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Mortality /Morbidity Study, 7 Counties Downwind of the Portsmouth Nuclear Site
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EXECUTIVE SUMMARY

A November 2022 report found mortality in Pike County, Ohio rising sharply in the past four decades compared to the U.S. (https://radiation.org/rphp-report-finds-soaring-death-rate-near-ohio-uranium-plant/). The Pike County death rate was slightly above the U.S. until the early 1990s, but now is among the highest in the nation. In addition, Pike County has the highest current cancer incidence rate of all counties in Ohio.

Findings called for follow-up analysis of health data, addressing socioeconomic factors' role in Pike County's health decline. In addition, it raised the question of whether toxic exposures to local residents from the Portsmouth Nuclear Site (PORTS) – home to the former Portsmouth Gaseous Diffusion Plant (PGDP) – extended beyond Pike County.

This report compares seven Ohio counties closest to/downwind of PORTS - study counties (Adams, Gallia, Jackson, Lawrence, Pike, Scioto, and Vinton) with six counties, also in Ohio, further from the plant - "control" counties (Athens, Guernsey, Jefferson, Meigs, Morgan, and Noble). Each has similar population density; racial/ethnic composition; and rates of poverty, education, unemployment, and health insurance. Findings include:

1. In the late 1990s, cancer incidence in both areas was 0.4% below the U.S. rate. By 2015-2019, the study counties rate exceeded the U.S. by 17.5%, versus 8.8% in control counties.

2. In the 1970s, infant death rates were slightly above the U.S. in both areas (+4.4% and +1.6%). However, by 1999-2020, the excesses were +31.9% (study) and +9.9% (control).

3. In the early 1970s, all-cause mortality rates in both areas were slightly above the U.S. But by the most recent five-year period (2017-2021), mortality in the study counties far exceeded the rate in the U.S. *and* control counties, specifically:

	Study Counties vs. U.S.	Control Counties vs. U.S.
Deaths 0-74, All Causes	+ 77.5%	+31.5%
Deaths 0-74, All Cancers	+ 60.8%	+26.0%
Deaths 25-54, All Causes	+109.6%	+47.7%

The large and growing gaps between study and control areas indicate that socio-economic factors – which have likely undergone similar changes over time - cannot account for most of the high rates near PORTS. Nevertheless, with 13,138 "excess" premature deaths (under age 75) in the seven study counties since 1974, a thorough evaluation of contamination from PORTS and the plant's current decommissioning process are in order.

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Background– PORTS and Uranium Enrichment.
The Portsmouth Gaseous Diffusion Plant (PGDP), located just south of Piketon in Pike County, Ohio, operated from 1954 to 2001. The plant occupies about one-quarter of the 3,777-acre PORTS site, owned and operated by the federal government.

The PGDP was one of three sizeable gaseous diffusion plants in the United States that initially produced enriched uranium for nuclear weapons and later also for commercial nuclear reactors. After the Cold War, production facilities were leased to the private sector. In 2001, enrichment operations were discontinued at the site (U.S. Department of Energy, 2022).

The PGDP enriched uranium for nearly 50 years. During that time, reprocessed high level radioactive waste was brought into the facility to extract the uranium it contained. This waste was run through nearly 100 acres of process buildings, contaminating the site with technetium, highly radioactive isotopes of uranium, and transuranic elements including neptunium, americium, and plutonium.

The U.S. Department of Energy's Office of Environmental Management began its environmental cleanup program at the site in 1989, an ongoing effort coordinated with the U.S. and Ohio Environmental Protection Agencies. Decontamination and decommissioning of the plant commenced in 2011 (U.S. Department of Energy, 2022).

Concerns have been raised that the open-air demolition of the process buildings is releasing radioactive airborne dust that is being transported offsite. When deactivation and decommissioning work was halted during the early months of the Covid pandemic, there was a cessation in enriched uranium present in the air.

Besides continuing open-air demolition, forthcoming uranium enrichment and projected formulation of depleted uranium for military use raise concerns about increased radioactive and other toxic contamination, both onsite and offsite. An ongoing nuclear reactor project, supported by a $5 million DOE grant, would create additional radioactive waste should a new reactor be constructed and operated at PORTS.

Introduction – Health Concerns from PORTS Operations Remain Unaddressed.
When ingested, all radioactive isotopes damage DNA in cells or kills them outright, leading to an elevated risk of disease and death. Several significant findings are clear after decades of study:

1. All humans are affected negatively by radiation exposure, even at the lowest doses (Committee on the Biological Effects of Ionizing Radiation, 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 is increased after radiation exposure

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

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 cancer rates closest to nuclear plants have often been documented (Radiation and Public Health Project, 2023).

Only a few studies on health in the area around PORTS, none of them recent, have been published (Jablon, 1990; National Institute for Occupational Safety and Health, 2001). In November 2022, the Radiation and Public Health Project (RPHP), a research and education group, issued a report on trends in Pike County morbidity and mortality rates compared with U.S. rates (Radiation and Public Health Project, 2022). The main findings of the report were:

1. Pike County's (age-adjusted) cancer incidence in 2010-2019 was 15% higher than the U.S., the highest rate of all 88 Ohio counties.

2. In the 1950s and 1960s, Pike County's (age-adjusted) cancer mortality was 12% below the U.S. Since 1993, the Pike County rate has exceeded the U.S., (peaking at +33%) in 2019-2020.

