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Race, Class, and the Distribution of Radioactive Wastes in Massachusetts

Douglas L. Anderton
John Michael Oakes
Michael R. Fraser

Objective. Inequity in the distribution of environmental burdens among social groups, for example, minority and disadvantaged segments of the population, is an important topic in policy research. This research has largely focused on hazardous waste facilities and Superfund sites. Yet federal mandates to the states raise similar concerns over the social distribution of low-level radioactive waste facilities (LLRWs). This study seeks to provide the first evaluation of equity in the distribution of LLRWs within a state.

Methods. We use data from the 1990 Census to compare selected characteristics of tracts with low-level radioactive waste facilities to tracts without, tracts nearby LLRWs to those more distant, and tracts with LLRWs, which may be more, and less, undesirable to other tracts.

Results. Findings suggest that communities with LLRWs differ from other tracts in their residents' racial composition, socioeconomic status, industrial employment, and housing characteristics. LLRWs more likely to be viewed as undesirable are even more likely to be located in areas with fewer white and affluent populations.

Conclusions. Despite difficulties in assessing the relative risks and benefits of LLRWs, our results support concern for environmental justice issues in the future siting of LLRWs and in mandated state planning for low-level radioactive waste long-term storage.

A growing interest in environmental equity has spurred recent research on the siting of locally unwanted land uses such as landfills, industrial facilities, and Superfund sites. It is generally agreed that racial and ethnic minorities and the economically disadvantaged are likelier to suffer disproportionate environmental burdens than more affluent members of society. Significant policy directives, including Presidential Executive Order 12898, have dictated that greater attention and concern be paid to environmental justice. Empirical research regarding specific locally unwanted land uses and environmental equity, however, has led to disparate conclusions.¹ As policy demands grow rapidly in the area of environmental equity, so does

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the need for policy-oriented research and specific empirical assessments of environmental equity for other environmental industries and land uses. This study presents an analysis of environmental equity for one specific type of facility: low-level radioactive waste facilities (LLRWFs).

Research on the relationship between the residential distribution of social groups and the location of environmental hazards related to industrial land use has increased dramatically since the United Church of Christ released a report alleging that commercial hazardous waste facilities and Superfund sites are more likely to be located in minority and lower-income communities.² But social scientists have long been interested in differences in living environments,³ the location of industries,⁴ the distribution of public goods and burdens,⁵ the political economy of place or location,⁶ and the distribution of pollutants.⁷ More recent environmental equity research has examined the empirically demonstrable relationships between specific environmentally suspect land uses and the demographic characteristics of host communities. Most of this research has been limited to commercial hazardous waste facilities or Superfund sites.⁸ While these land uses are important, there is a growing interest in, and policy need for, expanding the investigation to include other land uses that are either themselves environmentally suspect or required by new regulations to consider the issues of environmental equity.

Studies of specific types of facilities contribute to the general debate over the extent and practical remediation of environmental inequities. Such studies may also amplify or eliminate specific concerns, thereby aiding in the setting of realistic and responsible priorities. By identifying specific inequities, such studies may also suggest potential policy mechanisms or remedies ranging in scope from local zoning ordinances to national regulations or requirements. Specific land use studies are also necessary to provide comparative empirical data for use in the local assessment of equity now required in environmental impact statements.

This study addresses questions of environmental equity with respect to low-level radioactive waste facilities by comparing the characteristics of communities, more specifically census tracts, with and without LLRWFs. The study is limited to LLRWFs in Massachusetts. Results of the study may suggest whether environmental equity is, or should be, an issue in the siting of such facilities in the future and in the siting of more permanent storage facilities for the low-level radioactive wastes.

Low-Level Radioactive Waste in Massachusetts

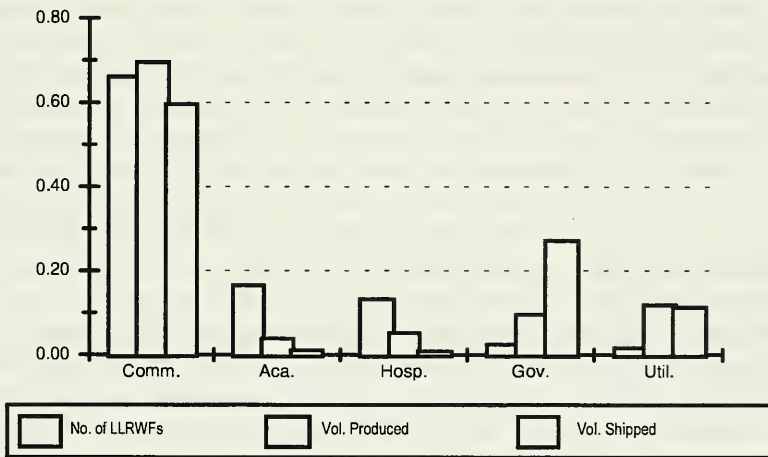
Low-level radioactive waste facilities are diverse. Those in Massachusetts are classified in five categories: academic, commercial, government, health, and utility.⁹ Academic LLRWFs generally use radioactive materials for research and training purposes. Commercial generators include biotechnology firms and other private companies that use radioactive materials in the research, development, and manufacture of goods and services. This category also includes environmental industries that either dispose of or decontaminate low-level radioactive waste generated by other sources. Local, state, and federal agencies that generate radioactive waste comprise the government generator category. Health and medical LLRWFs use low-level radioactive materials in the diagnosis, prevention, and treatment of disease. Utility companies generate low-level radioactive waste indirectly in the production of electricity by nuclear power plants and are the typical generators in the utility category. Many

LLRWs may be viewed as beneficial to the communities in which they are sited. Yet specific facilities in each of these categories have been a locally unwanted land use or have been contested on the specific grounds of environmental justice.

