Spotlight

EXCESS INFANT MORTALITY AFTER NUCLEAR PLANT STARTUP IN RURAL MISSISSIPPI

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Abstract

American utilities are considering ordering new nuclear power reactors, which would be the first such orders in the U.S. since 1978. One potential site would be the Grand Gulf plant near Port Gibson, Mississippi. In 1983-1984, the first two years in which the existing Grand Gulf reactor operated, significant rises were observed in local rates of infant deaths (+35.3%) and fetal deaths (+57.8%). Local infant mortality remained elevated for the next two decades. These changes match those experienced in the same five local counties during atomic bomb testing in the 1950s and 1960s. This report examines potential reasons why an indigent, largely African-American community may be at higher risk than other populations from exposure to an environmental toxin such as radiation. It also considers potential health risks posed by new reactors at Grand Gulf.

Disproportionate health risk from exposure to environmental toxins on populations with low socioeconomic status (SES) and/or those with high proportions of non-Caucasians has been an ongoing public health concern. Some reports contend that the elevated risk results from greater prevalence of undesirable health practices (e.g., smoking, alcohol consumption, inadequate diet) by low-SES/minority populations. However, a 16-year study of over 320,000 American men documents that mortality in blacks is higher even after adjusting for severity of illness and health practices (9% higher for cardiovascular deaths, 25% higher for cancer deaths, 26% higher for all other deaths). (1)

The issue of how environmental pollutants affect low-SES and minority populations is a complex one. Some experts conclude that environmental exposures raise health risk independent of race and income, (2) while some contend that low SES may 8be primarily responsible for higher disease rates. (3) In a test to control emissions at power plants in the Washington DC area (largely consisting of African-Americans), 51% of the mortality declines occurred in the 25% of the population lacking a high school education. (4) Still other studies document that low-SES populations are subjected to greater levels of harmful toxins because they reside in closer proximity to more polluting industries. Offending agents originate from landfills, incinerators, hazardous waste facilities, industrial plants, and old housing with poor air quality and lead-based paint. (5)

Some view the risk in terms of poor access to medical care. For example, the more affluent U.S. white population, which can afford screening tests such as mammograms more easily than blacks, have a female breast cancer incidence rate 12% higher than blacks in 2000-2004, (6) but a 26% lower death rate from the disease, probably because more breast tumors in white women are detected in early stages. (7) Thus, there is little agreement on why exposures to harmful pollutants contribute to higher morbidity and mortality among low-SES/minority groups.

One type of environmental toxin that may pose a disproportionately large health risk to low-SES/minority groups is ionizing radiation, in particular man-made fission products produced only by nuclear weapons and reactors. To date, virtually no research exists on whether those with socioeconomic disadvantages and racial minorities are at increased health risk from radiation exposure.

Nuclear weapons test fallout and nuclear reactor emissions represent relatively low-dose exposures to humans. After initial analyses of Hiroshima and Nagasaki survivors led experts to believe that low-dose exposures are harmless, subsequent reports have questioned this theory. Studies beginning in the late 1950s documented that pelvic X-rays to pregnant women nearly doubled the chance that the child would die of cancer by age ten. (8) (9) In 1997, a National Cancer Institute study estimated that as many as 212,000 Americans would develop thyroid cancer from exposure to radioactive iodine in bomb test fallout. (10) In 2000, the U.S. Department of Energy accepted the conclusion of research studies that nuclear weapons workers suffered from high levels of cancer and other immune disease, and instituted a compensation program for the victims. (11)

In the United States, the last nuclear power reactor order took place in 1978, but there has been recent interest in developing new reactors. Utilities have expressed an interest in building as many as 28 new reactors (12) New reactors would add low-dose radioactivity to local environments. This report will focus on the potential health risks of a recently-proposed new reactor at the Grand Gulf plant, located in southwestern Mississippi, an area with a majority of African-Americans that is disadvantaged socially, economically, and medically. By examining trends in local health outcomes after the startup of the existing Grand Gulf reactor, any excess vulnerability of a low-SES population exposed to radiation from a new reactor may be better understood.

