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Sustainable Rust Belt Manufacturing: An Exploration of Emission Rates during the Enforcement Era of the Great Lakes Water Agreement Act (GLWQA)

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ABSTRACT: The Great Lakes as a key global resource provides an abundance of freshwater as well as power for the entire region, but environmental degradation due to industrial discharge into the water supply has depleted the Great Lakes ecosystem. The Great Lakes Water Agreement Act (GLWQA) is a framework to protect and restore this ecosystem. It has changed in scope since its inception, and while the regulatory duties of the GLWQA have been noble, less input from Rust Belt industry and more power from the steering committee of the GLWQA have resulted in power struggles among its various stakeholders as deindustrialization has spread across the region. This study will analyze different eras' amendments to ascertain changes in water pollution as they relate to production output rates over the past generation in order to analyze the effects of the various rounds of water pollution enforcement versus Rust Belt industrial output compared to other states in the country.

KEYWORDS: Rust Belt Manufacturing, GLWQA, Great Lake

INTRODUCTION

The Great Lakes, consisting of Lake Superior, Lake Michigan, Lake Huron, Lake Erie and Lake Ontario, are the largest group of freshwater lakes on earth and contain 21% of the earth's freshwater. Of the 40 million gallons used daily from the Great Lakes, more than half is used for industrial power production (Environmental Law and Policy Center, 2019), and 95% of the freshwater used as drinking water in the US comes from the Great Lakes (The 71percent, 2020). The Great Lakes has been called "unquestionably a unique national and global resource" (Freedman & Monson, 1989, p. 285). Truly, the Great Lakes ecosystem is a vitally important aspect of American functionality.

The Great Lakes is today a region by itself constituting the world's third-largest economy (Desjardines, 2017). Martin (1999) stated that the Great Lakes includes "one of the world's largest concentrations of industrial" output (p. 15) and the Environmental Law and Policy Center (2019) noted that "agriculture, industrial manufacturing, fishing, and recreation together form an economic engine" (p. 1).

The Great Lakes has contributed heavily to the economic prowess of the Rust Belt geographic region. This area, also referred to as the Manufacturing Belt, consists of Midwest American states, most of which border the Great Lakes. The Rust Belt's rise in economic strength during the late nineteenth and early twentieth centuries is attributed to the coinciding rise of the manufacturing sector (Tanoos, 2010; Stiglitz, 2017). Many believe that this region, powered by the coal industry, helped the North win the Civil War and propelled the United States into global hegemony in the industrial era (Cooke, 2006; Biggers, 2014). Unfortunately, during the past several decades, the decline of US manufacturing has been accompanied by job loss attributed to plant closings in this region, providing the impetus for its more recent nickname "Rust Belt" (Deakin & Edwards, 1993; Chase, 2003; Brown, et al., 2008; Tanoos, 2010; Bernero & Peduto, 2016).

Reksulak et al. (2013) found that Rust Belt states witness comparatively higher industrial costs due to regulations compared to other areas of the country. Organizations in the Rust Belt have often blamed these regulations for inhibiting the region's industrial effectiveness (Isenberg, 2017). In particular, as Cooke (2006) and Biggers (2014) noted, since the Rust Belt is generally powered by the coal industry, fossil fuel regulations have especially negatively affected these economies. As such, Rust Belt stakeholders have been generally opposed to direct and indirect federal regulations.

Although deindustrialization-related job losses have been a negative trend associated with the Rust Belt, there is a potentially more pressing issue, being the coinciding phenomenon of the degradation of the ecosystem's vital water supply (Ahamad et al., 2021).

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Fischer (2003, p. 51) said that the Great Lakes especially has "been acutely vulnerable" to environmental degradation over the years. Water pollution constitutes discharged pollution into natural water bodies (Mambretti and Jimenez, 2020); past industrial activity has been found to be the largest culprit in the degradation of the quality of the Great Lakes' freshwater. In addition, climate change is negatively affecting the Great Lakes region more than other regions (Spring, 2001; Egan, 2017; Dempsey, 2019; Environmental Law and Policy Center, 2019; Crossman et al., 2020).

