

ARTICLES

WASTE AND CHEMICAL MANAGEMENT IN A 4°C WORLD

by Michael B. Gerrard

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SUMMARY

Many chemicals and hazardous substances are kept in places that can withstand ordinary rain, but not severe storms or floods. If these events occur and the chemicals are released, people and the environment may be endangered. This Article discusses the hazards posed to chemical and waste disposal facilities by extreme weather events that would be worsened as a result of climate change, and how U.S. laws do (or do not) deal with these hazards; and considers how the law would need to change to cope with what would happen to these facilities in a potentially 4°C world. It is adapted from a new book by the Environmental Law Collaborative (Katrina Kuh & Shannon Roesler eds., ELI Press forthcoming 2023).

Many chemicals and hazardous substances are kept in places that can withstand ordinary rain, but not severe storms or floods. If these events occur and the chemicals are released, people and the environment may be endangered. The law has a long way to go—using existing tools and developing new ones—in protecting against these hazards and coping with the damage when they do occur. This becomes even more urgent if, as Profs. J.B. Ruhl and Robin Kundis Craig have suggested in their seminal article,¹ we need to begin preparing for the possibility of a world that is up to 4°C (7.2°F) warmer.

U.S. sea levels today are about nine inches higher than a century ago.² By the end of the century, they could be another six feet or even higher (or lower).³ Just how high depends mostly on the levels of greenhouse gases (GHGs) we are still emitting, and on the rate of melting in Greenland and Antarctica. Moreover, flood risks are hardly limited to the coasts. Over the past century, annual precipitation and also extreme precipitation events have increased across most of the northern and eastern United States (and decreased across much of the southern and

western states), due mostly to GHG emissions.⁴ Each 1°F increase in temperature leads to more evaporation and 4% more water vapor in the atmosphere, meaning more rain.⁵ This affects inland areas as well as the coasts; flooding across the Midwest and South during 2019 affected nearly 14 million people.⁶

Hurricanes have been getting more frequent and intense since at least the 1970s, and that will continue.⁷ While climate change is making hurricanes stronger, it can also slow their lateral movement along the coast and even make them almost stand still, continuously drawing water from the ocean like a massive pump and, as they rotate, dumping torrents of rain on a location for days on end.⁸ That is what happened with Hurricane Harvey over the Houston

1. J.B. Ruhl & Robin Kundis Craig, *4° Celsius*, 106 MINN. L. REV. 191 (2021).
 2. U.S. GLOBAL CHANGE RESEARCH PROGRAM, VOLUME II: IMPACTS, RISKS, AND ADAPTATION IN THE UNITED STATES: FOURTH NATIONAL CLIMATE ASSESSMENT 39 (D.R. Reidmiller et al. eds., 2018), <https://nca2018.global-change.gov/> [hereinafter FOURTH NATIONAL CLIMATE ASSESSMENT].
 3. Jonathan L. Bamber et al., *Ice Sheet Contributions to Future Sea-Level Rise From Structured Expert Judgment*, 116 PNAS 11195 (2019), available at <https://doi.org/10.1073/pnas.1817205116>.

4. FOURTH NATIONAL CLIMATE ASSESSMENT, *supra* note 2, at 74; Megan C. Kirchmeier-Young & Xuebin Zhang, *Human Influence Has Intensified Extreme Precipitation in North America*, 117 PNAS 13308 (2020), available at <https://www.pnas.org/content/117/24/13308>.

5. *A Warming Earth Is Also a Wetter Earth*, NAT'L CNTRS. FOR ENV'T INFO. (Nov. 18, 2020), <https://www.ncei.noaa.gov/news/warming-earth-also-wetter-earth>; Andreas F. Prein et al., *The Future Intensification of Hourly Precipitation Extremes*, 7 NATURE CLIMATE CHANGE 48 (2017). See also Jiabo Yin et al., *Large Increase in Global Storm Runoff Extremes Driven by Climate and Anthropogenic Changes*, 9 NATURE COMM'NS 4389 (2018).

6. Sarah Almkhatar et al., *The Great Flood of 2019: A Complete Picture of a Slow-Motion Disaster*, N.Y. TIMES (Sept. 11, 2019), <https://www.nytimes.com/interactive/2019/09/11/us/midwest-flooding.html>.

