NUCLEAR CONTAMINATION AND HEALTH RISKS FROM THE ENTERGY PALISADES NUCLEAR REACTOR

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EXECUTIVE SUMMARY

The Entergy Palisades nuclear reactor in southwest Michigan has been in operation since 1971, making it the 9th oldest of 100 U.S. reactors. Over 1.3 million persons live within 50 miles of the plant. The purpose of this report is to examine information on radioactive emissions from Palisades and their potential adverse health consequences.

Major findings in the report include:

1. The plant stores massive amounts of high-level radioactive waste, mostly in a waste pool of water that must be constantly cooled to avoid a fire.

2. Palisades operated 93.5% of the time between 2006 and 2011, which means the aging and corroding reactor parts are being pushed to their maximum.

3. A 2006 report concluded that of 200 "near-miss" accidents at U.S. reactors from 1986 to 2006, four occurred at Palisades, among the highest of any U.S. reactor. Another five potentially harmful incidents occurred since 2010.

4. A 1982 federal estimate of 16,700 radiation poisoning cases and 13,000 cancer deaths after a meltdown to the Palisades reactor core would be greater today, due to higher population and effects beyond the study's geographic limits.

5. From 2001 to 2007, sharp increases in releases from Palisades for several types of airborne and liquid radioactivity were observed in data compiled by the U.S. Environmental Protection Agency.

6. In the late 1990s, the latest data available, tritium levels in Lake Michigan at South Haven (near Palisades) exceeded those of most U.S. reactors.

7. The Van Buren County death rate from all causes was 3 to 6 percent below the state in the 1970s and early 1980s, but has risen since, to a level 12.5% greater than Michigan (2003-2010). This change suggests that 1,330 "excess" deaths have occurred in the county since Palisades started operating. Elevated levels were observed for all age groups (especially children/young adults), both genders, and all major causes of death.

8. The Van Buren County death rate for all cancers combined was 10.5% below the Michigan rate in the 1970s, but is now 12.0% above the state (2005-2010). This rate is the highest of the 34 most populated Michigan counties.

Data presented in this report suggest a link between emissions from Entergy Palisades and elevated health risk. This finding is particularly important at this time, as the reactor has been operating for over 42 years. Regulatory decisions to allow the reactor to stay in operation have been made with no attention paid to health risks. The data should be shared with officials and local citizens in order that public health implications are fully understood, and are a criterion in decision making.

NUCLEAR CONTAMINATION AND HEALTH RISKS FROM
THE ENTERGY PALISADES NUCLEAR REACTOR

I. Introduction

A. Brief History of Entergy Palisades. The discovery of nuclear fission, or high energy from splitting uranium atoms, was first used for military purposes, i.e. the atomic bombs in Japan during World War II. Soon after, other uses of the fission process were introduced. One of these was the creation of electric power from the heat generated by fission. The "Atoms for Peace" speech given at the United Nations by President Dwight Eisenhower in 1953 opened the door for the development of reactors that would produce electricity, and the first reactor (Shippingport, near Pittsburgh) began operating in 1957.

Hundreds of reactors were proposed by electric utilities, who were interested based on the government's assurance that nuclear power could produce clean and cheap energy. In 1974, the U.S. Atomic Energy Commission predicted that the nation would have 1,200 reactors by the turn of the century. However, the total number of licensed U.S. reactors from early 1998 to early 2013 was just 104. Four reactors, Crystal River FL, Kewaunee WI, and San Onofre CA (2 reactors) have shut permanently in 2013.

The Entergy Palisades reactor was one of the earlier proposed nuclear power sites. Located five miles south of South Haven MI, Palisades is on Lake Michigan, in Van Buren County. It is 35 miles west of Kalamazoo MI and 45 miles north of South Bend IN.

According to an analysis by NBC News, which used 2010 Census data, 28,644 persons live within 10 miles of the plant. In addition, 1,326,618 persons live within 50 miles, including the cities of Kalamazoo and South Bend. Source: Bill Dedman, NBC News. Nuclear Neighbors: Population Rises Near US Reactors, April 4, 2011

The four counties closest to Entergy Palisades, in which nearly all residents live within 40 miles of the plant, are listed in Table 1, along with their 2010 populations. Nearly 600,000 persons live in these counties. Additionally, seasonal residents who have homes along Lake Michigan add to the population during the summer months and a large number of tourists pass through the area or enjoy the nearby beaches.

Table 1
2010 Population, Four Michigan Counties Closest to Entergy Palisades

County	Population
Allegan	111,408
Berrien	156,813
Kalamazoo	250,331
Van Buren	76,258
TOTAL	594,810

Source: U.S. Census Bureau, www.census.gov, state and county quick facts.

The origins of Entergy Palisades date back to the 1960s. Table 2 shows the dates of important steps in the original startup of Palisades. The reactor "went critical" – began producing radioactivity that generates electrical power – on May 24, 1971. It "went commercial" – began selling energy while operating at full power – on December 31, 1971.

Table 2
Dates of Selected Actions in Entergy Palisades Startup

Action	Date
Application Approved by AEC	June 3, 1966
Reactor Online	March 24, 1971
Reactor Reaches Initial Criticality	May 24, 1971
Reactor Becomes Commercial	December 31, 1971

Source: U.S. Nuclear Regulatory Commission, www.nrc.gov

The 855 megawatt (electric) Entergy Palisades reactor is now the 9th oldest of the 100 licensed operating reactors in the nation. Some would argue that since it actually was built by 1967, it is the oldest reactor. The U.S. Nuclear Regulatory Commission has granted 20-year license extensions after the initial 40-year licenses expire for 71 of the 100 U.S. reactors, and is expected to approve more. The NRC granted the 20-year extension for Entergy Palisades in 2007, allowing the plant to operate until 2031. Source: U.S. Nuclear Regulatory Commission, www.nrc.gov.

Just 30 miles southwest of Palisades is the Donald C. Cook nuclear plant, near Bridgman MI, in Berrien County. The Cook plant has operated two reactors, both considerably larger than Entergy Palisades, since 1975 and 1978.

B. Radioactive Waste. To produce electricity, nuclear power reactors split uranium-235 atoms, generating high energy to heat water into steam that is transformed into electrical power. This splitting process, known as fission, also produces over 100 radioactive chemicals not found in nature. These chemicals are the same as those found in the large clouds of fallout after above-ground atomic bomb tests.

Fission products, which take the form of gases and particles, include Cesium-137, Iodine-131, and Strontium-90. They are highly unstable atoms which emit alpha particles, beta particles, or gamma rays. When they enter the body, they harm various organs. Cesium seeks out the muscles (including the heart and reproductive organs), iodine attacks the thyroid gland, and strontium attaches to bone. Each causes cancer after breaking cell membranes and damaging cell DNA creating mutations, and is especially harmful to the fetus, infant, and child. Some decay quickly (Iodine-131 has a half-life of 8.05 days), while others remain for long periods (Strontium-90 has a half-life of 28.7 years, and Cesium-137 has a half-life of 30 years). Experts estimate that a radioactive chemical

does not disappear until the 10th half-life; thus, Cesium-137 will be present in the environment for 300 years.

Most of the radioactivity produced in reactors is contained within the reactor building and stored as high-level waste in deep pools of water that must be constantly cooled. At Entergy Palisades and other aging plants, the pools are becoming full. The Palisades pool reached capacity in 1993, and has shifted waste into dry casks on the beach, less than 150 yards from Lake Michigan, on a 55 foot deep sand dune. Source: Nuclear Resource and Information Service, http://www.nirs.org/reactorwatch/licensing/021794rosslandsmanltrnrcchairmanselin.pdf. About 25% of the waste nationally has been transferred to above-ground outdoor casks. **By 2010, Entergy Palisades maintained 585 metric tons of high-level radioactive waste on site.** The amount of radioactivity at the plant (129,918,600 curies) was close to estimates of releases from the 1986 Chernobyl meltdown, and hundreds of times more than releases from atomic bombs at Hiroshima and Nagasaki in 1945. Source: Alvarez R. Spent Nuclear Fuel Pools in the U.S.: Reducing the Deadly Risks of Storage. Institute for Policy Studies, May 2011.