Manufacturing in the Great Lakes has led to the industrial discharge into the water supply of chloride sources and other pollutants such as garbage disposal waste, sewer runoff and water softening products, along with other pollutant sources from chemical, steel, and food manufacturers (Sonzogni et al., 1983). As a result of past decades of industrial discharge into the Great lakes, the Great Lakes ecosystem has massive biological "dead zones" (Egan, 2017) where ecology is not active. Today, toxic substances in the Great Lakes aren't usually directly discharged directly into it but instead originate from regional landfill leaks and/or contaminated sites that eventually find their way to the Great Lakes (Carpenter, 2007).

The degradation of the quality of the freshwater in the Rust Belt and Great Lakes region has resulted in governmental regulations to limit water pollution. The US and Canada jointly passed the binational Great Lakes Water Agreement Act (GLWQA), enacted in 1972. Swain (1981) surmised "Both the United States and Canada have long recognized the importance of their boundary waters, and the need to preserve them as a priceless international resource and heritage" (p. 447). When it was first passed, Fischer (2003, p. 52) noted that regulatory means were part of water pollution control because past reductions in water emissions into the Great Lakes ecosystem have been due to "both to voluntary initiatives and regulatory controls on industrial sources" (Fischer, 2003, p. 52). The GLWQA began as a way to implement goals and actions for improving water quality in the Great Lakes and has been amended several times. It has been called the "centerpiece of the institutional architecture to address water quality in the Great Lakes" (Berardo et al., 2019, p. 9).

Private industry has been part of the guidance and writing process throughout, particularly in the leadup to the GLWQA (Martin, 1999; Grover and Krantzberg, 2018). While industries have been involved in the past development of the agreement (Freedman & Monson, 1989), an amendment, The Great Lakes Water Quality Initiative of 1990, involved more federal regulatory agencies including the EPA and less input from Rust Belt-based organizations, especially in the steering committee (National Water Quality Inventory, 1994). Industry eventually labeled it as too "stringent" because of its "requiring the states to adopt strict standards for waste disposal and discharge into the lakes" (Cox, 2013, p. 122). In 2001, the Great Lakes Charter Annex, a handshake agreement between governors of Rust Belt states and premiers of Canadian provinces, was formed to better coordinate the management of the Great Lakes water supply. The Annex received even more ardent opposition from Rust Belt industry (Inside Washington Publishers, 2004). In 2008, the Great Lakes Compact was signed between eight US states bordering the Great Lakes in order to better manage the water supply (Annin, 2018), with minimal input from private industry. Current solutions involve the lengthy and expensive process of dredging of shipping channels to alleviate issues such as massive amounts of toxic algae (Egan, 2017). As of 2022, the US Environmental Protection Agency (EPA) coordinates the American responsibilities within the GLWQA. In spite of opposition, much has been done over the past decades to mitigate water pollution in the Great Lakes.

Some critics say that regulations enacted on manufacturers in the Great Lakes need to go further to alleviate water degradation. Other pundits point out that the negative effects of climate change will hurt Great Lakes manufacturers more in the future than increased regulations in the present (Shin, 2013). However, contrary viewpoints say that regulations have gone too far and have inhibited efficient models of production (Beecher & Kalmbach, 2013; Keiser & Shapiro, 2019). A 2017 report noted that "the International Joint Commission, a US-Canadian panel that monitors Great Lakes water quality, states that efforts to clean up the lakes over 'the past 25 years are 'a mix of achievements and challenges'" (McCartney, 2017).

By 2019, public and private US sources had spent nearly $5 trillion in efforts to keep water in the US clean. In addition, Keiser and Shapiro (2019) noted that people may be willing to pay more in taxes to help keep clean these "iconic waters" (p. 66). Mambretti and Jimenez (2020) surmised that reaching solutions to global water pollution requires collaboration and an overall interdisciplinary approach, and experts have noted that the GLWQA certainly has room to evolve in its scope (Devy and Davis, 2020; Hale and Anderson, 2021).

