

Radiation and Public Health Project

Joseph J. Mangano, MPH, MBA, Executive Director
716 Simpson Avenue, Ocean City NJ 08226
odiejoe@aol.com
www.radiation.org
484-948-7965

Directors Robert Alvarez
Christie Brinkley
Lewis Cuthbert
Karl Grossman
Lisa Martino-Taylor
Mark Meinberg
Susan Shapiro

HEALTH TRENDS NEAR NUCLEAR FUEL SERVICES SITE

June 27, 2023

EXECUTIVE SUMMARY

The Nuclear Fuel Services (NFS) plant in eastern Tennessee (Unicoi County), which generates highly enriched uranium fuels for naval reactors, has operated since 1959. Since then, operations at the site have involved handling large quantities of enriched uranium, plutonium, and associated fuel components. Chronic and episodic releases of these chemicals into the environment have occurred, principally through air and water, creating scenarios for community exposure and potential health risk to humans.

No comprehensive study of health in the area of the plant has ever been conducted. This report analyzed mortality data from the U.S. Centers for Disease Control and Prevention, which produced results for four primary measures when Unicoi County rates were compared with U.S. rates:

All-Cause Mortality. Until the late 1990s, Unicoi County's all-cause death rate was about equal to the nation. The county rate has risen since, and is **now 44% above the U.S. rate.**

Premature Mortality. Until the early 1990s, Unicoi County's premature death rate (below age 74) was about equal to the U.S. The county rate is **now 61% above the U.S. rate.**

Cancer Mortality. Until the early 1990s, Unicoi County's cancer death rate was below the U.S. The county rate then exceeded the U.S., and is **now 39% above the U.S. rate.**

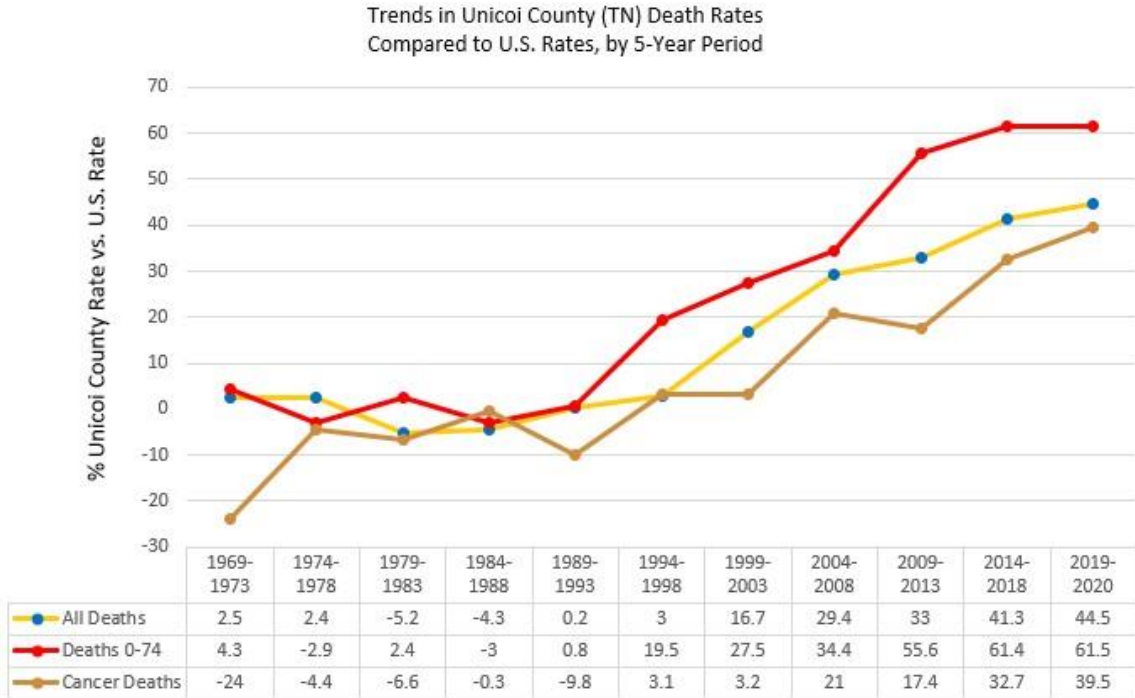
Excess Deaths. If the earliest county-national difference had continued thereafter, a total of 1639 fewer Unicoi County residents would have died from 1974-2020. **The 1639 figure can be described as "excess" deaths.**

Just 30-50 years ago, all-cause mortality in Unicoi County was roughly equivalent to the U.S., and its cancer mortality was below the U.S. Since then, the county rate moved higher than the national rate, and the county-nation gap has steadily grown since.

This trend was unexpected, in a county that historically had no unusually high rates. No change in demographics, health behaviors, or access to medical care that could account for this trend is obvious, so further investigation is merited.

Some factor or factors have accounted for the acceleration of Unicoi County rates. One potential cause is the continued operation of NFS and the greater accumulation of radioactivity in local air, water, and food. BWXT-Nuclear Fuel Services in northeast Tennessee (Unicoi County) was founded in Erwin in 1957. The company's primary

business has been the production of radioactive fuel for naval reactors. Routine and accidental releases of radioactive chemicals by NFS into the environment pose a potential health risk for humans. More detailed analyses of plant operations and local health hazards are warranted.