7. James P. Kossin et al., *Global Increase in Major Tropical Cyclone Exceedance Probability Over the Past Four Decades*, 117 PNAS 11975 (2020), available at <https://www.pnas.org/content/117/22/11975>.

8. James P. Kossin, *A Global Slowdown of Tropical-Cyclone Translation Speed*, 558 NATURE 104 (2018).

area in 2017, Hurricane Dorian over the Bahamas in 2019, and Hurricane Ian over Florida in 2022.⁹

This Article discusses the hazards posed to chemical and waste disposal facilities by extreme weather events that would be worsened as a result of climate change, and how U.S. laws do (or do not) deal with these hazards. It then considers how the law would need to change to cope with what would happen to these facilities in a 4°C world.

I. Current Law

Threats realized. According to the U.S. Government Accountability Office (GAO), “Over 11,000 facilities across the nation make, use, or store extremely hazardous chemicals in amounts that could harm people, the environment or property if accidentally released.”¹⁰ Large concentrations of these facilities are in the areas of New Orleans (hit by Hurricanes Katrina and Rita in 2005, Laura in 2020, and Ida in 2021) and Houston (hit by Hurricane Harvey in 2017). The high winds and rushing waters from these storms caused multiple releases of chemicals into the air or water. Storage tanks buckled, toppled over, or were washed away; the floating roofs atop several tanks sank or were dislodged; pipelines burst.¹¹

A 14-inch pipeline owned by Williams Companies spewed anhydrous hydrogen chloride for several hours at La Porte, Texas, mixing with moisture in the air to form hydrochloric acid and requiring neighboring residents to shelter in place.¹² At ExxonMobil’s Olefins Plant in Baytown, Texas, some 457 million gallons of stormwater mixed with untreated wastewater, including oil and grease, and surged into an adjacent creek.¹³ Hurricane Ida led to 55 reported oil spills, many of them from abandoned pipelines and offshore oil platforms near the Texas and Louisiana coastlines.¹⁴

During Harvey, chemical spills contributed to unhealthy levels of air pollution,¹⁵ and a chemical plant owned by Arkema Inc. exploded after the failure of an essential cooling system. More than a dozen emergency responders were injured, and carcinogens were released into the air. The company and two executives were indicted on criminal charges for reckless release of toxic chemicals, but the court found prosecutorial misconduct and incompetence and dismissed the charges; several civil lawsuits continue.¹⁶

Bio-Lab, a plant near New Orleans, burned to the ground during Hurricane Laura and released chlorine that it was producing for swimming pools, leading to another shelter-in-place order.¹⁷ Other hurricanes have caused severe damage to refineries and other petrochemical plants.¹⁸ One 2022 headline was especially vivid: “Florida County Sees Spike in Deadly Infections Caused by ‘Flesh-Eating’ Bacteria After Hurricane Ian.”¹⁹

Clean Air Act. As part of a comprehensive amendment to the Clean Air Act (CAA)²⁰ in 1990, the U.S. Congress adopted a new program on prevention of accidental releases of hazardous chemicals from stationary sources, called the §112(r) program.²¹ It provided that owners and operators of these sources “have a general duty . . . to identify hazards which may result from such releases using appropriate hazard assessment techniques, to design and maintain a safe facility taking such steps as are necessary to prevent releases, and to minimize the consequences of accidental

9. Elena Shao et al., *How Hurricane Ian Became So Powerful*, N.Y. TIMES (Sept. 30, 2022), <https://www.nytimes.com/interactive/2022/09/29/climate/hurricane-ian-florida-intensity.html>.

10. GAO, CHEMICAL ACCIDENT PREVENTION: EPA SHOULD ENSURE REGULATED FACILITIES CONSIDER RISKS FROM CLIMATE CHANGE 1 (2022) [hereinafter GAO REPORT].