In 2002, after decades of investigation revealing major scientific and technical unsuitability associated with the site, the George W. Bush administration designated Yucca Mountain in Nevada as a permanent waste site. In 2010, the Obama administration stopped all expenditures for building the site, and assembled a panel to further consider options for long-term waste storage. Some experts believe a permanent repository will never open; whatever the outcome, existing nuclear plants like Palisades will maintain waste for a long time.

Entergy Palisades is one of the U.S. nuclear plants that has begun to shift high-level waste from its pool to dry casks of concrete and steel, where it is stored (outside) on the grounds of the plant. This process began in 1993, despite fierce resistance, including a federal lawsuit brought by the Lake Michigan Federation (now Alliance for the Great Lakes), Don't Waste Michigan, and the State of Michigan (Attorney General Frank Kelley). Some consider dry cask storage to be less risky than fuel pools. However, any mode of storage, including dry casks, poses a safety risk, and waste cannot be shifted to dry casks until it has spent at least five years in pools. Entergy Palisades' oldest dry casks, Ventilated Storage Casks, or VSC-24s (for 24 Pressurized Water Reactor fuel assemblies per cask) became the subject of safety concerns, and none have been ordered since the late 1990s. Major vulnerabilities of dry casks include not being designed to withstand terrorist attack, as well as needing to be replaced before they leak, perhaps once a generation.

C. Long-Term Shut Downs. A 2006 Union of Concerned Scientists Report listed 51 instances when a U.S. nuclear reactor closed for over one year before restart. **One year-long outage occurred at Palisades, from August 11, 1973 to October 1, 1974**, not long after the reactor began operating. Source: Union of Concerned Scientists, Unlearned Lessons from Year-plus Power Outages, 2006. Numerous other long shutdowns less than one year have also occurred.

D. Aging Reactor, Operating Nearly All the Time. In the years 2006 to 2011, Entergy Palisades operated about 93.5% of the time, above the national rate of about 90%. This "operating factor" at Palisades by year was 98, 86, 99, 90, 92, and 96. Source: U.S. Nuclear Regulatory Commission Utilities have found ways to repair mechanical problems more quickly, or without having to shut down a reactor.

A high operating factor is viewed positively from an economic standpoint, as it allows more electrical power to be produced and sold. But from a health and safety standpoint, this pattern is highly undesirable. The long list of major safety repairs at Palisades since Entergy took over the plant's operation in 2007 include the most brittle reactor pressure vessel in the U.S., vulnerable to pressurized thermal shock; steam generators in need of replacement for the second time in the plant's history (the first was in the early 1990s); a badly corroded reactor lid that was supposed to have been replaced in July 2007; fire safety upgrades still not implemented, despite now being 33 years overdue; and control rod drive mechanisms that have suffered chronic seal leaks since 1972. Keeping aging and corroding parts in operation nearly 100% of the time increases the chance for a disastrous meltdown or greater levels of routinely released radioactivity.

II. Health Hazards Posed by Reactor Meltdowns

A. Description. Much of the health concern posed by nuclear reactors focuses on meltdowns. The radioactivity in a reactor core and waste pools must be constantly cooled by water, or the fuel will heat uncontrollably, causing a huge release of radioactivity. Meltdowns can be caused by mechanical failure (like at Chernobyl in 1986, when safeguard redundancy was deliberately shut off during testing), by act of nature (like the earthquake/tsunami at Fukushima in 2011), or by an act of sabotage.

The experience at Hiroshima and Nagasaki demonstrated how exposure to high levels of radioactivity can harm humans. Those closest to the bombs were vaporized, literally melting from the intense heat. But many other victims who survived the initial blast developed acute radiation poisoning, marked by symptoms such as nausea, vomiting, diarrhea, skin burns, weakness, dehydration, bleeding, hair loss, ulcerations, bloody stool, and skin sloughing (falling off) from the extreme heat. In addition, unexpectedly large numbers of bomb survivors in the two cities developed cancers over the following decades; thyroid and breast cancer had the greatest excesses. Source: Thompson DE et al. Cancer Incidence in Atomic Bomb Survivors. Part II: Solid Tumors, 1958-1987. Radiation Effects Research Foundation, Hiroshima Japan, 1994.

B. Estimates of Casualties. If a meltdown resulting in large scale releases of radioactivity from the reactor core or the waste pool occurred at Palisades, many would suffer from acute radiation poisoning (short term) and cancer (long term). In 1982, the Sandia National Laboratories submitted estimates to Congress for each U.S. nuclear plant in the case of core meltdown. Estimates for Entergy Palisades are given in Table 3.

Table 3
Estimated Deaths/Cases of Acute Radiation Poisoning and Cancer Deaths
Near Entergy Palisades, Following a Core Meltdown

Type of Effect	Casualties
Deaths, Acute Radiation Poisoning	1,700
Cases, Acute Radiation Poisoning	15,000
Deaths, Cancer	13,000

Source: Sandia National Laboratories, Calculation of Reactor Accident Consequences (CRAC-2) for U.S. Nuclear Power Plants. Prepared for U.S. Congress, Subcommittee on Oversight and Investigations, Committee on Interior and Insular Affairs. November 1, 1982. Published in New York Times and Washington Post the following day.

The Sandia figures are known as CRAC-2 (Calculation of Reactor Accident Consequences). **CRAC-2 estimated casualties for a core meltdown at the Entergy Palisades unit are 16,700 cases of acute radiation poisoning (1,700 fatal) and 13,000 cancer deaths**. Estimates would be much larger today, since the local population has grown since 1982 when the calculations were made. As mentioned earlier, with 1,326,618 persons living within 50 miles of Palisades, a meltdown would harm many. Source: Bill Dedman, NBC News. Nuclear Neighbors: Population Rises Near US Reactors, April 4, 2011.

C. Near-Miss Meltdowns. The threat of a meltdown from a nuclear power reactor is real, given the history of disasters at sites like Three Mile Island, Chernobyl, and Fukushima. But in addition to these, many more "near-miss" meltdowns have occurred. In 2006, on the 20th anniversary of the Chernobyl meltdown, Greenpeace USA released a report listing what its staff members considered to be the 200 events at U.S. nuclear reactors closest to a meltdown. Source: Greenpeace USA. An American Chernobyl: Nuclear "Near Misses" at U.S. Reactors Since 1986. Greenpeace, 2006.

Of these 200 "near-miss" meltdowns, four (4) occurred at the Palisades reactor, tied for the 8th highest total of any U.S. reactor. The greatest number at a single reactor was six. Three of the four occurred in the early 2000s, as the reactor aged. The other, which occurred in 1987, was judged by Greenpeace as having the 19th highest risk of the 200 listed. Table 4 lists these four events, the dates they occurred, and the reason accounting for the near-miss.

Table 4
"Near-Miss" Nuclear Meltdowns
At Entergy Palisades Reactor, 1986-2006

Date	Reason
July 14, 1987	Loss of offsite power
July 27, 2001	Smoke detectors were never installed in the cable room
September 11, 2001	Potential unavailability of safety equipment during fire
March 25, 2003	Loss of offsite power and loss of shut down cooling

The Union of Concerned Scientists has begun to track recent situations at U.S. reactors that have led to "near-misses," and other situations of increased risk. Sources: Union of

Concerned Scientists, Nuclear Power Information Tracker. http://www.ucsusa.org/nuclear_power/reactor-map/reactors/palisades.html. Union of Concerned Scientists. The NRC and Nuclear Power Plant Safety in 2012, March 2013. http://www.ucsusa.org/assets/documents/nuclear_power/NRC-nuclear-safety-2012-report.pdf (also 2011 and 2010 volumes).

