FERMI 2 NUCLEAR REACTOR AND RISING CANCER RATES

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EXECUTIVE SUMMARY

The Fermi 2 nuclear plant in Monroe County Michigan, just south of Detroit has operated since 1985. It has generated a large amount of highly radioactive waste. A portion is released into the environment, where it enters human bodies through breathing and the food chain.

This report addresses releases, and trends in Monroe County cancer death rates.Findings include:

1. Before Fermi 2 startup, the Monroe County rate was roughly equal to the U.S. rate.

2. Since 1988, the Monroe's rate steadily rose above the U.S. The county was 11.3% higher in the most recent 10 years (2009-2018), and 14.3% higher in 2014-2018 (1,794 deaths).

3. In 2014-2018, the county rate was significantly higher than the U.S. for each gender, all races, and all age groups; excesses are greatest for males, blacks, Hispanics, and children.

4. In the period 1968-1991, the county rate age 0-24 was 3.5% below the U.S.

5. In 1992-2018, as Fermi 2 operated, the county rate age 0-24 was 38.0% above the U.S., the highest rate of the 30 most populated Michigan counties.

6. In the past 40 years, assuming the county/national ratio for 1969 would not change, an additional 1,281 Monroe residents died of cancer, plus another 620 from other causes.

The findings show that more cancer deaths in Monroe County have occurred, than would be expected based on patterns in the years before Fermi 2 started. Because of the routine releases of radioactivity from Fermi 2, and because no other causes of this pattern are known, further review of county disease and death rates are warranted.

FERMI 2 NUCLEAR REACTOR AND RISING CANCER RATES

Introduction.

The Fermi 2 nuclear reactor at the Enrico Fermi Nuclear Generating Station is in Newport, (Monroe County). It achieved initial criticality (began generating radioactivity) on June 21,1985 and went commercial (began generating electricity for sale) on January 23, 1988. It is a boiling water reactor, with a capacity of 1202 megawatts electrical (MWe), typical for a large U.S. reactor started in the 1980s (U.S. Nuclear Regulatory Commission, 2021).

Fermi 2 is in northeast portion Monroe County, on Lake Erie, about 30 miles south of the center of Detroit. Toledo, Ohio, and Windsor, Ontario (Canada) are also proximate, each about 27 miles away. In 2010, 4,799,526 Americans lived within 50 miles of the reactor (Dedman, 2011).

The current county population is about 150,000 residents, up slightly from the 134,000 residents in 1985, when Fermi 2 began operations. Caucasians make up about 95% of the population. It has a poverty rate well below the state and national levels.

Virtually all 150,000 residents of Monroe County live within 25 miles of Fermi 2, and the majority of residents (including Monroe City and its suburbs) are within 10 miles.

Nuclear Power from Fermi and Health Risks.

Electric power from Fermi 2, and from all nuclear reactors, involves splitting uranium atoms to generate high heat, which is converted into electricity. The process of splitting uranium, known as fission, is the same used in detonating nuclear weapons. It creates over 100 chemicals not found in nature, each of which is carcinogenic, in the form of gases and tiny metal particles.

Most of these radioactive chemicals are stored at reactors, but some are released into the air and water. They enter human bodies through breathing, food, and water. Each chemical affects human biology differently. For example, radioactive iodine seeks out the thyroid gland, and radioactive strontium seeks out bone and teeth.

All radioactive isotopes damage DNA in cells or kills them outright, leading to an elevated risk of disease and death. Several major findings are clear after decades of study:

1. All humans are affected negatively by radiation exposure, even at the lowest doses (BEIR V, 1990)

2. The most severe effects of a dose are borne by the fetus and infant, whose immune systems are immature; by the frail elderly, whose immune systems are failing; and by those who are immunocompromised

3. The lag time between exposure and onset of disease or death may take several years, or even decades

4. While some cancers are known to be especially sensitive to radioactivity, such as thyroid cancer or bone cancer, the risk of all cancers are increased after radiation exposure

Numerous articles have appeared in the medical literature, documenting the excess in cancers after relatively low-dose exposures. A recent article in the Journal of the National Cancer Institute found 21 of the 26 studies determined an excess of cancer from low-level radiation (Gonzalez, 2020).