CONTENTS

	Page
Introduction	4
Nuclear Fuel Services and Health Risks	4
Study Methods	6
Results – Trends in Mortality, All Causes Combined, All Ages	7
Results – Trends in Premature Mortality (Age 0-74), All Causes Combined .	8
Results – Trends in Cancer Mortality	9
Results – Current Cancer Incidence	9
Results – Change in Mortality, by Age Group	10
Results – Change in Mortality, by Cause of Death	10
Results – Change in Infant and Child Mortality	11
Discussion	12
References	14
Appendices	16

Introduction

The BWXT-Nuclear Fuel Services (NFS) plant, which occupies about 80 acres in northeast Tennessee, is 0.5 miles southwest of the town of Erwin, in Unicoi County, and 0.2 miles from the Nolichucky River. NFS has conducted nuclear fuel fabrication and recovery of uranium from process streams since 1959, producing high-enriched (> 20% ²³⁵U atom fraction) and low-enriched uranium of < 20% ²³⁵U. The site also blends down enriched uranium into low-enriched uranium for use as fuel in commercial nuclear reactors (U.S. Nuclear Regulatory Commission, 2021a).

Operations at NFS involve handling hundreds of tons of enriched uranium, plutonium, and associated nuclear fuel components. Plant processes at NFS have resulted in chronic/daily and larger/episodic and accidental releases of radioisotopes into the environment, principally through air and water pathways. Emissions of radioisotopes and other toxic substances from NFS have created scenarios for community exposure and potential health risks to humans.

Unicoi County is situated in northeast Tennessee, on the border of North Carolina, nestled in the middle of the Blue Ridge Mountains. Its area of 186 square miles makes it one of the smallest counties in Tennessee, and it has a 2020 population of 17,928 most of whom reside in small towns and rural areas. Erwin residents account for one-third of Unicoi County's population.

Caucasians make up 91.5% of the county's 2020 population, well above the 59.3% figure for the U.S. Most of the other county residents are Hispanic (6.1%). Several socio-demographic measures in Unicoi County are worse than the same measures for the U.S., including above-average rates of poverty, disability, individuals without health insurance, and below-average rates of education.

The only major indicator in which Unicoi County does not demonstrate need is that English is spoken in most homes and the high school graduation rate is close to the national average. Table 1 provides statistical information on various sociodemographic indicators for the county and nation (U.S. Census Bureau, 2023).

Table 1

<u>Years</u>	<u>Indicator</u>	<u>Unicoi</u>	<u>U.S.</u>
2017-21	High school graduates, age >25	86.2%	88.9%
2017-21	College graduates, age >25	16.0%	33.7%
2017-21	With a disability, age <65	14.4%	8.7%
2017-21	English not spoken at home, age >5	5.6%	21.7%
2020	No health insurance, age <65	12.4%	9.8%
2020	Living below poverty	14.5%	11.6%

Nuclear Fuel Services and Health Risks.

NFS has three outfalls from which radioactivity is released. The main outfall empties directly into the Nolichucky River, while two others empty into Martin Creek.

Semi-annual reports of radioactive effluents released by NFS operations and concentrations in various local water locations include the following radioisotopes (U.S. Nuclear Regulatory Commission, 2021b):

Airborne:

Americium-241

Plutonium-238, -239/240, and -241

Technecium-99

Thorium-228, -230, and -232

Uranium-234, -235, and -238

Liquid:

Plutonium-238, and -239/240

Technecium-99

Thorium-228, -230, and -232

Uranium-233/234, -235/236, and -238

Each of the above isotopes takes the form of tiny metal particles, and each is carcinogenic when ingested. They can enter human bodies through breathing, food, and water. All radioisotopes have the potential to damage or destroy DNA in cells, leading to an elevated risk of disease and death. Several major findings are clear after decades of study:

- All humans are affected negatively by radiation exposure, even at the lowest doses (Committee on the Biological Effects of Ionizing Radiation, 1990).
- 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.
- The lag time between exposure and onset of disease or death may take several years, or even decades.
- While some cancers are known to be especially sensitive to radioactivity, such as thyroid cancer or bone cancer, the risk of all cancers increased with accumulative exposures to ionizing radiation.
- Exposure to radioactivity can be associated with risk for diseases other than cancer; a review of 5,000 articles focused on populations near the Chernobyl facility exposed to radiation after the 1986 meltdown documented high rates of disease and death for multiple organs (Yablokov, 2009).

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).

Respiring uranium aerosols and/or ingestion of uranium contaminated water or food leads to internal exposure. In addition to the radiological effects of internal exposure to alpha emitting isotopes, uranium can act as a mutagen by virtue of its chemical properties as a heavy metal, independent of its radiological properties. It has been reported that uranium exhibits a chemical genotoxicity, producing DNA strand breaks (Yazzie, 2003).

The U.S. government has conducted just one national study of cancer near nuclear plants, performed after an inquiry by 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). In part because it is a fuel facility, NFS was not included in this study.

The Radiation and Public Health Project (RPHP), a non-profit research and educational organization, has published 39 medical journal articles, mostly on health patterns and trends near nuclear power plants. Unexpectedly high rates of cancer closest to nuclear plants have often been documented (Radiation and Public Health Project, 2023).

