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Final Report: Program to Investigate Patterns of Environmental vs. In-Body Radioactivity Near the Brookhaven National Laboratory

Radiation and Public Health Project, Inc.

Joseph J. Mangano

FINAL REPORT
PROGRAM TO INVESTIGATE PATTERNS OF ENVIRONMENTAL VS. IN-BODY RADIOACTIVITY NEAR THE BROOKHAVEN NATIONAL LABORATORY

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Radiation and Public Health Project
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EXECUTIVE SUMMARY

The Radiation and Public Health Project (RPHP), a non profit research and education group, has collected and analyzed data on environmental and in-body radioactivity levels near the Brookhaven National Laboratories (BNL). RPHPs work is supported by Grant No. MTA-05-008 from the Citizens Monitoring and Technical Assessment Fund.

The work is important since BNL operated three nuclear reactors at the site in Suffolk County NY from 1950-1999. These reactors released considerable radioactivity into the air and water, contaminating the local environment. The other basis for the effort are certain patterns of health status in the local area. Specifically:

- From 1979-2001, the Suffolk County cancer death rate (whites) was 12.6% above the national rate, but only 0.1% higher for all other causes of death. This means that 7410 Suffolk cancer deaths are in excess of the U.S.

- During the same period, Suffolk County breast cancer death rate (whites) was 24.2% above the U.S., and was elevated for young, middle-age, and elderly women.

- From 1997-2001, 366 Suffolk County children under age 20 were diagnosed with cancer, a rate 15.5% above the national standard. Children are most susceptible to the damaging effects of radiation exposure.

- The 1997-2001 Suffolk County incidence rate of thyroid cancer, a condition highly sensitive to radiation exposure, was 30% above the New York State rate, and had tripled in the past 20 years.

- The area of Suffolk County with the highest incidence of breast, prostate, lung, and colorectal cancer is east (downwind) of BNL.

Suffolk County has a relatively well-educated, high-income population, and is not at obvious risk for high rates of disease and death. Thus, further exploration of potential causes of cancer, such as environmental pollution, is merited.

RPHP drew information on local levels of radioactivity from two sources. It used the extensive (but little analyzed) state and federal data on concentrations in the air, water, precipitation, and fish. It also collected and analyzed data on Strontium-90 concentrations in over 500 baby teeth donated by Suffolk County residents. Strontium-90 is a calcium-like substance only created in atomic weapons explosions and nuclear reactor operations. It is radioactive and carcinogenic.

Principal findings of the RPHP project are as follows:

1. Most Local Radioactivity Produced by BNL. Average 1996-2003 levels of chemicals emitting alpha and beta radioactivity in the Peconic River, which runs through BNL, is three to four times greater than those at Albany NY, which is not proximate to any

reactor. Thus, the difference between levels at the two sites can likely be attributed to BNL emissions.

2. BNL Contamination Higher Than at Other Sites. The average 1996-2003 level of beta-emitting radioactivity at Yaphank NY (on BNLs perimeter) was the highest of 35 U.S. sites, including six others near nuclear weapons plants. Thus, it is possible that emissions from BNL and resulting contamination are among the highest in the nation.

3. Sr-90 Decline Followed by Increase. Average Sr-90 concentrations in baby teeth from 42 zip code areas east of BNL declined in the 1980s, only to rise in the 1990s. This pattern is similar to those near each of six other U.S. nuclear plants for which at least 100 baby teeth were analyzed. It suggests that BNL emissions were rising in the years just prior to the last two reactor closings, in 1996 and 1999.

4. Sr-90 Trend Matches Some Environmental Trends. The increase following a decrease in Sr-90 levels in baby teeth were similar to patterns in the following types of environmental radioactivity

- Gross beta activity in the air at Upton NY, near BNL
- Cesium-134 in fish in BNL-area ponds

Other environmental radioactivity measures showed consistent increases in the 1980s and 1990s, nearly matching Sr-90 trends, including:

- Gross beta activity in precipitation at Yaphank NY
- Ruthenium-106 in fish in BNL-area ponds
- Gross alpha activity in the Peconic River

5. Declines After the Late 1990s. For many environmental radioactivity measures, average levels fell after the late 1990s. This may represent effects of closing the last two BNL reactors, in 1996 and 1999.

These findings identify BNL as likely contributing to local radioactive contamination in the environment and in the body. Understanding this is important to the public and officials as they consider attempt decontamination at BNL. Proceeding with decontamination using all deliberate haste will be important to lower radiation exposures and to lowering disease rates.

Further research is needed on the role that BNL plays in raising risk of diseases such as cancer in the local population. RPHP will be assessing this subject in the coming year, as a continuation of the current project.

PURPOSE AND OBJECTIVES/KEY TASKS

On October 6, 2003, Joseph Mangano, National Coordinator of the Radiation and Public Health Project (RPHP) signed Grant No. MTA-05-008, which had been previously signed by Robert Fisher, General Counsel of the Citizens' Monitoring and Technical Assessment Fund. The grant, which extends from September 26, 2003 to March 26, 2005, is in the amount of $49,980.00

The purpose of the grant is to support RPHP activities to review, analyze, and disseminate information on

1. in-body radioactivity levels using local baby teeth

2. radioactivity levels in air, water, and fish near Brookhaven National Laboratory (BNL)

According to the grant, RPHP will conduct the following activities, the results of which are contained in this report:

1. Review existing (state and federal) environmental radiation data reports for trends in environmental radioactivity

2. Collect and analyze radioactive concentrations in baby teeth

3. Compare radioactive concentrations in the BNL area with those near other DOE sites

The following documents can be used as references for this grant

1. April 25, 2003 proposal by RPHP to the Citizens Monitoring and Technical Assessment Fund outlining proposed activities

2. January 28, 2004 progress report by RPHP to the Fund

3. August 18, 2004 progress report by RPHP to the Fund

4. January 31, 2005 progress report by RPHP to the Fund

BACKGROUND

A. Radiation and Public Health Project. The Radiation and Public Health Project (RPHP) is a private non-profit research and educational organization. Founded in the mid-1980s and designated as a 501 (c) (3) group in 1996, RPHP's mission is to understand and disseminate information on the health risks of radioactive emissions from nuclear weapons and reactors. Its core group consists of health and scientific professionals, including:

Joseph J. Mangano, MPH MBA, National Coordinator and Director. Mr. Mangano is an epidemiologist who received his MPH degree from the University of North Carolina. He began working with the group on a part time basis in 1989, and is the author of a book and wrote the majority of RPHP's 21 medical journal articles.

Ernest J. Sternglass, PhD, Chief Scientist and Director. Dr. Sternglass is a radiation physicist who received his PhD from Cornell University. He spent 17 years working at the Westinghouse Corporation before moving to the University of Pittsburgh, where he continues to serve as Professor Emeritus. His work on health effects of exposure from emissions from nuclear weapons and facilities began in 1963, when he testified before Congress on the Partial Test Ban Treaty. He is the author of three books and 150 medical journal articles.

Jay M. Gould, PhD, Founder and Director. Dr. Gould is a statistician who received his PhD from Columbia University. His work as a statistical consultant and interest in nuclear weapons and reactors prompted him to found RPHP in the early 1980s when he encountered Dr. Sternglass. Dr. Gould has written two books, is co-author of many RPHP articles, and is the architect of the RPHP baby tooth study, the only research effort to measure in-body levels of radiation near U.S. nuclear plants.

Janette D. Sherman, MD, Research Associate. Dr. Sherman is an internist and toxicologist who received her MD degree from Wayne State University. She has a long history of research into the toxicological properties of various chemicals, in addition to radioactive ones. She is co-author of several RPHP articles and has written two books on harmful effects of chemical exposures. She is an adjunct professor at Western Michigan University in Kalamazoo MI.

William McDonnell, MA, Data Manager and Director. Mr. McDonnell wrote his master's thesis on radioactive waste in America, and was the New York organizer of the First Global Radiation Victims' Conference. He has co-authored two books written by Dr. Gould. RPHP relies on Mr. McDonnell's expertise in computer technology for all the group's data management activities.

Agnes Reynolds, RN, Research Associate. Ms. Reynolds is an obstetrics-gynecology nurse who became interested in RPHP after her son Jon was diagnosed with leukemia at age five. She has been active in collecting baby teeth for RPHP from children with cancer through pediatric oncology support groups.

Since 1994, RPHP has published 21 peer-reviewed articles, letters, and conference proceedings in medical and scientific journals. Each of these was required to receive approval from expert reviewers before publication. In addition, RPHP members have published five books during this time. A complete list of publications is attached as Appendix 1 to this report.

RPHP has found a dearth of research on rates of cancer and other diseases near U.S. nuclear plants. This gap has been partially filled by RPHP articles and books cited above. Numerous articles analyzing rates of childhood cancer near foreign nuclear plants exist in medical journals; at least 12 document high local levels near various plants in the United Kingdom alone. (1-12) By contrast, only four such articles exist on U.S. plants, even though the first weapons plant at Oak Ridge TN and electrical power plant at Shippingport PA began operations in 1943 and 1957, respectively. (13-16) These articles are limited, as they are relatively old, cover small geographic areas near each plant, and examine brief time periods.

In 2003, RPHP published an article documenting that from 1988-1997, cancer incidence in children under age ten near 14 of 14 nuclear plants in the eastern U.S. exceeded the national rate. With 3,669 cancer cases analyzed, elevated rates were highly significant. One of these areas was Suffolk County NY, location of the Brookhaven National Laboratory. The childhood cancer rate in Suffolk was 16.4% above the U.S. rate, and with 307 cases the difference was of borderline statistical significance. (17)

In addition to statistical studies, RPHP began the first clinical study of in-body radiation near U.S. nuclear plants in 1998, when it launched the "Tooth Fairy Project." The initiative involved collecting discarded baby teeth from children living near nuclear plants and testing them in a laboratory for concentrations of Strontium-90 (Sr-90). The RPHP effort is patterned after a study performed from 1958-1970 by researchers at Washington University in St. Louis measuring Sr-90 in teeth from atomic bomb test fallout. It also is similar to articles published in the 1990s on Sr-90 in baby teeth from nuclear plant emissions in Germany, Greece, the south Ukraine, and the United Kingdom. (18-21)

The RPHP tooth study has collected and tested over 4,000 teeth as of late 2004, many of them near six nuclear power plants and BNL. It has found that the average Sr-90 concentration in teeth is highest in counties closest to nuclear facilities; and, after a long decline in average Sr-90 after above-ground atomic weapons testing was banned, average Sr-90 rose 48.5% from the late 1980s to the late 1990s. (22)

One geographic focus of RPHPs tooth study has been Long Island, especially in Suffolk County, where BNL is located. Aided by celebrities and Long Island residents Alec Baldwin and Christie Brinkley, RPHP directors made several public appeals to Suffolk County residents to contribute teeth to the study. The group made its initial findings public at a Mineola NY press conference on June 6, 2001. The previous year, the advocacy group Standing for the Truth About Radiation (STAR) successfully lobbied the

Suffolk County legislature to appropriate $35,000 to support tooth study activities - even though the county health department never released the funds to RPHP or any other researchers. The county government also established a task force to investigate causes of an unexpectedly high number of local cases of childhood rhabdomyosarcoma, a soft tissue cancer; RPHP National Coordinator Joseph Mangano served on the task force. Mangano and RPHP founder Jay Gould attended a June 11, 2001 hearing at Adelphi University of the Senate Committee on Environment and Public Works convened by Senator Hillary Clinton to discuss cancer and potential environmental causes on Long Island. The following week, RPHP submitted written testimony to the Committee.