To ascertain how different amendments to the GLWQA have altered water pollution and production output rates over the past generation, this study will analyze data from Rust Belt states that discharge pollutants into the Great Lakes. The effects of the various rounds of water pollution enforcement versus industrial output will then be compared to those of other states in the country.

METHODOLOGY/RESULTS

The data for this study were mined using a cross-sectional analysis to assess water pollution resulting from industrial productivity/output in conjunction with several key GLWQA milestones. Therefore, this study focused on datasets from the first and subsequent years in which various water pollution regulations were enforced, including 2002 (one year after the GLCA was enacted), 2014 (the first year in which the GLWQA was fully enforced and implemented), and 2018 (one year after the International Joint Commission progress report and edicts).

The sample set of Rust Belt states was determined as follows: states that border the Great Lakes but are not generally considered to be part of the Rust Belt (New York to the east and Minnesota to the west), and those with comparatively smaller Great Lakes coastlines (Indiana with 45 miles and Illinois with 63 miles) were omitted, as was Iowa, a Rust Belt state with no coastline. That left Ohio (312 miles), Wisconsin (820 miles), Michigan (3,224 miles), and Pennsylvania (140 miles) as the sample set of Rust Belt states, with particular focus on Michigan due to its extensive coastline (Office for Coastal Management, 2020).

The data for total on-site and off-site disposal or release of chemicals (total pollution rates) were mined from the US Environmental Protection Agency's (EPA) Toxic Release Inventory (TRI) from the most recent year (2021) (EnviroEPA, 2022). The TRI is a publicly-available EPA database containing information on the release of toxic chemicals (Antisdel, 2017). In order to assess economic data specific to industrial output, statistics from the US Bureau of Economic Analysis (BEA) were used to ascertain annual state GDP specifically related to the manufacturing process, or "Annual Gross Domestic GDP by state, GDP current dollars" (Bureau of Economic Analysis, 2021). Then, a cross-sectional analysis of the data from these datasets was completed to create two indexes.

First, to obtain a comparable method for assessing pollution related to manufacturing output, GNP was divided by water pollution to produce a *pollution efficiency index (PEI)*; a larger PEI would indicate a more sustainable manufacturing process in terms of pollution (Tanoos, 2021). A PEI can determine successful states that manufacture at high rates while also polluting at low rates. A closer examination finds extreme values in the first two sample sets whose PEI was larger than 2,000,000 in at least one year: Arizona, Massachusetts, New Hampshire, and Rhode Island. These were deemed to be outliers.

$$PEI = \frac{GNP}{the\ amount\ of\ water\ popultion}$$

Figure 1. Pollution Efficiency Index equation

Table 1. Average PEIs of Rust Belt versus Non-Rust Belt States

	2002	2014	2018
With Extremes: Rust Belt PEIs vs. Non-Rust Belt PEIs	4.1	52.2	69.5
No Extremes: Rust Belt PEIs vs. Non-Rust Belt PEIs	.45	3.8	3.7

When omitting those four outlier states in the non-Rust Belt sample set, the Rust Belt states were producing comparably more efficiently in terms of pollution in 2002 (33,060.3 PEI versus 14,941.8 PEI) but by 2018, they were producing 3.8 times less efficiently (19,970.9 versus 75,349.9) compared to the non-Rust Belt states. By 2018, the Rust Belt's production efficiency was similar to that in 2014 (27,564.6 versus 74,673.7, or 3.71 times more efficient) (see Table 1). For this index, since the *p*-values were larger than 0.05, it can be claimed that the distributions of the two groups are roughly equal, and thus there is no significant difference between the two groups.

The results of the *f*-tests showed that the variances of the Rust Belt versus non-Rust Belt sample sets were different; specifically, the *p*-value for the *f*-test was less than 0.05, the level of significance (see appendix A). This result suggests that the Rust Belt sample set produces more efficiently in terms of water pollution.