The federal government has conducted just one study of cancer near nuclear plants, performed at the mandate of Senator Edward Kennedy. The study looked at cancer mortality from 1950 to 1984 and found no consistent link between cancer and proximity to nuclear plants. However, no federal update has been forthcoming (National Cancer Institute, 1990).

The Radiation and Public Health Project (RPHP), a non-profit research and educational organization, has published 38 medical journal articles, mostly on health patterns and trends near nuclear plants. Unexpectedly high rates of cancer closest to nuclear plants have often been documented (Radiation and Public Health Project, 2020).

The operation of the Fermi 2 nuclear plant for over 35 years provides an opportunity to study trends in local cancer rates, which are presented in this report.

Study Methods

Monroe County will be the focus of this report. The 1990 National Cancer Institute study selected the home county of each nuclear plant, sometimes adding an adjoining county. Since virtually all 150,000 Monroe residents reside within 25 miles of Fermi 2, and the majority reside within 10 miles, this report will analyze patterns in Monroe County.

The 1990 National Cancer Institute study selected the U.S. cancer rate as the control for each county and calculated a county vs. national ratio for cancer mortality, before and after startup of each plant. This report will follow the same formula. Mortality trends for all cancers combined will be the principal measure used in this report.

The source for the study will be the Centers for Disease Control and Prevention's "CDC Wonder" data base. Available online, CDC Wonder includes information on every U.S. death, each year from 1968 to 2018, as of late 2020 (U.S. Centers for Disease Control and Prevention, 2020).

The measure used in the study will be the rate of cancer deaths per 100,000 persons. These rates are adjusted to the 2000 U.S. census, a standard method in epidemiology to account for any unusual age distributions in the population, allowing for "apples to apples" comparisons. Age adjusted rates were used in the 1990 National Cancer Institute study.

The availability of over 50 years of data allows five 10-year periods to be studied. These will start with 1969-1978, and end with 2009-2018. The percent that Monroe County's cancer rate is greater than or less than the U.S. will be the key measure, as it was in the 1990 federal study.

The 1969-1978 county/national ratio will be the baseline or "expected" ratio for all future periods. Significance testing for later 10-year periods will be made to assess if the ratio differs from the expected. A p-value of .05 or less is the standard for significance, meaning that there is

a 95% or greater chance that changes in county/national ratios after 1978 are not due to random chance.

Results – Radioactive Emissions from Fermi 2

Studies assessing the relationship between radiation exposure and cancer typically consist of a "dose" and a "response." In this report, the "dose" is the unquantified exposure of Monroe County residents to routine releases from Fermi 2, and the "response" is cancer deaths.

It is not possible to precisely measure total in-body exposures to a population for various reasons:

1. Measurement is an involved process, sometimes involving autopsies.
2. There are many radioactive chemicals, making it impossible to measure each one.
3. Some chemicals decay quickly and are impossible to measure once they enter the body.
4. Each person in a population would have to be measured.
5. No regulatory body requires in-body measurements of persons living near nuclear plants.

The Radiation and Public Health Project (RPHP) has conducted the only study of in-body radioactivity near U.S. nuclear power plants. The "Tooth Fairy Project" measured Strontium-90 levels in 5,000 baby teeth, as did 1960s studies of fallout from above-ground atomic bomb tests.

Results of the RPHP tooth study, which were published in five medical journal articles, showed a 30-50% greater average concentration of Strontium-90 in areas closest to nuclear plants; increases through the 1980s and 1990s, and a matching of trends of Strontium-90 and cancer incidence in children under age five (Gould et al., 2003; Mangano, et al., 2006).

In the six years from 2006-2011, a total of 598.6 curies of radioactive tritium were released from Fermi 2. But in the following six-year period (2012-2017), the total jumped to 1205.0 curies, an increase of 101.3%, or slightly more than double. See Appendix 1 for yearly totals (U.S. Nuclear Regulatory Commission, 2021).

All gaseous releases of tiny metal particulates, containing various radioactive chemicals from Fermi 2 in 2016 was 1.84 millicuries of gaseous particulates, compared to a median of 0.129 for the 34 U.S. boiling water reactors, ranking Fermi #3. In 2017, it released 20.6 millicuries vs. a national median of 0.204, or 101 times greater, and the highest in the nation (Appendix 2) (U.S. Nuclear Regulatory Commission, 2021).