These include five events at Entergy Palisades:

- July 16, 2010. A recurring problem with reactor cooling water leaking past seals in the control rod drive mechanisms, despite workers replacing seals.

- August 9, 2011. One of three pumps used to provide cooling water to emergency equipment failed, as it had in September 2009.

- September 25, 2011. Workers found position of the emergency airlock door inadvertently shut off power to about half the instruments and controls in the main control room. The loss of control power triggered the automatic shutdown of the reactor and complicated operators' response.

- August 11, 2012. Reactor shut down due to water leaking from the reactor vessel, the latest in a series of continuing problems improperly resolved.

- October 23, 2012. A battle over a computer between workers that culminated in an operator storming out of the control room.

III. ACTUAL RADIOACTIVITY RELEASED FROM ENTERGY PALISADES

A. Official Radioactive Releases into the Environment. Utilities operating nuclear power plants are required to submit annual reports on environmental releases of radioactivity to the federal government. From 1970-1993, the Brookhaven National Laboratories collected and disseminated data for each nuclear plant on airborne emissions of "Iodine-131 and effluents," or those radioactive chemicals with a half-life of at least eight days, and most likely to enter the food chain and the body.

In this period Entergy Palisades emitted a total of 1.07 curies of I-131 and effluents, which is relatively typical of U.S. reactors. This total represents about 7.5% of the 14.20 curie official total from the 1979 Three Mile Island partial core meltdown. Comparisons of all U.S. plants were halted after 1993 by the U.S. government. Source: Tichler J, Doty K, Lucadamo K. Radioactive Materials Released from Nuclear Power Plants. NUREG/CR-2907. Upton NY: Brookhaven National Laboratories, annual reports.

More recent data on radioactive emissions into the environment are posted on the Internet for each year 2001-2009, by quarter, for most U.S. reactors. The data includes several types of airborne emissions, including fission and activation gases, iodine-131, particulates (half-life over eight days), and tritium. The web site, operated by the U.S. Nuclear Regulatory Commission, also provides quarterly levels of several types of liquid emissions, including dissolved/entrained gases, fission/activation products, and tritium. Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent.

These emissions data have limitations. Comparisons of levels by reactor are not given, and doing so is extremely resource intensive. Some years are missing for some reactors, and often the letters "ND" are given, meaning levels of that type of radioactivity were not detectable. Fortunately, the reporting for Palisades contains no quarters with missing data or non-detectable levels (except for airborne tritium in 2007). Table 5 shows annual amounts of several types of radioactivity for each year from 2001 to 2009.

Table 5
Annual Releases, Various Types of Radioactivity
From Entergy Palisades Nuclear Plant, in Curies
By Year, 2001-2009

Year	Airborne Fission + Activation Gases	Airborne Tritium	Liquid Tritium
2001	.0003	16.5	163
2002	.0019	19.6	155
2003	.0035	22.2	198
2004	28.90	99.2	342
2005	43.80	108.0	305
2006	39.10	115.0	838
2007	341.00	No data	839
2008	1.21	38.0	738
2009	34.30	41.1	297

Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent.

Average releases of airborne fission and activation gases increased over 10,000 times after 2001-2003, when the annual amount was about 2/1000 of a curie. Beginning in 2004, a huge increase occurred, with a peak in 2007 (341.0 curies). **Airborne tritium releases increased steadily from 2001 to 2006**, rising from 16.5 to 115.0 curies; no data were given in 2007, and levels fell for the two years after (while remaining well above the 2001-2003 levels). **Liquid tritium releases also rose sharply from 2001 to 2007**, increasing from 163 curies in 2001 to 839 curies in 2007 before declining (again, still well above 2001-2003 levels).

These numbers are much higher than, for example, a large medical center, with as many as 1,000 approved laboratory areas in which radioactive materials are used, that may have a combined inventory of only about two curies. While these elevated levels are within federally-permitted limits, the magnitude of the changes should raise questions about the safety of operations at Entergy Palisades. Source: Beyond Nuclear, 2012. http://www.beyondnuclear.org/storage/documents/Routine%20Releases_Dec%202012.pdf

As mentioned, comparing Entergy Palisades' emissions with those from other U.S. nuclear plants is extremely time-consuming. However, Table 6 examines emissions

during the year with the highest amount of airborne fission and activation gases released at Entergy Palisades (2007). Of the 65 U.S. nuclear plants, the Nuclear Regulatory Commission provides an actual level of releases in all four quarters for most; these plants, along with several with three quarters of data projected for a full year are used in the table (total 59 plants).

Table 6
U.S. Nuclear Power Plants (Total = 59)
With Greatest Airborne Releases of Fission and Activation Gases, 2007

Plant (Reactors)	State	Curies
1. La Salle (2)	IL	2629
2. Pilgrim (1)	MA	1553
3. Brunswick (2)	NC	1487
4. Calvert Cliffs (2)	MD	630
5. Fitzpatrick (1)	NY	623
6. Grand Gulf (1)	MS	622
7. Peach Bottom (2)	PA	538
8. Nine Mile Point (2)	NY	450
9. Palisades (1)	**MI**	**341**
10. Oconee (3)	SC	339

Source: U.S. Nuclear Regulatory Commission, Effluent Database for Nuclear Power Plants, www.reirs.com/effluent.

Entergy Palisades released the 9th highest (of 59 plants with complete data) of airborne fission and activation gases in 2007. Moreover, it had the 4th highest amount of releases for plants with one reactor. These findings suggest that in other years for other types of radioactive releases, Entergy Palisades may exceed most U.S. plants.

In summary, official data given on the federal web site on environmental releases from U.S. nuclear reactors are relatively limited; but the data that are available raise questions about the safety of the Entergy Palisades reactor, especially as the plant ages.

B. Official Radioactivity Levels in the Environment. The U.S. Environmental Protection Agency makes levels of environmental radioactivity at various sites in the U.S. publicly available. Measurements in air, water, and milk are included. The web site, called "Envirofacts," can be accessed at http://oaspub.epa.gov/enviro/erams_query.simple_query, and covers measurements taken since 1978.

One of the sites at this web site is South Haven MI, close to the Entergy Palisades plant. Unfortunately, the data on radioactivity levels in the South Haven environment are very limited. Only surface water readings are given. Only single annual (April) measurements from 1979 to 1990 are given; for the remainder of the 1990s, the term "ND" is given, and discontinued after 1999. There are only 11 radioactive chemicals that were measured, even though nuclear reactors create and release over 100. Finally, of the 117 measurements during 1979-1990, exactly one-third (39) were negative numbers,

reflecting the inability to calculate an exact amount of radioactivity – and making analysis of these statistics largely useless. (Negative numbers suggest that the machines and methods used are inadequate for accurately measuring relatively low levels of radioactivity).

For four (4) of the 11 chemicals included in the database there were no negative numbers. Results for three of these are given in Table 7, including Cesium-137, Cobalt-60, and Zirconium/Niobium-95.

Table 7
Environmental Radioactivity Concentrations
In South Haven MI (Lake Michigan) Surface Water
By Year, 1979-1990, in Picocuries per Liter

Date	Cesium-137	Cobalt-60	Zirconium/ Niobium-95
April 24, 1979	3.0	8.3	0.3
April 13, 1980	2.4	2.3	3.6
April 9, 1981	3.1	0.6	1.7
April 7, 1982	6.6	1.7	1.7
April 4, 1983	4.9	2.0	1.9
April 2, 1984	3.7	2.2	0.7
April 15, 1985	4.3	1.2	0.2
April 14, 1986	5.5	1.1	0.1
April 6, 1987	5.6	1.5	0.8
April 7, 1988	0.7	3.3	1.9
April 11, 1989	0.0	6.0	2.8
April 5, 1990	1.0	5.5	4.3

Source: Environmental Protection Agency. http://oaspub.epa.gov/erams/enviro_query.simple.query.