Next, to find an index to obtain a comparable method for assessing water pollution related to total pollution through the different eras of the GLWA's water pollution regulations, variables for both water pollution and total pollution were utilized. This metric of water pollution divided by total pollution, or "PCT", takes into account other types of pollution such as air pollution, soil

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contamination, plastic pollution, and so on, so that the PCT is representative of changes in water pollution versus these other forms of pollution. A lower PCT is more ideal because it represents comparably low water pollution and/or decreasing water pollution. Table 2 below shows the PCT for both sample sets (the four extremes were removed).

$$PCT = \frac{water\ pollution}{total\ pollution}$$

Figure 2. PCT equation

Table 2. Average PCTs of Non-Rust Belt/Rust Belt (no extremes)

	Rust Belt	Non
2002	3.55%	5.20%
2014	6.92%	4.96%
2018	7.36%	4.62%

As illustrated in Table 2, the Rust Belt states witnessed a sharp increase in PCT in 2014, which then leveled off in 2018. In contrast, the non-Rust Belt states saw a PCT which decreased over time.

The *f*-test was utilized to verify that the variance of two groups (state1=1 and state1=2) were unequal, resulting in less than .05 for 2014 and 2018. If the variances were the same, a standard *t*-test would have been utilized. Since the sample sets had unequal variance, or spreads of all the data points for each set, the next step was to test for significance of the disparity between the sets. de Winter (2013) suggested that the Welch test provides advantages over other tests of unequal variances, especially with unequal sample sizes, and when one sample was drawn from a small population as was the case with the Rust Belt sample. As such, this study applied both the Welch test and the Mann-Whitney U test, as shown in Table 3.

Table 3. PCT: P-values for full sample set

p-value of different tests when comparing PCT (Rust Belt versus Non-Rust Belt)			
	f-test	Welch test	Mann-Whitney U test
2002	0.05255	0.3438	0.4284
2014	0.02848	0.1015	0.9846
2018	0.03832	0.2562	0.8325

Table 4. PCT: P-values when extremes removed

p-value of different tests when comparing PCT (Rust Belt versus Non-Rust Belt)			
	f-test	Welch test	Mann–Whitney U test
2002	0.05082	0.2694	0.2553
2014	0.02746	0.0482	0.783
2018	0.03589	0.1514	0.9493

The results of the full sample set from Table 3 suggest that there is no significant difference between the two full sample sets during these years. However, when extreme values were omitted, the PCT *p*-values in the Welch test were less than 0.05, indicating that there is a statistically significant difference between the sample sets (see Table 4). As such, it can be claimed that the Rust Belt states witnessed increased water pollution in 2014 compared to the rest of the country.

REACTIONS/FUTURE STUDIES

Rust Belt states were polluting the water at higher rates than the rest of the country, but not if manufacturing-related GNP was included. While the Rust Belt did pollute their water supplies at increasing rates compared to the rest of the country, that difference has tapered off. In 2014, over 6.92% of the pollution coming out of the Rust Belt came from water pollution, compared to 3.55%

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in 2002. The percentage increased slightly to 7.36% in 2018. The data suggest that there is no significant difference between the means of the two sample sets during these years except the PCT in 2014 (after the extremes were removed). As such, GLWQA regulations and potential loopholes in those regulations at or before 2014 that caused the Rust Belt to pollute the water more that year should be scrutinized. Nevertheless, this trend seems to have been corrected. Certainly, the 2014 amendment could have been formed in response to this spike in Rust Belt water pollution trends.

The assertions of Devy and Davis (2020) and Hale and Anderson (2021) that the GLWQA's scope should continue to move forward are warranted. Beaven (2007) noted that the GLWQA should concentrate on not only reducing emissions into the water but also on adding nutrients, and Creed et al. (2006) added that the GLWQA can go further as it relates to ISO 31000 because although it has adequate risk-identification, it can still improve on risk analysis and risk evaluation.