While tritium and metal particulates do not represent all radioactivity, these findings suggest that Fermi 2 emissions may be larger than most U.S. reactors.

Results – Cancer Death Trends in Monroe County

In the 10-year period 1969-1978, before Fermi 2 began operations, the Monroe County death rate from malignant cancers was 4.5% below the U.S. In the following four decades, the county rate exceeded the U.S. by 2.0%, 5.6%, 7.1%, and 11.3%.In the most recent five-year period (2014-2018), the gap was 14.3%. About 360 Monroe County residents die of malignant cancer each year.

Rates are significantly different compared to the county/national ratio of -4.5% in 1969-1978. Had this ratio not changed after 1978, a total of 1,281 fewer Monroe residents would have not died of cancer. See table below and Appendix 3.

1969-1978	county **4.5% below** U.S.
1979-1988	county **2.0% above** U.S.
1989-1998	county **5.6% above** U.S.
1999-2008	county **7.1% above** U.S.
2009-2018	county**11.3% above** U.S.
(2014-2018)	county **14.3% above** U.S.

Each disparity between the county and nation after 1978 is statistically significant.

In 2019, the county cancer death rate (170.05 per 100,000) exceeded the U.S. rate (150.02) by 13.4%, based on 364 deaths to county residents.

Results – Current Cancer Death Patterns in Monroe County, by Gender, Race, and Age

In 2014-2018, the most recent, five-year period available, cancer mortality in Monroe County reached an all-time high of 14.3% above the U.S., based on 1,794 deaths to Monroe residents.A comparison of county and national rates, by gender, race, and age group, are in the table below and Appendix 4.

Total	county **14.3% above U.S.**
Males	county **18.1% above U.S.**
Females	county **10.4% above U.S.**
W, non-Hisp	county **10.2% above U.S.**
W, Hispanic	county **41.1% above U.S.**
B, non-Hisp.	county **29.8% above U.S.**
0-24	county **40.2% above U.S.**
25-44	county**49.5% above U.S.**
45-64	county **14.5% above U.S.**
65+	county **12.3% above U.S.**

The county rate exceeded the U.S. rate for males and females, each racial/ethnic group, and each age group. Excesses were especially large for minorities and young persons. The county rates for white Hispanics and black non-Hispanics were 41.1% and 29.8% greater, and persons age 0-24 and 25-44 were 40.2% and 49.5% greater.

Each difference is statistically significant except for age 0-24, white Hispanics, and black non-Hispanics, due to the small number of deaths in the period (8, 21, and 42).

Results – Current Cancer Death Patterns in Monroe County, by Type of Cancer

Ten cancers account for about 75% of all cancer deaths among U.S. residents. Data for these, along with benign neoplasms (non-malignant cancer,the 11th most common cause of cancer mortality) are presented for Monroe County and the U.S. for 2014-2018 (see table below and Appendix 5):

County rate is above U.S.	
Leukemia	county **42.2% above U.S.**
Brain and central nervous system cancer	county **36.4% above U.S.**
Bronchus and lung cancer	county **22.7% above U.S.**
Benign, in situ, and unknown behavior neoplasms	county **19.6% above U.S.**
Non-Hodgkin's lymphoma	county **19.1% above U.S.**
Ill-defined, secondary, and unspecified cancers	county **17.0% above U.S.**
Liver and intrahepatic bile ducts cancers	county **13.4% above U.S.**
Colorectal cancer	county **11.5% above U.S.**
Female breast cancer	county **9.2% above U.S.**
Pancreatic cancer	county **3.9% above U.S.**
County rate is below U.S.	
Male prostate cancer	county **3.0% below U.S.**

The 2014-2018 mortality for Monroe County residents was greater than the U.S. for all but prostate cancer. Rates for total cancers, lung/bronchus cancer, and leukemia were significantly greater. Leukemia deaths had the greatest excess (county rate 42.2% above the nation), followed by brain and central nervous system cancer (36.4% greater).

Results – Trends in Cancer Death Patterns in Monroe County Children

The child cancer death rate is low, due to recent improvements in treatment. Still, child cancer is the most often studied type of cancer when assessing the potential harms from radiation exposure.

The table below, along with Appendix 6, show trends in cancer mortality age 0-24 for Monroe County and the U.S., by comparing the periods 1968-1991 (24 years) and 1992-2018 (27 years) – essentially, the pre-Fermi and post-Fermi periods.