The greater familiarity with BNL led RPHP to request support from the Citizens Monitoring and Technical Assessment Fund to further investigate the extent of the contamination near BNL, and its effects on local health.

B. Brookhaven National Laboratory and Suffolk Cancer Rates. In 1950, the federal government opened the Brookhaven National Laboratory (BNL), located in the town of Upton NY in the center of Suffolk County in Long Island, about 60 miles east of New York City. BNL was designed as a center for research into various uses of the atom. To that end, three nuclear reactors operated at the site. The Brookhaven Graphite Research Reactor operated from 1950-1969, the Brookhaven Medical Research Reactor from - 1996, and the High Flux Beam Reactor from 1965- 1999.

For decades, BNL managers have been accused of ignoring the potential health and safety problems caused by toxic emissions from reactors - both radioactive and non-radioactive - entering the local environment. While contamination continued, and BNL was declared a Superfund site in 1989, BNL did little to investigate the extent of contaminants and whether it was harming health of the local population. In December 1996, a leak of radioactive tritium from BNL, which had gone undetected for at least 12 years, was discovered and publicized. The U.S. Energy Department produced a report the next year stating that BNL managers had showed a long-term disregard for excessive emissions and public safety. Ground water, which is used to supply private wells, was highly contaminated. In 1998, DOE terminated the contract of Associated Universities, a consortium of Ivy League scientists, for mismanagement of BNL.

From the outset of BNL operations, questions on excess disease rates to the local population have arisen. In 1969, University of Pittsburgh professor Ernest Sternglass presented an analysis comparing the liquid waste released from the BNL filter bed with infant mortality in Suffolk County. From a low of 21.5 millicuries in 1951, annual releases rose steadily to 177.8 and 219.1 millicuries in 1960 and 1961, before dropping back to 16.2 in 1968. The county's death rate to infants under age one was just under 20 per 1000 births for each of the years 1950, 1951, and 1952. But after 1954 it rose, reaching a peak of about 24 per 1000 in 1960 and 1961. A sharp decline followed, to 17 per 1000 in 1968, corresponding with the decrease in new liquid releases. (23)

Coinciding with the proliferation of BNL activities and toxic environmental releases was the drastic demographic change in Suffolk County. When the laboratory started nuclear

operations in 1950, Suffolk was a largely rural county. The post-World War II prosperity and the rise of the automobile led to a large exodus of city dwellers to the suburbs. From 1950 to 1970, Suffolk's population quadrupled, from 276,129 to 1,124,950. (24) The current (2003) population is estimated to be just under 1.5 million. Urbanization added environmental pollutants to the Suffolk environment, from sources like automobile exhaust, pesticides, herbicides, and industrial pollutants.

By the late 1980s, reports of high breast cancer rates in Long Island began to surface, grabbing the attention of health professionals, public officials, the media, and the public at large. The problem was most acute in Suffolk County, one of two counties that make up Long Island. In the early 1950s, Suffolk's breast cancer death rate for white females had been 5% below the U.S. average. But by the late 1980s, the local rate was 32% higher. Suffolk's rise of 40% during this time dwarfed the U.S. rise of 1%, and was the highest increase of any U.S. county with over 1 million residents. (25)

The most current data shows that breast cancer deaths in Suffolk County are elevated (Table 1). The age-adjusted rate for white females in Suffolk County from 1979-2001 was 24.2% above the U.S. rate. This excess is highly significant as 5,503 breast cancer deaths occurred in the county in the 23-year period. The county rate exceeds the U.S. rate for all age groups, including older women (+28.1%), middle aged women (+19.6%), and younger women (+20.1%). All of these are statistically significant. Excess breast cancer deaths total 1354.

Suffolk rates are high not just compared to the U.S., but to the region; the county has the 5th highest rate of the 62 New York counties, and the highest among the large urban/suburban counties. Whites are used here since they represent 91% of the county's female population and 95% of the breast cancer deaths, and thus provide more meaningful numbers. The 282 breast cancer deaths among black women during this period equates to a rate 2.9% above the U.S. average.

Table 1
Breast Cancer Mortality, White Females
U.S. vs. Suffolk County, 1979-2001

Age	Deaths	Population	Rate/100,000	% Above US
All U.S.	825,978	2,480,653,244	307.95*	
All Suffolk	5,503	14,343,180	382.53*	+24.2%
65+ U.S.	479,429	379,361,790	126.38	
65+ Suffolk	3,009	1,858,880	161.87	+28.1%
45-64 U.S.	283,390	509,154,726	55.66	
45-64 Suffolk	2,036	3,057,663	66.59	+19.6%
25-44 U.S.	62,390	743,279,895	8.47	
25-44 Suffolk	457	4,495,489	10.17	+20.1%

* Adjusted to the 2000 U.S. standard
All % differences significant at p<.00001, except for age 25-44, significant at p<.01
Source: National Center for Health Statistics, available at http://wonder.cdc.gov, underlying cause of death. Uses codes 174.0-174.9 (1979-1998) and c50-c50.9 (1999-2001).

The breast cancer mortality excesses correspond to elevated rates for all cancers in Suffolk County. Data for the same 1979-2001 time period show that the local age-adjusted cancer death rate was 12.6% above the U.S. rate, but only 0.1% higher for all other causes (Table 2). Because 58,806 white Suffolk residents died of cancer during this time, an excess cancer death count of 7,410 follows (58,806 x .126). Rates are significantly elevated for each age group except for children and adolescents under age 25, who died of cancer at only a 6.7% higher level than did American youth.

Table 2
Neoplasm (Cancer) Mortality, Whites
U.S. vs. Suffolk County, 1979-2001

Age	Deaths	Population	Rate/100,000	% Above US
65+ U.S.	7,006,866	638,487,995	1097.4	
65+ Suffolk	38,553	3,113,495	1238.3	+12.8%
45-64 U.S.	2,641,836	989,836,397	266.90	
45-64 Suffolk	17,210	5,985,524	287.53	+ 7.7%
25-44 U.S.	384,533	1,494,967,303	25.72	
25-44 Suffolk	2,572	8,862,350	29.02	+12.8%
0-24 U.S.	75,921	1,741,092,621	4.36	
0-24 Suffolk	471	10,121,708	4.65	+ 6.7%
All U.S.	10109156	4,864,384,316	208.09*	
All Suffolk	58,806	28,083,077	234.24*	+12.6*
(Other Causes)				
All U.S.	33240410	4,864,384,316	703.42*	
All Suffolk	167,577	28,083,077	703.87 *	+ 0.1%

* Adjusted to the 2000 U.S. standard
All % differences significant at p<.00001, except for age 0-24, which is not significant (p<.33)
Source: National Center for Health Statistics, available at http://wonder.cdc.gov, underlying cause of death. Uses ICD-9-CM codes 140.0-239.9 (1979-1998) and c00-d48.9 (1999-2001).

In addition to mortality, incidence of breast cancer and all cancers combined is elevated in Suffolk County. Table 3 shows that from 1997-2001 (the most recent data), the Suffolk breast cancer incidence rate was 11.9% above that of New York State. Based on this gap, 668 of the 5588 breast cancer cases diagnosed in Suffolk in those five years can be considered "excess." Table 3 also provides statistics on incidence of all cancers combined. Suffolk's rate is 6.7% and 10.4% higher than the state for males and females, respectively, which equates to 3095 excess cases over five years.

Table 3
Cancer Incidence, All Races
New York State vs. Suffolk County, 1997-2001
Female Breast Cancer and All Cancers Combined

Area	Cases	Rate/100,000*	% Over NYS	Excess Cases
(F) Breast Cancer				
NY State	69,305	131.4		
Suffolk	5,588	147.1	+11.9%	668
(M) All Cancers Combined				
NY State	229,887	570.2		
Suffolk	18,071	608.2	+ 6.7%	1204
(F) All Cancers Combined				
NY State	234,715	434.1		
Suffolk	18,239	479.1	+10.4%	1891
TOTAL EXCESS CANCER CASES, SUFFOLK COUNTY				3095

* Adjusted to the 2000 U.S. standard
All % differences significant at p<.00001. Source: New York State Cancer Registry, available at www.health.state.ny.us/nysdoh/cancer.

Breast cancer incidence rates in Suffolk County rose 34.3% from the early 1980s to the late 1990s (Table 4). Rates increased for each age group, except women 85 and over; the highest increases were women age 65-74 (up 55.6%) and 55-64 (up 44.3%). In the late 1990s, the Suffolk County breast cancer incidence rate exceeded the U.S. rate in five of seven age groups. The highest excesses occurred in young women age 25-34 (20.8% higher) and 35-44 (13.1% higher).

Table 4
Female Breast Cancer Incidence
Suffolk County vs. U.S.
1979-83 to 1994-98

	Cases		Population		Cases/100,000 Pop			1994-98
Age	1979-83	1994-98	1979-83	1994-98	1979-83	1994-98	% Ch.	%+/- US
25-34	102	106	523403	514745	19.5	20.6	+ 5.7	+20.8
35-44	361	580	454282	579639	79.5	100.6	+25.9	+13.1
45-54	615	1087	353732	489656	173.9	222.0	+27.6	- 5.4
55-64	717	1042	283375	285220	253.0	365.3	+44.3	+ 7.2
65-74	644	1172	204209	238810	315.4	490.8	+55.6	+11.5
75-84	448	711	118684	160312	377.5	443.5	+17.4	- 8.6
85+	153	252	38048	63441	402.1	397.2	- 1.2	+ 0.1
All*	3057	4950	3304622	3466272	88.6	119.0	+34.3	+ 4.1

* Adjusted to the 1970 U.S. standard
Source: New York State Department of Health, New York State Cancer Registry.

The excess number of cancer deaths in Suffolk County is especially unusual because the death rate for all other causes is virtually equal to the U.S. rate. Suffolk's socioeconomic data suggest its citizens are at lower risk for disease and death than the nation. For example, it has a more educated population, a higher rate of home ownership, a higher average income, and its poverty level is less than half of the U.S. rate (Table 5). These statistics suggest better personal health practices and greater access to medical care. Perhaps the only basic demographic difference is its population density (1556.0 persons per square mile, vs. 79.6 in the U.S.). Urbanization, and the resulting environmental problems that often accompany it, may play a role in high local cancer rates.