No apparent trends are observed in these data, which may be a result of only 12 measurements for each isotope. The latest three years (1988-1990) appear to show elevated levels for Cobalt-60 and Zirconium/Niobium-95, but unusually low levels for Cesium-137.

The 11th and final isotope for which measurements are provided on the Internet in South Haven surface water is tritium, or a radioactive chemical consisting of three sub-atomic particles in an atom of hydrogen, one proton and two neutrons (H-3). From 1978-1999, 81 quarterly measurements were made (no measurements after 1999 are posted on the government web site). It is not known if these measurements were discontinued, or continued and not posted on the Internet. Unfortunately, measurements from 1978 to 1995 were collected manually and only reported to the nearest hundred picocuries of tritium per liter of water. Of the 66 measurements, 65 were reported as 100, 200, 300, or 400, rendering any meaningful analysis moot. (However, the other measurement, on July 12, 1993 was 2500, denoting an unusually elevated level of tritium in Lake Michigan, and likely representing emissions from the Palisades plant).

Between October 1995 and July 1999, 15 measurements of tritium reported to the nearest picocurie were taken at the South Haven site. All but one was above zero. Again, no apparent pattern of increases or decreases over time was observed, and again an unusually high total of 1,718 picocuries of tritium per liter of water was found on October 13, 1997.

The NRC web site also measured tritium levels near 60 U.S. nuclear plants (56 power plants and 4 weapons plants) during the period 1995-1999. Each reading was a precise whole number, not rounded to the nearest hundred, as computer software was used in calculating concentrations. Only 23% of the 833 measurements were negative numbers; Table 8 shows the results for those near nuclear power plants with the highest and lowest averages (counting negative numbers as zero).

Table 8
Average Concentrations of Tritium in Surface Water, In Picocuries per Liter
Ten Sites Near Nuclear Power Plants with Highest Averages
And Four Sites with Lowest Averages, October 1995 to July 1999

Site	Plant	Samples	Average*
1. Doswell VA	North Anna	15	2735.1
2. Hartsville SC	H.B. Robinson	13	1855.3
3. Columbia SC	Virgil C. Summer	7	1137.4
4. Charlotte NC	McGuire	15	278.0
5. Diablo Canyon CA	Diablo Canyon	11	277.0
6. Gordon AL	Joseph M. Farley	14	202.6
7. Morris IL	Dresden	13	197.1
8. South Haven MI	**Palisades**	**15**	**185.2**
9. Daisy TN	Sequoyah	15	184.7
10. Oswego NY	Nine Mile Point	15	165.3
53. Oyster Creek NJ	Oyster Creek	6	11.2
54. Bradwood OR	Trojan	15	9.8
55. Bayside NJ	Salem/Hope Creek	6	6.2
56. Eureka CA	Humboldt	14	4.1

* Assumes negative numbers equal zero
Source: Environmental Protection Agency. http://oaspub.epa.gov/enviro/erams_query.simple_query.

Of the ten sites with the highest levels, only three are single-reactor plants (H.B. Robinson, Virgil C. Summer, and Palisades). All others have two reactors.

Average tritium concentrations in surface water near Entergy Palisades ranked 8th highest of 56 sites, due partly to the extremely high measurement of 1718 on October 13, 1997. (If median had been used, which eliminates the effect of

"outliers" Entergy Palisades still would have ranked 10th highest). For reasons not well understood, sites near the North Anna VA, H. B. Robinson SC, and Virgil C. Summer SC plants were consistently about 10 to 20 times above that of most other plants.

Appendix 2 shows results for all 60 sites near U.S. nuclear plants. The highest is in Allendale SC, close to the Savannah River Site, which manufactured tritium for nuclear weapons from the 1950s to the 1990s.

The available data on radioactive emissions from Entergy Palisades and environmental radioactivity levels near the reactor are generally limited, and precise conclusions cannot be drawn from them. However, the existing data show several patterns of unusually high levels, which suggest more frequent and more accurate measurements should be taken, especially as the reactor ages.

C. Radioactivity Levels in the Body. In the 1950s and 1960s, Washington University and the Greater St. Louis Committee for Nuclear Information collected 320,000 baby teeth, and tested them for levels of radioactive Strontium-90, found only in atomic bomb tests and nuclear reactor emissions. The St. Louis study found that for children born in 1964, just after above-ground bomb testing ended, the average Sr-90 level was **50 times greater** than for those born in 1950, just before testing began. After above-ground atom bomb tests were banned, Sr-90 averages declined about 50% from 1964 to 1969. Source: Rosenthal HL. Accumulation of Environmental 90Sr in Teeth of Children. Hanford Radiobiological Symposium, Richland WA, May 1969, 163-171.

From 1961-1982, the U.S. Atomic Energy Commission (later the U.S. Department of Energy) operated a program measuring Sr-90 concentrations in the vertebrae of 100 healthy adults in San Francisco and New York City who had died in accidents each year. Source: Klusek CS, Strontum-90 in Human Bone in the U.S., 1982. New York: Department of Energy Environmental Measurements Laboratory, 1982. The Energy Department terminated its program in 1982. Since then, the U.S. has been without a systematic government program of testing humans for radioactivity levels in their bodies.

From 1996 to 2006, the Radiation and Public Health Project (RPHP) research group conducted a baby tooth study measuring Sr-90 levels, known as the Tooth Fairy Project. The study is patterned on the St. Louis effort, which provides historical data on Sr-90 levels in the U.S. **The RPHP study of Sr-90 in baby teeth is the only study of in-body radioactivity for Americans living near nuclear reactors.**

RPHP collected and tested nearly 5000 teeth, mostly from California, Connecticut, Florida, New Jersey, New York, and Pennsylvania. It found a consistent pattern of elevated (30 to 50% higher) Sr-90 in baby teeth living in counties closest to reactors, and a 49% rise in Sr-90 for children born in the late 1990s vs. the late 1980s. (Source: Mangano JJ et al. An unexpected rise in strontium-90 in US deciduous teeth in the 1990s. The Science of the Total Environment 2003;317:37-51). Very few teeth from Michigan were collected and tested.

IV. HEALTH RISKS OF ENTERGY PALISADES

A. Introduction. Since the atomic era began in the 1940s, scientists have studied effects of exposures to man-made radioactivity. Elevated levels of illness and death are attributed to the Hiroshima and Nagasaki bombs; bomb tests in Nevada, the South Pacific, and the former Soviet Union; and the 1986 accident at the Chernobyl nuclear power plant. Each of these involved relatively high levels of exposure to radioactivity.

In addition, researchers have addressed effects of relatively low doses of radioactivity. The first to document hazards of low-dose exposures was British physician Alice Stewart. In the 1950s, Stewart showed that a pelvic X-ray to a pregnant woman nearly doubled the chance the baby would die of cancer before age 10. Source: Stewart AM, Webb J, and Hewitt D. A Survey of Childhood Malignancies. British Medical Journal, 1958;i:1495-1508.

Studies of low-dose exposures near nuclear reactors often focus on cancer in children. Radioactive chemicals are known to be more harmful to the young, particularly the developing fetus and infant. Body growth and cell division is most rapid early in life, and thus a damaged cell is most likely to cause harm. **There are at least 18 medical journal articles that identify elevated child cancer rates near different nuclear sites**, mostly power plants (see Appendix 2).

B. Defining Areas Closest to Entergy Palisades.
Defining which areas are most likely to be harmed by toxic emissions from Entergy Palisades is an inexact process. The most affected are a result of proximity and downwind location, along with the source of food and water. The prevailing wind direction in the area is, similar to most of the continental U.S., from west to east (usually from the northwest in colder months and from the southwest in warmer months).

Nearly all residents of four Michigan counties live within 40 miles of Entergy Palisades (Table 1). The reactor is located in Van Buren County, which has a population of just over 76,000 full time residents. A 1990 study by the National Cancer Institute that examined cancer rates near 62 U.S. nuclear plants used Van Buren County as the "study" county for Palisades, meaning that its residents are most likely to be exposed to radioactive contamination from Palisades through breathing and the food chain. Other factors contribute to radiation exposure levels, like in- and out-migration and the origin of water and food supply, and thus there is no perfect means of designating an area most likely to be exposed. But for purposes of this report, health patterns and trends in Van Buren County will be used.