3. Pike County's all-cause mortality was 1-5% above the U.S. in the 1980s and early 1990s. By 2019-2020, the county rate was 42% greater.

4. Pike County's all-cause premature (age 0-74) mortality rate was 85.0% above the U.S. in 2017-2020, nearly twice that of the nation.

These findings are all statistically significant, as over 400 Pike County residents die yearly from all causes. The report suggested that exposure to toxic emissions from PORTS contributed to these unexpected increases and recommended that further and more detailed studies be conducted.

Methods – Selection of Study and Control Counties.

This report will address two issues. First, it will analyze whether unexpectedly significant increases in morbidity and mortality observed in Pike County also exist in adjoining areas.

Second, it will compare trends near and downwind from PORTS ("study" counties) with trends in Ohio counties farther from PORTS that have similar demographics ("control" counties).

Toxic emissions from PORTS are released into the air and move with prevailing winds towards the east and southeast, where they enter the environment (soil, water, and food) through precipitation. Thus, concentrations should be greater in downwind areas vs. upwind areas and greater in proximate vs. distant areas.

The counties selected for this study are as follows:
Study counties – Adams, Gallia, Jackson, Lawrence, Pike, Scioto, Vinton
Control counties – Athens, Guernsey, Jefferson, Meigs, Morgan, Noble

Almost all residents of the study counties live within 50 miles of PORTS, while residents of control counties live much further from the site and are not directly downwind.

Table 1 compares the two sets of counties for various demographic measures:

Table 1
Comparison of Demographic Characteristics
Study Counties and Control Counties

Characteristic	Study	Control
Total Population, 2021	260,087	215,039
Persons per square mile	76.2	79.4
% Persons below poverty	21.2	22.4
% White, non-Hispanic	95.3	94.1
% Age 65 or older	19.0	19.9
% Age 25-44 with some college	50.1	57.1
% Age <65 with no health insurance	8.6	8.7
% Age > 16 unemployed	8.7	8.9

For each of the demographic measures, rates in the study and control counties are very similar. Therefore, comparing these two areas will explore the extent to which socioeconomic factors such as poverty contributed to local rates above the U.S. (U.S. Census Bureau, 2023).

Methods – Analysis of Morbidity and Mortality Trends.

This report will use the county and national mortality rates from the Centers for Disease Control and Prevention's "CDC Wonder" database. Available online, CDC Wonder includes information on every U.S. death, each year from 1968 to 2021, as of January 2023. County rates are based on where the decedent lived at the time of death (U.S. Centers for Disease Control and Prevention, 2022).

Morbidity rates (cancer incidence or the rate of newly-diagnosed cases) are taken from two sources. County rates are obtained from the state of Ohio's Department of Health (2023), while U.S. rates are from the Centers for Disease Control and Prevention (2022). Cases are assigned to the county of residence at the time of diagnosis.

The measures of health in the study and control areas will include the following:
1. Cancer incidence (all cancers combined)
2. Infant deaths (before the first birthday)
3. Mortality, all causes
4. Mortality, all causes, premature (age 0-74)
5. Mortality, all cancers premature (age 0-74)

Analysis of cancer incidence will compare the periods 1996-1999 and 2015-2019, as the Ohio Cancer Registry only began issuing data in 1996. Analysis of mortality will compare each five years from 1969-1973 to 2017-2021. Each incidence and death rate is age-adjusted according to the 2000 U.S. Census, a method commonly used in epidemiology (National Cancer Institute, 2022).

For mortality, the county-to-nation ratio in 1969-1973, the earliest available and during the early years of PORTS' operation, is the "expected" ratio for all subsequent periods. Ratios above the expected in subsequent five-year periods are considered "excess" deaths.

Statistical significance tests are used for any differences between local areas and the nation. A p-value of .05 or less means there is a 95% or greater chance that the difference between the local and national rates is not due to random chance.

Results – Cancer Incidence.

In 1996-1999, age-adjusted cancer incidence for both the study and control counties was 0.4% below the U.S. However, in the most recent period (2015-2019), local rates exceeded the nations by 17.5% and 8.8% for study and control counties. The most recent rate in both study and control rates was significantly greater than in the U.S.

In the most recent period, incidence rates in five of seven study counties were among the ten highest of 88 Ohio counties, ranked #s 1, 2, 3, 4, and 6 (Lawrence, Pike, Adams, Vinton, and Jackson). Conversely, just two of the six counties in the control group – Guernsey and Jefferson - ranked in the top 10 (Table 2 and Appendix 1).

Table 2
Incidence, All Cancers Combined
Local Counties vs. U.S.
1996-1999 and 2015-2019

	Cases/100,000 Pop. (n)		Rate vs. U.S.	
Year Diagnosed	Study	Control	Study	Control
1996-1999	479.6 (5639)	479.7 (4794)	**- 0.4%**	**- 0.4%**
2015-2019	525.9 (9240)	487.1 (7101)	**+17.5%**	**+ 8.8%**

The difference between incidence rates in the study counties and the U.S. has steadily increased for each period since 1996-1999 (-0.4%, -0.1%, +3.6%, +5.4%, and +17.5%); see Appendix 1.

Results – Infant Mortality (Age 0-1)

Infant mortality, or the rate of deaths before age one, is a frequently-used measure of population health. The U.S. rate has declined sharply through most of the 20th century, and into the 21st century, due to a variety of factors.

Table 3 provides infant mortality rates for both study and control counties, compared to the U.S. In 1968-1978, rates for both areas were slightly above the nation (+4.4% and +1.6%). During the following 20 years, the gap between the two groups grew (+8.9% and -3.2%).