11. Luis A. Godoy, *Performance of Storage Tanks in Oil Facilities Damaged by Hurricanes Catarina and Rita*, 21 J. PERFORMANCE CONSTRUCTED FACILITIES 441 (2007), available at <https://asc.libary.org/doi/10.1061/%28ASCE%290887-3828%282007%2921%3A6%28441%29>; Tarika Powell, *Hurricane Harvey Highlights Fossil Fuel and Petrochemical Loopholes*, SIGHTLINE INST. (Oct. 18, 2017), <https://www.sightline.org/2017/10/18/hurricane-harvey-highlights-fossil-fuel-and-petrochemical-loopholes/>.

12. Jordan Blum & Andrew Kragie, *Williams Cos. Says Its Pipeline Was Source of Chemical Leak During Harvey*, HOUS. CHRON. (Aug. 29, 2017), <https://www.chron.com/business/energy/article/Williams-Cos-claims-pipeline-that-caused-12123985.php>; Frank Bajak & Lise Olsen, *Hurricane Harvey’s Toxic Impact Deeper Than Public Told*, ASSOCIATED PRESS (Mar. 22, 2018), <https://apnews.com/article/houston-hurricane-harvey-storms-environment-hurricanes-1721dbf472284609bace453739ffb06>.

13. Robin Kundis Craig, *Cleaning Up Our Toxic Coasts: A Precautionary and Human Health-Based Approach to Coastal Adaptation*, 36 PACE ENV’T L. REV. 1, 12 (2018).

14. Blacki Migliozzi & Hiroko Tabuchi, *After Hurricane Ida, Oil Infrastructure Springs Dozens of Leaks*, N.Y. TIMES (Sept. 26, 2021), <https://www.nytimes.com/interactive/2021/09/26/climate/ida-oil-spills.html>; Ari Natter, *Ida Leaves Toxic Chemicals, Sewage Swirling in Its Wake*, BLOOMBERG

(Sept. 2, 2021), <https://www.bloomberg.com/news/articles/2021-09-02/ida-s-wake-leaves-toxic-chemicals-sewage-swirling-in-louisiana>.

15. Hiroko Tabuchi et al., *Mixing Water and Poison*, WRAL.COM (Feb. 6, 2018), <https://www.wral.com/mixing-water-and-poison/17318447/>; ENVIRONMENTAL INTEGRITY PROJECT, PREPARING FOR THE NEXT STORM: LEARNING FROM THE MAN-MADE ENVIRONMENTAL DISASTERS THAT FOLLOWED HURRICANE HARVEY 4 (2018).

16. Michelle Homer & Stephanie Whitfield, *Arkema Trial Ends When Judge Dismisses Last Two Criminal Charges, Ending Long Legal Drama*, KHOU-11 (Oct. 1, 2020), <https://www.khou.com/article/news/local/arkema-executives-cleared-after-judge-dismisses-charges/285-aa7e62aa-6774-4c41-89f8-5ac78cbcd561>; Charles P. Pierce, *The Chemical Plant Explosion in Texas Is Not an Accident. It’s the Result of Specific Choices*, ESQUIRE (Aug. 31, 2017), <https://www.yahoo.com/entertainment/chemical-plant-explosion-texas-not-135613629.html>; Lauren Mulhern, *The Arkema Chemical Facility Incident: How Regulation of Reactive Chemicals and Incorporation of Climate Change Risks in Emergency Response Planning Could Mitigate and Prevent Future Accidental Chemical Releases*, 30 COLO. NAT. RES. ENERGY & ENV’T L. REV. 143, 150 (2019); Prantil v. Arkema Inc., 986 F.3d 570 (5th Cir. 2021).

17. Kristen Mosbrucker, *Burned to the Ground After Hurricane Laura, a Chemical Plant Wants Millions in Tax Breaks to Rebuild*, ADVOCATE (Apr. 26, 2021), https://www.theadvocate.com/baton_rouge/news/business/burned-to-the-ground-after-hurricane-laura-a-chemical-plant-wants-millions-in-tax-breaks/article_69cfc020-a6c5-11eb-926f-d7af9c910e5b.html; Tristan Baurick, *Fire Fight at Hurricane Laura-Damaged Chemical Plant Near Lake Charles Continues Into 2nd Day*, NOLA.COM (Aug. 28, 2020), https://www.nola.com/news/environment/fire-fight-at-hurricane-laura-damaged-chemical-plant-near-lake-charles-continues-into-2nd-day/article_6cca4e36-e969-11ea-b1ba-53ec47f5a71b.html.