The Grand Gulf nuclear reactor is located near Port Gibson, Mississippi, 25 miles south of Vicksburg, on the east bank of the Mississippi River. The local area, defined as that within 30 miles of the reactor, consists of three Mississippi counties (Claiborne, Jefferson, and Warren) and two Louisiana parishes (Madison and Tensas). By 1810, slaves of African descent made up the majority of the population in this agricultural region. (13) Due to the extensive migration of southern blacks to northern cities in the 20th century, the proportion of blacks in the area's population fell from 78.5% to 56.5% from 1910 to 2000, and up to an estimated 58.0% in 2005. (14) This figure may currently be rising, as the great exodus of blacks has ended; the 2003-2004 excess of black births over deaths of 871 is far greater than the white reduction of -14. (7) The area, whose population has been relatively steady at about 90,000 since the late 1950s, is still largely rural; other than Vicksburg MS (25,000) and Talullah LA (8,500), no other town has a population greater than 2,000.

The five counties have long been beset by severe socioeconomic problems. The area currently falls far below standards for the nation and all other Louisiana and Mississippi counties in poverty status, unemployment, average income for employees, households headed by a female, and educational level (Table 1). Combined with a physician-to-population ratio well below national and state norms, the area can be described as high-risk for a variety of health problems. (15) Table 1 also includes 1960 data documenting the same disproportionate rates of socioeconomic disadvantages, indicating that these problems are long-standing ones. (16)

Table 1
Socioeconomic Indicators, Five Counties Near Grand Gulf Reactor Compared to Other Louisiana/Mississippi Counties and U.S.

Indicator	**5 Counties**	**Oth LA/MS**	**U.S.**
Current (2000 and after)			
% Individuals Below Poverty, 2004	23.5%	19.2%	12.7%
% Black, 2005	58.0%	34.4%	12.8%
Median Household Income, 2004 ($)	29778	34887	44334
% w/Supplemental Security Income, 2000	5.7%	4.1%	2.3%

% Adults >25 Not a HS Graduate, 2000	28.4%	25.9%	19.6%
% Civilian Labor Force Unemployed, 2000	7.5%	5.6%	4.0%
% Households with Female Head, 2000	21.7%	16.8%	12.2%
% Unemployment, 2006	7.0%	5.2%	4.6%
Active, Nonfederal Physicians/100,000 Persons as of December 31, 1999	107	213	254
Past (1960)			
% Families with Annual Income < $3,000	57.0%	41.7%	21.4%
% Civilian Labor Force Unemployed	6.9%	5.8%	5.1%
% Housing Units without Telephone	50.0%	40.0%	21.5%
% Housing Units Not Classified as "Sound, with All Plumbing Facilities"	62.3%	45.2%	26.0%
Source: U.S. Bureau of the Census, *Eighteenth and Twenty-Second U.S. Census of the Population*. Washington DC: U.S. Government Printing Office, 1960, 2000. Data on physicians from U.S. Bureau of the Census, *State and County Data Book*, 2003. Data on unemployment from U.S. Department of Labor, Bureau of Labor Statistics, local Area Unemployment Statistics, www.bls.gov/lau/.			

Materials and Method

This report will examine changes in local health status after the startup of the Grand Gulf reactor in 1982. Defining the local area as those counties as those within 30 miles of the plant corresponds to the National Cancer Institute's definition of study counties in its 1990 analysis of cancer rates near 62 U.S. nuclear plants. The Institute chose the closest counties, most roughly within 30 miles of plants, as the area more likely to be exposed to reactor emissions. (17) Because prevailing winds in nearby Jackson, Mississippi emanate from the north for eight months and from the south for four months, all five counties can be classified as downwind. (18)

Mortality rates for local infants under one year will be compared for the periods 1981-1982 (before Grand Gulf went critical, i.e., began operations producing radioactivity) and 1983-1984 (after criticality). Two-year periods were selected because previous reports showed unexpectedly large declines in infant mortality in the two years immediately following reactor shutdown. (19) (20) The developing fetus and infant are far more susceptible to radiation exposure than adults. Long term infant mortality trends after startup will be analyzed using the periods 1981-1982 and 1983-2004. The change in the five-county rates will be compared with those of the nation.