However, in the most recent period (1999-2020), the rate in the study counties moved well above control counties (+31.9% vs. 9.9%). With 620 infant deaths in this period, the gap in study counties is statistically significant (see Appendix 2).

Table 3
Infant Mortality (Death Rate < 1 Year)
Local Counties vs. U.S.
By Period, 1968-2020

	Local vs. U.S. Ratio	
Period	Study	Control
1968-1978	**+ 4.4%**	+1.6%
1979-1998	**+ 8.9%**	- 3.2%
1999-2020	**+31.9%**	+9.9%

Results – Mortality Trends, All Causes Combined

Any environmental health risk assessment should include mortality trends in persons of all ages, not just infants. This report provides information on mortality trends in the study and control areas. Because the Centers for Disease Control and Prevention makes public aggregate data on mortality for each year starting with the late 1960s, a series of five-year periods can be analyzed.

Table 4 and Figure 1 present all-cause mortality data for the earliest and latest five-year periods (1969-1973 and 2017-2021). It shows the percent difference between study/county rates and the U.S. for both periods, for ages 0-74 and over 75. Complete data are included in Appendix 3.

Table 4
Age-Adjusted Mortality, by Age
Local Counties vs. U.S.
All Causes Combined
Deaths 1969-1973 and 2017-2021

	% Rate vs. US 1969-1973		% Rate vs. US 2017-2021	
Age	Study	Control	Study	Control
0-74	+ 8.1	+ 6.2	**+77.5**	**+31.5**
75+	+11.9	+ 9.6	**+30.0**	**+15.6**

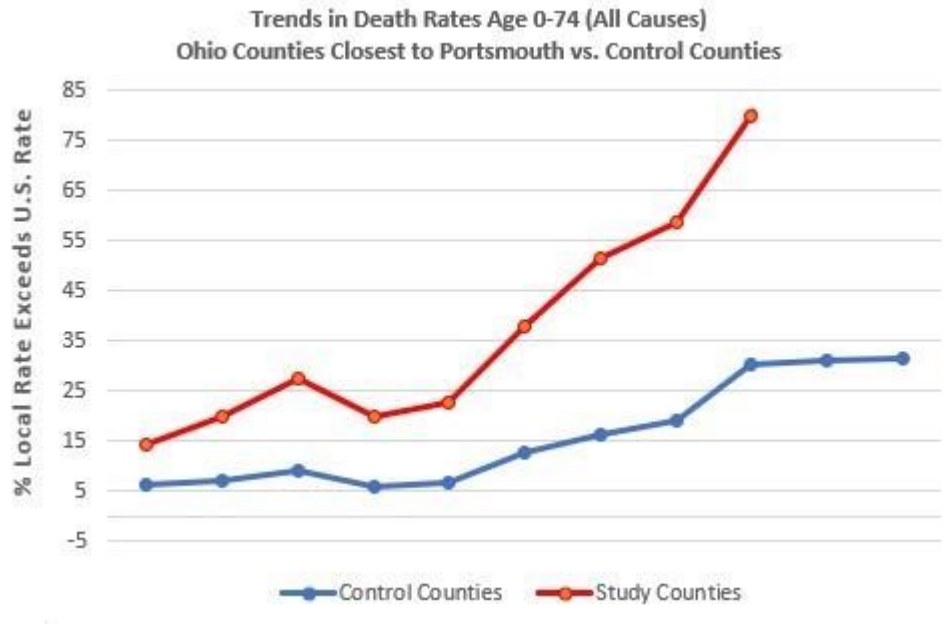

FIGURE 1 – ALL CAUSE MORTALITY 0-74, LOCAL VS. U.S.

In 1969-1973, the premature death rate (age 0-74) was nearly identical for study and control counties (+8.1% and +6.2% above the U.S.). But by 2017-2021, the excesses had grown, especially for the study counties (+77.5%, well above +31.5% for the control counties, based on 10,612 and 6,690 deaths). Few of the 3,100 U.S. counties have a death rate as high as the study area.

In 1969-1973, the death rate for persons 75 and older was also nearly identical (+11.9% and +9.6%). However, in the most current five-year period, the excesses increased, to +30.0% and +15.6%, based on 9,433 and 7,230 deaths, an increase less pronounced than in younger persons.

If the 1969-1973 excesses had remained constant, 11,646 fewer persons aged 0-74 and 1,492 persons aged 75 and older living in the study counties – a total of 13,138 - would have died after that. These figures can be considered "excess" deaths.

Results – Mortality Trends, All Cancers Combined

Over 20% of all U.S. deaths are due to cancer. Table 5 and Figure 2 present the excess in the study and control counties, compared to the U.S., for all cancers combined, for the periods 1969-1973 and 2017-2021, for age groups 0-74 and over 75. Detailed data are included in Appendix 4.

