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Improvements in local infant health after nuclear power reactor closing

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Between 1987 and 1998, operations ceased at 12 U.S. nuclear power reactors. One of these, Rancho Seco, is located in a densely populated area. After the reactor closed in 1989, significant decreases in mortality (all causes and from congenital anomalies) and cancer incidence were observed for fetuses, infants, and small children. These trends contrast with a worsening of infant health status after the plant opened in 1974. The data suggest that a relationship between nuclear emissions and adverse health effects exists, especially since fetuses and newborns are most sensitive to radiation. Because Rancho Seco released low levels of radionuclides into the local environment, the issue of health effects of prolonged, low-dose radiation exposure is raised. The matter becomes increasingly important as operators of several dozen aging U.S. reactors must soon decide whether to extend their operating licenses. *Environmental Epidemiology and Toxicology* (2000) **2**, 32–36.

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Introduction

From 1987 to 1998, utilities permanently closed 12 U.S. nuclear power reactors (U.S. Nuclear Regulatory Commission, 1999). No new orders have been placed since 1978, and thus, many units are aging; 36 of them began operations 25–30 years ago. Utilities running these units must soon decide whether to apply to the U.S. Nuclear Regulatory Commission for a new operating license or to close reactors.

To date, the principal issues associated with reactor closings have been waste management and plant decommissioning. Little consideration is given to health status among local residents. After the Partial Test Ban Treaty ended atmospheric atomic bomb testing in Nevada, and dietary levels of long-lived radioactive chemicals from fallout declined after peaking across the U.S. in 1964 (U.S. Public Health Service, 1968), progress in several infant health indicators accelerated. Long-term declines in fetal and infant mortality abruptly slowed during the atmospheric test era, but fell sharply thereafter (Whyte, 1992). The percentage of American babies born less than 2500 g, which rose 2% for whites and 35% for nonwhites from 1950 to 1966, plunged during the next decade (Mangano, 1998). Cancer incidence ages 0–4 in Connecticut, the only state with an established tumor registry, rose 61% from the early 1940s to the early 1960s before falling 24% in the first five years after the test ban (National Cancer Institute, 1986).

The fetus and infant are most susceptible to effects of radiation and other toxic chemicals. The developing fetus undergoes rapid cell growth, self-programmed cell death (apoptosis), and cell re-arrangement. The developing infant is similarly susceptible to cellular and metabolic damage. Unrepaired damage becomes magnified with time, increasing the risk of cancer, congenital malformations, underweight births, and fetal/infant deaths (Sherman, 1994).

Five of the 12 closed reactors are in areas at least 70 miles from any other nuclear power plant. In the first two years after closing, infant mortality rates in the closest counties downwind from the reactors fell 15 to 20% at each site (Appendix 1). The average U.S. two-year decline in infant mortality from 1985 to 1996 was 6.4%.

This report assesses potential health impacts of the closing of the Rancho Seco reactor (one of the five cited) on local fetuses and infants. Rancho Seco is located close to a highly populated area (25 miles southeast of Sacramento, California), making detection of significant trends more feasible. It had a large capacity of over 2700 megawatts (thermal), which could potentially affect the local population's health more than a small unit. No other nuclear reactor lies within 200 miles. It has been closed since June 7, 1989 (initial criticality began on September 16, 1974 and commercial operations on April 17, 1975), permitting a long-term analysis of subsequent health patterns to be made.