Table 5
Demographic, Income, and Poverty Differences
Suffolk County vs. U.S.

Indicator	U.S.	Suffolk
Population (estimated) July 1, 2003	290,809,777	1,468,037
Population (actual) April 1, 2000	281,421,906	1,419,369
2000 % Population 65 and over	12.4%	11.8%
2000 % Population Black	12.3%	6.9%
2000 % Population Asian	3.6%	2.4%
2000 % Population Hispanic	12.5%	10.5%
2000 % Population White, Non-Hispanic	69.1%	78.8%
2000 % English not spoken at home, >=5	17.9%	17.1%
2000 % High school grads, age 25 and over	80.4%	86.2%
2000 % Bachelor's or higher, 35 and over	24.4%	27.5%
2000 % Homeowner rate	66.2%	79.8%
1999 Median Household income	$41,994	$65,288
1999 Per capita money income	$21,587	$26,577
1999 % persons living below poverty	12.4%	6.0%
2000 square miles	3,537,438	912
2000 population/square mile	79.6	1556.0

Source: U.S Bureau of the Census. Available at www.census.gov, Quick Facts.

Public outcry over cancer in Long Island, especially about breast cancer in women, prompted Congress to authorize the Long Island Breast Cancer Study Project, to find environmental and other causes of the breast cancer outbreak. Most of the $30 million expended for this project consisting of 12 studies went to Columbia University, Memorial Sloan-Kettering cancer hospital, and State University of New York at Stony Brook. Project investigators reported in August 2002 that they had found no link between breast cancer and chemicals like DDT and PCBs. Environmentalists expressed great disappointment, not just with study results but with the methods used by authors.

Soon after the announcement, articles and editorials appeared in the mainstream media stating that breast cancer rates on Long Island had never been high to begin with, and that the $30 million study had been the result of political pressure rather than sound science.

The August 29, 2002 New York Times featured a lengthy article entitled "Epidemic That Wasn't." Several eminent health professionals were quoted:

- Dr. Deborah Winn, head of the extramural epidemiology program at the National Cancer Institute, said of the belief that incidence rates on Long Island are elevated: "I don't think it is reflective of any reality. I don't know where it comes from. It's myths."

- Dr. Michael B. Bracken, professor of epidemiology and public health at Yale University, said the study should never have begun. "It is an example of politicians jumping on the bandwagon and responding to the fears of their local population without really thinking through what is going on in science." (26)

Editorials called the breast cancer study "a wild goose chase" (27) and "wasteful investigation of activist-generated myths." (28) These pronouncements ignored the array of facts (many already discussed in this report) that did indeed identify Long Island, and especially Suffolk County, as having elevated breast cancer rates:

1. The county's breast cancer incidence rate for 1997-2001 was 11.9% higher than the New York State rate, and 12.6% higher in 1993-97. (29)

2. The eastern portion of Suffolk County (the 42 zip code areas east of Brookhaven) had a breast cancer incidence rate 23.2% above the New York State rate, higher than the remainder of Suffolk County (Table 6). The area also had high rates for the most common cancers. (29)

3. An especially sharp rise in breast cancer incidence occurred in female Suffolk residents. From 1979-83 to 1994-98, incidence rose 34.3% for all ages (adjusted for the 1970 U.S. standard). Rises were sharpest among women for women age 55-64 and 65-74, at 44.3% and 55.6%, respectively. (30)

4. A commonly-used reason why Long Island breast cancer rates were perceived to be elevated - the greater access to mammograms by a relatively affluent population - is not supported by incidence trends. From 1979-83 to 1994-98, breast cancer incidence for Suffolk women age 25-34 and 35-44, very few of whom are screened for the disease, rose 5.7% and 25.9%, respectively. In the latter period, local rates exceeded national ones by 20.8% and 13.1%, respectively.

5. Breast cancer incidence for Suffolk women over 85 declined and equals the U.S. rate, which casts doubt on another theory, that breast cancer is simply a matter of an aging population.

6. Suffolk County had been transformed from an area with low breast cancer mortality to one well above national norms, a pattern that continued at least through 2001.

Table 6
Incidence Rates, Most Common Cancers
Eastern Suffolk County vs. New York State
1993-1997

	Eastern Suffolk		% Above/Below NY State	
Type of Cancer	Cases	Expected	E. Suffolk	Other Suffolk
(F) Breast	742	602.1	+23.2%	+10.8%
(M) Prostate	767	621.5	+23.4%	+18.5%
(M) Lung	411	385.1	+ 6.7%	+ 3.5%
(F) Lung	353	275.4	+28.1%	+18.5%
(M) Colorectal	389	294.9	+31.9%	+ 4.7%
(F) Colorectal	331	290.2	+14.1%	+ 7.0%
TOTAL	2993	2469.2	+21.2%	+11.2%

See Appendix 2 for list of 42 zip codes/towns that make up eastern Suffolk county. "Expected" cases are based on New York state rates applied to Suffolk population. Prostate cancer represents years 1994-1998. All differences between eastern Suffolk and New York State rates are significant at $p<.05$ except for male lung ($p<.35$). Above types of cancer represent 55% of all malignancies in U.S. Source: New York State Department of Health, New York State Cancer Registry. Available at http://www.health.state.ny.us/nysdoh/cancer/.

One of the shortcomings of the federal breast cancer study is its omission of radiation as a potential risk factor for breast cancer. Neither Xray history nor exposure to ionizing radiation from nuclear plants such as Brookhaven were included in the questionnaire of Long Island women with and without breast cancer.

The omission of radiation from the breast cancer study occurred at the same time that shoddy safety practices at BNL that contaminated the environment became public knowledge. The dynamic of health officials ignoring radiation in reaction to a legislative initiative also occurred at the local level. In 2000, the Suffolk County legislature enacted two laws, at the urging of citizens and model/Suffolk resident Christie Brinkley. It authorized the expenditure of $35,000 to support the RPHP baby tooth study, and mandated the creation of a task force to determine if and why an excess level of childhood rhabdomyosarcoma was occurring on Long Island. Both of these were based on concerns about BNL contamination.

But both were effectively halted by the Suffolk County Health Department. The Commissioner of Health determined that, even though RPHP had tested thousands of teeth for radioactive Sr-90, that there were no entities that could effectively carry out a tooth study. The $35,000 was never spent, and the appropriation lapsed at the end of the fiscal year. The Commissioner also took nearly one year to convene a task force on rhabdomyosarcoma (which she chaired). Meetings were held infrequently, and little was accomplished when the task force stopped convening in 2003.

Ignoring the role of radiation exposure in the extensive debate over breast cancer and its potential causes in Suffolk County also ignores evidence of elevated levels of radiation

sensitive cancers. Of all toxic effects of radioactivity, childhood cancer is probably the most commonly accepted, and the most studied.

The most recent data from the New York State Cancer Registry reveals cancer incidence rates for children under age 20 for each county. Table 7 lists rates for the most populated New York counties in 1997-2001, which account for 81% of cancer cases in the state. Suffolk County has the 4th highest rate out of 16, with 366 children diagnosed in the five-year period; and adjoining Nassau County has the highest rate. Suffolk's rate of 18.6 cases per 100,000 children is 15.5% above the U.S. standard of 16.1.

Table 7
Cancer Incidence, Children Age Under 20
Largest New York Counties, 1997-2001

County	Annual Cases	Rate/100,000
1. NASSAU	354	20.3
2. New York	296	19.8
3. Niagara	58	19.3
4. SUFFOLK	366	18.6
5. Orange	98	18.6
6. Westchester	210	17.2
7. Queens	478	17.1
8. Monroe	176	16.9
9. Richmond	98	16.2
10. Rockland	69	16.1
--- United States ---		16.1
11. Erie	198	15.6
12. Kings	557	15.3
13. Albany	58	15.1
14. Dutchess	56	14.6
15. Bronx	295	13.8
16. Onandaga	80	12.1

* Adjusted to the 2000 U.S. standard
Source: New York State Cancer Registry, available at www.health.state.ny.us/nysdoh/cancer. Difference between Suffolk and U.S. rates significant at p<.055.

Another health indicator that may reflect radiation exposure to the public is thyroid cancer. This type of cancer is relatively rare (1-2% of all newly diagnosed cancer cases) and is relatively curable (about a 95% five-year survival rate). However, exposure to ionizing radiation - in particular radioactive iodine which seeks out the thyroid gland and kills cells and impairs their DNA - is the only documented risk factor for thyroid cancer. Various iodine isotopes such as I-129, I-131, I-133, and I-135 are part of the mix of chemicals produced only in nuclear weapons and nuclear reactors like those at BNL.

Thyroid cancer incidence from 1997-2001 in Nassau and Suffolk Counties exceeds the New York State rate. For Suffolk males and females, the excesses are 33% and 27%, respectively (Table 8). A total of 719 thyroid cancer cases (530 in females, 189 in males) were diagnosed in the county during this five-year period. The table also shows that in the past 20 years, thyroid cancer incidence has roughly tripled in Suffolk County, i.e., male and female rates have risen 211% and 192%, respectively. (A 200% increase means a rate has tripled). These rises are sharper for, and current rates exceed, both Nassau County and New York State. The 1997-2001 incidence rate in Suffolk County is approximately 30% above New York State (33.3% higher for males, 26.5% higher for females).

Table 8
Thyroid Cancer Incidence
Suffolk and Nassau Counties vs. New York State
1997-2001

	1997-01 Incidence			% Change
Area	Cases	Rate/100,000	% Above NYS	From 1976-81
Females				
Suffolk County	530	14.3	+26.5%	+192%
Nassau County	514	14.3	+26.5%	+160%
New York State	5687	11.3	---	+146%
Males				
Suffolk County	189	5.6	+33.3%	+211%
Nassau County	175	5.3	+26.2%	+ 65%
New York State	1858	4.2	---	+ 83%

* Adjusted to the 2000 U.S. standard
Source: New York State Cancer Registry, available at www.health.state.ny.us/nysdoh/cancer. Difference between Suffolk County and New York State 1997-01 rates and rate changes are significant ($p<.01$) for both males and females.

Local thyroid cancer mortality rates are also high. From 1979-2001, the age-adjusted thyroid cancer death rate for Suffolk County whites exceeded the U.S. rate by 21.1%, based on 135 deaths. The number of nonwhite deaths are small (5) and statistically insignificant.

The lessons of mismanagement at BNL creating a potential hazard to local health have unfortunately not been learned by all leaders. Dr. Praveen Chaudhari, who was appointed BNL director early in 2003, was asked about community concerns about the BNL reactors. His response was

"I've spoken to many people of divergent points of view, and the one consistent view is, the closing of the reactors was not commensurate with what actually happened.