RPHP has also performed the only study of in-body radiation near U.S. reactors. It found high and rising levels of Strontium-90 in baby teeth (Mangano, 2003), and a link between trends in Strontium-90 and local child cancer (Mangano, 2006).

The operation of NFS since the late 1950s provides an opportunity to study trends in local rates of cancer and other diseases, which are presented in this report.

Study Methods

The 1990 National Cancer Institute study selected the home county of each nuclear plant, sometimes adding an adjoining county. Since virtually all 18,000 Unicoi residents reside within 10 miles of NFS, this report will analyze patterns in Unicoi County.

The 1990 study selected the U.S. cancer rate as the control for each county and calculated a county vs. national ratio for cancer mortality for five-year periods. This report will use the same method, and will address cancer trends. In addition, all-cause mortality will be addressed, as exposure to radioactivity has been linked with various diseases other than cancer (Yablokov, 2009).

Thus, the principal measures analyzed in this report will include:

- Mortality from all cancers combined
- Mortality from all causes combined
- Premature mortality (death by age 74) from all causes combined

The data source for the study is the Centers for Disease Control and Prevention’s CDC Wonder data base. Available online, CDC Wonder includes aggregate mortality information on every U.S. state and county, each year from 1968 to 2020, as of mid-2023 (U.S. Centers for Disease Control and Prevention, 2023).

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 data from 1968-2020 allows 10 five-year periods to be studied, along with the latest two years available (2019-2020). The percent that Unicoi County’s cancer rate is greater than or less than the U.S. rate will be the key measure, as it was in the 1990 federal study.

The 1969-1973 five-year county/national ratio will be the baseline or “expected” ratio for all future periods. Any increase in the expected rate in future periods will be used to describe “excess” deaths.

Significance testing for subsequent 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 the difference between county and national ratios are not due to random chance.

Results – Trends in Mortality, All Causes Combined, All Ages

From the late 1960s to the late 1990s, the Unicoi County death/mortality rate was roughly equal to the U.S. rate. For each five-year period beginning 1969-1973 and ending 1994-1998, the Unicoi mortality rates ranged between 5.2% below and 3.0% above the U.S. None of these differences was statistically significant.

But after 1998, the death rate in Unicoi County abruptly jumped well above the national rate, and the gap has steadily grown since. The differences by five-year period were +16.7%, +29.4%, +33.0%, and +41.3%. The most recent period only includes two years (2019 and 2020); the county rate reached its highest mark, 44.5% above the national rate. All county-national differences since 1998 are statistically significant (see Table 2 and Appendix 1).

Table 2

<u>Years</u>	<u>Deaths, All Causes % Unicoi Rate vs. U.S.</u>
1969-1973	+ 2.5%
1974-1978	+ 2.4%
1979-1983	- 5.2%
1984-1988	- 4.3%
1989-1993	+ 0.2%

1994-1998	+ 3.0%
1999-2003	+16.7%
2004-2008	+29.4%
2009-2013	+33.0%
2014-2018	+41.3%
2019-2020	+44.5%

In 2014-2020, the Unicoi County mortality rate was 40.9% higher than that of the U.S. for white non-Hispanics, which make up over 90% of the county’s population. This finding indicates that differences in racial and ethnic compositions does not account for higher local rates in Unicoi County.

If the earliest county-national difference (2.5% higher in 1969-1973) had continued thereafter, a total of 1639 fewer Unicoi County residents would have died from 1974-2020, 15.9% of all deaths. The 1639 figure can be described as “excess” deaths. Currently, over 1,500 Unicoi County residents die every five years.

Preliminary data for 2021 shows that deaths in Unicoi County rose 9% from the prior year, while the national increase was just 2%, meaning the county-nation gap is highly likely to increase as data are finalized.

Results – Trends in Premature Mortality (Age 0-74), All Causes Combined

Another way to analyze changes in mortality is to focus on premature deaths, defined by the CDC as all deaths occurring before age 75, which is approximately the U.S. life expectancy (National Cancer Institute, 2023).

Table 3 shows that premature death rates in Unicoi County were roughly equal to that of the U.S. until the early 1990s. Thereafter, the county rate exceeded the U.S. rate, with the gaps growing in each successive period. Also see Appendix 2 for more detailed data.

Table 3

<u>Years</u>	<u>Deaths 0-74, All Causes % Unicoi Rate vs. U.S.</u>
1969-1973	+ 4.3%
1974-1978	- 2.9%
1979-1983	+ 2.4%
1984-1988	- 3.0%
1989-1993	+ 0.8%
1994-1998	+19.5%
1999-2003	+27.5%
2004-2008	+34.4%
2009-2013	+55.6%
2014-2018	+61.4%
2019-2020	+61.5%

In the seven years since 2014, the premature death rate in Unicoi County has been more than 61% above the U.S. rate for all races and ethnicities combined, and 60.9% greater for white non-Hispanics, which account for most deaths in the county. All Unicoi County rates in the past three decades are significantly different from those given for the U.S.

Since 1974, a total of 1,100 “excess” premature deaths have occurred in Unicoi County, which is 22.8% of all premature deaths.