The opening of Rancho Seco corresponds with an increase of local *in vivo* radioactivity. Estimates of dietary intake of Strontium-90 in urban west (mostly San Francisco) adults were made from 1961 to 1982, based on

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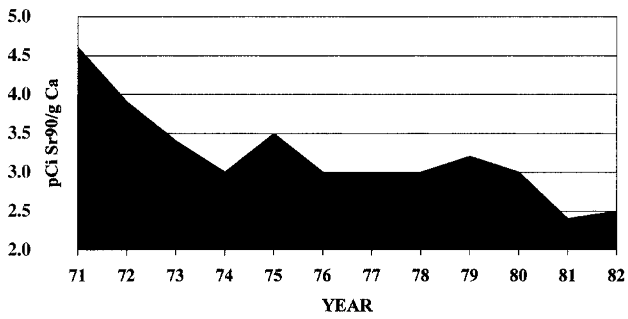

Figure 1. Adult Dietary Intake, Sr-90, Urban West.

post-mortem measurements of human bone. In the early 1970s, Sr-90 concentrations were falling, but from 1974 to 1980, the rate remained at or above 3.0 pCi of Sr-90 per gram of calcium in bone (Figure 1). During the same period, concentrations in urban northeast (mostly New York City) adults declined 22% (Klusek, 1984). It is possible that Sr-90 levels in San Francisco were affected by emissions from Rancho Seco; the reactor lies just 70 miles from the city, while a substantial portion of San Francisco food is grown in the nearest agricultural area, the Sacramento Valley.

Rancho Seco's closing reduced local levels of dietary radioactivity. In 1987, when the reactor was temporarily closed for repairs, an average of 1.91 pCi of Iodine-131 was present in Sacramento's pasteurized milk. After restart, levels rose to 2.67 and 2.54 in 1988 and 1989, but fell to 1.82 in 1990 (National Air and Radiation Environmental Laboratory, 1987–1990).

Methods

The analysis focuses on all-cause mortality for fetuses, infants, and young children; mortality from birth defect ages 0–4; and cancer incidence ages 0–4. County-specific data on California underweight births are unavailable before 1993, and thus not used. The source for mortality information is the National Center for Health Statistics annual compilation *Vital Statistics of the United States* (now available from 1979 to 1996 on the World Wide Web at http://www.cdc.gov, CDC Wonder). Cancer incidence is obtained from the California Cancer Registry. Population figures are decennial U.S. Census counts and estimates for all other years.

Those at greatest potential risk of adverse health effects from radioactive releases live in Amador, El Dorado, Placer, and Sacramento counties. The 1990 population in the region was 1.37 million, of whom three-fourths reside in Sacramento County. Most or all of the population in each county live within 50 miles of Rancho Seco, downwind (north and east) from the reactor (Bair, 1992). Although the Sacramento metropolitan area lies to the northwest, and technically not downwind of the reactor, it is included in the study because of its extreme proximity (10–15 miles). No data are available at the sub-county level.

Trends in infant health when the reactor began operating and when it closed were analyzed. Data for 1972–1973 were compared with 1974–1975, when radioactivity was introduced into the local food and water, and data from 1988 to 1989 (the last reported releases) were contrasted with 1990–1991. The first emissions from Rancho Seco reported to the U.S. Nuclear Regulatory Commission occurred in 1975, at 0.01 Ci of airborne radionuclides with half lives of

Table 1. Changes in health status before and after Rancho Seco closing, Amador, El Dorado, Placer, Sacramento Counties, 1988–1989 vs. 1990–1991.

	Four CA counties				U.S.			
	Number		No./1000 births		No./1000 births		Odds ratio	
Indicator	1988–1989	1990–1991	1988–1989	1990–1991	1988–1989	1990–1991	Local	U.S.
Fetal deaths, gestation > 20 weeks	271	288	6.1	5.8	7.5	7.4	0.957	0.987
Deaths < 1 year	424	397	9.5	8.0	9.9	9.1	0.843 (p<0.09)	0.919
Deaths < 1 year, congenital anomalies	90	79	2.0	1.6	2.0	1.9	0.791	0.942
[a]Death ages 1–4, excluding accidents, homicide, suicide	51	45	31.1	24.7	28.2	26.8	0.794	0.949
[a]Death ages 1–4, congenital anomalies	14	11	8.6	6.0	6.3	5.9	0.707	0.930
[a]Cancer cases, ages 0–4	39	27	23.7	14.9	19.8	21.0	0.628 (p<0.07)	1.062[b]

[a]Rate expressed as cases/deaths per 100,000 population.
[b]Change in 11 U.S. states and cities.