1968-1991 county **3.5% below U.S. (70 deaths)**

1992-2018 county **38.0% above U.S. (56 deaths)**

The county death rate moved from 3.5% below the nation to 38.0% above the nation, a statistically significant change. The 1992-2018 Monroe County rate was the highest of the 30 most populated counties in the state of Michigan, which account for nearly 90% of all Michigan residents under age 25 (Appendix 7).

Results – All-Cause Death Trends in Monroe County (Excluding Cancer)

Radiation can cause deaths from causes other than cancer. A review of over 5,000 studies showed that the 1986 Chernobyl meltdown was linked with multiple causes of death among workers and residents near the stricken reactor (total 986,000 in 19 years (Yablokov, 2009).

A comparison of the difference between Monroe County and U.S. mortality rates from all causes other than cancer in the most recent five decades is provided in the table below and Appendix 8.

1969-1978 county **2.3% above** U.S.

1979-1988 county **2.6% above** U.S.
1989-1998 county **3.6% above** U.S.
1999-2008 county **2.6% above** U.S.
2009-2018 county **6.6% above** U.S.

(2014-2018) county **6.8% above** U.S.

2019 county **6.9% above** U.S.

In 1969-1978 (pre-Fermi 2), the county rate was 2.3% above the nation. Since then, the county has exceeded the U.S., by 2.6%, 3.6%, 2.6%, and 6.6% (and 6.8% in the most recent five years). Excess (non-cancer) deaths in Monroe County number 620in the most recent 40 years, well below the excess cancer death total of 1,281.

Discussion

The Fermi 2 nuclear reactor has released radioactive materials into the environment since its startup in 1985. While no comprehensive analysis of each chemicalis possible, recent emissions show Fermi 2 may be one of the highest-emitting U.S. reactors.

The existence of over 50 years of mortality data in Monroe County, along with all U.S. counties, provides a basis for a review of health patterns before and after the startup of Fermi 2, using methodsfrom the only federal study (1990) of cancer near U.S. nuclear plants.

Cancer mortality in Monroe County, which was slightly less than the U.S. rate in the period before Fermi 2 startup, has gradually risen to a current peak of 11.3% above the U.S. in 2009-2018. The gap is still rising, as the excess was 14.3% in 2014-2018.

Current excesses are consistent for all Monroe County age groups, races, and ethnicities, and for both genders. Many factors can contribute to cancer risk and deserve further study. However, because the largest excesses occur among younger age groups, exposure to radioactivity may be a factor, as a dose of radiation is more harmful to the fetus, infant, and child than it is to adults.

In particular, the drastic shift in the Monroe County cancer death rate in persons age 0-24, from 3.5% below to 38.0% above the U.S. before and after Fermi 2 startup, raises the possibility that radiation exposure from the reactor has played a role. Since 1992, Monroe County has had the highest cancer death rate of the 30 most populated Michigan counties.

This report is the first epidemiological study of health in the population living closest to Fermi 2. Results call for continued efforts to understand the potential link between radiation and adverse health effects. Other available data that can be analyzed includes mortality from specific causes, cancer incidence, infant deaths, low weight births, and premature births.

Direct measurement of in-body radiation is also needed. Measurement of Strontium-90 in baby teeth has been the most frequently employed means of such measurement, as the natural loss of baby teeth makes collection of in-body sampleseasier than other methods. The Radiation and Public Health Project's study of 5,000 baby teeth, mostly near six U.S. nuclear plants, can be a prototype for such a study near Fermi 2.

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Appendix 1

Trends in Gaseous Releases of Tritium, in Curies
Fermi 2 Nuclear Plant, 2006-2011 to 2012-2017

Year	Curies
2006	111.3
2007	124.6
2008	79.1
2009	73.6
2010	117.6
2011	92.4
2012	215.9
2013	269.7
2014	185.4
2015	167.6
2016	231.9
2017	134.5

Six Year Totals:

2006-2011	**598.6**
2012-2017	**1205.0**

% Change +101.3%

Source: U.S. Nuclear Regulatory Commission. Radioactive Effluent and Environmental Reports. www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info-html.