Now, if I was a neighbor of Brookhaven, not knowing what was going on and suddenly learning that something will be coming my way in my drinking water, or in my soil, I'd worry about it, too. And I might respond in a certain way. But the newspapers got involved, and they had a story to write. The net result was that it all spiraled out of proportion." (31)

Other leaders may share Dr. Chaudhari's rather casual attitude towards safety. During a June 2000 conference held at the Laboratory, Dr. Otto Raabe of the University of California stated "there are few things in life safer than low-level radiation." Dr. Bernard Cohen of the University of Pittsburgh went further by saying "low levels of radiation stimulate the immune system, which then protects against cancer." (32) These statements, which have no empirical support, are irresponsible and even dangerous to attempts to protect the public from harmful effects of radiation exposure.

The business community also has demonstrated reticence towards attempts to understand BNL's impact on local health. One 1998 editorial in Long Island's largest newspaper by a banker and leader of the Association for a Better Long Island stated that

"Today, Long Island is home to the latest assault on science and progress as protestors and pickets call for the closing of the Brookhaven National Laboratory. These people are not content with a vigorous federal cleanup of environmental contamination. They simply want to return us all to the Dark Ages." (33)

These actions and attitudes of leaders described above, plus the continuing contamination at the BNL site, are the basis for RPHP's current project under the Resolve program. Public officials have not demonstrated a diligence to understand the extent of contamination at BNL, nor have tried to assess if it has raised cancer risk to local residents. What is needed is an investigation truly independent of any prior government effort, to best obtain objective answers to these problems.

At very least, contamination patterns and trends must be studied, and compared with in-body radioactivity to determine how much of the contamination entered local human bodies. RPHP will accomplish this goal in this grant under Round 5 of the Resolve program. The next question, whether this contamination actually raised the risk of cancer and other diseases, will be addressed later under Round 6.

The need for projects assessing contamination and effectively decontaminating the BNL area is underscored by the potential to improve local public health by lowering disease rates. Brookhaven's last two reactors ceased operations in 1996 and 1999. While decontamination is still a future proposition, reactor closings suggest reduced levels of new emissions from BNL.

The question of whether these lower emissions result in less disease probably will take years to fully answer. However, current data on health status can be analyzed to understand if any improvements in local health were immediately forthcoming. The more vulnerable fetus and infant are most likely to benefit. Table 9 compares mortality

rates in Suffolk County infants less than one year while the two BNL reactors operated (1994-95) and during/after closing (1996-2001). The rate declined 16.0% in the county, compared to just a 9.2% decline nationwide. While this difference falls short of statistical significance, it may portend future improvements to the health in the period after BNL shutdown.

Table 9
Change in Infant Mortality Rate
Before and After BNL Shutdown
1994-1995 to 1996-2001
Suffolk County vs. U.S.

	Deaths Under 1 Yr		Live Births		Deaths/1000 Births		
Area	1994-95	1996-01	1994-95	1996-01	1994-95	1996-01	% Ch.
Suffolk	250	618	40805	119888	6.13	5.15	-16.0%
U.S.	61293	168443	7852356	23758105	7.81	7.09	- 9.2%

Source: National Center for Health Statistics, available at http://wonder.cdc.gov, underlying cause of death. The difference between the U.S. and Suffolk reduction is not significant ($p<.17$).

METHODS USED

A. Trends in Environmental Radioactivity.

1. Data from the New York State Department of Health.

RPHP does not collect any samples of environmental radioactivity. This task has long been assigned to each state's health department. In New York, the department's Bureau of Environmental Radioactivity Protection in Albany measures samples of environmental radioactivity near each of the state's nuclear sites, and publicly reports data.

The Health Department began the New York State program in 1963. From 1972-1981, the Department of Environmental Protection assumed authority, only to have it transferred back to the Health Department beginning in 1982. Because the Department makes environmental radioactivity data available from 1982 forward, the RPHP project will focus on this period.

The New York program covers radioactivity levels in fallout, vegetation, milk, surface water, air, and fish. Exactly which measurements are taken vary by site. At BNL, the following measurements are made:

- Gross beta in air, Upton NY (picocuries per cubic meter), weekly
- Gross alpha in water, Peconic River (picocuries per liter), monthly
- Gross beta in water, Peconic River (picocuries per liter), monthly
- Tritium in water, Peconic River (picocuries per liter), monthly
- Strontium-90 in fish bones near three BNL ponds (picocuries per kilogram), annually
- Cesium-134, Cesium-137, Ruthenium-106, and Potassium-40 in ponds, annually

The Health Department has collected large volumes of data, but few analysts have attempted to understand patterns and trends in environmental radioactivity. Annual reports from the Health Department - which are only available through 1994 - occasionally include a graph of historical trends of one radionuclide. In 1996, as controversy swirled around BNL, a newspaper article reported extraordinary levels of radioactive contamination in the Peconic River. Suffolk County legislator Michael Caracciola asked the Suffolk County Health Department for its opinion of contamination around the lab. The department yielded to the state Bureau of Environmental Radiation Protection, which issued a report stating that "water discharges from BNL have contributed to observed concentrations" of various radioactive chemicals. However, the Bureau added that "radiation doses are too small" to be considered harmful. (34)

RPHP has collected annual volumes of environmental radiation data measurements from the Health Department from 1982-2003. (The final nine years of data proved difficult to obtain. No data had been publicly issued since 1994, and months of request to the Department for the data proved fruitless. Finally, after a Freedom of Information law request and intervention by New York State Assemblywoman Ginny Fields of Suffolk County, the state released the information to RPHP in July 2004). These 22 years of data on the above-listed types of radioactivity measurements will provide RPHP with a basis for evaluating contamination. RPHP will

- Examine trends at the various BNL sites over time
- Compare BNL-area patterns with that in Albany, far from any nuclear plant

2. Data from the federal government
   The U.S. Environmental Protection Agency (EPA) also measures radioactivity levels near nuclear sites. The federal government engages in this activity because regulatory authority for nuclear plants lies with the federal government, both for nuclear weapons plants (U.S. Department of Energy) and for nuclear power plants (U.S. Nuclear Regulatory Commission).

   The EPA has conducted measurements near 60 sites across the U.S. since 1975, and issues them in quarterly volumes (available online beginning in 1996). One of these sites operated by the Agency is at Yaphank NY, very close to BNL. Initially, little data was reported at Yaphank; but from 1984-2003, a variety of measurements have been taken at Yaphank, including:

- Gross beta in airborne particulates (picocuries per cubic meter), monthly
- Gross beta in precipitation (picocuries per liter), monthly
- Tritium in precipitation (nanocuries per liter), quarterly
- Plutonium and uranium in air (picocuries per cubic meter), semiannually
- Plutonium and uranium in precipitation (picocuries per liter), semiannually

RPHP had no trouble obtaining data from the early 1980s to the present, especially since recent years are available online. Only nine months of data are available for each of the years 2001, 2002, and 2003, but this still provides an adequate picture of current levels of contamination.

The project will analyze data in several ways

- Examine trends at the Yaphank site over time
- Compare Yaphank patterns with those near other nuclear weapons sites, including Barnwell SC (near the Savannah River facility), Berkeley CA (near Lawrence Livermore), Denver CO (near Rocky Flats), Idaho Falls ID (near Idaho National), Knoxville TN (near Oak Ridge), and Santa Fe NM (near Los Alamos).

Individual measurements for each of the types of radiation listed, from both state and federal sources, were entered into an Excel spreadsheet. Mean and median levels were calculated, but only means were used. Data in this report will be combined in four-year periods, which ensures that sufficient numbers of measurements will minimize differences between means and medians.

B. Trends in In-Body Radioactivity

Patterns of environmental radioactivity near BNL will be compared with patterns of radioactivity in the bodies of BNL-area residents. This comparison will address the issue of whether radioactivity emitted from BNL actually enters the human body. It also sets

up a future analysis of whether radioactive emissions from BNL have raised cancer risk among local residents.

Studying in-body radioactivity is the optimal means of understand radiation's effects. However, it is a difficult undertaking, often involving autopsies, biopsies, or blood or urine samples. In 1958, during the period when hundreds of above-ground atomic bomb tests were conducted by the United States and Soviet Union, Dr. Herman Kalckar of the National Institutes of Health called for the study of fallout's buildup in human bodies through an analysis of baby teeth. Kalckar wrote that

"It is generally recognized that young children take up radioactive strontium and caesium more intensely than adolescents and adults . . . Such an International Milk Teeth Radiation Census would contribute important information concerning the amount and kind of radiation received by the most sensitive section of any population, namely, the children." (35)

Researchers in a number of nations responded by studying the buildup of radioactive Strontium-90 in baby teeth during bomb testing. Sr-90 is one of 100-plus chemicals produced by fission, i.e. the bombarding of uranium atoms by neutrons, only occurring in atomic bomb explosions and nuclear reactor operations. It is chemically similar to calcium; when ingested by breathing or the food chain, it quickly attaches to bone and teeth.

Like the other 100-plus chemicals found only in nuclear weapons and reactors, Sr-90 is radioactive and carcinogenic. It kills and injures healthy cells, and its beta particles can penetrate into the bone marrow, where white blood cells so critical to the immune response are formed. During the protests against the continued atmospheric bomb testing in the early 1960s, Sr-90 was singled out as particularly potent threat to the health of humans, especially the young.

In the U.S., a coalition of scientists from Washington University in St. Louis and the Greater St. Louis Committee for Nuclear Information combined to collect baby teeth and test them for Sr-90 concentrations in a laboratory. From 1958-1970, the coalition collected about 320,000 teeth, by far the largest of all tooth studies worldwide. Researchers found that babies born in 1964 (when large-scale atmospheric tests ceased after the Partial Test Ban Treaty) had about 50 times as much Sr-90 in their teeth at birth as did babies born in 1950, before tests in Nevada had begun. (36)

The St. Louis study ended in 1970 when the Nixon administration discontinued funding. Two other publicly funded American studies of in-body radioactivity were conducted. One was a study of Sr-90 in children's bones in 30 U.S. cities from 1962-1971 and the other examined Sr-90 in adult bones in Chicago, New York, and San Francisco from 1954-1982. Both were discontinued when government funding ended. Each found a similar rise in Sr-90 during bomb testing, and a rapid decline after the Treaty. (37) (38)

Until 1998, no studies of radioactivity in bodies of persons living near U.S. nuclear plants had ever been conducted. RPHP began its Tooth Fairy Project in that year, patterned after the St. Louis study, to build a data base of in-body radioactivity patterns near plants. The data base would

- reveal whether in-body radioactivity increased with proximity to plants
- assess any trends of increase or decrease in in-body radioactivity
- serve as the "dose" portion of an eventual dose-response analysis of low-dose radiation's effects on cancer risk

Early in the study, RPHP generated considerable interest from Suffolk County. The controversies over both breast cancer and Brookhaven were peaking, and the group received support from the Standing for Truth About Radiation (STAR) advocacy group. In particular, STAR Board members Alec Baldwin and Christie Brinkley spoke out publicly about the importance of the tooth study.