18. Majid Ebad Sichani et al., *Hurricane Risk Assessment of Petroleum Infrastructure in a Changing Climate*, 6 FRONTIERS BUILT ENV’T art. 104 (2020); Ana Maria Cruz et al., *Identifying Hurricane-Induced Hazardous Material Release Scenarios in a Petroleum Refinery*, 2 NAT. HAZARDS REV. 203 (2001).

19. Emily Mae Czachor, *Florida County Sees Spike in Deadly Infections Caused by “Flesh-Eating” Bacteria After Hurricane Ian*, CBS NEWS (Oct. 17, 2022), <https://www.cbsnews.com/news/hurricane-ian-florida-flesh-eating-bacteria-infections-flooding-lee-county/>.

20. 42 U.S.C. §§7401-7671q, ELR STAT. CAA §§101-618.

21. 42 U.S.C. §7412(r).

releases which do occur.” Congress told the U.S. Environmental Protection Agency (EPA) to adopt regulations and to require facility owners and operators to prepare and implement “risk management plans.” These plans came to include “off-site consequences analyses,” but in 1999 Congress, two years before the 9/11 attacks but already concerned that terrorists might use this information to find targets, amended the law to make it much more difficult for the public to obtain these analyses.²²

Then, in 2013, the explosion of a fertilizer plant in the town of West, Texas, killed 15 people, and President Barack Obama directed EPA to strengthen the chemical safety rules. EPA issued stronger regulations in January 2017, one week before President Obama left office. The Donald Trump Administration rescinded the stronger rules.²³ In February 2022, GAO found that about 3,200 facilities covered by the program are in locations that may be at risk from the effects of climate change—flooding, storm surge, wildfire, and sea-level rise.²⁴ In August 2022, EPA proposed a new rule that followed GAO’s recommendation to explicitly require consideration of climate change in preparing their risk management plans.²⁵ Under existing regulations, the risk management plans must be updated every five years.²⁶

Similar to the risk management plans required by EPA, which are designed to protect the environment and the community, the Occupational Safety and Health Administration (OSHA) requires “process safety management plans” to protect workers.²⁷ The plans required by EPA must consider the effects of a chemical release on the nearby community; the plans required by OSHA generally look only at the effects in the workplace, and there is no explicit requirement to consider climate change. Both EPA and OSHA require companies, in carrying out these plans, to follow “recognized and generally accepted good engineering practices” (RAGAGEP).

The RAGAGEP practices are established by such non-profit organizations as the American Society of Mechanical Engineers, the American National Standards Institute, and the National Fire Protection Association.²⁸ Some of these practices implicitly consider various effects of cli-

mate change (such as flooding and wildfires), but few if any explicitly discuss climate change or the conditions it will cause in the future.²⁹ Changes to these practices could have a significant impact on industrial practices, as several consulting firms have gone into the business of auditing companies for their compliance with the RAGAGEP.

As part of the same 1990 amendments to the CAA, Congress created the Chemical Safety and Hazard Investigation Board, modeled after the National Transportation Safety Board, to investigate accidents at chemical plants and recommend corrective measures.³⁰ However, it did not begin operations until Congress finally funded it in 1998, and the Trump Administration tried without success to dismantle it. It has conducted useful investigations, but with a very limited staff it has never been able to look into more than a small fraction of chemical plant incidents.³¹ In 2020, the Board issued a short guidance document for how chemical plants should deal with extreme weather events, acknowledging an increase in flooding in recent years, but not mentioning climate change.³² An October 2022 report from EPA’s Office of Inspector General found that the Board is still severely understaffed, and has only two of five authorized members.³³