Table 2. Changes in health status before and after Rancho Seco closing, Amador, El Dorado, Placer, Sacramento counties, 1988–1989 vs. 1990–1996.

Indicator	Number 1990–1996	Odds ratio Local	U.S.	Significance
Fetal deaths, gestation >20 weeks	No data available after 1992			
Deaths <1 year	1214	0.761	0.840	0.02
Deaths <1 year, congenital anomalies	267	0.799	0.876	0.23
[a]Cancer cases, ages 0–4	153	0.746	1.066[b]	0.0003
[a]Deaths 1–4, excluding accidents, homicide, suicide	146	0.689	0.836	0.05
[a]Deaths 1–4, congenital anomalies	27	0.460	0.798	0.06

[a]Rate expressed as cases/deaths per 100,000 population.
[b]Change in 11 U.S. states and cities from 1988–1989 to 1990–1993.

over 8 days including barium-140, cesium-137, iodine-131, strontium-89, and strontium-90. The last emissions were reported in 1989, at a level of 0.0003 Ci (Brookhaven National Laboratory, 1970–1992). The post-closure period is also extended to 1990–1996 to assess longer-term trends. No data are yet available after 1996.

Death rates for infants under 1 year are expressed as deaths per 1000 births, while death and cancer incidence rate ages 1–4 are per 100,000 persons. Odds ratios are used to express rate changes in the periods before and after reactor startup/closing. A ratio of 0.900 represents a 10% decline in rate.

Results

Available fetal/infant health measures show a lack of progress from 1972–1973 to 1974–1975 in the four county region. Locally, the fetal death rate (gestation over 20 weeks) fell 1.8% (O.R.=0.982) versus a 7.5% drop in the U.S. (O.R.=0.925). The infant death rate rose 1.9% (O.R.=1.019), while the national rate declined by 9.4% (O.R.=0.906). The number of deaths from congenital anomalies increased 18.6% (O.R.=1.186) while falling 6.9% nationally (O.R.=0.931); no age-specific data by cause at the county level exist, but the majority of congenital anomaly deaths occur in infancy.

By the late 1980s, more fetal/infant health data had become available. The California Cancer Registry initiated a comprehensive database of all cancers diagnosed in the state beginning in 1988. Age-specific congenital anomaly death records became available from the National Center for Health Statistics beginning in 1979. Table 1 shows trends in these radiation-sensitive disorders plus all-cause death rates from 1988–1989 to 1990–1991, before and after the closing of Rancho Seco.

Immediately after the reactor closed, local rates of deaths from all causes, deaths from congenital anomalies, and cancer cases declined faster than the U.S. average. The fall in mortality was especially sharp for congenital anomaly deaths ages 0–1 and 1–4 (O.R. 0.791 and 0.707). Cancer cases age 0–4 also experienced a rapid decline (O.R. 0.628) at a time when the national rate was rising in the 11 U.S. states and cities with available data (Mangano, 1999). When the post-closing period was extended to 1990–1996, local decreases continued to surpass national trends (Table 2). Declines for all but one measure, are statistically significant.

Discussion

Fetal and infant health near Rancho Seco lagged following reactor startup, and improved significantly for at least 7 years after closing. In the Rancho Seco area, fetuses were exposed to radioactive emissions consumed in the maternal diet from 1974 to 1989. Radioisotopes with a short physical half-life disappear soon after emissions cease, while levels of longer-lived radioisotopes diminish gradually.

Because rates declined for children aged 1–4 in the first 2 years after closure, it appears that reducing exposures after birth to those exposed *in utero* may arrest the development of cancer or delay the onset of death almost immediately.