In 1999, RPHP mailed 15,000 letters signed by Baldwin to randomly selected Suffolk County households with children age 6-18, or those most likely to keep a discarded baby tooth. In addition, some parents donated teeth after hearing of the study in media reports. Parents can obtain special tooth mailing envelopes by calling a toll free number (800-582-3716) or by visiting the RPHP web site at www.radiation.org and downloading a form resembling the tooth envelope.

Eventually, over 500 teeth from Suffolk were submitted for study, the most from any U.S. county. The distribution of teeth is roughly representative of the county's population; most teeth are from the more-populated western portion of Suffolk.

RPHP asks each tooth donor to supply the following information:

- Mother's name
- Phone number
- Address
- Child's name
- Birth date (month, day, year)
- Birth weight (pounds, ounces)
- Location where mother carried the baby (city, state, county, zip code)
- Location where child was born (city, state, county, zip code)
- Location during first/second/third year of life (city, state, county, zip code)
- Water source (well, municipal, bottled, other)
- Mother's age at birth of child
- Age of child when tooth was lost or date of tooth loss

RPHP assures donors of the confidentiality of all individual information on children and parents. Upon receipt of envelopes containing teeth, RPHP data managers assign a unique control number to each tooth and logs it into a computerized data base. Teeth are periodically sent in batches to REMS, Inc., a radiochemistry laboratory in Waterloo,

Ontario, Canada. Laboratory personnel document Sr-90 concentrations by separately measuring Sr-90 activity (in picocuries) and calcium mass (in grams) in the teeth. REMS personnel, headed by radiochemist Dr. Hari Sharma, are blinded from any information about each tooth. The techniques employed for measuring Sr-90 are presented in Appendix 3.

Sr-90 concentrations for each tooth at the time it was lost by the child are converted to levels at birth, creating a standardized measure that can be compared regardless of how old the tooth is. This technique was used in Sr-90/baby teeth studies in St. Louis and in foreign nations. This conversion is made using the decay rate of a 28.7 year physical half-life for the radionuclide, using the month of birth and the month of tooth analysis. In baby teeth, the vast majority of Sr-90 uptake occurs during pregnancy (from the mother's bone stores and diet) and early infancy (the diet).

In some teeth, no radioactivity could be detected. RPHP assigned a ratio of 0.2 picocuries of Sr-90 per gram of calcium to each tooth, since all teeth have some trace of Sr-90 in them.

When RPHP received support from the Citizen's Monitoring and Technical Assessment Fund, Round 5, it had already tested 304 baby teeth from Suffolk County, using its privately-raised resources. The Fund support was used to pay the laboratory for testing the remaining 211 teeth.

C. Correlation of Trends

The core of this report will be the comparison of trends in environmental radioactivity near Brookhaven and trends in in-body (baby tooth) radioactivity. This comparison will help document whether chemicals produced from and emitted by Brookhaven actually enters the bodies of local residents, where it can be harmful.

The significance of any changes in environmental or in-body radioactivity will be tested using a t-test. For example, if average radioactivity in teeth rises over time from 1 to 2 picocuries of Strontium-90 per gram of calcium, and 50 measurements are involved in each sample, the following formula will be used.

+/- {1/(sqrt 50} x 2 = .2828 (for second set of measurements)
+/- {1/(sqrt 50) x 1 = .1414 (for first set of measurements)

$\{2 - 1\}/ (\text{sqrt}((.2828^2 + (.1414^2))) = 3.16$ (z score)

In a basic statistics table for the area under a normal curve for various z scores, 3.16 equates to a p value of <.002. This means there is a less than 2 in 1000 chance that the difference is due to random chance. This is statistically significant, along with any other p value <.05, a standard customarily used by statisticians.

Accompanying the t test for significance is the calculation of a confidence interval for each measurement. Again, using the above example of two sets of 50 teeth each, the

confidence interval represents a combination of the error due to sample size and error due to testing inaccuracy. Each tooth carries an inaccuracy reading of 0.7 picocuries of Strontium-90 per gram of calcium, as conservatively estimated by REMS laboratory.

The formula for confidence intervals are as follows:

Sample size = 1 / (SQRT 50) = .1414
Counting error = .7 / (SQRT 50) = .099

Error at 95% level of confidence = +/- 2 x {SQRT $((.1414)^2 + (.099)^2)$} = +/- .344

95% Confidence Interval for Sample 1 = 0.656 - 1.344
95% Confidence Interval for Sample 2 = 1.656 - 2.344

Because the two intervals do not overlap, the difference is statistically significant.

The measurements of each type of environmental radioactivity carries its own specific counting error.

RESULTS

A. STRONTIUM-90 IN BABY TEETH

1. Geographic Patterns. A total of 1296 baby teeth from all areas were tested using the same scintillation counter and the same testing methods. Of these, nearly half were from Long Island, including 522 from Suffolk County and 105 from Nassau County. Teeth are assigned to a geographic area according to where the mother lived during pregnancy, since most Strontium-90 in baby teeth is taken up during pregnancy and early infancy.

   The 95 baby teeth from persons born before 1979 are excluded from the study. Above-ground nuclear weapons test fallout from entered the environment and body, peaked in the years 1963-64, and rapidly declined after large scale testing was consigned to underground sites. By the early 1980s, very little Sr-90 from bomb testing should remain in the body, and thus analysis of radioactivity excluding bomb test fallout can be undertaken by using only post-1979 data. About 98% of the tooth donors born after 1979 were born from 1980-1993.

   Over half of the baby teeth born after 1979 are from Long Island, with the great majority from Suffolk County. Because the county is the location of the Brookhaven Labs, these 503 teeth from Suffolk will be the focus for the study. The average concentration of radioactivity in these teeth - given in average picocuries of Sr-90 per gram of calcium at birth - is 1.28. This figure is slightly higher than Nassau County in western Long Island (1.24), but below the figure for all other areas (1.45). Many teeth from other areas are in New York City and its northern suburbs, central New Jersey, southeast Florida, and California, near nuclear power plants. (Table 7)

   Table 7
   Average Strontium-90 Concentration in Baby Teeth
   By Geographic Area, Persons Born After 1979

Area	No. Teeth	Avg. Sr90/Ca
(Suffolk County)	503	1.28
(Nassau County)	101	1.24
Long Island	604	1.27
Other Areas	597	1.45
TOTAL	1201	1.36

Note: Average represents picocuries of Sr-90 per gram of calcium in baby teeth at birth.

Virtually all of Suffolk County lies within 30 miles of Brookhaven. The county's 936 square mile area has a wide, flat shape. Thus, portions of the county are better classified as east-west of the plant, rather than north/south.

The county is divided into five portions. Two are east of Brookhaven (under 10 miles and 10-40 miles distant). The other three are west of Brookhaven (under 5 miles, 5-15

miles, and 15-30 miles distant). Results for neighboring Nassau County are also given. Forty-three (43) of the 503 Suffolk teeth and 7 of the 101 Nassau teeth (about 9%) are excluded from the analysis because results obtained by the REMS lab lacked sufficient accuracy. If a tooth contains little healthy enamel, because only a fragment is sent to the lab or decay/fillings are present, REMS may not always be able to measure the Sr-90 concentration with much accuracy.

The highest average Sr-90 levels in Suffolk County are found in the western portion, while the lowest levels are found east of Brookhaven. The average for Nassau County lies between the figures for western and eastern Suffolk (Table 10). There are many potential explanations for this finding. In addition to emissions from Brookhaven, radioactive chemicals generated by other nuclear plants can enter bodies of Long Islanders through breathing and the food chain. The nearest such plants are

- Millstone (near New London CT, as close as 11 miles across the Long Island Sound north of NE Suffolk County);
- Indian Point (near Peekskill NY, as close as 35 miles from NW Suffolk County); and
- Oyster Creek (near Toms River NJ, as close as 55 miles from SW Suffolk County).

Sr-90 can also be ingested from distant food products that are imported from outside the local area.

Table 10
Average Strontium-90 Concentration in Baby Teeth
By Geographic Area of Long Island, Persons Born After 1979

Area	No. Teeth	Avg. Sr90/Ca
15-40 miles W of BNL	207	1.34
5-15 miles W of BNL	103	1.27
< 5 miles W of BNL	26	1.35
Total W of BNL	336	1.32
<10 miles E of BNL	43	1.18
10-40 miles E of BNL	81	0.76
Total E of BNL	124	0.91
Suffolk County	460	1.21
Nassau County	94	1.13
Long Island	554	1.19

Note: 43 teeth from Suffolk, 7 from Nassau with inaccurate measurements are excluded. Inaccuracy defined as a tooth with a quench factor over 1.15 (see methodology section).

2. Trends. Of particular importance to this project is the trend over time in Sr-90 concentration in Long Island as a whole, and in each part of the Island. Table 11 provides a summary of such trends, by dividing the teeth into four-year birth cohorts

(1982-85, 1986-89, and 1990-93). There appears to be diverging trends east and west of BNL. For the portion of Suffolk County west of Brookhaven, there is no clear pattern. But in the 43 zip code areas east of Brookhaven, the trend is clearer. Average Sr-90 declined from 1982-85 to 1986-89 (1.18 to 0.82), but rose to 1990-93 (0.90). The five teeth tested from persons born east of BNL in 1994-97 show a continuing rise (1.07). Although five teeth in a birth cohort is not significant, RPHP uses it with confidence. In each of six areas near U.S. nuclear power plants, a similar increase was documented from the periods 1990-93 to 1994-97. (22)

Table 11
Trends in Average Strontium-90 Concentration in Baby Teeth
By Geographic Area of Long Island, Persons Born 1982-1993
By Four-Year Birth Cohort Groups

	Number of Teeth			Average pCi Sr90/g Ca			
Area	1982-5	1986-9	1990-3	1982-5	1986-9	1990-3	1994-7
15-40 miles W of BNL	26	92	87	1.25	1.47	1.23	
5-15 miles W of BNL	12	41	47	1.16	1.15	1.42	
< 5 miles W of BNL	3	12	7	1.31	1.84	0.47	
Total W of BNL	41	145	142	1.23	1.40	1.25	
<10 miles E of BNL	6	15	18	1.66	1.01	1.24	
10-40 miles E of BNL	11	25	38	0.92	0.70	0.74	
Total E of BNL	17	40	56	1.18	0.82	0.90	1.07 (5 teeth)
Suffolk County	58	185	197	1.21	1.27	1.15	
Nassau County	11	40	39	1.50	1.06	1.05	
Long Island	69	225	236	1.26	1.24	1.14	

A reversal of the downward trend of Sr-90 concentrations, which had begun with the passage of the Partial Test Ban Treaty in 1963 that ended large-scale above-ground atomic bomb tests, is significant. It represents an increase in a CURRENT source of radioactivity, not left-over bomb test fallout. Moreover, the reversal in eastern Suffolk County may represent the closest approximation to BNL's effects on radiation in the bodies of Long Islanders. Prevailing winds tend to blow west to east -- from the northwest in the cold weather, from the southwest in the warm weather -- in the New York metropolitan area. Thus, the majority of the radioactive gases and particles emitted from Brookhaven may be entering the eastern part of Suffolk.