Appendix 2
Gaseous Releases of Particulates, 2016 and 2017, in Millicuries
Fermi 2 vs. Median of 34 U.S. Boiling Water Reactors

Year	Fermi 2	Median U.S.	Fermi 2 vs. U.S.	Fermi Rank
2016	1.84	0.129	**13 times greater**	**3 of 34**
2017	20.6	0.204	**101 times greater**	**1 of 34**

Source: U.S. Nuclear Regulatory Commission. Radioactive Effluent and Environmental Reports.https://www.nrc.gov/reactors/operating/ops-experience/tritium/plant-info.html. A millicurie represents 1/1000th of a curie.

Appendix3
Mortality Trend, Malignant Cancers
Monroe County vs. United States
By 10-Year Period, 1969-2018

Yr. of Death	U.S. Rate	Monroe County Rate (Deaths)	% Monroe is +/- U.S.	Excess Deaths
1969-1978	201.08	192.07 (1,626)	**- 4.5%**	---
1979-1988	209.51	213.62 (2,154)	**+ 2.0%***	140
1989-1998	210.27	221.99 (2,648)	**+ 5.6%***	267
1999-2008	188.70	202.11 (2,969)	**+ 7.1%***	344
2009-2018	161.70	179.90 (3,357)	**+11.3%***	530
TOTAL				**1,281**

Rates are deaths per 100,000, adjusted to 2000 U.S. population. Cancer codes include 140.0-209.9 (ICD-8, 1969-1978); 140.0-208.9 (ICD-9, 1979-1998); C00-C97.9 (ICD-10, 1999-2018). * County actual/expected rate significantly different (P <.05). Excess death calculation = 1969-1978 county/national ratio (-4.5%), minus actual ratio, times number of deaths in 10-year period. Example: 1979-1988 excess = ((.02 –(-.045)) x 2154 = 140. Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.

Appendix4
Mortality, Malignant Cancers
Monroe County vs. United States
By Age, Race, and Gender, 2014-2018

Category	U.S. Rate	Monroe County Rate (Deaths)	% Monroe is +/- U.S.
Total	155.27	177.45 (1794)	**+14.3%***
Males	184.91	218.36 (948)	**+18.1%***
Females	133.50	147.37 (786)	**+10.4%***
W, non-Hisp	160.49	176.82 (1659)	**+10.2%***
W, Hispanic	115.94	163.63 (21)	**+41.1%**
B, non-Hisp	181.81	235.99 (42)	**+29.8%**
0-24	2.54	3.56 (8)	**+40.2%**
25-44	18.34	27.42 (46)	**+49.5%***
45-64	168.10	192.43 (469)	**+14.5%***
65+	882.79	991.26 (1211)	**+12.3%***

Rates are deaths per 100,000, adjusted to 2000 U.S. population. Cancer codes include C00-C97.9 (ICD-10. * County ate significantly different (P <.05). Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.

Appendix5
Mortality, Malignant Cancers
Monroe County vs. United States
By Most Common Types of Cancer, 2014-2018

Category	U.S. Rate	Monroe County Rate (Deaths)	% Monroe is +/- U.S.
Total	155.27	177.45 (1734)	**+14.3%***
Bronchus/lung	38.40	47.11 (472)	**+22.7%***
Female breast	20.12	21.97 (113)	**+ 9.2%**
Maleprostate	18.79	18.22 (74)	**- 3.0%**
Colorectal	13.60	15.16 (145)	**+11.5%**
Pancreas	11.02	11.45 (113)	**+ 3.9%**
Ill Defined	9.55	11.17 (111)	**+17.0%**
Liver	6.64	7.53(77)	**+13.4%**
Leukemia	6.21	8.83(84)	**+42.2%***
Non-Hodgkin's Lymphoma	5.45	6.49(61)	**+19.1%**
Brain/central nervous system	4.37	5.96(57)	**+36.4%**
Benign Neoplasms	4.24	5.07(50)	**+19.6%**

Rates are deaths per 100,000, adjusted to 2000 U.S. population. * County rate significantly different (P <.05). ICD-10 codes include total (C00-C97); bronchus/lung (C34); female breast (C50); male prostate (C61); colorectal (C18-C20); pancreas (C25); ill-defined, secondary, and unspecified sites (C76-C80); liver and intrahepatic bile ducts (C22); leukemia (C91-C95); non-Hodgkin's lymphoma (C82-C85); brain and central nervous system (C71-C72); and benign neoplasms - in situ, benign, and unknown behavior – (D00-D48). Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.