Van Buren health indicators can be compared to Michigan or the United States. Table 9 presents selected demographic characteristics for the county, state, and nation.

Table 9
Current Demographic Characteristics
Van Buren County, Michigan, and the U.S.

Characteristic	Van Buren	Michigan	United States
2010 Population	76,258	9,883,635	308,747,508

2011 % < 18 Years	25.1	23.2	23.7
2011 % > 64 Years	14.2	14.1	13.3
2011 % Female	50.6	50.9	50.8
2011 % White	91.6	80.2	78.1
2011 % White Non-Hisp.	82.2	76.4	63.4
2011 % Black	4.4	14.3	13.1
2011 % Hispanic	10.5	4.5	16.7
2007-11 % Foreign Born	4.8	6.0	12.8
2007-11 % HS Grad age 25+	84.6	88.4	85.4
2007-11 % Below Poverty	18.9	15.7	14.3

Source: U.S. Census Bureau, www.census.gov

Both the state and nation are similar to Van Buren in proportions of age and gender, and educational level. Van Buren has a higher poverty rate than Michigan or the U.S. But the percent of Van Buren's residents who are foreign born (4.8%) is much more similar to Michigan's (6.0%) than that of the U.S. (12.8%). Also, the proportion of white non-Hispanic residents in Van Buren (82.2%) is much closer to Michigan (76.4%) than the U.S. (63.4%). Based on this data, Van Buren's health patterns will be compared to those of Michigan. Moreover, because 91.6% of the county's population is currently white (the proportion was even higher in the past), health analyses will be restricted to whites only. Non-whites often have much higher morbidity and mortality rates, and using whites only will eliminate any racial factors affecting state-county comparisons.

C. 1990 Federal Study of Cancer Near U.S. Nuclear Plants. The federal government conducts no systematic tracking of disease and death rates among persons living near nuclear plants. The only large-scale federal study on cancer near nuclear reactors was prepared by the National Cancer Institute (NCI) in 1990, after Senator Edward M. Kennedy wrote to the National Institutes of Health director James Wyngaarden about an article on elevated leukemia rates near the Pilgrim plant in Massachusetts. NCI concluded there was no link between cancer risk and proximity to reactors, even though study methods have received criticism. Source: Jablon S. et al. Cancer in Populations Living Near Nuclear Facilities. Washington DC: U.S. Government Printing Office, 1990.

Entergy Palisades was one of the 62 nuclear plants included in the NCI's 1990 study. The project analyzed cancer mortality in five-year periods before and after reactor startup in the period 1950 to 1984. It used the Standard Mortality Ratio (SMR), or the county rate divided by the U.S. rate, as a measure of mortality. The only cancer incidence available for the report was near reactors in Connecticut and Iowa, the only states with operating and reliable cancer registries before 1984.

As mentioned, the NCI selected Van Buren as the "study" county, or that most proximate to Entergy Palisades with the greatest exposures to releases from the reactor. Table 10 shows the change in SMR for all cancers before (1950-1971) and after (1972-1984) the startup of Entergy Palisades.

Table 10
Standard Mortality Ratio, Various Types of Cancers
Van Buren (MI) County, 1950-1971 and 1972-1984

	Std. Mortality Ratio (Deaths)		
Type of Cancer	1950-71	1972-84	% Change
All+	0.95 (1783)	0.95 (1434)	---
Leukemia	1.02 (88)	0.93 (59)	- 9
Hodgkins Disease	1.08 (21)	1.46 (13)	+35
Non-Hodgkins Lymphoma	1.00 (49)	0.92 (43)	- 8
Multiple Myeloma	1.32 (27)	0.85 (21)	- 36
Stomach	0.93 (144)	1.09 (66)	+17
Colorectal	1.01 (300)	0.91 (191)	- 10
Liver	0.95 (68)	0.72 (16)	- 24
Trachea, Bronchus, Lung	0.96 (270)	0.99 (366)	+ 3
Female Breast	0.87 (138)	0.97 (126)	+11
Thyroid	0.42 (3)	0.51 (2)	+21
Bone and Joint	0.68 (9)	1.04 (6)	+53
Bladder	1.38 (84)	0.93 (38)	- 33
Brain/Other Nervous Sys.	1.12 (43)	0.85 (32)	- 24

+Excluding Leukemia. Source: Jablon S. et al. Cancer in Populations Living Near Nuclear Facilities. Washington DC: U.S. Government Printing Office, 1990.

The NCI analysis found that the Van Buren County total cancer death rate was 5% below the U.S. (SMR = 0.95) in the periods before and after Entergy Palisades' startup. Of the 13 types of cancer examined, the SMR rose in six and declined in seven. No change was statistically significant.

The NCI study has been criticized for using only mortality data (not incidence data), and for using insufficient time periods after reactor startup, since there may be a latency between exposures and a diagnosis of cancer. Only 13 years of cancer data were used after Palisades' startup. The latest data are 1984 deaths, meaning the study is outdated.

In May 2009, the U.S. Nuclear Regulatory Commission published a notice in the Federal Register, announcing it was pursuing another study of cancer near nuclear plants. After dropping its initial choice of subcontractor (Oak Ridge Associated Universities), the NRC selected the National Academy of Sciences to conduct the study. The NAS has convened a panel to assess the feasibility of such a study, and to conduct and present it. While the planning stage continues as of this writing, there will be no public release of the study, whether or not it is completed, until at least 2015.

D. Infant Mortality. Infant mortality is one of the most frequently employed measures of community health status. Moreover, because the developing fetus and infant are especially sensitive to harmful biological effects of radiation exposure, any change in health status from adding or removing environmental radioactivity will first be observed in the youngest.

Table 11 shows trends in the Van Buren County infant death rate (compared to the state of Michigan) for whites in the periods before (1968-1971) and after (1972-2010) the Palisades plant was fully operational.

Table 11
Infant Mortality (Deaths Age 0-1 per 1,000 Live Births), Whites
Van Buren County vs. Michigan,
Before and After Palisades Startup

	Deaths/1000 Live Births			
Period	County	Mich.	County Deaths	% County vs. Mich.
1968-1971	24.59	18.25	93	**+34.7**
1972-2010	8.92	8.71	336	**+ 2.4**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov.

The county's infant death rate was 34.7% above the state rate in the period 1968-1971. Thereafter, the county rate was 2.4% above the Michigan rate. No unexpected result from added exposure to radioactive releases from Entergy Palisades can be observed from these data. A total of 429 infants born to white Van Buren County residents died from 1968 to 2010.

E. Mortality from All Causes. Another commonly-used measure of public health is the death (mortality) rate from all causes. When Entergy Palisades began operating in 1971, over 500 Van Buren County residents died each year, a number that now exceeds 650. Thus, analyzing trends for five-year periods will provide large numbers of deaths to analyze, increasing the chances of obtaining significant results.

Table 12 shows the local age-adjusted mortality rate compared to the state rate for each five-year period beginning in 1968. One period (1973-1978) covers six years, and the last period (2009-2010) is only two years pending the addition of future mortality data. Only whites are included, as they represent about 93% of the population in the latest period, and higher proportions in the past.

Table 12
Mortality, All Causes Combined, Whites, All Ages
Van Buren County vs. Michigan
Five Year Periods, 1968-2010

	Deaths/100,000

Period	Local	Mich.	Local Deaths	% Local vs. Mich.
1968-1972	1206.1	1246.3	2690	**- 3.2%**
1973-1978 (6 yr)	1047.3	1113.6	3116	**- 6.0%**
1979-1983	952.7	1011.0	2629	**- 5.8%**
1984-1988	1016.9	982.4	2928	**+ 3.5%**
1989-1993	900.8	906.1	2786	**- 0.6%**
1994-1998	889.6	875.8	2953	**+ 1.6%**
1999-2003	886.7	852.7	3084	**+ 1.6%**
2004-2008	892.2	790.5	3257	**+12.9%**
2009-2010 (2 yr)	856.1	760.5	1313	**+12.6%**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population.