Table 5
Age-Adjusted Mortality, by Age
Local Counties vs. U.S.
All Cancers Combined
Deaths 1969-1973 and 2017-2021

	% Rate vs. US 1969-1973		% Rate vs. US 2017-2021	
Age	Study	Control	Study	Control
0-74	+ 9.1	+ 1.9	**+60.8**	**+26.0**
75+	+ 0.7	- 2.6	**+17.6**	**+ 5.5**

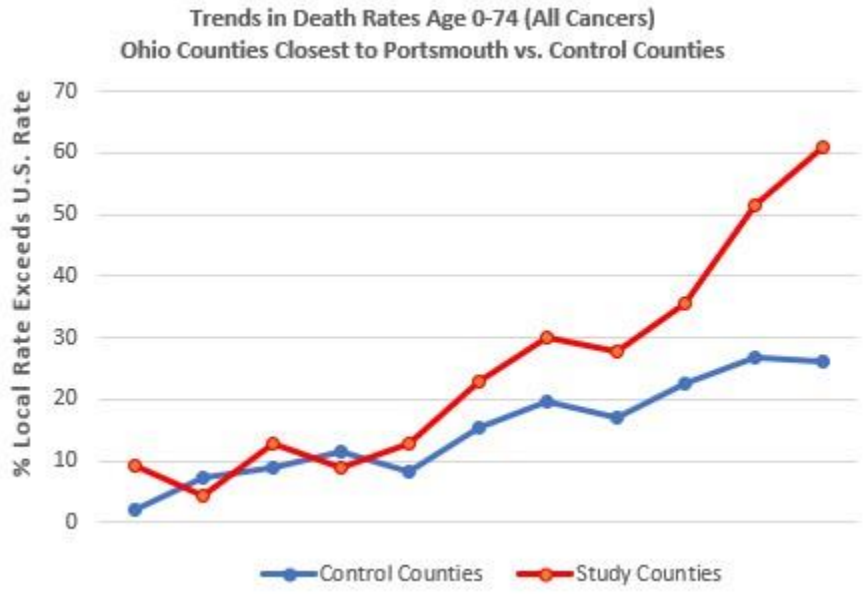

FIGURE 2 – ALL CANCER MORTALITY 0-74, LOCAL VS. U.S.

In 1969-1973, the premature death rate for cancer (age 0-74) was slightly above the U.S. for study and control counties (+9.1% and +1.9%). However, by 2017-2021, the excesses had grown, especially for the study counties (+60.8%, well above +26.0% for the control counties, based on 2,377 and 1,580 deaths).

In 1969-1973, the cancer death rate for persons 75 and older was similar in the two areas (+0.7% and -2.6%). In the most current five-year period, the excesses increased, to +17.6% and +5.5%, based on 1,407 and 1,076 deaths. Again, increases in the elderly were less than in younger persons.

Results – Premature Mortality, By Age

The preceding statistics show that the difference between local and national mortality rates is much greater for persons aged 0-74 than for those 75 and older. In the most current five-

year period (2017-2021), the death rate in study counties was 77.5% above the U.S., compared to just 31.5% greater in control counties.

While local death rates in the elderly exceed the U.S. – with excesses increasing over time – the especially large gap for those aged 0-74 raises the most questions. Deaths under age 75, defined as "premature deaths," suggest further exploration of reasons for these patterns.

Table 6 presents mortality rates for each age group age 0-74 in study and control counties, compared to the U.S. Deaths for the most recent period (2017-2021) are used. Appendix 5 includes detailed data.

Table 6
Age-Adjusted Mortality by Age Group
Local Counties vs. U.S., Age 0-74
All Causes Combined, 2017-2021

	% Rate vs. U.S. (Deaths)	
Age	Study	Control
0-1	+ 31.6 (107)	+ 32.5 (105)
1-4	+ 60.2 (24)	+105.6 (21)
5-14	+ 31.1 (30)	+ 21.0 (19)
15-24	+ 10.3 (135)	- 24.4 (113)
25-34	**+ 95.9** (456)	**+ 47.1** (272)
35-44	**+135.9** (1345)	**+ 55.7** (413)
45-54	**+ 97.9** (1504)	**+ 42.4** (821)
55-64	+ 74.7 (3144)	+ 27.6 (1947)
65-74	+ 58.2 (4364)	+ 23.1 (3009)
TOTAL	+ 77.5 (10612)	+ 31.5 (6690)

While local rates are elevated (above the U.S.) for each age group, the largest gaps are in young and middle-aged adults. In the study counties, the excesses for ages 25-34, 35-44, and 45-54 are 95.9%, 135.9%, and 97.9% - well above control area excesses (47.1%, 55.7%, and 42.4%).

Results – Mortality, Age 25-54

The high current local death rates ages 25-54 raise the question of whether there has always been an excess. Table 7 and Figure 3 show death rates for the five-year periods 1969-1973 and 2017-2021; Appendix 6 provides more detailed data.

Table 7
Age-Adjusted Mortality, All Causes Combined, Age 25-54
Study Counties vs. Control Counties, Compared to U.S.
Five-Year Periods 1969-1973 and 2017-2021

	Deaths/100,000 Pop. (n)		Rate vs. U.S.	
Period	Study	Control	Study	Control
1969-1973	405.4 (1662)	407.3 (1598)	+ 4.6	+ 5.1
2017-2021	556.5 (2805)	391.6 (1506)	**+109.4**	**+47.4**