Figure 1 presents the percentage distribution of LLRWs, volume of waste produced, and volume of waste shipped by facility category for the LLRWs in this study. The figure shows that of the 121 LLRWs examined, about 66 percent are commercial. They produce about 70 percent of the 340,000 cubic foot low-level radioactive waste stream and about 60 percent of the 119,000 cubic foot stream shipped to other facilities for disposal. Although specific data on radioactivity — measured in curies — were not available, research suggests that commercial facilities generate and ship about 65 percent of the curies produced per year.¹⁰ Despite their smaller numbers and volume of waste generated, utility LLRWs produce the next largest proportion of curies, 32 percent. Consequently, commercial and utility LLRWs are of particular interest.

Figure 1

Relative Percentages of the Number of LLRWs, Volume of LLRW Produced, and Volume of LLRW Shipped by Category and for Facilities in 1993 Study



In 1980, the federal Low-Level Radioactive Waste Policy Act required states to develop plans for radioactive waste management and disposal. The urgency of state-level planning increased significantly when one of the county's largest disposal sites, in Barnwell, South Carolina, was scheduled to be closed to future out-of-state wastes. The decision to limit such waste there was rescinded, and the site, along with others in Clive, Utah, and Hanford, Washington, still receives low-level radioactive waste from Massachusetts. Meanwhile, courts have maintained that the 1980 legislation continues to compel states to comply with the obligation to provide for disposal of waste generated within their borders.¹¹ In Massachusetts, the need for disposal facilities has also been heightened by the accumulation of low-level wastes from the state's two nuclear facilities, Yankee Rowe, now closed and nearly decommissioned, in Rowe, and Pilgrim in Plymouth.¹² However, prospective planning for

long-term LLRW storage facilities in Massachusetts and many other states is creating the familiar “not in my backyard” syndrome with growing concerns over equity in the distribution of existing and future sites.¹³

Low-Level Radioactive Waste Facility Research Requirements

Empirical assessment of environmental equity is difficult. Complexity stems from both the conceptual ambiguity in the term “equity” and the great methodological difficulties inherent in risk analyses.¹⁴ These problems are most pronounced when the risks and benefits of facilities are more difficult to determine or presume. As a result, most attempts to assess environmental equity simply assess the sociodemographic distribution of “plausible” environmental burdens across communities. Under the dictum “do no harm,” it may appear reasonable to focus on plausible environmental burdens and neglect potential benefits. But researchers should not lose sight of the fact that benefits from many specific facilities may be appreciable and that greater harm might result from removing a facility from a community.

As more and more communities with low-level radioactive waste facilities become concerned about low-level radioactive waste in their neighborhoods, tension has developed between the economic benefits and opportunities that are created through the use of low-level radioactive materials and the risks such materials pose to public health and safety. For example, despite their arguable benefits, commercial decontamination facilities, utility-operated facilities, and similar industrial enterprises are likely to be seen as environmental burdens that should either be removed or for which the community should be compensated. At the same time, few would argue that a hospital using radioactive materials in the treatment of disease or a university research firm generating low-level radioactive waste should be moved out of an inner-city neighborhood. Such services are necessary and create a localized public good in terms of employment opportunities, health care for neighborhood residents, and broader social benefits.

Nonetheless, at the time of their siting, many of these facilities are viewed as undesirable land uses by the communities in which they are to be located. The cumulative wastes from many benign or beneficial LLRWs require some long-term disposal or storage facility, which in turn is seen by many residents as a huge environmental burden or harm. The empirical assessment of environmental equity cannot easily resolve these complex issues nor incorporate neutrally such ethical distinctions between good and bad LLRWs. Such differentiations are ultimately rooted in the relative value communities place on benefits and burdens of specific facilities and their ability to externalize burdens by relegating waste storage to other communities while expropriating facility benefits for their own community. Environmental equity policies have adopted the more neutral stance that all types of environmental burdens should receive attention if they are socially distributed in a biased fashion that is plausibly harmful to any specific social group or stratum.

Although hazardous waste facilities, Superfund sites, air pollution levels, lead pollution levels, and similar environmental burdens have been evaluated for environmental inequities, no similar study regarding low-level radioactive wastes has been published. LLRWs are, in most cases, less identifiable potential nuisances or threats than industrial facilities or sites. This may be because these sites are less clearly viewed as locally undesirable land uses. The broad standardized data avail-

able for other types of facilities, for example, the Toxic Release Inventory, Resource Conservation and Recovery Information System, and so forth, are not available nationwide for LLRWFs.

The federal mandate to consider cumulative environmental burdens within communities that may be unfairly subjected to such burdens clearly extends to the question of whether LLRWFs are distributed in a consistently inequitable fashion. New requirements to address environmental equity in the environmental impact statements filed for new LLRWFs must include some empirical guidance or baseline data concerning the existing distribution of facilities. Of course, there is also interest in knowing the distribution of current facilities before planning a permanent storage or disposal facility. While our study is limited to Massachusetts, similar concerns are being expressed across the nation.