Results – Trends in Cancer Mortality

Because radioactivity is known to raise cancer risk, this report includes trend data on cancer deaths. In Table 4 (below), in the five-year period 1969-1973, the Unicoi County cancer death rate was 24.0% below the U.S. In the following periods up to 1993, the rate in Unicoi County was also below that of the U.S.--anywhere from 1 to 10% less.

But in the following five-year periods, Unicoi County’s cancer death rate exceeded that of the U.S., with the excess growing over time (+3.1%, +3.2%, +21.0%, +17.4%, +32.7%, and +39.5%).

The total of excess deaths starting 1974 was 772, or 34.4% of the 2,242 Unicoi County cancer death during this time. Currently, over 300 Unicoi residents die of cancer every five years. Also see Appendix 3 for more detailed data.

Table 4

<u>Years</u>	<u>Deaths, All Cancers % Unicoi Rate vs. U.S.</u>
1969-1973	- 24.0%
1974-1978	- 4.4%
1979-1983	- 6.6%
1984-1988	- 0.3%
1989-1993	- 9.8%
1994-1998	+ 3.1%
1999-2003	+ 3.2%
2004-2008	+21.0%
2009-2013	+17.5%
2014-2018	+32.7%
2019-2020	+39.5%

Results – Current Cancer Incidence

Data on cancer incidence, or newly-diagnosed cases, are collected by registries in each of the 50 states and the District of Columbia. The Tennessee registry data on the Internet only includes the past decade, a shorter period than most states, and thus no long-term trend analysis can be made.

The National Cancer Institute makes available cancer incidence data for each of the 3,100 U.S. counties for the most recent five-year period (2015-2019). In that period, there were 625 new cancer cases diagnosed in Unicoi County residents. The county's rate was 2.8% below the nation. Of the 615 cases diagnosed in white non-Hispanics, the county rate was 0.7% above the U.S.

The Unicoi County incidence rate exceeded the U.S. rate in 8 of the 10 most common cancers, with only prostate and breast cancer below the national rate. Appendix 4 provides detailed data on incidence.

Results – Change in Mortality, by Age Group

The high and rising total death rates in Unicoi County can be further analyzed, using several variables. One approach is to analyze trends by age at death.

Table 5 (below) and Appendix 5 show the Unicoi County death rate versus that of the U.S., for each age group. To assess trends over time, the periods 1968-1978 (earliest years available) and 2007-2020 (when the county-national gap peaked) are used.

Table 5

<u>Age</u>	<u>Deaths, All Causes</u>		
	<u>% Unicoi Rate vs. U.S.</u>		
	<u>1968-1978</u>	<u>2007-2020</u>	<u>Change</u>
0-24	+ 32.7%	+ 41.6%	+ 8.9%
25-34	- 23.1%	+ 52.6%	+75.5%
35-44	- 0.4%	+ 92.6%	+92.2%
45-54	+ 4.5%	+ 49.4%	+44.9%
55-64	- 5.4%	+ 49.2%	+54.6%
65-74	+ 1.7%	+ 48.2%	+49.9%
75-84	- 2.5%	+ 32.9%	+35.4%
85+	+16.5%	+ 18.4%	+ 1.9%
TOTAL	+ 4.1%	+ 37.5%	+33.4%
0-74	+ 2.3%	+ 51.3%	+49.0%

In 1968-1978, the Unicoi County death rate exceeded the U.S. in 4 of 8 age groups. But in 2007-2020, the county was higher than the U.S. for all age groups. The greatest percentage excesses occurred in persons between the age of 25 and 74.

The age-adjusted county mortality rate for all ages combined moved from 4.1% higher to 37.5% higher than the U.S.; the increase for persons 0-74 was sharper (2.3% higher to 51.3% higher).

Results – Change in Mortality, by Cause of Death

Another approach to analyzing mortality is by cause of death. Table 6 (below) shows the Unicoi death rate age 0-74, compared to the U.S., for each of eight major causes of death,

for the periods 1968-1978 and 2007-2020 in Table 6 (Appendix 6 has more detailed information). The eight groups account for over 90% of all deaths in persons 0-74.

Table 6

<u>Cause of Death</u>	<u>Deaths, All Causes, Age 0-74</u>	
	<u>% Unicoi Rate vs. U.S.</u>	
	<u>1968-1978</u>	<u>2007-2020</u>
Neoplasms (Cancers)	- 11.3%	+39.2%
Diseases of the Circulatory System	+ 7.1%	+58.9%
Accidents, Suicide, Homicide	+11.2%	+62.7%
Diseases of the Respiratory System	- 8.0%	+99.4%
Diseases of the Digestive System	- 33.2%	+53.6%
Endocrine/Nutritional/Metabolic Diseases	+43.2%	+ 4.3%
Diseases of the Nervous System	+ 3.8%	+72.2%
Infectious and Parasitic Diseases	+ 8.4%	- 1.1%
All Other Causes	+18.2%	+61.3%
Total	+ 2.3%	+51.3%

Unicoi County’s current (2007-2020) death rates in six of the eight groups, plus the “all other causes” category, are significantly higher than the U.S. rate. The largest excess is diseases of the respiratory system, which is 99.4% higher (virtually double).