Statistical significance of the difference between local and national rate changes will be calculated. A z-score, which can be converted into a p-value of significance, is obtained by using the following standard test:

(O - E) / SQRT [((1/SQRT N_1)* E)SQUARE + ((1/ SQRT N_2)* E)SQUARE]

Where
O = observed rate, or local rate in the period after nuclear plant startup
E = expected rate, or local rate in the period before nuclear plant startup adjusted for change in U.S. rate
N_1 = number of local deaths in the period before nuclear plant startup
N_2 = number of local deaths in the period after nuclear plant startup

The Standard Mortality Ratio (SMR) for the five-county area is calculated by the formula O / E, where O is the observed rate (local rate after nuclear plant startup) and E is the expected rate (local rate in the period after nuclear plant startup adjusted for change in U.S. rate). The 95% confidence interval for each local SMR can be constructed through the formula

O +/- [((1/SQRT N_2) * SMR)] * 1.96

Each of the variables O, N_2, and SMR are explained above, and 1.96 represents the number of standard deviations in a 95% confidence interval.

The existing Grand Gulf reactor was granted a 40-year operating license by the U.S. Nuclear Regulatory Commission on June 16, 1982, and achieved initial criticality (began producing fission products) on August 18 of that year. Grand Gulf is Mississippi's first and only nuclear reactor. River Bend, near Baton Rouge LA, lies 85 miles south, while Waterford 3, near New Orleans LA, is 135 miles southeast. Both of these facilities began operating in 1985, so when Grand Gulf went critical, no nuclear reactor existed within 250 miles of the site.

A similar analysis testing the theory of whether ionizing radiation exposure is particularly harmful to a low-income, mostly minority population will be attempted using infant mortality data from the period of large-scale atmospheric atomic weapons testing. Short term changes (1950-1951 vs. 1952-1953) and long-term changes (1950-1951 vs. 1952-1963) after testing began will be analyzed, using the methods described above.

Nuclear reactors emit over 100 radioisotopes into the atmosphere and water, in gaseous and particulate form, from routine operations and maintenance activities. Prior to 1982, the primary exposure to these fission products in the Grand Gulf area was from atomic bomb test fallout. From 1951 to 1962, the U.S. detonated 100 nuclear devices above the Nevada desert before the Partial Test Ban Treaty ended atmospheric testing. (21) Fallout from 106 additional U.S. tests in the south Pacific and dozens of Soviet tests in Kazakhstan also contributed to the buildup of worldwide environmental radioactivity, during this time.

Fallout clouds from tests drifted eastward with prevailing winds across the continental U.S., and entered the environment primarily through precipitation. The national average concentration of long-lived radioactive isotopes in milk and water peaked during 1963 and 1964 (as the Treaty went into effect), before declining sharply. The contiguous states of Arkansas, Louisiana, and Mississippi received the highest amounts, perhaps because high levels of precipitation enabled more radioactivity to enter the diet. In the first quarter of 1964, the national average concentration of Strontium-90 (one of the radionuclides in fallout, with a physical half life of 28.7 years) reached a high of 25 picocuries per liter of pasteurized milk.

Of 60 U.S. cities where measurements were taken, the highest level was recorded at Minot ND (77), followed by three cities in the southeast, namely New Orleans LA, Little Rock AR, and Jackson MS, at 54, 43, and 41, respectively. (22) But after large scale atmospheric weapons tests ended, levels dropped considerably. By July 1982, the Sr-90 level had plummeted in the three cities to 4.0, 2.9, and 3.9, respectively. (23) Thus, any change in environmental radioactivity levels after 1982 in the Grand Gulf area may partially represent reactor emissions from Grand Gulf.

Results

Changes in Environmental Radioactivity After Reactor Startup

The startup of the Grand Gulf reactor in 1982 introduced fission gases and particles into the local environment from routine operations, periodic refueling of reactors, and accidental emissions. The radioisotopes emitted from nuclear reactors are taken up by humans either from inhalation or from the food chain after returning to earth via precipitation. While estimating increased dose to local residents is not possible with available data, the added radioactivity to the local environment can be expressed in several ways. The first is emissions of airborne "Iodine-131 and effluents" or all radionuclides with a half life of eight days or more, which are most likely to enter the food chain. No detectable emissions were reported in 1981 and 1982, but a total of 231 microcuries were recorded in 1983 and 1984. The second is "liquid effluents: mixed fission and activation gases", which increased from 0 to 30,000 microcuries. (24)

Another means of expressing the added burden of radioactivity is by examining trends in local environmental radioactivity concentrations. Concentrations in Port Gibson MS water near Grand Gulf are reported to the U.S. government for various isotopes. Because many of the measurements for these isotopes are less than zero, it is likely that the devices employed to are unable to detect low dose radioactivity. Thus, data for more general isotopes (gross alpha and tritium) are used. Table 2 shows that the average levels of each isotope rose from 1981-1982 to 1983-1984. (23) It is logical that these rising levels result from current emissions, not decay of residual bomb test fallout.