To initiate an environmental equity survey of LLRWFs, our study describes the demographic characteristics of Massachusetts communities that house low-level radioactive waste generators and compares them to the demographic characteristics of Massachusetts communities that do not. These comparisons help to determine whether specific categories of Massachusetts residents live disproportionately in areas where low-level radioactive waste is generated, treated, contained, or stored. The result of these comparisons leads to a better understanding of what types of communities host low-level radioactive waste facilities and what kinds of individuals reside nearest to both the benefits and the risks that these sites bestow upon their neighbors. We hope that these results provide some preliminary guidance to further research, the preparation of environmental impact statements for LLRWFs, and considerations of equity in deriving long-term solutions to the disposal or storage of low-level radioactive wastes.

Data Collection and Methods

We obtained the data in our study from the Massachusetts Low-Level Radioactive Waste Board in the form of a list of 125 low-level radioactive waste generators operating in the commonwealth in 1993, including facility addresses, telephone numbers, names of the facility radiation safety officers, and the type of facility. We dropped four facilities from our study because missing or out-of-state addresses could not be determined. We cover the remaining 121 facilities on the waste board list in our analysis.

We computer-matched, or geo-coded, facility addresses to their corresponding 1990 census tract number. In cases of ambiguous or missing addresses, we surveyed the facility to obtain the correct information.¹⁵ The 121 facilities were located in 84 different Massachusetts census tracts. Of the 84 tracts with LLRWFs, 80 percent had only one, 15 percent had two or three, and 5 percent had more than three facilities.¹⁶

We selected data from the 1990 decennial census of population and housing for each of the 1,331 census tracts in Massachusetts¹⁷ and added information indicating the presence and number of LLRWFs. We culled nine variables from this larger file to summarize the demographic characteristics of the tracts. The variables correspond to those used in similar studies of environmental equity.¹⁸

Six of the nine summary tract characteristics chosen for further analysis reflect hypotheses that environmental burdens are disproportionately placed in communities with higher proportions of minorities or disproportionately low-income popula-

tions. We selected percentage of white persons, percentage of black persons, and percentage of Hispanic persons of any origin and race to characterize their racial and ethnic composition. Similarly, we selected the percentage of families below the poverty line (for nonfarm families of four), percentage of households receiving public assistance in 1989, and percentage of adult males, age sixteen and over, employed in the civilian labor force to summarize the socioeconomic characteristics of the population.

Three additional variables reflect alternative hypotheses that environmental burdens are distributed primarily in areas of industrial activity, newly built neighborhoods, or affordable siting opportunities. To summarize the industrial and land-use characteristics of tracts, we obtained the percentage of those employed in industrial occupations (precision production, craft, repair, operator, fabricator, and laborer), the percentage of owner-occupied housing built before 1960, and the mean dollar value of the owner-occupied housing stock. The nine variables in this analysis provide demographic characteristics relevant to the study of environmental equity and allow for a direct comparison with prior studies.

We evaluated equity by comparing the characteristics of tracts with LLRWFs to tracts without LLRWFs. To reduce confounding influences (for example, the spurious correlation of minority residence and commercial enterprises owing to their being more likely in metropolitan areas) these comparisons are limited to those Massachusetts tracts which have no LLRWFs but lie within counties or census-defined metropolitan statistical areas that contain at least one LLRWF. This research design also ensures comparability with prior studies and, in all, only eighteen rural Massachusetts tracts were excluded from the comparisons.¹⁹

Analysis

To identify possible inequity in the distribution of low-level radioactive waste tracts containing one or more facility, we compared tracts without facilities, applying several different statistical tests. Table 1 presents the results of t-tests for the difference between the average characteristics of tracts with and without at least one low-level radioactive waste facility. However, some community characteristics analyzed have strongly skewed distributions, so we also computed an alternative test, a Wilcoxon Z statistic, for significant differences in the median community characteristics of tracts with and without LLRWFs. The two statistical tests address different plausible hypotheses of distributional inequity, each with its own strengths. The number of LLRWF tracts and other tracts varies according to the availability of data.²⁰

Overall, LLRWF tracts are in areas with a significantly lower percentage of white residents and a significantly higher percentage of black residents than tracts without LLRWFs. These tracts also have a higher percentage of Hispanic residents, though the real difference between the means is less than 0.25 of a percentage point. Although the substantive difference in some community characteristics is not great, statistical significance does provide a preliminary indication of possible racial and ethnic residential inequities in the distribution of low-level radioactive wastes in Massachusetts. A comparison of families living below the poverty line shows that LLRWF tracts and other tracts do not differ significantly. In fact, tracts without LLRWFs have a significantly higher percentage of households receiving public

Table 1

Comparison of Communities with Low-Level Radioactive Waste Facility (LLRWF) to Communities without LLRWFs in Massachusetts Metropolitan Statistical Areas or Counties with at Least One LLRWF, 1990

Community Characteristic	Tract Mean		Cases	t-Test	Wilcoxon Z
	LLRWF	Other			
Percentage White	83.74	88.21	84	-1.88 ^a	-3.87 ^b
Percentage Black	7.33	5.97	84	1.01	3.34 ^b
Percentage Hispanic	5.79	5.55	84	0.28	2.94 ^b
Percentage Families below Poverty Line	11.63	11.48	83	0.10	-1.43
Percentage Households Receiving Public Assistance	7.79	8.77	83	-1.04	-1.92 ^a
Percentage Males Employed	92.56	91.63	83	1.92 ^a	1.48
Percentage Industrial Employment	16.64	23.03	84	-6.11 ^b	-5.46 ^b
Percentage Housing Built before 1960	57.24	61.76	83	-1.79 ^a	-1.89 ^a
Mean Value of Housing Stock (1000 \$)	220.49	177.83	76	3.81 ^b	4.93 ^b