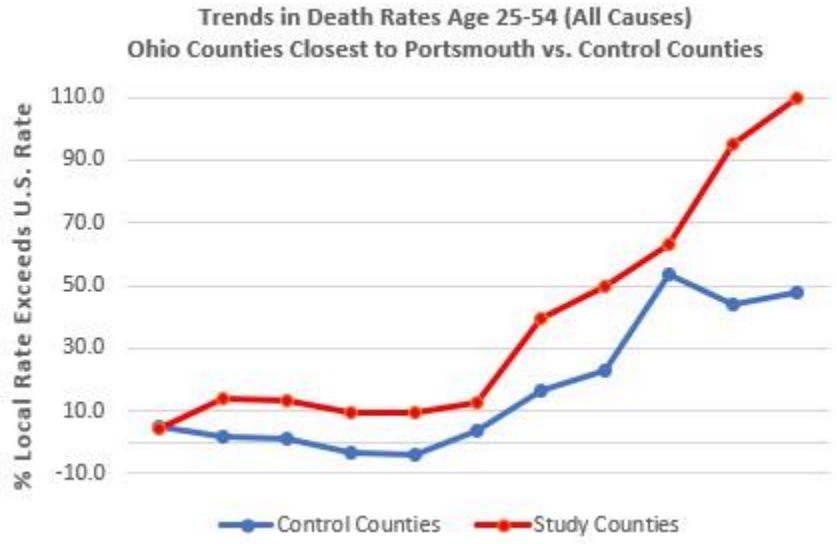

FIGURE 3 – ALL CAUSE MORTALITY 25-54, LOCAL VS. U.S.

In 1969-1973, the death rate for persons 25-54 was slightly above the U.S. for study and control counties (+4.6% and +5.1%). By 2017-2021, the excesses had grown, especially for the study counties (+109.4%, well above +47.4% for the control counties, based on 2,805 and 1,506 deaths).

Table 8 provides 2017-2020 data for 11 major categories of death age 25-54, which account for 98% of all recent U.S. deaths in this age group, comparing local and national rates. Appendix 7 includes detailed data.

Table 8
Age-Adjusted Mortality by Cause
Study Counties vs. U.S., Age 25-54
All Causes Combined, 2017-2020

Code	Cause	% Rate vs. U.S. (Deaths)
A00-B99	Infectious and parasitic diseases	**+111.8** (59)
C00-D48	Neoplasms (cancers)	**+ 88.4** (323)
E00-E88	Endocrine, nutritional, and metabolic diseases	**+109.8** (105)
F01-F99	Mental and behavioral disorders	**+ 87.9** (44)
G00-G98	Diseases of the nervous system	**+103.3** (50)
I00-I99	Diseases of the circulatory system	**+106.6** (402)
J00-J98	Diseases of the respiratory system	**+181.5** (110)
K00-K92	Diseases of the digestive system	**+ 53.5** (100)
N00-N98	Diseases of the genitourinary system	**+ 62.9** (24)
R00-R99	Symptoms, signs, abnormal findings	**+ 42.9** (20)
V01-Y89	Accidents, suicide, homicide	**+143.9** (853)*
TOTAL		**+110.8** (2135)

* Includes accidental poisoning by/exposure to drugs/X40-X44 (+281.0%, n = 543); other accidents/V01-X39, X45-‘X59,Y10-Y89 (+65.5%, n = 144); suicide/X60-X84 (+59.8%, n = 113); homicide/X85-Y09 (+21.2%, n = 41)

For each of the 11 major categories of death, the study area rate was +42.9% or more above the U.S.; in 9 of 11, the excess was at least +87.9%. The highest excess was in respiratory system diseases, at +181.5%, or nearly triple the U.S. rate.

The category with the most deaths was “external causes” – accidents, suicide, and homicide, which accounted for 40% of deaths 25-54 (853 of 2135). These causes are not known to be caused by environmental toxins such as those released by PORTS. However, consistently high rates among other causes – all medical conditions and diseases - raise concern about their causes.

Only nine deaths caused by COVID-19 occurred among the 25-54 age group in 2020, and thus COVID-19 is not a significant factor in these patterns.

County-specific rates for age 25-54 is another way to express this regional mortality data. Table 9 shows the mortality rate ages 25-54 for 2017-2020 for each county in the study and control groups.

Table 9
Age-Adjusted Mortality, by County
Local Counties vs. U.S., Age 25-54
All Causes Combined, 2017-2020 (U.S. Rate = 251.1)

County	Rate/100,000 (Deaths)	% vs. U.S.	OH Rank
Study Counties			
Adams	464.6 (194)	+ 85.0	8
Gallia	541.9 (230)	+115.8	3
Jackson	422.2 (211)	+ 68.1	12
Lawrence	497.7 (465)	+ 98.2	4
Pike	545.1 (228)	+117.1	2
Scioto	618.7 (706)	+146.4	1
Vinton	494.7 (101)	+ 97.0	5
TOTAL	529.3 (2135)	**+110.8**	
Control Counties			
Athens	277.8 (232)	+ 10.6	
Guernsey	354.2 (204)	+ 41.1	
Jefferson	413.4 (382)	+ 64.6	13
Meigs	472.5 (166)	+ 88.2	6
Morgan	283.9 (60)	+ 13.1	
Noble	277.0 (47)	+ 10.3	
TOTAL	353.3 (1091)	**+ 40.7**	

The death rate of 25-54 in each of the seven study counties is at least 68.1% greater than the U.S. Each is among the highest in Ohio (#s 1, 2, 3, 4, 5, 8, and 12). Rates in Scioto, Pike, and Gallia counties are the three highest in the state, each more than double the U.S. rate.

The rate in each of the control counties also exceeds the U.S. standard. However, 3 of the 6 counties are just 10-13% higher; only two counties rank high among the 88 Ohio counties (#s 6 and 13).