Table 2 Average Concentrations of Gross Alpha and Tritium In Port Gibson MS Drinking Water and Surface Water For the Periods 1981-1982 and 1983-1984			
Indicator	**Avg. picocuries/liter**		**Percent Change**
	1981-82	**1983-84**	**'81-2 to '83-4**
Drinking Water			
Gross Alpha	2.19	3.22	+47
Tritium	228.6	233.3	+ 2
Surface Water			
Tritium	214.3	222.2	+ 4

Source: U.S. Environmental Protection Agency. Environmental Radiation Data. Montgomery AL: Office of Radiation Programs. Reports are made quarterly for tritium, annually for gross alpha.
Note: Measurements for 1983-84 tritium include one from October 1982, because Grand Gulf reactor had already reached criticality.

Grand Gulf Area Health Changes to Infants After Reactor Opening

Table 3 documents that the local death rate for fetuses with a gestation period over 20 weeks rose +57.8% (41 to 60 deaths) from 1981-1982 to 1983-1984, significantly different than declines in the nation and two-state area at p<.05 (SMR 1.69, CI 1.26 – 2.12). The local infant mortality rate for persons under one year increased +35.3% (55 to 69 deaths), also significantly different from national and two-state declines at p <.05 (SMR 1.45, CI 1.11 – 1.79). Higher infant mortality occurred for both local whites (+50.0%) and blacks (+28.3%). An especially high 96.6% increase was documented for those infants dying in the first 24 hours after birth.

Table 3 Change in Fetal/Infant Death Rates, Five Counties Nearest Grand Gulf Compared to Other Louisiana/Mississippi Counties and the U.S. 1981-1982 vs. 1983-1984					
Indicator	**D/1000 Births (n)**		**% Ch. Rate**		**SMR (95% CI)**
	1981-82	**1983-84**	**5 Cos.**	**U.S.**	
Fetal Deaths (gestation >20 weeks)	11.0 (41)	17.3 (60)	+57.8**	-6.8	1.69 (1.26 – 2.12)
Infant Deaths, <1 yr	14.7 (55)	19.9 (69)	+35.3*	-6.4	1.45 (1.11 – 1.79)
- Whites	12.7 (18)	19.0 (25)	+50.0	-6.7	1.60 (0.97 – 2.23)
- Blacks	16.1 (37)	20.6 (44)	+28.3	-5.2	1.35 (0.95 – 1.75)
- Age under 1 day	4.5 (17)	8.9 (31)	+96.6**	-5.6	2.11 (1.37 – 2.85)
- Age 1-364 days	10.2 (38)	11.0 (38)	+ 7.8	-6.9	1.16 (0.79 – 1.53)

Source: National Center for Health Statistics, Vital Statistics of the United States, annual volumes. Available at http://wonder.cdc.gov, underlying cause of death). Standard Mortality Ratio expressed as local change compared to expected change, using U.S. as expected. ** = p<.01; * = p<.04).

Table 4 documents that the change in infant mortality for the five counties was compared for the period just before reactor startup (1981-1982) and the 22 years following (1983-2004). The rate decreased by 7.9%, significantly different than the 27.5% national decline at p<.05 (SMR 1.27, CI 1.15-1.39).

Table 4 also documents changes in the five-county area before and after the onset of Nevada atomic bomb tests. The short term change, covering the periods 1950-1951 and 1952-1953, was an increase of 42.9%, significantly different from the U.S. decrease of 2.5% at p<.0001 (SMR 1.47, CI 1.29-1.66). The long-term local change during atmospheric testing, comparing 1950-1951 to 1952-1963, was 35.8%, significantly greater than the national decline of 8.4% at p<.0001 (SMR 1.48, CI 1.40-1.56).

