.
Dependent variable is worried (1=worried a great deal; 4=worried not at all).

The two location variables show bigger site-by-site differences than distance differences. That is, Oak Ridge (2.00) and Fernald (2.04) respondents manifested the most worry and Idaho (2.56), which has high level nuclear waste, the least. The second location variable (L2) showed that those who lived more than 20 miles from the site had slightly higher worry scores than those who lived within 20 miles. We expected that these location variables were confounded by other factors, including respondent familiarity with the site.

Among the six demographic variables (D1-D6), the strongest difference was for the site familiarity indicator (D6). Those who had never heard of the site had a much higher worry score than those who had worked there (1.84 vs. 2.80). Many of the other demographic results were interesting. Non-Hispanic Whites had notably less worry than their Black, Native and Hispanic American counterparts (mean 2.29 vs. 1.74). The poorest group earning less than \$25,000 a year was more worried than the most affluent group with family income more than \$100,000 a year (1.90 vs. 2.55). Consistent with the income difference, those without a high school degree were more concerned than those with a post baccalaureate education (1.89 vs. 2.43). The only demographic characteristic that did not show large differences was age. However, the younger the age group, the greater the worry about the DOE site.

Bivariate relationships do not clarify the relative importance of different independent variables. Consequently, principal components and regression analyses were used to get a better sense of the correlation of the dependent composite worry variable with the independent variables.

Many of the independent variables were correlated. Therefore, principal components analysis was used to collapse the 36 independent variables into 11 new variables that are linear combinations of the original 36. Each of the 11 variables had an eigenvalue ≥ 1.0 , which is the equivalent of at least one of the original variables. Also, 11 new statistically created variables are not correlated. Therefore, there is no collinearity among the independent variables. The principal components analysis produced so-called "factor scores" for each of the 11 principal components for every respondent. The 11 sets were correlated with the dependent worry variable (Table 5). To simplify the interpretation of the regression results, we reversed the worry scores. That is, 4=worried a great deal, 3=worried some, 2=worried not much, and 1=not at all worried.

The strongest of the 11 variables created by principal components analysis measured "general environmental concerns." The seven factor loadings show concern about agriculture, polluted water, waste disposal, natural disasters, terrorism, losing open space and an overall worry about local en-

Table 5. Correlation between Worry and Principal Components

Component name and variables	Factor loadings (r value between original variables and component)	r value between component and worry
General environmental concerns: Agricultural activities are affecting the local environment Drinking water is polluted Disposal of wastes from manufacturing and mining affect the local environment Natural disasters will cause serious damage in the area An act of terrorism will affect the area Overall worry about local environmental problems Area losing open space	0.662 0.654 0.632 0.627 0.616 0.574 0.459	0.507*
Government efforts to protect the local environment: State government is doing too little Local government is doing too little Federal government is doing too little Environment should be given priority over economic growth	0.845 0.795 0.791 0.433	0.273*
Socioeconomic status: Respondent education completed Respondent family income Respondent voted in an election during the last two years	0.772 0.770 -0.477	-0.243*
DOE trust: Trust DOE to manage waste left on the site Trust DOE to manage any new waste left on the site DOE will make sure underground materials will not pollute outside the site boundary DOE communicates honestly with people in the area DOE will be able to clean up the site	0.837 0.825 0.809 0.764 0.761	-0.176*
Personal experience: Fernald respondent Personal experience with DOE site Idaho respondent	0.885 -0.658 -0.414	0.175*
Savannah River/African American respondent: Savannah River respondent African American respondent	0.811 0.703	0.136*
Female respondent:	0.750	0.134*
Respondent age: Age of respondent Length of residence in the county Voted an election during the last two years	0.786 0.668 0.452	-0.096*
Rocky Flats respondent: Rocky Flats respondent Traffic congestion a major concern Idaho respondent	0.823 0.513 -0.433	0.069*
Nearby resident: Oak Ridge respondent Respondent lives within 20 miles of the site Idaho respondent	0.795 -0.665 -0.456	0.049*
Hanford respondent	0.855	0.009

*Correlations are significant at $p \leq 0.01$.

Multiple r value for the 11 variables was 0.709.

vironmental problems. This general environmental concern component had a correlation of 0.507 with the worry variable.

The second component, which we called "government efforts to protect the local environment," consisted of three variables that measured the public's perception of federal,

state, and local government efforts to protect the environment. The fourth variable in this set measured respondents' choices between economic growth and environmental protection. This government effort component had a correlation of 0.273 with the worry variable. In essence, it shows that some

respondents believe that the three major levels of government are not doing enough to protect the environment, and they prefer environmental protection over economic growth. These respondents were more worried about the DOE site than were their counterparts.

The third component measured socioeconomic status, including education completed and family income. It also indicated if a respondent had voted in an election during the last two years. The correlation of -0.243 shows that higher socioeconomic status respondents were less worried than their lower socioeconomic status counterparts.

The fourth component was called "DOE trust." The component consisted of five variables that measured respondents' assessment of the DOE's capacity to effectively manage existing waste, new waste, and communicate with the public. The correlation of -0.176 shows that less trusting respondents were more worried about activities on the DOE site than their more trusting counterparts.

The fifth component focused on personal experience at two of the six sites. Respondents who lived near the Fernald site in Ohio were more worried than were respondents who were familiar with the DOE site and lived near the Idaho facility. This "personal experience" component had a correlation of 0.175 with worry.

The sixth component focused on African-American respondents disproportionately from the Savannah River site. It had a correlation of 0.175 with the worry dependent variable. In other words, African Americans living near this site were more concerned than were other respondents.