In 1968-1972, before Entergy Palisades became fully operational, the local rate was -3.2% than the Michigan rate. A decade later, the county rate began to exceed the state, and the gap increased, until 2004-2010, when the local rate was nearly 13% greater. The number of actual deaths above that expected if the county rate had remained -3.2% below the state after 1972, is **1,330 excess deaths**.

In the most recent period (2003-2010), the county-state gap was greatest. Table 13 provides county-state comparisons in this period for four age groups and each gender.

Table 13
Mortality, All Causes Combined, Whites, All Ages
Van Buren County vs. Michigan
By Race/Ethnicity, Gender, and Age Group, 2003-2010

	Deaths/100,000			
Group	County	Mich.	County Deaths	% County vs. Mich.
All Persons	885.3	787.0	5,215	**+12.5**
Gender				
Males	1072.9	932.7	2,715	**+15.0**
Females	735.8	673.9	2,500	**+ 9.2**
Age at Death				
0-24	69.0	57.0	131	**+21.0**
25-44	169.4	138.4	244	**+22.4**
45-64	630.3	564.9	1,049	**+11.6**
65+	5304.5	4748.7	3,791	**+12.5**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population.

In the period 2003-2010, the local age-adjusted mortality rate for all deaths exceeded the state by 12.5%, and was elevated for each age group, along with males and females. All differences were statistically significant at p<.05, except for the age group 0-24, which fell short at p<.13. Local death rates were especially high for young persons. The rates for persons who died at age 0-24 and 25-44 were 21.0% and 22.4%, respectively, above the state.

Only 128 of the 5215 deaths in this period were white Hispanics, due to the small proportion of Latino residents in the county, and their relatively younger age mix. The rate for white non-Hispanics in Van Buren was 11.3% greater than in the state (885.5 vs. 785.5).

Another way to examine mortality patterns in Van Buren County is by cause of death. Table 14 compares local and state 2003-2010 age-adjusted mortality rates for the eight (8) most common causes, which account for 93.4% of Michigan deaths. At least 100 deaths to Van Buren County residents occurred in each of these categories.

Table 14
Mortality, Most Common Causes of Death, Whites, All Ages
Van Buren County vs. Michigan, 2003-2010

Cause	Deaths/100,000 County	Mich.	County Deaths	% County vs. Mich.
All Causes	885.3	787.0	5,215	**+12.5***
Circulatory System	311.2	280.4	1,818	**+11.0***
Neoplasms (Cancer)	205.5	188.5	1,256	**+ 9.0***
Respiratory System	89.9	76.2	527	**+17.9***
Homicide, Suicide, Accidents	74.4	53.3	422	**+39.6***
Nervous System	45.0	43.0	258	**+ 4.5**
Endocrine, Nutr., Metabolic	39.5	34.2	233	**+15.5**
Digestive System	36.6	28.7	222	**+27.4***
Mental/Behavioral Diseases	30.5	28.7	173	**+ 6.2**
All Other	52.9	54.0	306	**- 2.2**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population. * = statistically significant at p<.05

The Van Buren mortality rate exceeded the state rate for all eight of the most common causes of death. Of these, five were statistically significant. The greatest excesses were recorded for homicide/suicide/accidents (+39.6%), digestive system diseases (+27.4%), and respiratory system disorders (+17.9%). The Van Buren rate for the "all other" category, which is a combination of many causes of death, is 2.2% below the state rate.

While homicides, suicides, and accidents are not an outcome of radiation exposure, disease of all other organ systems could be affected by emissions from Palisades.

It would be helpful to understand whether or not the elevated mortality rate in Van Buren County is part of an area-wide pattern. Table 15 displays the 2003-2010 mortality rates for whites in the four counties closest to Entergy Palisades, compared to the state rate.

Table 15
Mortality, All Causes Combined, Whites, All Ages
Van Buren County and Three Adjoining Counties vs. Michigan, 2003-2010

	Deaths/100,000			
County	County	Mich.	County Deaths	% County vs. Mich.
Allegan	780.9	787.0	6,629	- 0.8
Berrien	796.3	787.0	11,141	+ 1.2
Kalamazoo	765.7	787.0	14,008	- 2.7
Van Buren	885.3	787.0	5,215	**+12.5***

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population. * = statistically significant at p<.05

The mortality rate in Allegan, Berrien, and Kalamazoo Counties are all well below the Van Buren rate, and roughly comparable to the state. No county rate (among these four) is significantly different than the state, other than Van Buren. Thus, any factors affecting Van Buren County's death rates appear to have much less (or no) effect in surrounding counties.

F. Cancer Mortality. The disease most closely linked with radiation exposure is cancer. The U.S. Centers for Disease Control and Prevention web site containing mortality data by cause for each year from 1968-2010 provides an opportunity to examine the trend in Van Buren County cancer death rates for whites (compared to those of Michigan) over time. Table 16 shows the comparison, by periods of about a decade each.

Table 16
Mortality, Malignant Cancers, Whites, All Ages
Van Buren County vs. Michigan
By 10-to-12 Year Period, 1968-2010

	Deaths/100,000			
Period	County	Mich.	County Deaths	% County vs. Mich.
1968-1978 (11 yrs.)	182.9	204.2	963	**- 10.5**
1979-1988 (10 yrs.)	207.5	209.0	1198	**- 0.7**
1989-1998 (10 yrs.)	212.1	208.0	1377	**+ 1.9**
1999-2010 (12 yrs.)	195.6	188.0	1745	**+ 4.0**
2005-2010 (6 yrs.)	204.5	182.6	953	**+12.0**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population

In the period 1968-1978, before Entergy Palisades began operating and its earliest years of operation, the Van Buren cancer death rate was -10.5% below that of Michigan's. But in the following decade, the gap closed to -0.7%, and exceeded the state in the succeeding decades (+1.9% and +4.0%). **In the latest six years (2005-2010), the Van Buren County cancer death rate was +12.0% greater than the state, significantly higher than the deficit of -10.5% in the period 1968-1978.**

The +12.0% county-state excess is based on 953 deaths from cancer to Van Buren County residents. **In the six-year period 2005-2010, the cancer mortality rate in Van Buren County was the highest of the 34 most populated counties in Michigan**, each of which has at least 53,000 residents and which account for 88% of the state's total population. Appendix 3 lists cancer mortality rates for these 34 counties.

While radiation exposure is a known risk factor for developing cancer, exposures at young ages are most harmful. Thus, an analysis of cancer mortality trends for young persons in Van Buren County is merited. Table 17 presents trends in mortality rates for malignant cancer among Van Buren County whites, compared to the state of Michigan, for persons who died before their 45th birthday. This group includes most cancers first diagnosed in childhood and early adulthood. Many of these cancers actually originate from a mutation in cells that began years earlier.

Table 17
Mortality Trends, Malignant Cancers, Whites, Age 0-44
Van Buren County vs. Michigan
By Period, 1968-2010

	Deaths/100,000			
Period	County	Mich.	County Deaths	% County vs. Mich.
1968-1978 (11 yrs.)	20.89	20.13	60	+ **3.8**
1979-1988 (10 yrs.)	21.17	16.44	79	**+28.8**
1989-1998 (10 yrs.)	13.83	13.72	62	+ **0.8**
1999-2010 (12 yrs.)	15.47	12.03	77	**+28.6**

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population

In the earliest period (1968-1978), the county rate was +3.8% greater than the state. But in the periods following, the excesses were +28.8%, +0.8%, and +28.6%. None of these increases are statistically significant, as the number of deaths involved are relatively small. Cancer mortality among Van Buren children and young adults have been greater than expected after the startup of Palisades.