Discussion

A November 2022 Radiation and Public Project report found high and rising cancer incidence and mortality rates among Pike County residents beginning in the 1970s. Pike's mortality rates for cancer and all causes are now much greater than the U.S. rate – among the highest of 3,100 U.S. counties. The report cited earlier studies by Northern Arizona University that detected various radioactive chemicals produced by PORTS in the local environment.

The report raised numerous questions, namely 1) whether environmental contamination and elevated disease and death rates extended beyond Pike County and 2) the extent to

which local socioeconomic conditions affected rates. This report addresses both issues. First, it compares a group of seven counties (including Pike) closest to/downwind from PORTS ("study" counties) to six demographically similar counties in eastern Ohio further from PORTS ("control" counties). Local rates in both groups are compared with the U.S.

Essentially, findings from the initial report were upheld. The gap between local and national cancer incidence is rising in both groups, especially rapidly in the study area. Among the seven study counties are those ranked 1st, 2nd, 3rd, and 4th highest of 88 Ohio counties.

All-cause mortality rates in local areas were slightly above the U.S. in the early 1970s. But currently, both are substantially higher than the nation, especially in the study area. The most significant gaps are in persons who died prematurely (before age 75); the current premature death rate in the study counties was 77.5% above the U.S. Excess deaths in the study area since 1974 are 13,138.

Those residents of study counties who died at age 25-54 have a death rate more than twice the U.S. Scioto, Pike, Gallia, Lawrence, and Jackson counties, all in the study area, have the five highest death rates age 25-54 of all Ohio counties.

While Pike County morbidity and mortality rates are typically among the highest in Ohio, high and rising rates exist in each study county. In addition, the gap between rates in study and control counties, which were minimal half a century ago, is growing, a growth that shows no signs of stopping. Thus, the two issues posed by the November 2022 report have been addressed.

With demographic factors like poverty and access to health care not accounting for much of the decline in health in southern Ohio, the role that exposure to toxic chemicals produced and released by PORTS has played in local health should be more closely assessed. Simultaneously, educating public officials and the public at large about these unexpected trends must occur if future health is to improve.

Appendix 1
Age-Adjusted Cancer Incidence
Study Counties and Control Counties vs. U.S.
All Cancers Combined, 2015-2019

County	Cases	Rate/100,000	Rank of 88 OH Counties
Study Counties			
Lawrence	2260	560.0*	1
Pike	984	541.7*	2
Adams	970	535.5*	3
Vinton	464	530.8*	4
Jackson	1086	525.7*	6
Gallia	1046	513.2*	---
Scioto	2418	494.0*	---
Control Counties			
Guernsey	1378	516.9*	8
Jefferson	2491	514.8*	10
Meigs	794	494.1*	---
Athens	1530	476.0	---
Morgan	490	453.6	---
Noble	418	349.7	---
2015-2019			
STUDY COUNTIES	9240	525.9*	**+17.5%** vs. U.S.
CONTROL COUNTIES	7101	487.1*	**+ 8.8%** vs. U.S.
1996-1999			
STUDY COUNTIES	5639	479.6	**- 0.4%** vs. U.S.
CONTROL COUNTIES	4794	479.7	**- 0.4%** vs. U.S.

Period	U.S. Rate	Study Area Rate (Cases)	% Study Area vs. U.S.
1996-1999	481.7	479.6 (5639)	**- 0.4%**
2000-2004	484.9	484.3 (7310)	**- 0.1%**
2005-2009	483.5	500.8 (7996)	**+ 3.6%***
2010-2014	461.4	486.5 (8185)	**+ 5.4%***
2015-2019	447.5	525.9 (9240)	**+17.5%***

Sources: U.S.: Centers for Disease Control and Prevention (https://wonder.cdc.gov/cancer-v2019.HTML). Local: Ohio Department of Health (https://publicapps.odh.ohio.gov/EDW/DataBrowser/Browse/StateLayoutLockdownCancers)
* Local rate significantly different than U.S. at P <.05

Appendix 2
Infant Mortality (Death Rate < 1 Year)
Study and Control Counties vs. U.S.
By Period, 1968-2020

Period	Infant Deaths per 100,000 Population			% versus U.S.	
	U.S.	Study	Control	Study	Control
1968-1978	17.72	18.50 (834)	18.00 (671)	+ **4.4%**	+1.6%
1979-1998	9.65	10.52 (899)	9.34 (544)	+ **8.9%**	- 3.2%
1999-2020	6.42	8.47 (620)	7.05 (354)	**+31.9%***	+9.9%

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* Local rate significantly different than U.S. at P <.05

Appendix 3
Age-Adjusted Mortality, All Causes Combined
Study and Control Counties vs. U.S., 1969-1973 to 2017-2021