Table 4
Change in Standard Mortality Ratio, Five Counties Nearest Grand Gulf
Infants Under One Year, Before and After Atomic Bomb Testing and Reactor Startup
Short Term and Long Term Effects

Period	D/1000 Births (n)		% Ch. Rate		SMR (95% CI)
	Before	After	5 Cos	US	
Reactor Startup					
- 1981-82 vs. 1983-84	14.7 (55)	19.9 (69)	+35.3	- 6.8	*1.45 (1.11–1.79)
- 1981-82 vs. 1983-04	14.7 (55)	13.6 (446)	- 7.9	-27.5	*1.27(1.15 -1.39)
Bomb Testing					
- 1950-51 vs. 1952-53	32.3 (177)	46.1 (252)	+42.9	- 2.5	+1.47 (1.29-1.66)
- 1950-51 vs. 1952-63	32.3 (177)	43.9 (1361)	+35.8	- 8.4	+1.48 (1.40-1.56)

Source: National Center for Health Statistics, Vital Statistics of the United States, annual volumes. Available at http://wonder.cdc.gov, underlying cause of death). Standard Mortality Ratio expressed as local change compared to expected change, using U.S. as expected. += p<.0001; * = p<.05).

Discussion

When a nuclear reactor commences operations, it adds over 100 man-made radioactive isotopes to the local environment through routine and accidental releases. Each kills cells or damages cell membranes and DNA strands in various organs of the body. Airborne releases of radioactive gases and particles enter the body through breathing and the food chain. In southwestern Mississippi near the Grand Gulf nuclear plant, these particles had essentially not existed the local atmosphere since the cessation of above-ground nuclear weapons testing in Nevada in 1963, until Grand Gulf began producing radioisotopes in 1982. While emission levels from reactors are relatively low, studies of effects on local health are warranted. While all humans are at risk after radiation exposure, the age cohort most likely to be immediately affected by exposure to radioactivity is the fetus and infant, whose under-developed immune system may be less capable of repairing damage to rapidly-dividing cells.

Official data show that higher emissions in the first two years of Grand Gulf operations were accompanied by higher concentrations of various radioisotopes in local water, according to U.S. government data. These radioisotopes enter the bodies of local residents in varying ways. While it is impossible to analyze all vectors of exposure to Grand Gulf particles and gases, exposures from inhalation is expected to be highest among local residents. Any exposures from drinking water would also be highest among local residents, as all municipal water is taken from local wells. (25) Exposures from milk consumption may not reflect Grand Gulf emissions, as most locally-sold milk is produced out of state. (26) Exposures from other foods vary, as some are produced locally and others are not.

The first two years after Grand Gulf startup resulted in significant increases in local rates of fetal deaths (+57.8%) and infant deaths (+35.3%), which rose especially rapidly for babies less than one day old (+96.6%). These changes are consistent with the large declines in local infant death rates observed near closed nuclear reactors in the first two full years after shutdown. (19) (20) Unexpectedly high mortality among the youngest in a population supports the belief that these groups are most susceptible to damage from toxins such as ionizing radiation. The statistical significance of these temporal trends suggests strongly that they are not due to random chance. Moreover, they are similar to the rise in local infant mortality in the first two years after Nevada atomic bomb testing began.

The unexpected rise in local mortality rates to fetuses and infants immediately after Grand Gulf activation should consider potential confounding factors. Socioeconomic change is not likely to account for the difference over the short term. The local population size did not change appreciably in the two years before and after reactor activation (97195, 96657, 95058, and 95177), suggesting no substantial influx of high-risk or exodus of low-risk residents. (7) Local unemployment rates are not available each year, but the annual U.S. percentages (7.6, 9.7, 9.6, and 7.5) suggest no dramatic difference between 1981-1982 and 1983-1984. (27) An elevated local poverty level has existed for decades, and probably did not change appreciably in 1983-1984. Coupled with no apparent short-term change in poverty and unemployment levels is access to medical care, which also was not markedly different in the short term. Although local statistics are not maintained, smoking rates are not likely to have changed appreciably in the two years after Grand Gulf startup.

Mortality in each of the five counties closest to the reactor also demonstrated an unexpectedly large increase in the first 22 years of reactor operations, compared to the two years immediately prior. This finding is consistent with the short-term trend, is statistically significant, and suggests that elevated 1983-1984 infant death rate in the five counties near Grand Gulf was not an anomaly, but indicative of a longer-term pattern. It also is consistent with local changes in infant mortality after atmospheric nuclear weapons testing began.