^ap < .10

^bp < .01

assistance. Tracts with LLRWFs have a lower percentage of employed males, but the difference between the means is slight. Overall, there is no substantial indication of socioeconomic inequities in the distribution of low-level radioactive wastes in the commonwealth. LLRWF tracts show significantly less industrial employment than non-LLRWF tracts. On average, LLRWFs tracts contain significantly newer housing than tracts without LLRWFs, and their housing stock is worth more than that of tracts without LLRWFs. That is, unlike most other hazardous waste facilities and sites studied, LLRWFs do not appear to be primarily located in industrial areas. This is significant in that many of the explanations for the location of hazardous waste facilities emphasize their location near the industrial market and infrastructure of metropolitan areas.

Although census tracts are a standard unit of analysis, it is also important to consider the wider area around the tracts with facilities. Prior equity research has indicated that neighboring areas may be substantially different from those which actually contain specific facilities. Table 2 compares those tracts nearest those with LLRWFs, that is, those whose centroid falls within two miles of the centroid of the nearest tract with an LLRWF, to other more distant tracts. The differences between the means of the "surrounding area" tracts and more distant tracts are statistically significant for all nine descriptive variables in the analysis. Surrounding area tracts have a lower percentage of white residents, a higher percentage of black residents, and a higher percentage of Hispanic residents. Unlike the data presented in Table 1, however, surrounding area tracts have significantly more families living below the poverty line than other tracts. The other variables are consistent with the results of Table 1; surrounding area tracts have more families on public assistance, fewer employed males, less industrial employment, newer housing, and a higher mean value of housing than other tracts. Overall, these surrounding areas do not appear as substantially different as the surrounding areas for commercial hazardous waste facilities.²¹

Some detail of residential distributions may be obscured by aggregation in defining a specific surrounding area. To provide greater detail, Figures 2, 3, and 4 provide graphs of the average of three central equity variables — percentage of black residents, percentage of Hispanic residents, percentage of impoverished families — by the distance, in miles, to the nearest LLRWF. For comparison, each graph also illustrates, across all tracts, the average of each characteristic, represented by a horizontal line.

Figure 2 shows that the average percentage of black residents rises from just over 7 percent in tracts with at least one LLRWF to approximately 12 percent for tracts within one mile of the centroid of LLRWF tracts. These percentages are higher than the average percentage of blacks by about 6.5 percent. At two miles out, the average falls to about 9 percent, then continues to fall almost monotonically until about twelve miles out. Figure 3 shows that the average percentage of Hispanics in communities with, or near, LLRWFs is much greater than one would normally expect, but again falls dramatically as the distance from an LLRWF increases. Figure 4 illustrates that the average percentage of families below the poverty line rises sharply in the neighborhoods closest to LLRWF communities but is erratically distributed about the overall mean, affirming the findings in Table 1 and indicating that the results of Table 2 may suffer somewhat from aggregation over the arbitrary definition of surrounding areas.

Table 2

Comparison of Communities within Two Miles of a Community with at Least One Low-Level Radioactive Waste Facility (LLRWF) to Communities without LLRWFs in Massachusetts Metropolitan Statistical Areas or Counties with at Least One LLRWF, 1990

Community Characteristic	Tract Mean		Cases		t-Test	Wilcoxon Z
	LLRWF	Other	LLRWF	Other		
Percentage White	79.63	91.52	393	905	-8.78 ^a	-12.66 ^a
Percentage Black	10.24	4.24	393	905	5.68 ^a	9.63 ^a
Percentage Hispanic	9.93	3.67	393	905	7.86 ^a	11.53 ^a
Percentage Families below Poverty Line	15.24	9.88	384	897	7.11 ^a	7.51 ^a
Percentage Households Receiving Public Assistance	11.05	7.71	386	898	5.60 ^a	4.53 ^a
Percentage Males Employed	90.83	92.06	389	898	-3.32 ^a	-2.05 ^a
Percentage Industrial Employment	20.67	23.45	389	900	-3.93 ^a	-5.21 ^a
Percentage Housing Built before 1960	72.95	56.54	386	899	13.88 ^a	12.54 ^a
Mean Value of Housing Stock (1000 \$)	195.50	174.13	368	879	3.94 ^a	2.40 ^a

^ap < .01

p < .05

Figure 2

Mean Percentage of Black Persons by Distance in Miles to Nearest LLRWF Tracts in Massachusetts, 1990

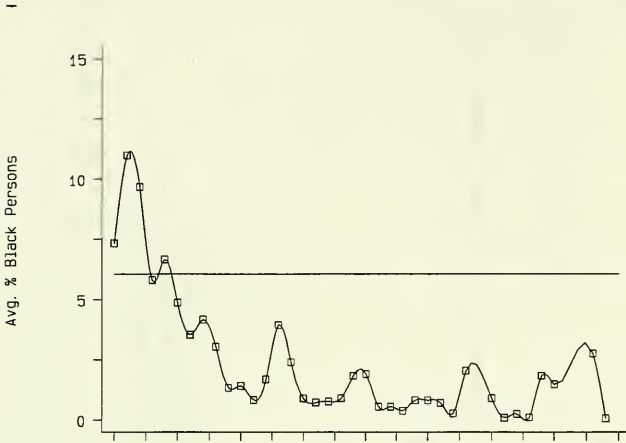


Figure 3

Mean Percentage of Hispanic Persons by Distance in Miles to Nearest LLRWF Tracts in Massachusetts, 1990