Results – Change in Infant and Child Mortality

Infants and children are much more susceptible to the harmful effects of exposure to the radiological and chemical effects of uranium and other NFS-derived chemical and/or radiological agents. In Table 7 (below), the trends in the ratio of Unicoi versus U.S. death rates for persons dying before age 15 are presented (Appendix 7 contains more detailed data).

Table 7

<u>Years</u>	<u>Deaths All Causes (0-14)</u>
	<u>% Unicoi Rate vs. U.S.</u>
1968-1978	+ 4.7%
1979-1998	+19.0%
1999-2020	+38.8%

In 1968-1978, the Unicoi County infant death rate was just 4.7% above the U.S. rate. But in the subsequent periods, the gap grew to 19.0% higher and most recently to 38.8% higher.

Because only about two children under age 15 residing in Unicoi County die each year, periods longer than five years (used in most of this report) were not used to generate larger numbers for analysis. Even with this change, none of the three excesses were statistically significant. Still, the trend toward higher excesses in Unicoi County are clear, just as they are for other mortality categories presented in this report.

Discussion.

The operation of Nuclear Fuel Services since the late 1950s has resulted in decades of low-level, ongoing as well as elevated episodic/accident-level exposures to the community. The pollutant footprint of NFS in Erwin is apparent from recent findings of elevated uranium concentrations along with enriched $^{235}\text{U}/^{238}\text{U}$ compositions in an attic from Erwin (Ketterer, 2023).

Nevertheless, no studies on local disease and death rates have been attempted. Historically, NFS has never been subject to a rigorous off-site evaluation of its contamination footprint in Erwin and Unicoi County, and this report underscores the need for community environmental monitoring.

This report analyzes statistics, mainly derived from Centers for Disease Control and Prevention sources. It presents trends in the percent that the Unicoi County rate is greater than or less than that of the U.S. The report includes death rates from all causes combined (all ages, and premature/age 0-74); death rates for all cancers combined; incidence rates for all cancers combined; premature deaths by age and by cause of death; and infant mortality.

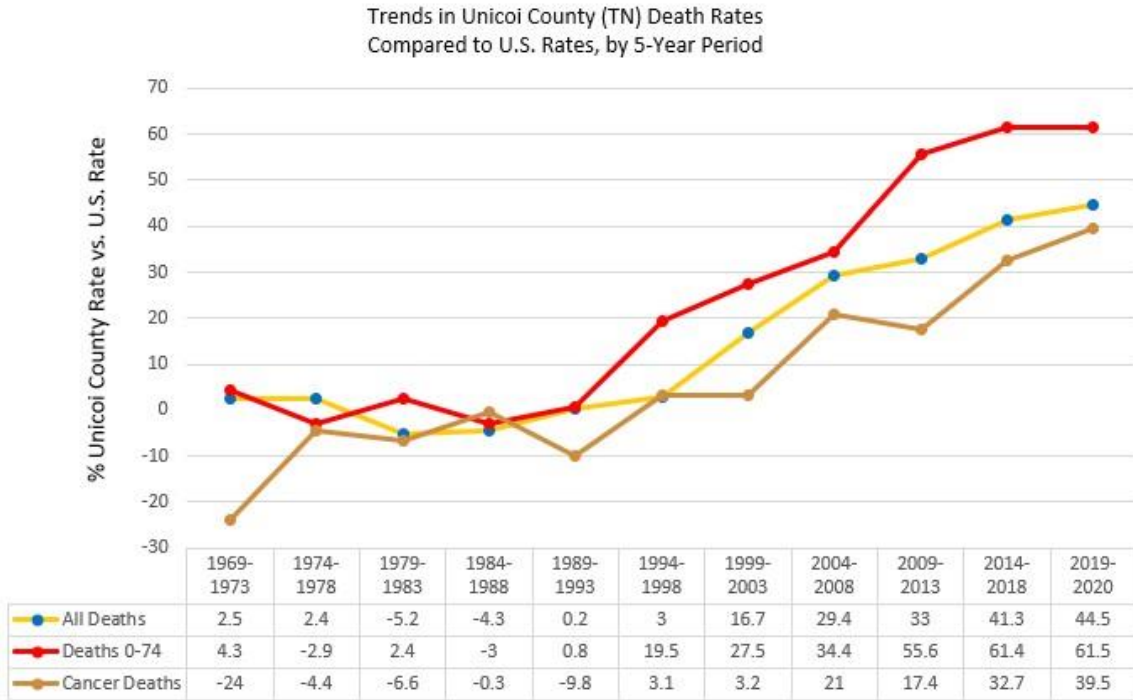
From the late 1960s to the early 1990s, the Unicoi County death rates were virtually equal to the U.S. rate. However, county rates have exceeded the national rate ever since, and the gap continues to grow. Most recently (2019-2020), the county rate was

- 1) 44.5% higher for all deaths;
- 2) 61.5% higher for premature deaths; and
- 3) 39.5% higher for all cancers.

Similar trends were observed for other health measures.

Figure 1 presents trends in mortality for all causes/all ages, mortality for all causes/age 0-74, and cancer mortality/all ages for Unicoi County:

Figure 1



The abrupt, large-scale, and enduring changes in Unicoi County to a high-death and high-cancer county were unexpected. Moreover, the changes are unexplained by changes in any known major risk factor, such as access to medical care, poverty, and/or health behaviors.