		Rate/100,000 (Deaths)		% +/- U.S. Rate		Excess
Period	U.S. Rate	Study	Control	Study	Control	Deaths
All Causes Combined, Age 0-74						
1969-1973	636.3	688.0 (8106)	675.6 (7379)	**+ 8.1**	**+ 6.2**	----
1974-1978	559.3	629.4 (7878)	600.3 (6736)	+12.5	+ 7.3	260
1979-1983	507.5	601.7 (7889)	553.0 (6545)	+18.6	+ 9.0	607
1984-1988	482.1	549.3 (7287)	510.9 (6024)	+13.9	+ 6.0	437
1989-1993	454.4	526.4 (7080)	485.4 (5684)	+15.8	+ 6.8	503
1994-1998	424.8	530.6 (7399)	479.0 (5607)	+24.9	+12.8	755
1999-2003	393.1	530.5 (7480)	457.8 (5342)	+35.0	+16.5	1242
2004-2008	360.6	503.9 (7482)	429.4 (5251)	+39.7	+19.1	1399
2009-2013	335.1	501.9 (7916)	436.2 (5561)	+49.8	+30.2	1401
2014-2018	337.9	562.6 (9073)	443.4 (5999)	+66.5	+31.2	3012
2019-2020	368.6	652.5 (4247)	469.4 (2598)	+77.0	+27.3	2030
TOTAL 1974-2020		73,731	55,347			**11,646 (15.8%)**
2017-2021	363.4	645.0 (10612)	477.9 (6690)	**+77.3**	**+31.5**	
All Causes Combined, Age 75+						
1969-1973	10361.8	11597.1 (6032)	11358.0 (5843)	**+11.9**	**+ 9.6**	----
1974-1978	9246.2	10209.8 (5998)	10018.1 (5489)	+10.4	+ 8.3	- 24
1979-1983	8767.1	9499.1 (6197)	9372.1 (5507)	+ 8.3	+ 6.9	- 5
1984-1988	8708.0	9565.6 (6859)	9348.8 (5861)	+ 9.8	+ 7.4	7
1989-1993	8300.0	9201.5 (7158)	9129.8 (6130)	+10.9	+10.0	-100
1994-1998	8175.1	9380.1 (7745)	9301.9 (6700)	+14.7	+13.8	- 93
1999-2003	8135.2	9544.8 (8238)	9203.7 (7050)	+17.3	+13.1	157
2004-2008	7536.6	8984.9 (8014)	8608.6 (6761)	+19.2	+14.2	216
2009-2013	7050.4	8451.5 (7951)	8131.0 (6636)	+19.9	+15.3	183
2014-2018	6807.2	8569.5 (8612)	7826.0 (6718)	+25.9	+15.0	741
2019-2020	7116.1	8947.1 (3753)	7907.2 (2852)	+25.7	+11.1	462
TOTAL, 1974-2020		70,525	59,704			**1,492 (2.1%)**
2017-2021	6968.3	9061.6 (9433)	8054.9 (7230)	**+30.0**	**+15.6**	

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* All local rates significantly different than U.S. at P <.05

Appendix 4
Age-Adjusted Mortality, All Cancers Combined
Study and Control Counties vs. U.S., 1969-1973 to 2017-2021

Period	U.S. Rate	Rate/100,000 (Deaths) Study	Control	% +/- U.S. Rate Study	Control	Excess Deaths
All Cancers Combined, Age 0-74						
1969-1973	133.5	145.7 (1672)	136.0 (1470)	+ 9.1	+ 1.9	----
1974-1978	134.5	140.1 (1726)	144.2 (1602)	+ 4.2	+ 7.2	-187
1979-1983	135.5	152.8 (1976)	147.4 (1724)	+12.8	+ 8.8	- 63
1984-1988	137.0	149.1 (1972)	152.8 (1793)	+ 8.8	+11.5	-195
1989-1993	135.0	152.4 (2053)	145.9 (1707)	+12.9	+ 8.1	- 64
1994-1998	126.4	155.2 (2186)	146.0 (1729)	+22.8	+15.5	2
1999-2003	116.3	151.2 (2184)	139.1 (1653)	+30.0	+19.6	70
2004-2008	104.5	133.5 (2065)	122.4 (1652)	+27.8	+17.1	72
2009-2013	95.8	129.7 (2168)	117.3 (1608)	+35.4	+22.4	152
2014-2018	87.2	132.1 (2308)	110.6 (1641)	+51.5	+26.8	397
2019-2020	81.2	134.6 (978)	103.6 (641)	+65.8	+27.6	293
TOTAL 1974-2020		19,616	15,750			**487 (2.5%)**
2017-2021	80.0	128.6 (2377)	100.8 (1580)	+60.8	+26.0	
All Cancers Combined, Age 75+						
1969-1973	1224.7	1233.5 (662)	1193.2 (640)	+ 0.7	- 2.6	----
1974-1978	1262.7	1204.2 (730)	1282.1 (716)	- 4.6	+ 1.5	- 69
1979-1983	1322.8	1241.7 (828)	1360.6 (813)	- 6.1	+ 2.9	-102
1984-1988	1372.9	1433.8 (1046)	1435.7 (919)	+ 4.4	+ 4.6	- 37
1989-1993	1452.0	1452.9 (1153)	1574.9 (1080)	+ 0.1	+ 8.5*	-134
1994-1998	1452.3	1499.5 (1249)	1593.0 (1167)	+ 3.3	+ 9.7*	-121
1999-2003	1443.2	1532.9 (1335)	1566.8 (1212)	+ 6.2	+ 8.6	- 76
2004-2008	1384.8	1458.4 (1313)	1487.2 (1171)	+ 5.3	+ 7.4	- 71
2009-2013	1307.2	1384.5 (1293)	1378.1 (1104)	+ 5.9	+ 5.4	- 36
2014-2018	1215.6	1370.5 (1370)	1316.9 (1110)	+13.2*	+ 8.3	22
2019-2020	1140.4	1354.8 (566)	1247.1 (443)	+18.8*	+ 9.4	35
TOTAL, 1974-2020		10,873	9,735			**-589 (-5.4%)**
2017-2021	1156.8	1360.8 (1407)	1220.6 (1076)	+17.6*	+ 5.5	

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* All local rates 0-74 significantly different than U.S. at P <.05, except for 1969-1973 (control) and 1974-1978 (study).