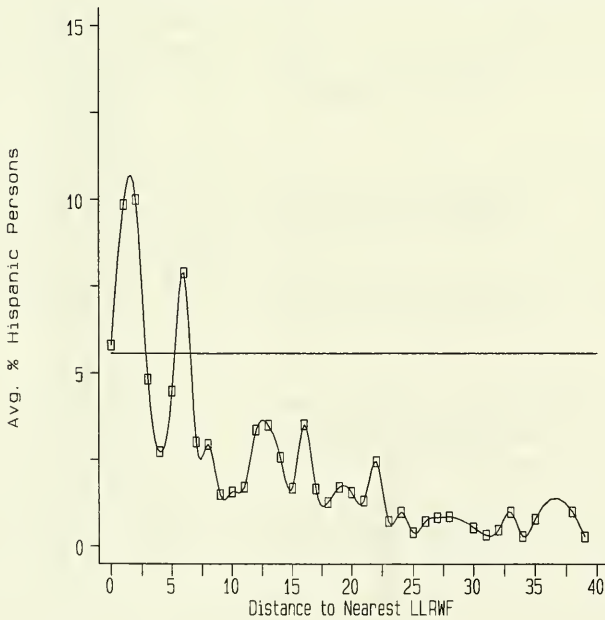
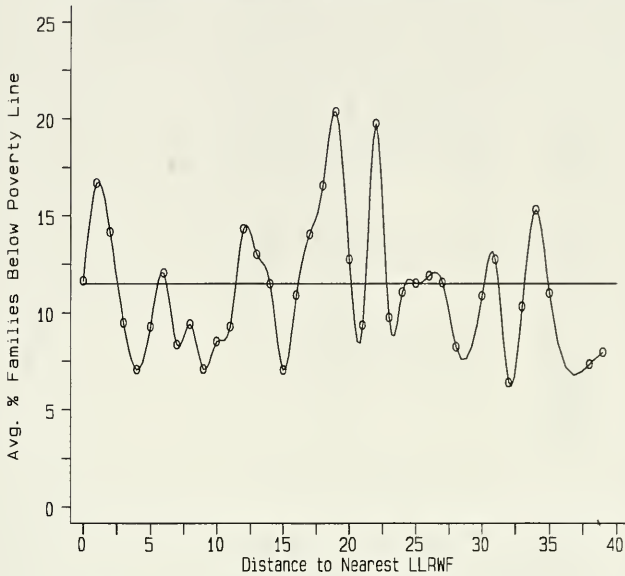


Figure 4

Mean Percentage of Families below Poverty Line by Distance in Miles to Nearest LLRWF Tracts in Massachusetts, 1990



One limitation of these comparisons is that it is quite difficult to distinguish between locally undesirable, or potentially harmful, LLRWFs and those which may be viewed as either desirable or beneficial. However, it is possible to distinguish some categories of LLRWFs that may indicate their potential acceptance by communities. Table 3 compares a subset of fifty-eight tracts containing LLRWFs classified as academic, government, or hospital generators to all other tracts in the analysis (four of these tracts also contain corporate or utility generators). The fact that these facilities are largely small-scale LLRW generators and noncommercial might suggest that they are indicative of the least politically controversial, and perhaps most desirable, of the LLRWFs. The results of this analysis are mixed.

In academic, government, and hospital LLRWF tracts, the average percentages of white, black, and Hispanic residents are roughly equal to those in other tracts. Yet comparing median percentages, there are more black and Hispanic residents in these tracts. Fewer residents live below the poverty line or receive public assistance in this subset of facility tracts, using either differences in average or median community characteristics. Similarly, these LLRWF tracts have a greater percentage of employed males, a smaller percentage of persons employed in industrial occupations, and more new and greater-valued housing stock. In short, there is mixed evidence of racial/ethnic inequity, and academic, government, and hospital LLRWF tracts appear to be generally less prosperous and marginally less industrial than other neighborhoods.

Table 4 presents a comparison of the thirty tracts with commercial or utility generators to the other tracts in the analysis. Historically, these types of waste generators have drawn more scrutiny and less acceptance than the other LLRWF categories. Fewer white persons and more black and Hispanic persons live in tracts with at

Table 3

Comparison of Massachusetts Low-Level Radioactive Waste Facility (LLRWF) Communities Classified as Academic, Government, or Hospital Compared to Communities without LLRWFs in Massachusetts Metropolitan Statistical Areas or Counties with at Least One LLRWF Classified as Academic, Government, or Hospital