The pattern in Unicoi County resembles that found in Salem County, New Jersey, where three large nuclear power reactors started operating in 1976. Prior to startup, county cancer and all-cause mortality were equal to or slightly below the U.S. rate, but after several years of operation, county rates were uniformly high with a growing excess (Mangano and Sherman, 2019). Like Unicoi County, Salem County is a sparsely populated area, consisting of small towns and rural areas, with no presence of another major industry.

The documentation of radioactive releases from Nuclear Fuel Services, along with radioactivity present in local air, water, and soil indicate that a health hazard exists. Exposures to radiation, even at low levels, have been found to increase risk of diseases like cancer, through documentation of a linear no-threshold dose-response relationship (Committee on the Biological Effects of Ionizing Radiation, 1990).

This report represents an initial attempt to understand any impact Nuclear Fuel Services may have had on local health. Future analyses of health patterns could also be conducted, between and among Unicoi County and adjoining areas. Most importantly, findings should be shared with officials and the public at large; understanding past impact is a crucial tool to preventing any future risks.

References:

Committee on the Biological Effects of Ionizing Radiations (BEIR), National Research Council. Health Effects of Exposures to Low Levels of Ionizing Radiation: BEIR V. Washington DC: National Academy Press, 1990.

Gonzalez AB, Daniels RD, Cardis E, et al. Epidemiological studies of low-dose ionizing radiation and cancer: Rationale and framework for the monograph and overview of eligible studies. JNCI Monographs. 2020;56:97-113.
<https://doi.org/10.1093/jncimonographs/Igaa009>.

Ketterer M. Letter to residents of Erwin, TN and surrounding communities. May 18, 2023.

Mangano JJ, Gould JM, Sternglass EJ, Sherman JD, McDonnell W. An unexpected rise in US deciduous teeth in the 1990s. Sci Total Environ. 2003;317(1-3):37-51. Doi: 10.1016/S0048-9697(03)00439-X.

Mangano JJ. A short latency between radiation exposure from nuclear plants and cancer in young children. Int J Health Serv. 2006;36(1):113-135. Doi: 10.2190/5GRE-KQ1B-UTM1-KHQ1.

Mangano J, Sherman J. Increase in mortality for all causes and all cancers combined before and after startup of a nuclear power plant in New Jersey, USA. J Environ Prot. 2019;10:488-499. <https://radiation.org/increases-in-mortality-for-all-causes-and-all-cancers-combined-before-and-after-startup-of-a-nuclear-power-plant-in-new-jersey-usa-2019/>. Accessed May 11, 2023.

National Cancer Institute, National Institutes of Health. Cancer in Populations Living Near Nuclear Facilities. Volumes I-III. NIH Publication No. 90-874. Washington DC: U.S. Government Printing Office, July, 1990.

National Cancer Institute. Premature Death.
<https://www.cancer.gov/publications/dictionaries/cancer-terms/def/premature-death>. Accessed May 11, 2023.

Radiation and Public Health Project. www.radiation.org. Accessed May 11, 2023.

U.S. Census Bureau. State and County Quick Facts: Unicoi County, Tennessee.
<https://www.census.gov/quickfacts/fact/table/unicoicountytennessee,US/PST045221>. Accessed May 11, 2023.

U.S. Centers for Disease Control and Prevention. CDC Wonder: Mortality.
<https://wonder.cdc.gov>. Accessed May 11, 2023.

U.S. Nuclear Regulatory Commission. Nuclear Fuel Services.

<https://www.nrc.gov/info-finder/decommissioning/fuel-cycle/nuclear-fuel-services.html>.
Last updated March 25, 2021. (a)

U.S. Nuclear Regulatory Commission. Frequently Asked Questions About the Nuclear Fuel Services Fuel Fabrication Facility. <https://www.nrc.gov/materials/fuel-cycle-fac/fuel-fab/nfs-faqs.html#2a7>. Last Updated March 24, 2021. (b)

Yablokov AV, Nesterenko VB, Nesterenko AV. Chernobyl: Consequences of the Catastrophe for People and the Environment. *Annals of the New York Academy of Sciences*, Volume 1181. Boston MA: Blackwell Publishing, 2009.

Yazzie et al. Uranyl acetate causes DNA single strand breaks in vitro in the presence of ascorbate (Vitamin C). *Chem. Res. Toxicol.* 2003;16(4):524–530.
<https://doi.org/10.1021/tx025685q>.
https://pubs.acs.org/doi/full/10.1021/tx025685q?casa_token=6_f_hoQx9D4AAAAA%3A3tpHmlv5H3TGIC4-ssUQtFxawk27e6VIN5AYamoxO0DJ1qRGNEiE1CTJEt3Bp7PPkr_ozQu2gPIAQ.

Appendix 1
Mortality, All Causes, All Ages
By Five-Year Period, 1969-2020
Unicoi County vs. U.S.