Appendix 6
Mortality, Malignant Cancers
Monroe County vs. United States
Persons Age 0-24, 1968-1991 vs. 1992-2018

Yr. of Death	U.S. Rate	Monroe County Rate (Deaths)	% Monroe is +/- U.S.
1968-1991	5.262	5.077 (70)	**- 3.5%**
1992-2018	3.024	4.172 (56)	**+38.0%***

Rates are deaths per 100,000 population, unadjusted. Cancer codes include 140.0-209.9 (ICD-8, 1968-1978); 140.0-208.9 (ICD-9, 1979-1998); C00-C97.9 (ICD-10, 1999-2018). * County rate change significantly different after 1991 (P <.05). Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.

Appendix 7
Mortality, Malignant Cancers
30Most Populated Michigan Counties vs. U.S.
Persons Age 0-24, 1992-2018

County	Deaths	Population	Rate	% County is +/- U.S.
Monroe	56	1,342,276	4.172	**+38.0%**
Wayne	632	18,725,400	3.375	+11.6%
Oakland	337	10,244,394	3.290	+ 8.8%
Macomb	233	6,950,396	3.352	+10.8%
Kent	187	5,907,611	3.165	+ 4.6%
Genesee	136	4,048,465	3.359	+11.1%
Washtenaw	76	3,511,717	2.164	- 28.4%
Ingham	88	3,175,141	2.772	- 8.7%
Ottawa	81	2,654,860	3.051	+ 0.9%
Kalamazoo	59	2,567,962	2.298	-24.0%
Saginaw	64	1,914,343	3.343	+10.6%
Muskegon	52	1,602,184	3.246	+ 7.3%
Berrien	48	1,422,119	3.375	+11.6%
Livingston	51	1,513,120	3.370	+11.5%
St. Clair	40	1,440,348	2.777	- 8.2%
Jackson	45	1,401,796	3.210	+ 6.1%
Calhoun	41	1,261,791	3.249	+ 7.5%
Allegan	38	1,023,778	3.712	+22.7%
Eaton	31	951,823	3.257	+ 7.6%
Bay	36	929,424	3.873	+28.1%
Lenawee	37	901,347	4.105	+35.7%
Isabella	23	880,602	2.612	-13.6%
Lapeer	23	797,031	2.886	- 4.6%
Midland	31	756,548	4.098	+35.5%
Grand Traverse	18	699,271	2.574	-14.9%
Clinton	24	658,270	3.646	+20.6%
Shiawassee	19	648,764	2.929	- 3.2%
Marquette	17	631,722	2.691	-11.0%
Ionia	12	615,160	1.951	-35.5%
St. Joseph's	12	580,855	2.066	-31.7%

Rates are deaths per 100,000 population, unadjusted. Cancer codes include 140.0-208.9 (ICD-9, 1979-1998); C00-C97.9 (ICD-10, 1999-2018). Note: U.S. 1992-2018 rate was 3.024. Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.

Appendix 8

Mortality Trend, All Causes Excluding Cancer
Monroe County vs. United States
By 10-Year Period, 1969-2018

Yr. of Death	U.S. Rate	Monroe County Rate (Deaths)	% Monroe is +/- U.S.	Excess Deaths
1969-1978	945.72	967.54(7,455)	**+2.3%**	---
1979-1988	779.34	799.74(7,518)	**+2.6%***	23
1989-1998	696.43	721.17(8,140)	**+3.6%***	106
1999-2008	632.30	648.83(9,148)	**+2.6%***	27
2009-2018	567.88	605.57 (10,799)	**+6.6%***	464
TOTAL				**620**
(2014-2018)	568.80	607.44(5,702)	**+6.8%***	256
2019	565.24	604.08 (1,201)	**+6.9%***	55

Rates are deaths per 100,000, adjusted to 2000 U.S. population. * Cancer codes include 140.0-208.9 (ICD-9, 1979-1998); C00-C97.9 (ICD-10, 1999-2018). County actual/expected rate significantly different (P <.05). Excess death calculation = 1969-1978 county/national ratio (+2.3%), minus actual ratio, times number of deaths in 10-year period. Example: 1979-1988 excess = (.023 - .026) x 7,518 = 23. Source: U.S. Centers for Disease Control and Prevention, https://wonder.cdc.gov.