Community Characteristic	Tract Mean		Cases LLRWF	Other	t- Test		Wilcoxon Z
	LLRWF	Other			LLRWF	Other	
Percentage White	87.10	87.96	58	1240	-0.38	-2.10 ^a	
Percentage Black	6.57	6.03	58	1240	0.36	1.94 ^b	
Percentage Hispanic	5.29	5.58	58	1240	-0.28	1.65 ^b	
Percentage Families below Poverty Line	9.43	11.58	58	1223	-1.51	-2.33 ^a	
Percentage Households Receiving Public Assistance	7.17	8.78	58	1226	-1.69 ^b	-1.81 ^b	
Percentage Males Employed	93.07	91.62	58	1229	2.83 ^c	2.17 ^a	
Percentage Industrial Employment	18.07	22.83	58	1231	-3.74 ^c	-3.32 ^c	
Percentage Housing Built before 1960	55.34	61.76	58	1227	-2.34 ^a	-2.45 ^a	
Mean Value of Housing Stock (1000 \$)	221.97	178.52	55	1192	3.28 ^c	4.33 ^c	

^ap < .05

^bp < .10

^cp < .01

Table 4

Comparison of Massachusetts Low Level Radioactive Waste Facility (LLRWF) Communities Classified as Corporate or Utility Compared to Communities without LLRWFs in Massachusetts Metropolitan Statistical Areas or Counties with at Least One LLRWF Classified as Corporate or Utility

Community Characteristic	Tract Mean		Cases	t-Test	Wilcoxon Z	
	LLRWF	Other				LLRWF
Percentage White	75.43	87.81	30	1138	-2.52 ^a	-4.22 ^b
Percentage Black	9.67	6.21	30	1138	1.44	3.76 ^b
Percentage Hispanic	7.29	5.79	30	1138	1.12	3.29 ^b
Percentage Families below Poverty Line	16.29	11.05	29	1124	1.65	1.15
Percentage Households Receiving Public Assistance	9.39	8.32	29	1127	0.55	-0.24
Percentage Males Employed	91.85	91.87	29	1130	-0.02	-0.42
Percentage Industrial Employment	12.79	21.68	30	1131	-6.23 ^b	-5.04 ^b
Percentage Housing Built before 1960	59.19	61.39	29	1128	-0.46	-0.33
Mean Value of Housing (1000 \$)	230.48	184.31	24	1096	1.89 ^c	2.25 ^c

^ap < .05

^bp < .01

^cp < .10

least one commercial or utility LLRWF. A higher percentage of families live below the poverty line, and more households receive public assistance in these tracts; however these differences are not statistically significant. Almost equal percentages of male employment are found in areas with and without corporate and utility LLRWFs. However, the percentage of persons industrially employed is significantly lower in the commercial and utility LLRWF tracts. Fewer houses were built before 1960, indicating newer housing in these LLRWFs, but this result is not statistically significant. Housing in commercial and utility LLRWF tracts has a higher mean value than housing in other tracts. In short, neighborhoods with commercial or utility LLRWFs have higher percentages of minority residents and fewer residents who are industrially employed than other areas.

All these relationships examine each variable in isolated association with the presence of one or more LLRWFs. Many of these variables are, however, interrelated, and bivariate analyses may obscure important multivariate relationships. For example, it may be that when the percentage of male employment is controlled statistically, the percentage of families in poverty is no longer significantly related to the location of LLRWFs. These multivariate relationships are essential to understanding the character of environmental inequities.

To provide a multivariate analysis, we employed logistic regressions estimating how the odds of a tract containing one or more LLRWFs are related to community characteristics, net of other included characteristics. It was necessary to exclude some variables from the analysis because of problems of multicollinearity. The variables included are those which are statistically significant in one of the tables. The selection criteria based on the marginal significance of the variables is reasonable and coincidentally eliminates the problems of multicollinearity in the regression.

Table 5 presents the results of such a logistic regression with the presence of at least one LLRWF as the dependent variable. In this regression, the percentage of white residents is significant. LLRWFs are slightly less likely to be in neighborhoods with a higher percentage of whites. A tract with a 10 percent higher white population, for example, is only about 82 percent as likely to contain an LLRWF (that is, $\exp[(10)(-0.020078)] = 0.82$ to 1). A tract with a higher percentage of housing built before 1960 is also less likely to contain an LLRWF, although the effect is less substantial. These results are consistent with those of Tables 1, 3, and 4 in the direction of significant effects. However, compared with the simple bivariate tests, industrial employment, value of housing, and the percentage receiving public assistance appear less significant. Most of these differences arise because these community characteristics are correlated with the percentage of white residents.

The evidence of inequity in the distribution of low-level radioactive wastes in Massachusetts appears to be primarily limited to a slightly lower likelihood of LLRWFs being located in neighborhoods with a higher percentage of whites. From earlier tabulations it might also be argued that LLRWFs, especially commercial- and utility-operated ones, are more likely to be found in Hispanic neighborhoods. In any case, without significant additional analyses it is difficult to associate risk or benefit with these facilities. However, a preliminary finding of inequitable distribution is, at the least, grounds for concern and attention in the siting, and related impact statements, of additional LLRWFs and in the commonwealth's planning for a more permanent storage or disposal facility.