<u>Period</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>County Deaths</u>	<u>% County vs. U.S. Rate</u>	<u>Excess Deaths</u>
1969-1973	1223.28	1253.47	791	+ 2.5	----
1974-1978	1083.56	1109.95	806	+ 2.4	- 1
1979-1983	1005.94	953.69	799	- 5.2	- 62
1984-1988	978.54	936.44	892	- 4.3	- 61
1989-1993	927.92	929.86	958	+ 0.2	- 26
1994-1998	829.50	918.85	1017	+ 3.0	+ 56
1999-2003	860.33	1003.91	1186	+ 16.7*	+168
2004-2008	793.69	1026.91	1270	+ 29.4*	+342
2009-2013	740.33	984.90	1303	+ 33.0*	+397
2014-2018	728.31	1029.28	1427	+ 41.3*	+554
2019-2020	775.79	1120.63	645	+ 44.5*	+271
Total Deaths and Excess			10303		1639 (+ 15.9%*)
W Non-Hisp. 2014-20	759.32	1070.25	2048	+ 40.9*	

Rates are deaths per 100,000 persons per year, adjusted to 2000 U.S. standard population. * = Difference between county and U.S. rates are significant at $P < .05$. Excess deaths are the difference between the actual rate and expected rate (1969-1973 difference). For example: Unicoi County excess 2014-2018 over 1969-1973 = $(41.3\% - 2.5\%) \times 1427 = 554$. Source: U.S. Centers for Disease Control and Prevention, <https://wonder.cdc.gov>.

Appendix 2
Mortality, All Causes, Age 0-74
By Five-Year Period, 1969-2020
Unicoi County vs. U.S.

<u>Period</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>County Deaths</u>	<u>% County vs. U.S. Rate</u>	<u>Excess Deaths</u>
1969-1973	636.35	663.96	499	+ 4.3	----
1974-1978	559.31	542.98	441	- 2.9	- 32
1979-1983	507.47	519.54	451	+ 2.4	- 9
1984-1988	482.12	467.58	441	- 3.0	- 32
1989-1993	454.44	458.01	442	+ 0.8	- 15
1994-1998	424.77	507.69	502	+ 19.5*	+ 76
1999-2003	393.11	501.03	505	+ 27.5*	+116
2004-2008	360.63	484.69	521	+ 34.4*	+157
2009-2013	335.06	521.21	601	+ 55.6*	+308
2014-2018	337.89	545.38	641	+ 61.4*	+366
2019-2020	368.58	595.19	286	+ 61.5*	+164
Total Deaths and Excess			4831	1100 (+ 22.8%*)	
W Non-Hisp. 2014-20	347.82	559.80		+ 60.9*	

Rates are deaths per 100,000 persons per year, adjusted to 2000 U.S. standard population. * = Difference between county and U.S. rates are significant at $P < .05$. Excess deaths are the difference between the actual rate and expected rate (1969-1973 difference). For example: Unicoi County excess 2014-2018 over 1969-1973 = $(61.4\% - 4.3\%) \times 641 = 366$. Source: U.S. Centers for Disease Control and Prevention, <https://wonder.cdc.gov>.

Appendix 3
Mortality, All Cancers, All Ages
By Five-Year Period, 1969-2020
Unicoi County vs. U.S.

<u>Period</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>County Deaths</u>	<u>% County vs. U.S. Rate</u>	<u>Excess Deaths</u>
1969-1973	202.17	153.55	106	- 24.0*	----
1974-1978	205.18	196.08	153	- 4.4	+ 30
1979-1983	210.31	196.34	174	- 6.6	+ 30
1984-1988	214.64	214.04	213	- 0.3	+ 50
1989-1993	217.44	196.03	206	- 9.8	+ 29
1994-1998	209.37	215.86	241	+ 3.1	+ 65
1999-2003	201.12	207.51	253	+ 3.2	+ 69
2004-2008	186.35	225.45	293	+ 21.0*	+132
2009-2013	173.30	203.40	285	+ 17.4*	+118
2014-2018	159.50	211.59	305	+ 32.7*	+173
2019-2020	149.02	207.90	119	+ 39.5*	+ 76
Total Deaths and Excess			2242		772 (+ 34.4%*)
W Non-Hisp. 2014-20	161.99	206.88		+ 27.7*	

Rates are deaths per 100,000 persons per year, adjusted to 2000 U.S. standard population. * = Difference between county and U.S. rates are significant at $P < .05$. Excess deaths are the difference between the actual rate and expected rate (1969-1973 difference). For example: Unicoi County excess 2014-2018 over 1969-1973 = $(32.7\% - (-24.0\%)) \times 305 = 173$. Source: U.S. Centers for Disease Control and Prevention, <https://wonder.cdc.gov>.

Appendix 4
 Cancer Incidence, 2015-2019
 Selected Categories and Most Common Cancers
 Unicoi County vs. U.S.