Again, examination of confounding factors is warranted before making any conclusions about long-term trends after reactor startup. While no local rates of smoking are maintained, U.S. data shows that since the mid-1980s, African-American males have somewhat higher smoking rates than white males, while African-American females have a somewhat lower rate than white females. (28) Thus, the high proportion of African-American residents near Grand Gulf does not suggest that smoking rates are higher than elsewhere in the region or nation.

Many other potential co-factors can be examined in the analysis of short- and long-term health changes in a small area such as that near Grand Gulf. But while consideration of such co-factors should continue, a truly comprehensive look is beyond the scope of a report such as this, since little statistical data is readily available. In light of this lack of information, the possibility that exposure to Grand Gulf radioactivity increased local death rates should be considered.

While all persons living near a nuclear reactor may be at increased health risk after radioactivity is emitted into the environment, the question of whether low-SES populations are at particular risk is raised. The five Louisiana and Mississippi counties within 30 miles of Grand Gulf provide an opportunity to test this theory. The area has long experienced relatively high proportions of poverty; under-educated residents; poor working conditions; unemployment; and sub-standard living conditions. Decades of practices that denied equality in medical care to blacks or the poor in the region may further raise the health risk to local residents.

Table 5 compares the change in infant mortality rates in counties within 30 miles of a new reactor for Grand Gulf and 13 other areas near nuclear plants started since 1982. Only reactors located at least 60 miles from any other operating nuclear facility at startup are included. Rates two years before and after startup are compared. (7) The year of startup is counted in the "before" period if the reactor opened during the second half of that year, and in the "after" period if the reactor opened during the first half of the year. For each area, the 1999 poverty rate and the 2000 percent of minorities (persons other than white non-Hispanics) are given. (14) Counties and years used in the table are presented in Appendix 1.

Table 5
Change in Infant Death Rates, Two Years Before and After Reactor Startup
Reactors Beginning Operations Since 1982

Reactor	Date Critical	No. Infant Deaths		% Ch. Rate	% Minority In 2000*	% Below Poverty, 1999
		Before	After			
Grand Gulf	8/18/82	55	69	+35.3	58.5	26.2
Diablo Canyon	4/29/84	112	132	+13.0	35.8	13.7

River Bend	10/31/85	229	227	+10.5	45.9	19.1
Seabrook	6/01/89	227	256	+ 9.8	12.8	7.8
Comanche Peak	4/30/90	46	48	+ 7.6	15.4	10.1
Palo Verde	5/25/85	540	664	+ 6.5	33.8	11.7
S. Texas Project	3/08/88	17	15	+ 0.9	43.8	17.5
Perry	6/06/86	89	91	+ 0.4	5.4	6.7
Shearon Harris	1/03/87	273	292	- 2.7	33.9	10.3
Susquehanna	9/10/82	130	118	- 4.6	3.9	10.8
U.S.				- 6.0+	30.9	12.4
Waterford	3/04/85	653	597	- 6.5	48.8	19.6
Clinton	2/27/87	92	76	- 18.9	12.6	10.4
Callaway	10/02/84	76	58	- 23.6	12.1	11.8
Wolf Creek	5/22/85	39	25	- 27.4	10.2	11.4

* % of 2000 population other than white non-Hispanic
+ Average two-year decline in infant death rate from 1981-92
Source: U.S. Nuclear Regulatory Commission (date critical); National Center for Health Statistics (infant deaths); U.S. Bureau of the Census (minority, poverty data).

Of the 14 areas, the largest rise in infant deaths occurred near Grand Gulf, the area with the greatest percentage of minorities (58.5%, vs. 30.9% nationally) and the highest poverty rate (26.2%, vs. 12.4% nationally). The area near the River Bend reactor outside Baton Rouge LA, which also has relatively high levels of poverty and minorities, had the 3rd highest increase in infant death rate. Conversely, the three areas with the largest declines in infant death rates (Clinton, Callaway, and Wolf Creek, all in sparsely populated Midwestern areas of the U.S.) had percentages of minorities and poverty well below the U.S. standards.