The seventh component distinguished between female and male respondents. Female respondents tended to be more worried, measured by the correlation of 0.134 with worry.

The remaining four components had correlations of less than 0.1 with the worry variable. The first of these was an "age" component, which contrasted respondents who have lived in the area for many years and who voted in an election during the last two years with their younger counterparts who had not voted in an election during the last two years. The older respondents tended to be less worried than their younger counterparts, as suggested by the -0.096 correlation with the worry variable.

The second of the four less correlated components, number nine of 11 overall, compared Rocky Flats respondents who were distressed about traffic congestion and other elements of sprawl in the Denver area with respondents, disproportionately from the Idaho site, who were not. This Rocky Flats factor was correlated 0.069 with worry.

The 10th component contrasted more worried Oak Ridge area residents who lived more than 20 miles from the site with Idaho respondents who lived within 20 miles of the site.

The correlation was 0.049. The 11th component was a Hanford resident factor, and it was not correlated with the worry variable.

Overall, the principal components analysis produced 11 uncorrelated independent variable components that included 33 of the 36 independent variables in one or more of the components. These 11 components had a multiple correlation of 0.709 with the composite worry variable.

Discussion

This study constituted one part of a three pronged effort to explore what people who live near six major U.S. Department of Energy nuclear weapons facilities worry about regarding the site and other local risks. Before reviewing the results and indicating their public policy implications, we reiterate the study's limitations, all of which are related to resource limitations for the study and are common to every survey study. First, the number of surveys at each site was limited to 225. We would have felt more confident if resources had allowed 400 or 800 samples at each site. Second, while we could compare each of the six sites, we would have benefited by having a national sample with the same questions to provide context. Third, while we asked about 15 potentially worrisome site activities, our original list was more than double that list. Fourth, we also had to eliminate questions that might have helped us better understand the predictors of worry. For example, we had to substantially reduce the number of trust questions. It would have been helpful to have had questions about public future use preferences (e.g., hunting, fishing, hiking, commercial, industrial). Fifth, as noted earlier, the literature offers some potentially interesting hypotheses about the role of the mass media in these results. Coverage that is critical of the DOE and a great deal of coverage, even if more positive than negative, would be expected to amplify public fears. Currently, we are examining the relationship between the results of this study, local mass media coverage at these sites, and topics that the community advisory boards at each of the six sites discuss.

The five limitations of the current study should be addressed in future research. Future research should also address the possibility that the United States might decide to build new electricity generation facilities using nuclear fuel. The public will connect nuclear power and the nuclear waste legacy at these sites because some of these sites could host generating facilities and/or be the repository for more waste and technology development. Future surveys should add questions about these subjects.

Given these caveats, the study showed, as expected, that with regard to the DOE sites the public was more worried about threats to water supply, workers, and transportation-re-

lated accidents than they were about impacts on jobs, archeological sites and ecological systems. With regard to cleanup of the site, the study showed that most people who live within 50 miles of one of these six nuclear weapons sites were mildly to moderately concerned about the legacy. Other environmental issues in their counties, such as open space, water pollution, and local manufacturing and mining operations were considered slightly more worrisome by most of the respondents. The exceptions were Hanford and Savannah River where the nuclear legacy ranked second and third in priority.

Two of the most interesting findings from questions 1 and 2 merit follow-up. One was the great concern respondents in these areas showed toward the loss of open space, an observation most commonly identified with large metropolitan regions. Second, the low relative risk regarding on-site fires and explosions merits further investigation. We suggest that these two findings will be most effectively investigated with focus groups and face-to-face interviews rather than in large scale surveys.

The predictors of worry (question 3) were interesting because of their variety. As suggested by theory, the biggest drivers were concern about the surrounding local environment. Yet, distrust of the DOE, self-identification as female, African American, relatively low income and less education, and lack of familiarity with the site were associated with more worry.

The research has implications for the DOE, state and local government, community advisory boards, and other stakeholders. On the one hand, respondents are not terrified of these sites; other local environmental problems are equally or in some cases more worrisome to them. There is no emergency; the DOE and other groups have time to think about what they want to do. On the other hand, the public is worried about a predictable set of direct and indirect threats to human health. The demographic predictors of greater worry are that those who are not knowledgeable about the site, live further away from it, who are relatively poor, and non-White are the most concerned.

This implies that the DOE needs to increase efforts to communicate with segments of the public that are likely to be difficult to reach and not necessarily trusting of what the DOE will say to them. This is not an easy challenge, especially for this Department, which bred a culture of secrecy in order to guard the secrets of its technology. Not until 1993 did the Department declare that it needed to open itself to public scrutiny (OEM 1995a). Arguably, the Atomic Energy Commission was the most secretive federal department ever and the DOE took up the secrecy mantle. The first part of the challenge will be to accept that it is essential that the DOE, other federal agencies, and the community advisory boards

try to build and sustain a DOE-stakeholder link that will need to last in perpetuity at some of these sites, and that link needs to include efforts to reach out to people who do not live in the immediate area of the site and do not know a lot about the DOE's activities. The second part of the challenge is that the DOE must accept the reality that the vast majority of people base their personal risk analyses more on emotions, some of which are unconscious, and previous experience than they do on deliberative linear reasoning. Trying to directly confront emotion and experience-based perceptions as irrational will be counterproductive to building the trust needed to engage the public in an ongoing multi-generational dialogue that is essential at these nuclear weapons legacy sites. These two challenges, in our opinion, are as difficult and perhaps more sobering than the scientific, engineering, economic and legal challenges the DOE faces in managing these waste sites in perpetuity.

Endnote

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