<u>Type of Cancer</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>County Cases</u>	<u>% County vs. U.S. Rate</u>
All	449.4	463.6	625	- 2.8
Under Age 50	106.5	141.2	70	+ 32.6
Over Age 65	1977.5	1788.6	360	- 9.6
White Non-Hispanic	466.6	469.7	615	+ 0.7
Most Common Cancers:				
Lung/Bronchus	56.3	67.2	100	+ 19.4
Female Breast	128.1	123.2	80	- 3.8
Male Prostate	109.9	80.5	60	- 26.8
Colorectal	37.7	43.5	60	+ 15.4
Melanoma of the Skin	22.9	26.4	35	+ 15.3
Non-Hodgkin's Lymp.	19.0	19.9	30	+ 4.7
Bladder	19.4	24.5	35	+ 26.3
Kidney/Renal	17.3	23.0	25	+ 32.9
Oral Cavity/Pharynx	12.0	14.7	20	+ 22.5
Liver/Bile Duct	8.6	10.4	15	+ 20.9

Rates are cases per 100,000 persons per year, adjusted to 2000 U.S. standard population.
 None of the differences between county and U.S. rates are significant at $P < .05$.
 Source: National Cancer Institute (www.statecancerprofiles.cancer.gov)

Appendix 5
Mortality, by Age Group
1968-1978 and 2007-2020
Unicoi County vs. U.S.

<u>Age</u>	1968-1978				2007-2020			
	<u>U.S. Rate</u>	<u>County Rate</u>	<u>Deaths</u>	<u>% County vs. U.S. Rate</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>Deaths</u>	<u>% County vs. U.S. Rate</u>
0-24	139.7	185.4	132	+ 32.7*	61.6	87.2	58	+ 41.6*
25-34	145.6	112.0	25	- 23.1	117.8	179.8	48	+ 52.6*
35-44	285.8	284.5	58	- 0.4	187.1	360.3	110	+ 92.6*
45-54	683.8	714.6	148	+ 4.5	411.6	615.1	224	+ 49.4*
55-64	1551.2	1466.9	253	- 5.4	882.4	1316.2	505	+ 49.2*
65-74	3352.3	3410.6	434	+ 1.7	1848.6	2740.3	828	+ 48.2*
75-84	7463.5	7275.3	463	- 2.5	4668.3	6204.5	1073	+ 32.9*
85+	16810.4	19579.9	261	+ 16.5	13787.5	6331.3	1047	+ 18.4*
Total	1161.8	1209.4	1774	+ 4.1	745.7	1025.1	3893	+ 37.5*
0-74	602.8	616.8	1050	+ 2.3	343.2	525.3	1773	+ 53.1*

Rates are deaths per 100,000 persons per year. * = Difference between county and U.S. rates are significant at P < .05.
Source: Source: U.S. Centers for Disease Control and Prevention, <https://wonder.cdc.gov>.

Appendix 6
Mortality, by Cause of Death, Age 0-74
1968-1978 and 2007-2020
Unicoi County vs. U.S.

1968-1978

<u>Cause</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>Deaths</u>	<u>% County vs. U.S. Rate</u>
Neoplasms	135.9	120.6	204	- 11.3
Diseases of the Circulatory System	258.4	276.6	478	+ 7.1
Accidents, Suicide, Homicide	71.3	79.2	132	+ 11.2
Diseases of the Respiratory System	33.0	30.4	52	- 8.0
Diseases of the Digestive System	29.6	19.8	33	- 33.2
Endocrine/Nutritional/Metabolic Diseases	14.4	20.6	35	+ 43.2
Diseases of the Nervous System	6.9	7.2	12	+ 3.8
Infectious and Parasitic Diseases	6.2	6.7	12	+ 8.4
All Other	47.2	55.8	92	+ 18.2
Total	602.8	616.8	1050	+ 2.3

2007-2020

<u>Cause</u>	<u>U.S. Rate</u>	<u>County Rate</u>	<u>Deaths</u>	<u>% County vs. U.S. Rate</u>
Neoplasms	92.4	128.6	486	+ 39.2*
Diseases of the Circulatory System	81.3	129.2	468	+ 58.9 *
Accidents, Suicide, Homicide	56.5	91.8	220	+ 62.7*
Diseases of the Respiratory System	25.5	50.9	192	+ 99.4*
Diseases of the Digestive System	17.4	26.7	90	+ 53.6*
Endocrine/Nutritional/Metabolic Diseases	16.7	17.4	62	+ 4.3
Diseases of the Nervous System	10.9	18.7	66	+ 72.2*
Infectious and Parasitic Diseases	10.9	10.8	34	- 1.1
All Other	31.7	51.2	155	+ 61.3*
Total	343.2	525.3	1773	+ 53.1*

Rates are deaths per 100,000 persons per year, adjusted to 2000 U.S. standard population.

* = Difference between county and U.S. rates are significant at P < .05.

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

Appendix 7
 Infant + Child Mortality (< 15 Years)
 Unicoi County vs. U.S., by Period

<u>Year</u>	<u>Infant/Child Deaths</u>		<u>Death Rate</u>		<u>% County vs. U.S. Rate</u>
	<u>U.S.</u>	<u>County</u>	<u>U.S.</u>	<u>County</u>	
1968-1978	934,721	67	160.30	167.77	+ 4.7
1979-1998	1,063,778	65	91.60	108.98	+ 19.0
1999-2020	787,469	49	58.44	81.11	+ 38.8

Rates are deaths per 100,000 persons per year, adjusted to 2000 U.S. standard population.
 None of the differences between county and U.S. rates are significant at P < .05.
 Source: Source: U.S. Centers for Disease Control and Prevention, <https://wonder.cdc.gov>.