G. Cancer Incidence. In addition to cancer mortality (deaths) data, information on incidence (diagnosed cases) in Van Buren County can also indicate a potential link with radioactive emissions from Entergy Palisades. Unfortunately, cancer incidence data are only available for more recent years, compared to mortality data which begins in 1968.

The National Cancer Institute only provides county-specific cancer incidence data on its State Cancer Profiles web site for the period 2005-2009. However, Michigan's Cancer Registry makes annual county-specific cancer incidence data available on its web site, for each year from 1985 to 2010. Trends since 1985 can be analyzed, but a comparison of cancer incidence before and after the startup of Entergy Palisades is not possible, as all years are after 1971 (Table 18).

Table 18
Incidence Trends, All Cancers Combined, Whites
Van Buren County vs. Michigan
By Five-Year Period, 1985-2010

	Cases/100,000			
Period	County	Mich.	County Cases	% County vs. Mich.
1985-1990 (6 yrs.)	481.8	468.8	1734	+ 2.8
1991-1995	477.4	514.7	1561	- 7.3
1996-2000	455.5	503.7	1577	- 9.6
2001-2005	464.0	501.9	1715	- 7.5
2006-2010	445.1	471.4	1791	- 5.6

Source: Michigan Cancer Registry. http://www.cancer-rates.info/mi/index.php. Rates age adjusted to 2000 U.S. Standard Population

In the late 1980s, the Van Buren cancer incidence rate was 2.8% above the Michigan rate. For each five-year period since then, the Van Buren rate has been lower than the state. No evidence of any link between Entergy Palisades' emissions and cancer risk can be discerned from these data.

H. Child Cancer Incidence. Another health condition sensitive to radiation is childhood cancer. As mentioned, a dose of radiation causes much more genetic and cellular damage to the fetus, infant, and young child than the same exposure does to an adult. However, it is not possible to examine trends in child cancer incidence by Michigan counties, as the State Cancer Registry web site only provides incidence data for all cancers combined.

In the most recent available period (2005-2009), cancer incidence among children age 0-19 for each Michigan county with at least 15 cases in the five year period is provided on the Internet. Van Buren did not have at least 15 cases, and thus no data are provided. Whether child cancer incidence in Van Buren is high remains unknown. Source: National Cancer Institute, State Cancer Profiles. www.statecancerprofiles.cancer.gov

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions. This report has addressed patterns of radioactive emissions from the Entergy Palisades nuclear plant, and potential links with adverse health effects among those living closest to the plant. The plant has been in operation since 1971, making it the 9th oldest reactor in the U.S., and over 1.3 million persons live within 50 miles.

The potential adverse health consequences posed by Entergy Palisades are enormous. The plant contains 585 metric tons containing nearly 130,000,000 curies of high-level radioactive waste (as of 2010). Much of this radioactivity is stored in a deep pool of constantly-cooled water; loss of cooling water could result in a disastrous fire and massive release of radioactivity, which would poison many thousands of persons. The remainder of the waste has been transferred to "dry" steel and concrete casks, which are stored outside on the plant's grounds.

The plant's operating record is a concern. From 1986-2006, four "near-miss" meltdown situations occurred at the reactor, one of the highest totals in the U.S., and at least five other serious incidents occurred since 2010. In addition, the fact that the reactor operated a very high 93.5% of the time from 2006-2011 raises the risk of routine emissions and a meltdown, as the plant's aging parts are corroding.

Data provided on government web sites on emissions from Entergy Palisades and radioactivity in local air, water, and food are limited. However, there appeared to be a large, steady rise in various types of airborne and liquid radioactivity from 2001 to 2007. Moreover, the level of tritium in Lake Michigan at South Haven, close to Palisades, exceeded most sites in surface waters nationwide near reactors in the late 1990s.

Many, but not all, local health indicators examined in this report support a statistical link with the operation of Entergy Palisades. The Van Buren County all cause mortality rate for whites, which had been slightly below the Michigan rate in the 1970s, steadily rose until the current (2003-2010) rate was 12.5% above the state. A total of 1330 "excess" deaths were calculated after Entergy Palisades began operating. Elevated mortality rates were observed for all age groups (especially children and young adults), both genders, and all major causes of death in 2003-2010.

Van Buren's mortality rate for all cancers combined (whites) was -10.5% below the state in the period 1968-1978, but +12.0% above the state for the most recent period (2005-2010). The current Van Buren rate was the highest of any of the 34 most populated counties in Michigan, which account for 88% of the state's population.

Cancer incidence data for Michigan counties exists for each year from 1985 to 2010, and thus no analysis can be made of rates before and after Entergy Palisades' startup. However, no inference can be made of rising incidence rates in the county since the mid-1980s.

B. Recommendations. This report has provided information about the potential adverse health consequences the Entergy Palisades nuclear facility poses to local residents. Some

questions have been raised, especially the steadily rising mortality rate (all causes) and cancer mortality rate in Van Buren County.

While these data should be taken seriously, they should be followed up with additional studies, of both contamination levels and health status measures. Citizen-based monitoring of environmental radioactivity levels can be one way to improve existing data, and should be encouraged. The unexpected and steady rise in local death rates, especially cancers, should be taken seriously by health officials, who should conduct their own studies to examine potential causes – among them, releases of hazardous radioactivity and toxic chemicals from Entergy Palisades.

Continued operations of Entergy Palisades, now at the advanced age of 42 years, should include such a "report card" of performance for which operators have not been held accountable in the past, so that sound decisions can be made that best protect public health.

APPENDIX 1
Tritium Concentrations in Surface Water, in picocuries per liter
Near 56 Nuclear Power Plants and 4 Nuclear Weapons Plants
October 1995 - June 1999

NUCLEAR POWER PLANTS				(ALL)	(- ARE 0)
LOCATION	REACTOR	SAMPLES	TOT pCi	AVG pCi	AVG pCi
Doswell VA	North Anna	15	41027	2735.1	2735.1
Hartsville SC	H.B. Robinson	13	24119	1855.3	1855.3
Columbia SC	Virgil C. Summer	7	7962	1137.4	1137.4
Charlotte NC	McGuire	15	4170	278.0	278.0
Diablo Canyon CA	Diablo Canyon	11	2955	268.6	277.0
Gordon AL	Joseph M. Farley	14	2747	196.2	202.6
Morris IL	Dresden	13	2557	196.7	197.1
South Haven MI	**Palisades**	**15**	**2758**	**183.9**	**185.1**
Daisy TN	Sequoyah	15	2753	183.5	184.7
Oswego NY	Nine Mile Point	15	2480	165.3	165.3
Newport News VA	Surry	14	2210	157.9	162.8
Broad River SC	Catawba	11	1439	130.8	139.0
Homestead FL	Turkey Point	14	1709	122.1	133.9
Waterford CT	Millstone	16	1541	96.3	115.1
Zion IL	Zion	12	1280	106.7	108.3
Victory WI	LaCrosse	14	1467	104.8	107.6
Decatur AL	Browns Ferry	15	1287	85.8	88.3
Two Creeks WI	Kewaunee	14	1206	86.1	86.1
Scottsboro AL	Sequoyah	15	1033	68.9	74.9
Southport NC	Brunswick	15	775	51.7	74.7
Philadelphia PA	Limerick	43	2546	59.2	67.4
Croton on Hudson NY	Indian Point	14	768	54.9	62.4
Conomingo MD	Peach Bottom	15	843	56.2	57.1
Chelsea NY	Indian Point	17	732	43.1	50.9
Little Rock AR	Arkansas One	15	685	45.7	49.0
Danville PA	Susquehanna	15	618	41.2	45.7
Buhl ID	--------	14	586	41.9	42.9
East Haddam CT	Conn. Yankee	15	535	35.7	40.9
Rulo NE	Cooper	7	271	38.7	38.7
Platteville CO	Fort St. Vrain	15	542	36.1	38.6
Baxley GA	Edwin I. Hatch	13	433	33.3	38.2
Wiscasset ME	Maine Yankee	15	411	27.4	35.9
Port Gibson MS	Grand Gulf	15	486	32.4	35.8
Northport WA	--------	15	335	22.3	35.1
LeRoy KS	Wolf Creek	16	306	19.1	34.8
Red Wing MN	Prairie Island	15	372	24.8	34.1
New Orleans LA	Waterford	15	432	28.8	32.7
Monticello MN	Monticello	15	373	24.9	32.3
Clay Station CA	Rancho Seco	15	360	24.0	31.4
Wheeling WV	Beaver Valley	15	262	17.5	30.5
Vernon VT	Vermont Yankee	13	275	21.2	29.1
Boulder City NV	--------	12	210	17.5	27.2
Cedar Rapids IA	Duane Arnold	15	263	17.5	26.3
Moline IL	Quad Cities	8	197	24.6	24.6