Reported emissions from each of the 14 reactors in the first two years of operations constitute relatively low doses. (23). This fact, plus strong diversity in trends between the areas near Grand Gulf and the three midwestern reactors provide further evidence that SES indicators of low SES, like high poverty levels and a large minority population, enhance toxic effects of radioactivity.

This study only examines one factor that can potentially contribute to mortality. Moreover, while the mechanisms of how race and SES may raise susceptibility to environmental pollution merit consideration, they are not fully addressed here, and more detailed and pertinent information is needed before drawing conclusions. There may be socioeconomic/racial differences in sources of water consumed, along with variations in other dietary practices affecting the amount and types of radioactivity entering bodies, each of which merit greater investigation.

This initial review of SES/race as a factor in susceptibility to radioactive chemicals has not yet attempted a dose-response analysis, which would involve comparing the health risk of high- and low-SES populations to varying doses of exposure. The report on the population near Grand Gulf has yet to examine disease-specific mortality data. Investigating specific causes of death would reveal if the largest increases in rates occurred among immune-related disorders such as cancer. Testing the theory using county-specific incidence data, perhaps the rates of premature or low-weight births, would augment the mortality data presented here.

Experts have offered differing explanations why higher morbidity and mortality rates are often observed in low-SES groups and in racial minorities. Although more studies are emerging, it is not likely that this debate will be concluded soon, and a variety of factors contributing to these elevated rates may eventually be identified.

The relation of exposure of low-SES/minority groups to environmental toxins is a part of this discussion. One such toxin that has not been studied to date is the addition of ionizing radiation into the body. Whether the increase in mortality rates to infants near Grand Gulf after 1982 was due solely, or even primarily, to radioactivity cannot be conclusively stated. However, the distinct and significant changes in short-term and long-term health status patterns in the five county area - similar to those observed after nuclear weapons testing began - indicate that exposure to these chemicals may be one factor in the unexpected negative trends in health. The high-risk profile of the area may play a role in this relationship, a factor that should be investigated more rigorously. Health status and potential vulnerability of poor and largely African-American populations like that in southwestern Mississippi should be fully considered as part of any responsible policy decision to allow a new nuclear reactor to commence operations.

Appendix 1
Counties Within 30 Miles of Nuclear Reactors
Plus Two-Year Periods Before and After Startup
Cited in Table 5

Reactor	Date Critical	Two-Yr Period		Counties
		Before	After	
Grand Gulf	8/18/82	'81-82	'83-84	Claiborne MS, Jefferson MS, Warren MS, Madison LA, Tensas LA
Diablo Canyon	4/29/84	'82-83	'84-85	San Luis Obispo CA, Santa Barbara CA
River Bend	10/31/85	'84-85	'86-87	East Baton Rouge LA, East Feliciana LA, Iberville LA, Point Coupee LA, West Feliciana LA, Wilkinson MS
Seabrook	6/01/89	'87-88	'89-90	Rockingham NH, Strafford NH, Essex MA
Comanche Peak	4/30/90	'88-89	'90-91	Bosque TX, Erath TX, Hood TX, Johnson TX, Somervell TX
Palo Verde	5/25/85	'83-84	'85-86	Maricopa AZ
South Texas Project	3/08/88	'86-87	'88-89	Jackson TX, Matagorda TX
Perry	6/06/86	'84-85	'86-87	Ashtabula OH, Geauga OH, Lake OH
Shearon Harris	1/03/87	'85-86	'87-88	Chatham NC, Durham NC, Harnett NC, Lee NC, Orange NC, Wake NC
Susquehanna	9/10/82	'81-82	'83-84	Columbia PA, Luzerne PA, Montour PA, Schuykill PA
Waterford	3/04/85	'83-84	'85-86	Ascension LA, Jefferson LA, LaFourche LA, Orleans LA, St. Charles LA, St. John the Baptist LA, St. James LA
Clinton	2/27/87	'85-86	'87-88	DeWitt IL, Logan IL, McLean IL, Macon IL, Piatt IL
Callaway	10/02/84	'83-84	'85-86	Audrain MO, Boone MO, Callaway MO, Cole MO, Gasconade MO, Montgomery MO, Osage MO
Wolf Creek	5/22/85	'83-84	'85-86	Allen KS, Anderson KS, Coffey KS, Franklin KS, Greenwood KS, Lyon KS, Osage KS, Woodson KS

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