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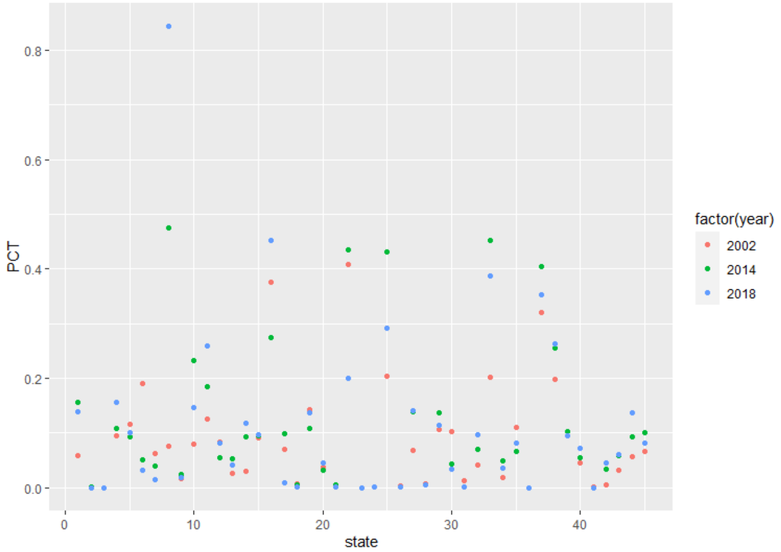
Appendix A.

PEI means of both sample sets: P-value for various tests of significance

Year	*f*-test	Welch test	Mann–Whitney U test
2002	0.05494	0.2041	0.1514
2014	<<0.01	0.2357	0.1729
2018	<<0.01	0.06307	0.5669

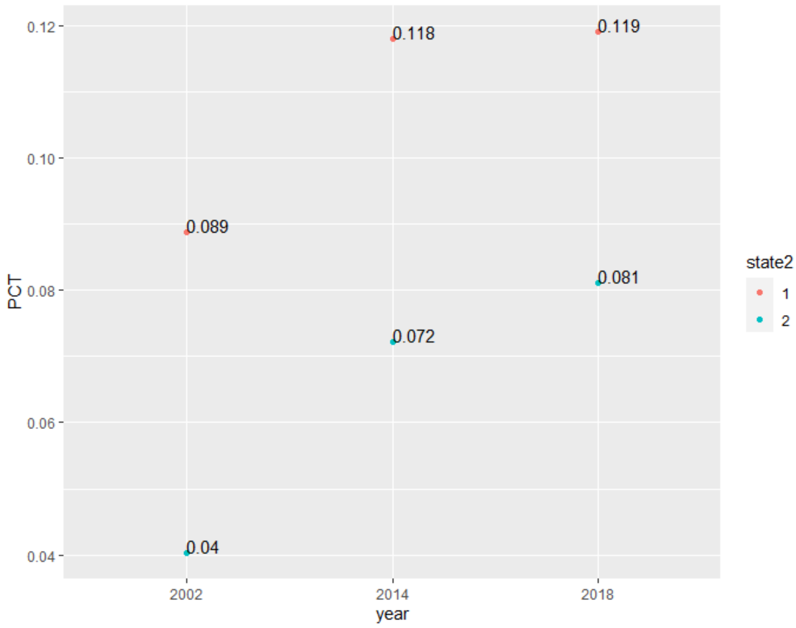
Appendix B.

PCT when no extremes are removed (by state)



Appendix C.

PCT when no extremes are removed (by year)



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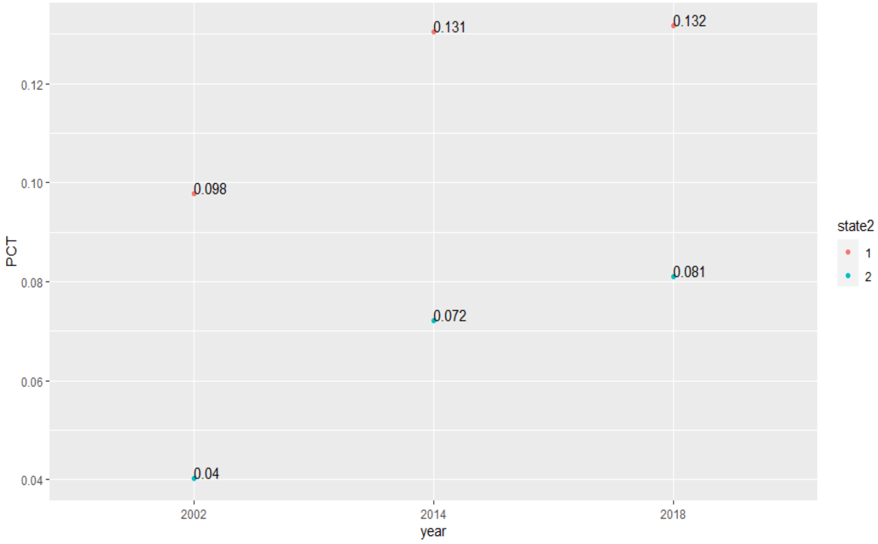
Appendix D.