Table 5

Logit Regression Predicting Communities with LLRWFs from Select Characteristics of Communities without LLRWFs in Massachusetts Statistical Areas or Counties with at Least One LLRWF

Community Characteristic	Coefficient
Percentage White Persons	-0.020078 ^a
Percentage Households Receiving Public Assistance.	-0.037310
Percentage Males Employed	0.014142
Percentage Industrial Employment	-0.026648
Percentage Housing Built before 1960	-0.009003 ^b
Mean Value of Housing Stock (1000 \$)	0.000003
Constant	-1.477346
Chi-square (8 df)	29.60
Probability > Chi-square	0.00
Total Observations	1,246
Total LLRWF Tracts	75

^ap < .05

^bp < .10

Conclusions

The demand for, and scope of, environmental equity research has grown rapidly in recent years. This investigation is expanding to address a variety of locally unwanted land uses. In addition, under the impetus of recent governmental policy initiatives, the needs encountered in preparation of environmental impact statements, and a general research interest in cumulative environmental burdens, the range of environmental equity concerns to receive research attention will undoubtedly continue to increase. Yet most research and political concern has been directed at specific industries and facilities that process or store potentially hazardous wastes on site. We have attempted to expand the discussion of such sites to include facilities that generate, process, or store low-level radioactive wastes on site. It is particularly important to address this group of facilities at a time when many states are in the process of attempting to locate new long-term low-level radioactive waste storage sites. The setting of such a facility is imminent in Massachusetts, the state we have chosen to study, and a number of other states.

Concerns over inequity in the current distribution of LLRWFs should translate into the valid consideration of environmental equity in siting a longer-term storage facility. The establishment of such a facility is almost certain to be viewed as a locally undesirable land use by communities. The permanence of such a facility, the volume of wastes envisioned, stigmas concerning disposal facilities, and the high emotions attached to radioactive wastes in particular guarantee that the siting of such facilities will be politically charged. However, when one turns to existing LLRWFs, the lines are not so clearly drawn.

Many facilities studied as environmental equity research expands have positive as well as negative effects on their communities. In some cases the negative effects and nuisance factors are so overwhelming that the sites may be considered unambiguously undesirable by the community. In other cases, a community may either be

unaware of a potential environmental burden or judge the facility as desirable in light of enormous positive attributes. These are not easy issues. A seemingly undesirable landfill may be judged desirable, a facility to be sought after by a given community for the jobs and revenues it produces. Conversely, an apparently beneficial hospital or university may be judged locally unacceptable for its burden on community services and residential environs. Both these common instances illustrate the difficulties in reaching simple judgments concerning equity, which, in addition, may alter over time for a given facility. Nonetheless, the distribution of current LLRWFs is certain to be a valid concern in future siting of these facilities and more permanent storage sites.

Our findings for the commonwealth of Massachusetts suggest that black people and people of Hispanic origin are somewhat more likely to live in tracts with at least one LLRWF or in tracts nearby such facilities, for example, within two miles of the LLRWF tract centroid. This finding is especially surprising given the relatively small percentage of the Massachusetts population that is comprised of blacks and Hispanics. Statistical results are mixed concerning socioeconomically disadvantaged populations and insignificant in multivariate models controlling for other effects. Families who live near tracts with LLRWFs are more clearly socioeconomically disadvantaged — below the poverty level or receiving public assistance — than those who live in either LLRWF tracts or in tracts more than two miles away.

The industrial and employment characteristics that have explained the presence of some hazardous waste facilities in other studies do not account for the location of LLRWFs. Males in LLRWF tracts and nearby tracts are less likely to be employed, though the differences are small. The percentage of the population employed in industrial occupations is actually much lower in LLRWF tracts than in other tracts or not statistically significant in multivariate analyses. This finding is consistent with the unique nature of LLRWFs. They are often academic, corporate, government, and health-related institutions, not the industrial facilities or service companies commonly associated with hazardous and toxic waste. These findings also suggest that perhaps greater attention be paid in future research to the unique equity issues associated with facilities that are not likely to be linked with the industrial infrastructure of metropolitan areas. Many patterns of residence emerged in metropolitan areas of the United States over a long course of community development dominated by long-term land use impacts from industry, transportation, immigration, and other factors. These historical patterns of development and residence may underlie much of the inequity associated with industrial land uses. However, for more recent environmental hazards and those more loosely coupled to historically industrial areas, we may find much different patterns in the social distribution of environmental hazards.

Distinguishing various types of facilities may provide some additional indication of inequity in the distribution of LLRWFs. We might presume that facilities classified as academic, government, or hospital generators may be viewed in a somewhat more favorable light by communities than those identified as corporate and utility facilities, especially since this includes low-level storage at the state's nuclear power plants and private companies more clearly identifiable as handling radioactive wastes. This comparison reveals that academic, government, and hospital facilities are located in tracts that are characterized by a large percentage of white residents and small percentages of black and Hispanic residents, with fewer families below the poverty line and receiving public assistance than in other tracts. Corpo-

rate and utility generators are located in tracts with a lower percentage of white residents than other tracts, a higher percentage of black and Hispanic residents, more families living below the poverty line, and more households receiving public assistance than in other tracts. These findings provide some additional evidence that racial and ethnic minorities and the economically disadvantaged are living closer to low-level radioactive waste facilities that are likelier to be considered undesirable than the white and more affluent residents of the commonwealth. This research also suggests that efforts either to identify significant and real environmental risks, or to study facilities known to be unsuitable land uses at the time of siting, may reveal different patterns of inequity than studies including an undifferentiated group of enterprises that are plausibly harmful.