It is noteworthy that, while health risks of these emissions are yet unknown, the highest incidence of cancer in Suffolk County occurs in the eastern portion (shown earlier in the report). The eastern part of the county is the least densely populated, and is home to fewer polluting industries than in western Suffolk or Nassau.

B. ENVIRONMENTAL RADIOACTIVITY LEVELS NEAR BROOKHAVEN

1. Comparison with other areas.

a. Gross Alpha and Beta in Water. As mentioned in the Methods Used section, there are several types of environmental radioactivity near Brookhaven monitored by government regulatory agencies. Two of these are broad measures of radioactivity in water, tracked for decades by the New York State Department of Health. One is "gross alpha" and the other "gross beta", representing all radioactivity giving off alpha and beta particles. Because the only other type of radioactivity produced by nuclear plants is gamma (from several chemicals like tritium), gross alpha and gross beta are a rough indicator of total radioactivity in an area.

The state health department takes monthly samples of gross alpha and beta activity in the Peconic River, which runs directly through the BNL complex. Department officials also make the same measurements in water near other New York state nuclear sites, and make weekly measurements at Albany, which is not near any nuclear plant. Average levels in the Peconic for a recent period (1996-2003) are just below three times higher than Albany for gross alpha, and about four times higher for gross beta (Figure 1). A total of 72 measurements from the Peconic (average of 3.13 and 7.04 picocuries per liter of water for gross alpha and beta) and 357 from Albany (1.23 and 1.73) are used.

The significance of the Albany-Peconic differences in gross alpha and beta levels in water is that they document that most radioactivity near Brookhaven is likely to be produced by the labs.

b. Gross Beta in Precipitation. Another type of radioactivity measurement is gross beta found in precipitation. Since the late 1970s, the U.S. Environmental Protection Agency has compiled monthly readings at sites around the nation, including Yaphank (which is located close to the border of the Brookhaven site). Again, using the most recent eight-year period (1996-2003), average gross beta at Yaphank can be compared to other sites.

Of the 35 locations surveyed by the EPA, the highest average levels of gross beta were found at Yaphank. The average picocuries of gross beta per liter of water at the site is more than double the national average (4.83 vs. 1.95, with Yaphank excluded). Some stations such as Trenton NJ are not close to any nuclear plant. Others such as Harrisburg PA are close to plants (Harrisburg is near Three Mile Island). Others are close to Department of Energy sites, but all fall short of Yaphank's average (Table 12 and Figure 2). Average concentrations at Yaphank are about double those near other DOE sites. They are significantly higher than five of six DOE sites.

Table 12
Average Gross Beta Levels in Precipitation
Sites Near Department of Energy Nuclear Sites, 1996-2003

Site	Nearby Facility	Measurements	Avg. Gross Beta
Yaphank NY	Brookhaven Lab	76	4.83
Idaho Falls ID	Idaho National	68	4.15
Knoxville TN	Oak Ridge	76	3.14
Barnwell SC	Savannah River	59	2.40
Santa Fe NM	Los Alamos	20	2.37
Denver CO	Rocky Flats	60	2.25
Berkeley CA	Livermore	32	0.69

Note: Average represents picocuries of gross beta activity per liter of precipitation. Yaphank average significantly higher than each site ($p<.01$) with the exception of Idaho Falls ($p<.32$). Source: U.S. Environmental Protection Agency. Environmental Radiation Data Report. Montgomery AL: National Air and Environmental Laboratory. Quarterly volumes (www.epa.gov/narel).

2. Trends in Environmental Radioactivity Near Brookhaven, Compared to Albany.

a. Gross Beta in Air. The New York State Department of Health also measures weekly gross beta activity in the air for various sites near nuclear plants in the state (including Upton, the town closest to Brookhaven). Data are available for the 22-year period 1982-2003, so analysis of trend data is possible. Statistics are divided into the same four-year periods used in analysis of Sr-90 in baby teeth.

In Albany, the average concentration of beta in air has remained relatively constant over time, at about 12 to 13 picocuries per cubic meter of air. But at Upton, a very different pattern is evident. Figure 3 shows a decline from 1982-85 to 1986-89, followed by increases for each period thereafter.

Gross beta in the air measured at Upton nearly tripled since the late 1980s. The average concentration of 5.81 picocuries per cubic meter rose to 16.20 from 1986-1989 to 2002-2003. With about 200 measurements in each four-year period, this increase is statistically significant ($p<.00001$). It also means:

- Environmental radioactivity near BNL is rising
- This rise may be continuing, even though nuclear operations at BNL ceased in 1999
- Trends in radioactivity near BNL is largely a function of lab operations, not a phenomenon that affects the whole state

3. Trends in Environmental and In-Body Radioactivity Near Brookhaven.

a. Gross Beta in Air. The trend in airborne gross beta activity at Upton can be compared with that of Sr-90 in local baby teeth. The trend in Sr-90 in the 42 Suffolk County zip code areas east of BNL is quite similar to that of gross beta in Upton air (using areas west of the site produces dissimilar trends). The decline from 1982-85 to 1986-89 was replaced by an increase for the next two four-year periods for both indicators (Figure 4 and Table 13). While the number of samples may be small in

some cases, preliminary evidence suggests that environmental and in-body patterns are similar, meaning that Brookhaven emissions enter the environment and then enter local bodies.

Table 13
Trends in Gross Beta Levels in Air, Upton NY
Compared to Trends in Strontium-90 in Baby Teeth, Eastern Suffolk County
By Four-Year Periods, 1982-2003

	Average Radioactivity (samples)		% Change from Pervious Period	
Period	Sr-90 in Teeth	Gross Beta in Air	Sr-90 in Teeth	Gross Beta in Air
1982-85	1.18 (17)	9.34 (162)	-	-
1986-89	0.82 (40)	5.81 (156)	- 31%	- 38%
1990-93	0.90 (56)	9.33 (137)	+10%	+61%
1994-97	1.07 (5)	11.37 (170)	+19%	+22%
1998-01		15.50 (204)		+36%
2002-03		16.20 (101)		+ 5%

Note: Figures represent average picocuries of Sr-90 per gram of calcium in baby teeth at birth, and average picocuries of gross beta activity per cubic meter of air. The increase in gross beta concentration from 1986-89 to 2002-03 is significant ($p<.00001$).

b. Gross Beta in Precipitation. Government regulators also measure gross beta in precipitation, as well as in air. Again, this measure represents a meaningful measure of environmental radioactivity because it includes numerous beta-emitting chemicals that are only produced in nuclear weapons and reactors.

Table 12 and Figure 2 show that gross beta in precipitation measured at Yaphank is the highest of any U.S. station. The average concentration of gross beta tripled from 1982-85 to 1998-2001 (1.64 to 4.97 picocuries per liter), before dropping slightly after 2001. Again, the changes in average Sr-90 concentration in eastern Suffolk baby teeth are roughly comparable with changes in gross beta in Yaphank precipitation (Table 14 and Figure 5).

Table 14
Trends in Gross Beta Levels in Preciptation, Yaphank NY
Compared to Trends in Strontium-90 in Baby Teeth, Eastern Suffolk County
By Four-Year Periods, 1982-2003

	Average Radioactivity (samples)		% Change from Pervious Period	
Period	Sr-90 in Teeth	Gross Beta in Prec	Sr-90 in Teeth	Gross Beta in Prec
1982-85	1.18 (17)	1.64 (17)	-	-
1986-89	0.82 (40)	1.82 (39)	- 31%	+11%
1990-93	0.90 (56)	2.17 (46)	+10%	+19%
1994-97	1.07 (5)	3.96 (44)	+19%	+82%
1998-01		4.97 (37)		+26%
2002-03		4.45 (16)		- 10%

Note: Figures represent average picocuries of Sr-90 per gram of calcium in baby teeth at birth, and average picocuries of gross beta activity per liter of precipitation. The increase in gross beta concentration from 1986-89 to 2002-03 is significant ($p<.03$).

c. Five Specific Radioactive Chemicals in Local Fish. The New York State Department of Health makes quarterly measurements of levels of five radioactive chemicals in fish living in ponds on the BNL grounds, including:

- Cesium-134, with a half life of 2.06 years
- Cesium-137, with a half life of 30 years
- Ruthenium-106, with a half life of 1.02 years
- Potassium-40, with a half life of 1.3 billion years
- Strontium-90, with a half life of 28.7 years

Table 15 shows the trends in cesium-134 and ruthenium-106 in fish from Brookhaven ponds, compared to trends in Sr-90 in baby teeth in eastern Suffolk County. Of the five chemicals, Cs-134 and Ru-106 are most likely to represent current emissions from BNL, as they have relatively short half lives. The other three isotopes decay very slowly, and may well represent earlier emissions.

Trends in Cs-134 and Ru-106 in fish are relatively similar to Sr-90 in baby teeth - especially Cs-134 (Figures 6 and 7). Interestingly, after 1997 the average concentration fell sharply for both Cs-134 and Ru-106 in fish. This may represent the closing of the last two BNL reactors in 1996 and 1999 - although gross beta in air and precipitation continued to rise after this period. No data exist on fish levels after 2001 as of this writing.

Table 15
Trends in Cesium-134 and Ruthenium-106 in Fish Living in Brookhaven Ponds
Compared to Trends in Strontium-90 in Baby Teeth, Eastern Suffolk County
By Four-Year Periods, 1982-2001

	Average Radioactivity (samples)			% Change from Pervious Period		
Period	Sr-90	Cs-134	Ru-106	Sr-90	Cs-134	Ru-106
1982-85	1.18 (17)	20.6 (11)	74.6 (11)	-	-	-
1986-89	0.82 (40)	16.6 (18)	77.8 (18)	- 31%	- 20%	+ 4%
1990-93	0.90 (56)	18.2 (19)	92.6 (19)	+10%	+10%	+19%
1994-97	1.07 (5)	19.2 (20)	141.5 (20)	+19%	+ 5%	+53%
1998-01		4.6 (19)	48.4 (19)		- 76%	- 66%

Note: Figures represent average picocuries of Sr-90 per gram of calcium in baby teeth at birth, and average picocuries of cesium-134 and ruthenium-106 per kilogram of fish. Change in average Cs-134 from 1986-89 to 1994-97 not significant ($p<.63$). Change in average Ru-106 from 1986-89 to 1994-97 of borderline significance ($p<.09$).