PCT when extremes are removed (by year)



Appendix E.

List of States: Pollution and Manufacturing Statistics, 2002

	Total Pollution 2002(Total On-site and Off-site Disposal or Other Releases (pollution): (millions of lbs)	Water Pollution 2002 (millions of lbs)	GNP 2002 (related to manufacturing: millions of USD)
Alabama	123.7	7.2	21,249.6
Alaska	549.4	.0665	918.6
Arizona	329.6	.0071	22,328.7
Arkansas	37.0	3.5	14,711.1
California	50.3	5.8	162,315.4
Colorado	26.2	5.0	14,876.6
Connecticut	11.8	.7495	25,948.8
Delaware	12.1	.9288	3,352.4
Florida	139.1	2.3	30,935.4
Georgia	130.6	10.5	44,628.1
Hawaii	3.6	.4546	979.6
Idaho	63.6	5.3	5,266.5
Kansas	26.8	.7216	15,032.2
Kentucky	97.3	3.0	25,013.5
Louisiana	127.4	11.6	21,226.3
Maine	9.6	3.6	4,500.3
Maryland	45.2	3.2	15,434.6
Massachusetts	9.1	.0658	36,977.7
Mississippi	61.7	8.8	10,828.0
Missouri	113.8	4.4	29,758.0
Montana	33.7	.1031	1,270.2
Nebraska	32.1	13.1	7,394.8

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Nevada	465.4	.0929	3,157.1
New Hampshire	4.5	.0069	6,542.9
New Jersey	23.6	4.8	44,999.4
New Mexico	16.0	.0688	4,522.4
North Carolina	129.1	8.8	69,174.9
North Dakota	25.5	.1974	1,758.9
Oklahoma	29.2	3.1	11,562.0
Oregon	25.5	2.6	20,655.7
Rhode Island	1.0	.0124	4,647.7
South Carolina	72.8	3.0	26,114.0
South Dakota	11.9	2.4	3,683.3
Tennessee	155.8	3.0	35,047.2
Texas	271.5	30.0	105,120.4
Utah	177.7	.0632	8,427.4
Vermont	.3723	.1192	2,906.0
Virginia	90.4	18.0	34,504.1
Washington	23.3	2.2	31,866.4
West Virginia	96.3	4.3	5,557.4
Wyoming	18.6	.021	955.6
Rust Belt			
Michigan	135.1	.8341	84,070.9
Ohio	281.8	8.9	83,777.7
Pennsylvania	169.6	9.7	74,670.1
Wisconsin	45.2	3.0	43,013.3

Appendix F.

List of States: Pollution and Manufacturing Statistics, 2014

	Total Pollution 2014(Total On-site and Off-site Disposal or Other Releases (pollution): (millions of lbs)	Water Pollution 2014 (millions of lbs)	GNP 2014 (related to manufacturing: millions of USD)
Alabama	91.2	14.2	33,282.3
Alaska	1,100.0	.7965	1,589.4
Arizona	78.9	.0011	24,016.5
Arkansas	42.1	4.6	17,638.4
California	31.2	2.9	264,400.1
Colorado	29.6	1.5	22,293.7
Connecticut	2.1	.0848	29,319.7
Delaware	6.1	2.9	4,021.6
Florida	64.7	1.6	42,820.0
Georgia	69.0	16.0	52,572.2
Hawaii	2.9	.5341	1,671.2
Idaho	50.7	2.8	7,264.3
Kansas	22.2	1.2	21,811.9
Kentucky	73.4	6.9	34,759.1
Louisiana	139.3	13.3	49,488.5