Appendix 5
Age-Adjusted Mortality, All Causes Combined
Study and Counties vs. U.S., by Age Group 0-74, 2017-2021

		Rate/100,000 (Deaths)		% +/- U.S. Rate	
Age	U.S. Rate	Study	Control	Study	Control
0-1	547.2	720.1 (107)	724.8 (105)	+ 31.6*	+ 32.5*
1-4	23.7	38.0 (24)	48.8 (21)	+ 60.2	+105.6*
5-14	13.7	18.0 (30)	16.6 (19)	+ 31.1	+ 21.0
15-24	77.6	85.6 (135)	58.6 (113)	+ 10.3	- 24.4
25-34	145.7	285.5 (456)	214.4 (272)	**+ 95.9***	**+ 47.1***
35-44	227.0	535.7 (1345)	353.6 (413)	**+135.9***	**+ 55.7***
45-54	438.8	868.3 (1504)	624.7 (821)	**+ 97.9***	**+ 42.4***
55-64	964.3	1684.5 (3144)	1230.5 (1947)	+ 74.7*	+ 27.6*
65-74	1932.0	3057.1 (4364)	2379.1 (3009)	+ 58.2*	+ 23.1*
TOTAL	363.4	645.0 (10612)	477.9 (6690)	+ 77.5*	+ 31.5*

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* Local rate significantly different than U.S. at P <.05

Appendix 6
Age-Adjusted Mortality, All Causes Combined, Age 25-54
Study and Control Counties vs. U.S., by Periods (1969-1973 to 2017-2021)

		Rate/100,000 (Deaths)		% +/- U.S. Rate		Excess
Period	U.S. Rate	Study	Control	Study	Control	Deaths
1969-1973	387.4	405.4 (1662)	407.3 (1598)	+ 4.6	+ 5.1	----
1974-1978	337.9	384.7 (1676)	343.8 (1322)	+13.9*	+ 1.7	213
1979-1983	298.5	338.0 (1616)	302.4 (1156)	+13.2*	+ 1.3	188
1984-1988	278.9	304.3 (1396)	268.8 (1022)	+ 9.1*	- 3.6	184
1989-1993	273.5	299.7 (1510)	262.2 (1074)	+ 9.6*	- 4.1	214
1994-1998	257.1	288.9 (1600)	266.6 (1204)	+12.4*	+ 3.7	160
1999-2003	241.2	335.7 (1932)	280.8 (1309)	+39.2*	+16.4*	450
2004-2008	237.0	354.0 (2071)	291.6 (1349)	+49.4*	+23.0*	557
2009-2013	225.2	367.5 (2104)	346.4 (1492)	+63.2*	+53.8*	206
2014-2018	234.3	457.5 (2401)	337.0 (1347)	+95.3*	+43.8*	1297
2019-2020	269.2	544.9 (1083)	374.0 (566)	+106.5*	+41.7*	707
TOTAL 1974-2020		(17,289)	(11,841)			+**4,177 (24.2%)**
2017-2021	265.7	556.5 (2805)	391.6 (1506)	**+109.4***	**+47.4***	

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* Local rate significantly different than U.S. at P <.05

Appendix 7
Age-Adjusted Mortality, by Cause, Age 25-54
Study Counties vs. U.S., 2017-2020

	Rate/100,000 (Deaths)		% +/- U.S. Rate
Code (Cause)	U.S.	Study	Study Counties
A00-B99 (Infectious/parasitic)	6.8	14.4 (59)	**+111.8***
C00-D48 (Neoplasms)	40.5	76.3 (323)	**+ 88.4***
E00-E88 (Endocrine)	12.3	25.8 (105)	**+109.8***
F01-F99 (Mental/behavioral)	5.8	10.9 (44)	**+ 87.9***
G00-G98 (Nervous system)	6.1	12.4 (50)	**+103.3***
I00-I99 (Circulatory system)	47.2	97.5 (402)	**+106.6***
J00-J98 (Respiratory system)	9.2	25.9 (110)	**+181.5***
K00-K92 (Digestive system)	15.9	24.4 (100)	**+ 53.5***
N00-N98 (Genitourinary system)	3.5	5.7 (24)	**+ 62.9**
R00-R99 (Signs/symptoms)	3.5	5.0 (20)	**+ 42.9**
*V01-Y89 (Accid., sui., hom.)	90.3	220.2 (853)	**+143.9***
TOTAL	251.1	529.3 (2135)	**+110.8***

* Includes accidental poisoning by/exposure to drugs/X40-X44 (+281.0%*, n = 543); other accidents/V01-X39, X45-‘X59,Y10-Y89 (+65.5%*, n = 144); suicide/X60-X84 (+59.8%*, n = 113); homicide/X85-Y09 (+21.2%, n = 41)

Most Common Causes of Death, by Category:
Infectious/parasitic – septicemia, hepatitis C, E-coli
Endocrine – diabetes mellitus
Mental/behavioral – Parkinson’s, Alzheimer’s
Circulatory – heart disease, stroke
Respiratory – pneumonia, chronic obstructive pulmonary disease
Digestive – liver disease (including cirrhosis)
Genitourinary – kidney failure, urinary tract infection

Source: U.S. Rates: Centers for Disease Control and Prevention (https://wonder.cdc.gov/ucd-icd10.html).
* Local rate significantly different than U.S. at P <.05

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