Trends in the three slow-decaying chemicals in fish are inconsistent (Table 16). Strontium-90 and cesium-137 declined steadily during the past 20 years. Current (1998-2001) levels are 92% and 61% less than the average from 1982-85 for these two chemicals. However, levels of potassium-40 (K-40) actually rose after 1993; the 1998-2001 average is 46% above what it was during 1982-85. While quarterly readings are fewer in number and less accurate than weekly or monthly ones, these conflicting trends are puzzling nonetheless. Figure 10 displays the steady decline in cesium-137 levels in fish, while Figure 11 shows the starkly different trend for potassium-40.

Table 16
Trends in Strontium-90, Cesium-137, and Potassium-40 in Fish Living in BNL Ponds
By Four-Year Periods, 1982-2001

	Average Radioactivity (samples)			% Change from Pervious Period		
Period	Sr-90	Cs-137	K-40	Sr-90	Cs-137	K-40
1982-85	330 (17)	423 (11)	2221 (11)	-	-	-
1986-89	247 (17)	301 (16)	2529 (17)	- 25%	- 29%	+14%
1990-93	229 (21)	266 (19)	2394 (19)	- 7%	- 12%	- 5%
1994-97	81 (32)	233 (30)	3340 (30)	- 65%	- 12%	+40%
1998-01	27 (20)	164 (20)	3235 (20)	- 67%	- 30%	- 3%
% Change from 1982-85 to 1998-01				- 92%	- 61%	+46%

Note: Figures represent average picocuries of strontium-90, cesium-137 and potassium-40 per kilogram of fish living in Brookhaven ponds. Change in average Sr-90 from 1986-89 to 1994-97 significant ($p<.02$). Change in average Cs-137 from 1986-89 to 1994-97 not significant ($p<.43$). Change in average K-40 from 1986-89 to 1994-97 not significant ($p<.35$).

d. Gross Alpha and Beta in Water. Earlier in this report, average levels of all alpha- and beta-emitting radioactivity in the Peconic River running through BNL was found to

be three to four times higher than levels in Albany. Trends in these two measures of environmental radioactivity were also examined, based on monthly measurements conducted by the New York State Department of Health.

Average levels of gross alpha in the Peconic rose steadily from the early 1980s to the late 1990s, then declined sharply. The initial trend is somewhat similar to that of Sr-90 in baby teeth in eastern Suffolk County (Table 17 and Figure 8). Trends in average gross alpha and beta concentrations in the river are different. The rapidly rising average gross alpha changed to a sharp decline after 1993 (Figure 9). These trends may indicate increasing emissions from BNL reactors during their last years of operation, and a reduction after their closing, although it is difficult to pinpoint when this reversal occurred.

Table 17
Trends in Gross Alpha Levels in Water, Peconic River
Compared to Trends in Strontium-90 in Baby Teeth, Eastern Suffolk County
By Four-Year Periods, 1982-2003

	Average Radioactivity (samples)		% Change from Pervious Period	
Period	Sr-90 in Teeth	Gross Alpha in Pec	Sr-90 in Teeth	Gross Alpha in Pec
1982-85	1.18 (17)	1.63 (26)	-	-
1986-89	0.82 (40)	2.13 (35)	- 31%	+31%
1990-93	0.90 (56)	2.94 (42)	+10%	+38%
1994-97	1.07 (5)	3.70 (24)	+19%	+26%
1998-01		3.08 (42)		+17%
2002-03		1.17 (10)		- 62%

Note: Figures represent average picocuries of Sr-90 per gram of calcium in baby teeth at birth, and average picocuries of gross alpha activity per liter of water in the Peconic River. Change in average gross alpha from 1986-89 to 1994-97 significant ($p<.06$).

e. Plutonium and Uranium in Air, Precipitation. The EPA also measures concentrations of various forms of plutonium and uranium in the air and precipitation at various sites across the U.S., including Yaphank. Uranium - actually a combination of U-234, 235, and 238 - is found in rocks. It is mined and refined to produce a pure form of uranium-235, which is used in nuclear reactors and weapons. Plutonium is a product of the bombardment of uranium atoms with neutrons in reactors, and can also be used in the explosion of atomic weapons. There are 15 forms of plutonium, and EPA measures Pu-238, 239, and 240.

Each of these chemicals decays slowly, with half lives of:

Uranium-234	246,000 years
Uranium-235	700 million years
Uranium-238	4.5 billion years
Plutonium-238	87 years
Plutonium-239	24,000 years
Plutonium-240	6,500 years

The EPA has measured levels of these chemicals in composite air samples since the 1970s, and Yaphank data are available from 1983-1998. Measurements were made on a quarterly basis until 1985, then semiannual figures were reported until EPA converted to annual data in 1997. Table 16 shows that Pu-238 in Yaphank air rose in the 1980s, and in the 1990s remained at levels higher than the early 1980s. Pu-239 and 240 have steadily declined during this time.

U-234 and 238 have the highest airborne levels of these six isotopes. Average concentrations rose from the early 1980s to the early 1990s for both, only to fall sharply in the 1990s. Levels of U-235 rose and fell, but are at higher levels than in the early 1980s, a pattern similar to plutonium. These patterns may be linked to the operation and cessation of Brookhaven reactors. None are similar to the pattern of Sr-90 in baby teeth of children living in eastern Suffolk County.

Table 16
Trends in Airborne Plutonium-238/239/240 and Uranium-234/235/238 at Yaphank NY
By Four-Year Periods, 1982-2001

	Average Radioactivity					% Change from Pervious Period				
Period	Pu238	Pu239*	U234	U235	U238	Pu238	Pu239*	U234	U235	U238
1982-85	0.22	0.74	9.25	0.42	8.23	-	-	-	-	-
1986-89	0.33	0.34	10.74	0.55	9.49	+50%	-54%	+16%	+31%	+15%
1990-93	0.28	0.27	11.63	0.45	9.80	- 15%	-21%	+ 8%	- 18%	+ 3%
1994-97	0.28	0.15	6.34	0.52	5.75	- 0%	-44%	-45%	+16%	- 41%
1998-01+										
% Change from 1982-85 to 1994-97						+27%	- 80%	- 31%	+24%	-30%

* Includes Pu240 + Only a single annual reading from 1998 available at www.epa.gov/narel
Note: Figures represent average nanocuries of plutonium-238, 239, and 240 and uranium-234, 235, and 238per cubic meter of air at Yaphank. Some plutonium readings were recorded as "not detectable" by the EPA, and counted as 0.1 nanocuries per cubic meter of air. Each period includes eight measurements, except for 1994-97, which had six. No changes are statistically significant due to small number of samples.

The annual report for 1998 shows that concentrations of each of these chemicals were lower than the 1994-97 average.

The EPA measurements of plutonium and uranium in Yaphank precipitation are limited. They began in 1987 and ceased in 1996. Data from 1988 and 1990 are not reported. Some measurements represent an entire year, some half a year, and some a three-month period. Levels are very low (the highest average is U-234, with just over .03 picocuries per liter of precipitation). Any time trends would have little meaning, and are not done here.

f. Gross Beta in Air. The EPA reports also include figures for gross beta in Yaphank air. While these figures are reported beginning in 1983, they are virtually all measured as 0.0, 0.1, or 0.2 picocuries per liter, and thus are not meaningful.

g. Tritium in Water, Precipitation. The New York State Department of Health measures monthly levels of tritium in the Peconic River. Tritium is a radioactive form of hydrogen with a half life of 12.8 years. In 1982-85, an average of 3759 picocuries per liter was recorded in 26 measurements. Thereafter, a steady decline occurred, reaching a low of just 124 picocuries (10 measurements) in 2003.

The EPA measures tritium in precipitation at Yaphank on a quarterly basis. For each reading since 1983, levels are either 0.1 or 0.2 nanocuries per liter, giving little meaning to any analysis of trends over time.

h. Radioactivity Levels in Milk. Neither EPA nor the state health department measures radioactivity in milk near the Brookhaven site. The closest EPA readings are in New York City, and the closest state data are in Albany and Rochester. Hence, no analysis is possible on locally-produced milk.

i. Radioactivity Levels Generated by BNL. In its Round 5 proposal, RPHP indicated it might approach Brookhaven personnel for any other measurements of environmental radioactivity it made or knew of. Because of the large volume of publicly-available data for over 20 years from state and federal regulators, RPHP saw no need to take this step.

DISCUSSION

Environmental Concerns, BNL, and Cancer on Long Island. For several decades, widespread concerns over harmful effects of environmental pollutants have existed on Long Island. The region's demographics -- high educational levels, low unemployment, high income, etc. -- suggest that it a low-risk area, devoid of the classical risk factors such as poverty, lack of education, and lack of access to medical care.

At the same time, concerns persist about pollution threatening local public health. One source of pollution is radioactivity from the Brookhaven National Laboratories (BNL), located on eastern Long Island. The complex first opened in 1951, and operated three nuclear reactors (which closed in 1969, 1996, and 1999). Contamination from BNL releases have been extensive.

Suffolk County, where BNL is located, makes up the eastern portion of Long Island. Its current population of just under 1.5 million. From 1979-2001, the Suffolk County death rate for all causes other than cancer was equal to the U.S. rate. However, Suffolk's death rate for cancer was 12.6% above the nation's, representing 7410 additional deaths. Cancer death rates in Suffolk are above U.S. rates for children, non-elderly adults, and the elderly.

Breast cancer rates have been elevated in Suffolk County as well. From 1979-2001, a time when 5503 white Suffolk residents died from the disease, mortality from breast cancer was 24.6% above the U.S. rate. In the past decade, breast cancer incidence in the county is about 12% above the New York state rate, with the highest rates in the area east of Brookhaven.

The belief that environmental pollution may have accounted for elevated breast cancer rates has concerned the Long Island public since the late 1980s, resulting in a multimillion dollar study sponsored by the federal government. The study finding of no link between any environmental pollutant and breast cancer has been followed by reports suggesting that breast cancer rates on Long Island are not unusually high. However, the above data document that local breast cancer rates are elevated, indicating that more investigation is merited.

While rates of radio-sensitive conditions such as breast cancer, childhood cancer, and thyroid cancer are elevated in Suffolk County, the impact of BNL on local public health has yet to be studied. The rationale often used for the lack of studies is that radiation levels are below official "permissible" limits, and thus are not harmful. This argument is presumptive. It is countered by previous research showing that low dose exposures from pelvic X-rays to pregnant women, occupational exposures in nuclear weapons plants, and fallout from atomic bomb tests harmed humans.

Environmental Radioactivity Near BNL. State and federal officials have measured environmental radioactivity in the air, water, precipitation, and fish near BNL for many

years. While almost no analysis of these patterns has been performed to date, this report assembled these data and analyzed patterns and trends.