Maine	10.2	2.8	5,518.8
Maryland	8.3	.8183	19,450.3
Massachusetts	7.8	.0357	48,745.0
Mississippi	70.1	7.6	16,165.4
Missouri	70.2	2.2	36,468.2
Montana	37.7	.2257	3,021.6
Nebraska	26.7	11.6	12,926.6
Nevada	286.6	.0037	6,174.5
New Hampshire	.7663	.000663	7,399.3
New Jersey	12.3	5.3	46,036.3
New Mexico	20.4	.0356	3,671.2
North Carolina	61.8	8.6	90,974.8
North Dakota	43.5	.2024	3,665.0
Oklahoma	26.9	3.7	18,053.3
Oregon	25.6	1.1	28,355.8
Rhode Island	.4718	.000769	4,306.6
South Carolina	46.7	3.3	31,181.5
South Dakota	6.2	2.8	4,174.1
Tennessee	84.2	4.2	47,177.1
Texas	254.4	16.7	202,207.5
Utah	209.3	.1262	16,272.8
Vermont	.3091	.1248	2,742.6
Virginia	43.5	11.1	40,223.7
Washington	21.4	2.2	62,620.4
West Virginia	36.7	2.0	7,177.8
Wyoming	18.2	.0121	1,744.0
Rust Belt			
Michigan	63.1	2.2	86,085.2
Ohio	116.8	6.9	104,944.1
Pennsylvania	87.2	8.2	86,730.0
Wisconsin	37.8	3.8	56,877.1

Appendix G.

List of States: Pollution and Manufacturing Statistics, 2018

	Total Pollution 2018(Total On-site and Off-site Disposal or Other Releases (pollution): (millions of lbs)	Water Pollution 2018(millions of lbs)	GNP 2018 (related to manufacturing: millions of USD)
Alabama	78.9	11.0	37,617.1
Alaska	972.0	.5281	1,842.6
Arizona	170.5	.000897	28,943.5
Arkansas	36.3	5.7	19,323.8
California	34.4	3.5	320,738.6
Colorado	24.4	.768	25,750.7
Connecticut	2.1	.0331	29,658.9
Delaware	6.4	5.4	4,802.3

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Florida	61.2	1.1	56,186.9
Georgia	50.5	7.4	63,316.8
Hawaii	2.9	.7499	1,999.5
Idaho	34.3	2.8	8,607.4
Kansas	24.0	.9888	27,574.4
Kentucky	50.8	6.0	37,745.2
Louisiana	146.0	14.3	52,248.1
Maine	11.5	5.2	6,169.5
Maryland	6.2	.0624	24,449.8
Massachusetts	3.4	.0075	52,613.6
Mississippi	61.5	8.4	18,773.9
Missouri	60.2	2.7	39,006.6
Montana	51.3	.0747	3,320.0
Nebraska	18.5	3.7	13,538.2
Nevada	339.1	.0265	7,919.2
New Hampshire	.4295	.000956	9,693.0
New Jersey	12.7	3.7	52,261.8
New Mexico	16.7	.0421	4,177.6
North Carolina	55.0	7.8	100,739.6
North Dakota	30.2	.1731	3,989.5
Oklahoma	31.4	3.6	18,465.1
Oregon	20.7	.7025	34,053.9
Rhode Island	.4278	.000999	5,094.4
South Carolina	37.0	3.6	38,389.7
South Dakota	7.5	2.9	5,134.8
Tennessee	88.7	3.2	54,969.3
Texas	217.4	17.8	237,661.6
Utah	291.3	.1233	19,581.7
Vermont	.3639	.1284	3,106.1
Virginia	34.5	9.1	45,274.5
Washington	30.2	2.9	64,551.8
West Virginia	30.7	2.2	8,085.3
Wyoming	21.4	.0055	2,259.9
Rust Belt			
Michigan	78.5	3.6	99,232.7
Ohio	113.2	6.8	111,490.6
Pennsylvania	55.0	7.5	91,486.9
Wisconsin	31.7	2.6	63,078.7

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