Like other U.S. nuclear power reactors, Rancho Seco emitted low levels of radiation, meaning only small doses were received by the local population. Over its 15-year operating life, 0.1397 Ci of airborne radioactivity with half-lives over 8 days were reported. This figure is about 1/100th of the 14.2 Ci escaping from Three Mile Island during its partial meltdown in late March 1979 (Brookhaven National Laboratory, 1970–1992).

Harmful effects of low-dose radiation exposure to the very young were first demonstrated in the 1950s, when *in utero* pelvic X-rays were associated with an elevated risk of the child developing cancer before age 10 (Stewart et al., 1958). Subsequently, childhood cancer has been positively correlated with other low-dose exposures, including background gamma radiation (Knox et al., 1988; Hatch and Susser, 1990) and emissions from various European reactors (Heasman et al., 1986; Roman et al., 1989;

Gardner et al., 1990; Viel and Richardson, 1990; Goldsmith, 1992; Michaelis et al., 1992; Schmitz-Feuerhake et al., 1997). In the U.S., elevated childhood cancer rates (Johnson, 1981; Goldsmith, 1989; Jablon et al., 1991) and unexpectedly high fetal deaths, infant deaths, and underweight births (DeGroot, 1972; Sternglass, 1972) have been documented near American reactors. Rises in U.S. infant mortality, leukemia, and hypothyroidism after Chernobyl, which added only slightly to the radioactivity in milk and water, have been reported (Gould and Sternglass, 1989; Mangano, 1996, 1997). Each of these reports addresses the presence or addition of environmental radioactivity, suggesting that a negative correlation between adverse health effects and removal of reactor emissions might exist.

There are several limitations to this analysis. Information on uptake of radioactivity is limited; measurements of Sr-90 in vertebrae ended in 1982, while monthly milk concentrations of Barium-140, Cesium-137, and Iodine-131 reported in 60 U.S. cities ceased in 1990. The study mostly covers death rates; aside from cancer, no local disease incidence registries exist. No examination is made of effects to the adolescent and adult populations. Finally, radiation exposure is just one of many potential factors affecting infant health, and it is very difficult exactly to determine what proportion of disease rate declines is due to Rancho Seco's closure.

Future assessments should address not just the Rancho Seco area's infants and children, but persons of all ages living near closed plants. Studies should move beyond the scope of statistical analysis, and measure *in vivo* levels of radioactivity, similar to the study of Sr-90 in St. Louis baby teeth in the 1950s and 1960s (Reiss, 1961; Mangano et al., 2000). With many reactors aging, a thorough knowledge of the relationship between long-term low-dose exposure and health effects to humans is a critical factor in the decision whether or not to continue operations (Nussbaum and Kohnlein, 1994).

Appendix 1

Change in Infant Mortality, Two Years Before and After Reactor Closing, Downwind Counties Within 50 Miles of Reactor, Areas with No Other Power Reactors Within 70 Miles

Reactor (Closing Date)	Infant Deaths		Per 1000 Births		%
Counties	Before	After	Before	After	Change
LaCrosse (1987)	36	30	10.27	8.69	– 15.3
-LaCrosse WI					
-Vernon WI					
Rancho Seco (1989)	418	390	9.39	7.89	– 16.0
-Amador CA					
-El Dorado CA					
-Placer CA					
-Sacramento CA					
Fort St. Vrain (1989)	83	72	8.53	7.22	– 15.9
-Larimer CO					
-Weld CO					
Trojan (1992)	253	204	8.34	6.85	– 18.0
-Columbia OR					
-Multromah OR					
-Clark WA					
-Cowlitz WA					
-Wakhiakum WA					
Millstone/Haddam Neck (1995)	166	130	7.46	6.16	– 17.4
-Middlesex CT					
-New London CT					
-Tolland CT					
-Windham CT					
-Kent RI					
-Washington RI					
U.S. Average, 1985-96					– 6.4

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