Plymouth MA	Pilgrim	14	237	16.9	20.7
Lusby MD	Calvert Cliffs	14	199	14.2	20.3
San Onofre CA	San Onofre	11	-80	-7.3	17.6
Ft. Pierce FL	St. Lucie	15	9	0.6	16.0
El Paso TX	--------	4	-42	-10.5	14.8
Matagorda TX	South Texas Project	14	123	8.8	13.6
Crystal River FL	Crystal River	15	-66	-4.4	12.4
Toledo OH	Davis Besse	11	3	0.3	11.2
Oyster Creek NJ	Oyster Creek	6	-85	-14.2	11.2
Bradwood OR	Trojan	15	7	0.5	9.8
Bayside NJ	Salem/Hope Creek	6	-54	-9.0	6.2
Eureka CA	Humboldt	14	-262	-18.7	4.1
TOTAL		779	120305	154.4	
NUCLEAR WEAPONS PLANTS					
Allendale SC	Savannah River	13	13154	1011.8	1011.8
Kingston TN	Oak Ridge	13	6233	479.5	483.3
Oak Ridge TN	Oak Ridge	14	4904	350.3	352.3
Richland WA	Hanford	14	671	47.9	49.3

APPENDIX 2
JOURNAL ARTICLES (18) THAT IDENTIFY ELEVATED LEVELS OF CHILDHOOD CANCER NEAR NUCLEAR PLANTS

Sharp L, McKinney PA, Black RJ. Incidence of childhood brain and other non-haematopoietic neoplasms near nuclear sites in Scotland, 1975-94. Occupational and Environmental Medicine 1999; 56(5): 308-314.

Busby C, Cato MS. Death rates from leukaemia are higher than expected in areas around nuclear sites in Berkshire and Oxfordshire. BMJ 1997; 315(7103): 309.

Black RJ, Sharp L, Harkness EF, McKinney PA. Leukaemia and non-Hodgkin's lymphoma: incidence in children and young adults resident in the Dounreay area of Carthness, Scotland in 1968-91. Journal of Epidemiology and Community Health 1994; 48(3): 232-236.

Draper GJ, Stiller CA, Cartwright RA, Craft AW, Vincent TJ. Cancer in Cumbria and in the vicinity of the Sellafield nuclear installation, 1963-90. BMJ 1993; 306(6870): 89-94.
43.

Goldsmith JR. Nuclear installations and childhood cancer in the UK: mortality and incidence for 0-9 year-old children, 1971-1980. The Science of the Total Environment 1992; 127(1-2): 13-35.

Kinlen LJ, Hudson CM, Stiller CA. Contacts between adults as evidence for an infective origin of childhood leukaemia: an explanation for the excess near nuclear establishments in west Berkshire? British Journal of Cancer 1991; 64(3): 549-554.

Ewings PD, Bowie C, Phillips MJ, Johnson SA. Incidence of leukemia in young people in the vicinity of Hinkley Point nuclear power station, 1959-86. BMJ 1989; 299(6694): 289-293.

Cook-Mozaffari PJ, Darby SC, Doll R, Forman D, Herman C, Pike MC, Vincent T. Geographical variation in mortality from leukemia and other cancers in England and Wales in relation to proximity to nuclear installations, 1969-78. British Journal of Cancer 1989; 59(3): 476-485.

Roman E, Beral V, Carpenter L, Watson A, Barton C, Ryder H, Aston DL. Childhood leukaemia in the West Berkshire and Basingstoke and North Hampshire District Health Authorities in relation to nuclear establishments in the vicinity. BMJ (Clinical Research Edition) 1987; 294(6572): 597-602.

Forman D, Cook-Mozaffari P, Darby S, Davey G, Stratton I, Doll R, Pike M. Cancer near nuclear installations. Nature 1987; 329(6139): 499-505.

Heasman MA, Kemp IW, Urquhart JD, Black R. Childhood leukemia in northern Scotland. Lancet 1986; 1(8475): 266.

Gunay U, Meral A, Sevinir B. Pediatric malignancies in Bursa, Turkey. Journal of Environmental Pathology, Toxicology, and Oncology 1996; 15(2-4): 263-265.

McLaughlin JR, Clarke EA, Nishri ED, Anderson TW. Childhood leukemia in the vicinity of Canadian nuclear facilities. Cancer Causes and Control 1993; 4(1): 51-58.

Viel JF, Pobel D, Carre A. Incidence of leukaemia in young people around the La Hague nuclear waste reprocessing plant: a sensitivity analysis. Statistical Medicine 1995; 14(21-22): 2459-2472.

Hoffmann W, Dieckmann H, Schmitz-Feuerhake I. A cluster of childhood leukemia near a nuclear reactor in northern Germany. Archives of Environmental Health 1997; 52(4): 275-280.

Mangano JJ, Sherman J, Chang C, Dave A, Feinberg E, Frimer M. Elevated childhood cancer incidence proximate to U.S. nuclear power plants. Archives of Environmental Health 2003; 58(2): 74-82.

Spix C, Schmiedel S, Kaatsch P, Schultze-Rath R, Blettner M. Case-control study on childhood cancer in the vicinity of nuclear power plants in Germany 1980-2003. European Journal of Cancer 2008; 44(2); 275-284.

Sermage-Faure C, Laurier D, Goujon-Bellec S, Chartier M, Guyot-Goubin A, Rudant J, et al. Childhood leukemia around French nuclear power plants – the Geocap study, 2002-2007. Int J Cancer 2012; 131(5): E769-E780.

Appendix 3
Mortality, Malignant Cancers, Whites, All Ages
34 (of 83) Largest Counties in Michigan, 2005-2010
That Represent 88% of Total Michigan Population

County	Cancer Deaths	Deaths/ 100,000
1. Van Buren	**953**	**204.47**
2. St. Clair	2234	203.72
3. Genessee	4581	199.53
4. Tuscola	795	199.42
5. Calhoun	1714	199.00
6. Isabella	612	198.15
7. Wayne	14258	196.75
8. Jackson	2023	196.31
9. St. Joseph	802	195.79
10. Montcalm	793	194.71
11. Shiawassee	915	193.31
12. Bay	1579	192.93
13. Lapeer	1032	191.06
14. Macomb	10251	188.74
15. Monroe	1785	188.22
16. Muskegon	1891	186.75
17. Saginaw	2274	184.70
18. Lenawee	1235	184.02
19. Barry	711	183.22
20. Eaton	1231	182.84
21. Kalamazoo	2488	182.46
22. Berrien	1907	180.24
23. Ionia	631	178.88
24. Allegan	1196	178.45
25. Midland	1004	177.33
26. Ingham	2283	174.57
27. Livingston	1760	173.73
28. Marquette	794	171.30
29. Oakland	11328	168.60
30. Washtenaw	2427	164.20
31. Kent	5011	163.02
32. Grand Traverse	932	154.71
33. Clinton	679	154.22
34. Ottawa	2154	150.01

Source: U.S. Centers for Disease Control and Prevention, http://wonder.cdc.gov. Rates age adjusted to 2000 U.S. Standard Population