The Peconic River that runs through BNL contains three to four times more radioactivity (gross alpha and beta) than in Albany, which is not near any nuclear reactor, meaning most local radioactivity near BNL represents releases from the plant. Radioactivity levels in local precipitation (gross beta at Yaphank) are twice what they are near other DOE sites, and the highest of any U.S. station measured.

Trends in local radioactivity can be addressed using a variety of measures. Table 17 summarizes the findings, which vary. Some indicators have shown a consistent increase since the early 1980s. Others have shown a decrease until the late 1980s, to be followed by an increase. The most consistent finding is that after 1997, average levels for most indicators declined as the final two BNL reactors ceased operations.

Table 17
Trends in Radioactivity Levels Near Brookhaven National Laboratories
By Four-Year Periods Beginning 1982-85, Ending 1998-2001 plus 2002-03

		Change in Average Radioactivity Levels		
Indicator	Location	Early-Late 1980s	After Late 1980s	After 1997
Gross beta, air	Upton (NYS)	down	up	up
Gross beta, precip.	Yaphank (EPA)	up	up	up
Cs-134, fish	BNL ponds (NYS)	down	up	down
Ru-106, fish	BNL ponds (NYS)	up	up	down
Sr-90, fish	BNL ponds (NYS)	down	down	down
K-40, fish	BNL ponds (NYS)	up	up	down
Gross alpha, water	Peconic R. (NYS)	up	up	down
Pu, U, air	Yaphank (EPA)	mixed	mixed	down
Pu, U, precip.	Yaphank (EPA)	insufficient data to assess any trends		
Gross beta, air	Yaphank (EPA)	measurements too low to be meaningful		
Tritium, water	Peconic R. (NYS)	down	down	down
Tritium, precip.	Yaphank (EPA)	measurements too low to be meaningful		

Strontium-90 in Baby Teeth. The RPHP baby tooth study is the first large-scale research initiative to measure in-body levels of radioactivity near U.S. nuclear reactors. RPHP collected and tested 522 baby teeth from Suffolk County, and another 105 from Nassau, making Long Island the area that contributed the most teeth thus far.

Average Sr-90 levels in Suffolk County are somewhat below that of other areas, with the highest averages occurring in the western portion of Suffolk. Trends in the western portion of the county (west of BNL) showed an increase from 1982-85 to 1986-89, followed by a decrease from 1986-89 to 1990-93. Averages in the 42 zip code areas making up eastern Suffolk showed a different trend; rates decreased before 1986-89, and increased thereafter. The rise of 0.82 to 1.07 average picocuries of Sr-90 per gram of calcium at birth represents a 30% increase from 1986-89 to 1994-97. Despite the small

number of teeth in the youngest group (5), this pattern matches all of those at other nuclear power reactors studied. Moreover, because prevailing winds blow from west to east, the Sr-90 patterns in eastern Suffolk may be most similar to changes in environmental radioactivity from BNL emissions.

The Sr-90 pattern matches/closely matches (or does not match) the following trends in BNL environmental radioactivity:

Match/Close Match:
Gross Beta in Air, Upton
Gross Beta in Precipitation, Yaphank
Cesium-134 in Fish, BNL Ponds
Ruthenium-106 in Fish, BNL Ponds
Potassium-40 in Fish, BNL Ponds
Gross Alpha in Water, Peconic River

No Match:
Strontium-90 in Fish, BNL Ponds
Cesium-137 in Fish, BNL Ponds
Plutonium, Uranium in Air, Yaphank
Tritium in Water, Peconic River

In general, the matching trends correspond to those measures of radioactivity with relatively fast-decaying chemicals. For example, Cesium-134 and Ruthenium-106 have half-lives of 2 and 1 year, respectively. Gross alpha and beta contains a substantial proportion of chemicals with short half-lives. These measurements represent, to a great degree, current emissions of radioactivity. The "no match" groups tend to represent those chemicals with long half lives, which may reflect prior emissions, such as from the early years of BNL operations or of atomic bomb test fallout prior to the Test Ban Treaty of 1963.

Because of the matching of trends in Sr-90 in baby teeth and short-lived radioactive chemicals, the data suggest that BNL emissions are the primary component of in-body radioactivity in eastern Suffolk County.

Conclusions. The findings described above lead to the following conclusions:

1. Environmental radioactivity near BNL is high relative to other nuclear plants

2. A considerable proportion of environmental radioactivity near BNL represents emissions from the laboratory

3. A considerable proportion of the in-body Strontium-90 represents emissions from BNL among children of eastern Suffolk County, and is the reason average Sr-90 levels rose 30% in the area from 1986-89 to 1994-97

4. Beginning in the early 1990s (and by some measures, earlier) local environmental radioactivity levels near BNL experienced a sustained increase, likely representing BNL emissions

5. Reductions in many types of environmental radioactivity near Brookhaven since 1997 probably represent the reduced emissions from the site due to the closing of two reactors

6. High cancer rates in Suffolk County, particularly in the eastern portion of the county, may be linked to BNL emissions entering human bodies

7. More detailed investigation is needed to determine if elevated levels of breast cancer, childhood cancer, and other conditions are (at least partially) due to BNL emissions.

8. Policy makers, researchers, scientists, and the general public can benefit from understanding these relationships, to further reduce future emissions and radioactivity levels as a means of preventing disease.

DISSEMINATION OF RESULTS

The findings presented in this report represent a unique contribution to understanding causes of cancer on Long Island. They also constitute a first step in assessing Brookhaven's role in raising disease risk to the local population.

Because nuclear facilities are still relatively new (all less than 60 years), much remains to be learned about the extent to which they contaminated the environment, and harmed public health. Documenting that Brookhaven emissions likely were high, rose in the 1980s and 1990s, and are linked with in-body radioactivity trends has not occurred near this facility.

With Long Islanders and various officials still trying to solve the cancer puzzle, including the role of BNL, it is critical that the information in this report be approopriately disseminated. Thus, RPHP is planning two public presentations as the grant period expires.

The first will be an event primarily for members of the press, to be held on a weekday afternoon, at an appropriate Long Island setting. The second will be a presentation targeted at the general public, also in Long Island. While all details of these events are not finalized as of this writing, they will likely include

- Notifying BNL officials, and invite them to attend and comment

- Requesting the presence of a celebrity, such as Alec Baldwin or Christie Brinkley

- Including representatives of one or more environmental advocacy groups to support these events

- Publicizing the events to Long Islanders to the greatest extent possible

- Inviting each of the 600-plus Long Island baby tooth donors to attend

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Appendix 2
Zip Codes and Post Office Addresses
For 42 Areas Making Up Eastern Suffolk County

10-40 mi. E of BNL

Zip Code	P.O. (Town)
11901	Riverhead
11930	Amagansett
11931	Aquebogue
11932	Bridgehampton
11935	Cutchogue
11937	East Hampton
11939	East Marion
11942	East Quogue
11944	Greenport
11946	Hampton Bays
11947	Jamesport
11948	Laurel
11952	Mattituck
11954	Montauk
11956	New Suffolk
11957	Orient
11958	Peconic
11959	Quogue
11962	Sagaponack
11963	Sag Harbor
11964	Shelter Island
11965	Shelter Island Heights
11968	Southampton
11969	Southampton
11970	South Jamesport
11971	Southold
11975	Wainscott
11976	Water Mill
11977	Westhampton
11978	Westhampton Beach

<10 mi. E of BNL

Zip Code	P.O. (Town)
11933	Calverton
11934	Center Moriches
11940	East Moriches
11941	Eastport
11949	Manorville
11950	Mastic
11951	Mastic Beach
11955	Moriches
11960	Remsenberg
11967	Shirley
11972	Speonk
11973	Upton

Other Zip Codes
Less than 5 miles west of BNL (8)
First three digits 117 --- 13, 19, 78, 86, 92; First three digits 119 --- 53, 61, 80

5 to 15 miles west of BNL (19)
First three digits 117 --- 05, 15, 20, 27, 33, 38, 41, 42, 55, 63, 64, 66, 72, 76, 77, 84, 85, 90, 94

All Other Suffolk All other zip codes with first three digits 117 or 118, not listed above

Appendix 3
Determination of Strontium-90 to Calcium Ratio

Strontium-90 in deciduous teeth was determined under the direction of Hari D. Sharma, Professor Emeritus of Radiochemistry and president of REMS, Inc., Waterloo, Ontario, Canada, using the following procedure.

A tooth is dried for 12 hours at 110 degrees centigrade, then ground to a fine powder. Approximately 0.1 gram of the powder is weighed in a vial, then digested for a few hours with 0.5 milliliter of concentrated nitric acid along with solutions containing 5 milligrams of Sr2+ and 2 milligrams of Y3+ carriers at about 110 degrees centigrade on a sand bath. The solution is not evaporated to dryness. The digested powder is transferred to a centrifuge tube by rinsing with tritium-free water. Carbonates of Sr, Y, and Ca are precipitated by addition of a saturated solution of sodium carbonate, then centrifuged. The carbonates are repeatedly washed with a dilute solution of sodium carbonate to remove any coloration from the precipitate. The precipitate is dissolved in hydrochloric acid, and the pH is adjusted to 1.5 to 2 to make a volume of 2 milliliters, of which 0.1 milliliter is set aside for the determination of calcium The remaining 1.9 milliliters are mixed with 9.1 milliliters of scintillation cocktail Ultima Gold AB, supplied by Packard Bioscience BV in a special vial for counting. A blank with appropriate amounts of Ca2+, Sr2+, and Y3+ is prepared for recording the background.

The activity in the vial with the dissolved tooth is counted four times, 100 minutes each time, for a total of 400 minutes, with a Wallac WDY 1220X Quantulus low-level scintillation spectrometer. The spectrometer has special features so that the background count-rate in the 400 to 1,000 channels is 2.25 plus or minus 0.02 counts per minute. The background has been counted for over 5,000 minutes so that the error associated with the background measurement is about 1 percent . The overall uncertainty or one sigma associated with the measurement of Sr-90 per gram of calcium is plus or minus 0.7 picocuries per gram of calcium.

The efficiency of counting was established using a calibrated solution of Sr-90/Y-90 obtained from the National Institute of Standards and Technology, using the following procedure. The calibrated solution is diluted in water containing a few milligrams of Sr2+ solution, and the count-rate from an aliquot of the solution is recorded in channel numbers ranging from 400 to 1,000 in order to determine the counting efficiency for the beta particles emitted by Sr-90 and Y-90. It is ensured that the Y-90 is in secular equilibrium with its parent Sr-90 in the solution. The counting efficiency was found to be 1.67 counts per decay of Sr-90 with 1.9 milliliters of Sr-90/Y-90 solution with 25 milligrams of Ca2+, 5 milligrams of Sr2+, 2 milligrams of Y3+, and 9.1 milliliters of the scintillation cocktail.

The calcium content was determined using a Varian A-A 1475 atomic absorption spectrophotometer by flame spectroscopy at a wave length of 422.7 nanometers, using acetylene plus air as fuel.