Proving environmental burdens are inequitable requires information about risks and benefits of specific facilities, which are at best difficult to obtain. However, our findings suggest that a degree of environmental inequity characterizes the overall distribution of LLRWs within Massachusetts regardless of their risks or benefits. Despite the fact that many of these differences are not substantively large, they are statistically significant biases of interest in a population with a relatively small percentage of minority residents in the first place. These findings strongly suggest that the imminent siting of more permanent low-level radioactive waste facilities must consider environmental equity among siting concerns. In finding some evidence of inequitable distributions of LLRWs in Massachusetts, our research also raises the need for further studies of such facilities and the need to extend this research to other regions of the country facing similar planning needs and concerns over environmental equity. Most facilities and land uses surveyed in recent environmental equity research are those of decades past. Environmental equity research on both LLRWs and the potential sites proposed for newly mandated long-term storage facilities offers the opportunity for prospective research and studies of import to the current planning and siting efforts. ❁

Notes

1. Government Accounting Office, "10 Studies on Demographics Near Waste Facilities," RCED-95-158R (Washington, D.C.: U.S. GAO, 1995).
2. United Church of Christ, Commission for Racial Justice, "Toxic Wastes and Race in the United States: A National Report on the Racial and Socioeconomic Characteristics of Communities with Hazardous Waste Sites" (New York: United Church of Christ, 1987).
3. Louis Wirth, *On Cities and Social Life* (Chicago: University of Chicago Press, 1964).
4. Alfred Weber, *Theory of the Location of Industries* (Chicago: University of Chicago Press, 1929).
5. Robert L. Lineberry, *Equality and Urban Policy: The Distribution of Municipal Public Services* (Beverly Hills: Sage, 1977).
6. John R. Logan, "Notes on the Growth Machine: Toward a Comparative Political Economy of Growth," *American Journal of Sociology* 82, no. 2 (1976): 349–352.
7. Brian J. L. Berry, *The Social Burdens of Environmental Pollution: A Comparative Metropolitan Data Source* (Cambridge, Mass.: Ballinger, 1977).
8. United Church of Christ, "Toxic Wastes and Race in the United States"; Douglas L. Anderton, Andy B. Anderson, Peter H. Rossi, John Michael Oakes, Michael R. Fraser, Eleanor W. Weber, and Edward J. Calabrese, "Hazardous Waste Facilities: 'Environmental Equity' Issues in Metropolitan Areas," *Evaluation Review* 18, no. 2 (1994): 123–140; Douglas L. Anderton, Andy B. Anderson, John Michael Oakes, and Michael R. Fraser, "Environmental Equity: The Demographics of Dumping," *Demography* 31, no. 4 (1994): 229–248;

- Rae Zimmerman, "Social Equity and Environmental Risk," *Risk Analysis* 13, no. 6 (1993): 649–666; Philip H. Pollock III and M. Elliot Vittes, "Who Bears the Burdens of Environmental Pollution? Race, Ethnicity, and Environmental Equity in Florida," *Social Science Quarterly* 76, no. 2 (1995): 294–310.
9. Massachusetts Low-Level Radioactive Waste Management Board, "1992 Massachusetts Low-Level Radioactive Waste Survey Report" (Boston: Commonwealth of Massachusetts, 1993).
 10. *Ibid.*
 11. This opinion is clear in both the U.S. Supreme Court, *New York v. United States*, 505 U.S. 144, 152 (1992), and in a similar 3rd Circuit Court of Appeals opinion in *Appalachian States LLRW Commission v. O'Leary*, 93 F.3d 103, 105, 110.
 12. Approximately one percent only of the LLRW from decommissioning Yankee Rowe remains on site at present.
 13. Michael O'Hare, Lawrence Bacow, and Deborah Sanderson, *Facility Siting and Public Opposition* (New York: Van Nostrand Reinhold, 1983).
 14. John A. Hird, *Superfund: The Political Economy of Environmental Risk* (Baltimore: Johns Hopkins University Press, 1994); Howard Latin, "Good Science, Bad Regulation, and Toxic Risk Assessment," *Yale Journal of Regulation* 5, no. 1 (1988): 89–149.
 15. We also conducted a telephone survey of a systematic, random sample of radiation safety officers to confirm that addresses on the MLLRWMB list were sites where low-level radioactive materials were used or stored.
 16. Tracts from eight metropolitan statistical areas — Boston, Fitchburg-Leominster, Lawrence, Lowell, Pawtucket, Salem-Gloucester, Springfield, and Worcester — account for all but two tracts with LLRWs. They contain 60, 1, 3, 2, 2, 4, 3, and 7 LLRWs, respectively.
 17. U.S. Department of Commerce, Bureau of the Census, *1990 Decennial Census, Summary Tape File 3* (Washington, D.C., 1990).
 18. United Church of Christ, "Toxic Wastes and Race in the United States"; Anderton et al., "Hazardous Waste Facilities"; Anderton et al., "Environmental Equity."
 19. Douglas L. Anderton, "Methodological Issues in the Spatiotemporal Analysis of Environmental Equity," *Social Science Quarterly* 77, no. 3 (September 1996): 508–515; Vicki Been and Francis Gupta, "Coming to the Nuisance or Going to the Barrios? A Longitudinal Analysis of Environmental Justice Claims," *Ecology Law Quarterly* 24, no. 1 (1997): 1–56; John Michael Oakes, Douglas L. Anderton, and Andy B. Anderson, "A Longitudinal Analysis of Environmental Equity in Communities with Hazardous Waste Facilities," *Social Science Research* 25 (1996): 125–148.
 20. Some data are suppressed by the Census Bureau to prevent identification of persons or households and some are inappropriate for a given area population.
 21. Anderton et al., "Environmental Equity."