Resource Conservation and Recovery Act. EPA has issued detailed regulations under the Resource Conservation and Recovery Act (RCRA)³⁴ for the storage of certain chemicals,³⁵ but they apply only to hazardous wastes, not to useful products or to materials that will be used. Moreover, RCRA regulates the units that are most vulnerable to storms—above-ground storage tanks—only if they are holding oil or its products like gasoline.³⁶ A law enacted after the chemical disaster in Bhopal, India, in 1984, the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA),³⁷ requires companies storing large quantities of certain hazardous substances (not only wastes) to report their inventories and make some other disclosures, but it does not impose substantive requirements that would help make sure the tanks do not leak or burst.³⁸

This gaping regulatory gap was on display in January 2014 in Charleston, West Virginia, when a large leak developed at a tank holding a chemical used as a cleansing agent in the coal mining industry. The liquid poured into the Elk

22. Pub. L. No. 106-40, 113 Stat. 207 (1999).

23. Juliet Eilperin, *Trump Administration Scales Back Safety Rules Adopted After Deadly Chemical Explosion*, WASH. POST (Nov. 21, 2019), <https://www.washingtonpost.com/climate-environment/2019/11/21/trump-reverses-safety-rules-adopted-after-deadly-chemical-explosion/>.

24. GAO REPORT, *supra* note 10, at 19. See also DAVID FLORES ET AL., CENTER FOR PROGRESSIVE REFORM ET AL., PREVENTING “DOUBLE DISASTERS”: HOW THE U.S. ENVIRONMENTAL PROTECTION AGENCY CAN PROTECT THE PUBLIC FROM HAZARDOUS CHEMICAL RELEASES WORSENER BY NATURAL DISASTERS 6 (2021).

25. 87 Fed. Reg. 53556 (Aug. 31, 2022).

26. 40 C.F.R. §68.36.

27. 29 C.F.R. §1910.119.

28. Memorandum from Thomas M. Galassi, Director, Directorate of Enforcement Programs, OSHA, to Regional Administrators, RAGAGEP in Process Safety Management Enforcement (May 11, 2016), <https://www.osha.gov/laws-regs/standardinterpretations/2016-05-11>; U.S. EPA, *Complying With Process Safety Information (PSI) Resulting From New and Updated Recognized and Generally Accepted Good Engineering Practices (RAGAGEP)*, <https://www.epa.gov/rmp/complying-process-safety-information-psi-resulting-new-and-updated-recognized-and-generally> (last updated July 12, 2022).

29. GAO REPORT, *supra* note 10, at 33.

30. 42 U.S.C. §7412(f)(6).

31. Ian Bennett, *Mitigating the Next Disaster: Strengthening the U.S. Chemical Safety and Hazard Investigation Board*, 42 N.Y. ENV’T LAW. 31 (2022).

32. U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD, SAFETY ALERT—2020 HURRICANE SEASON: GUIDANCE FOR CHEMICAL PLANTS DURING EXTREME WEATHER EVENTS (2020), https://www.csb.gov/assets/1/6/extreme_weather_-_final_w_links.pdf.

33. OFFICE OF INSPECTOR GENERAL, U.S. EPA, FISCAL YEAR 2023: U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD TOP MANAGEMENT CHALLENGES (2022). The U.S. Senate recently confirmed a third member. See News Release, U.S. Senate Committee on Environment & Public Works, Carper Applauds Confirmation of Chemical Safety Board Nominees (Dec. 13, 2022), <https://www.epw.senate.gov/public/index.cfm/press-releases-democratic?ID=D1019D37-1F3D-4299-99B3-7DA49573C5CA>.

34. 42 U.S.C. §§6901-6992k, ELR STAT. RCRA §§1001-11011.

35. 40 C.F.R. pt. 264.

36. *Id.* pt. 112.

37. 42 U.S.C. §§11001-11050, ELR STAT. EPCRA §§301-330.

38. 42 U.S.C. §11022.

River and rendered the water supply for 300,000 people undrinkable for weeks. The spill occurred during a spell of record low temperatures caused by a “polar vortex” (a phenomenon that some link to climate change³⁹), causing “frost heaving” that deformed the ground surface on which the tank was sitting.

Though the tank was corroded, it was not subject to EPA’s tank regulations because it contained a useful product—neither waste nor oil. The company and some of its managers were prosecuted criminally and fined, not because the tank was substandard, but because the company did not have a permit under the Clean Water Act (CWA)⁴⁰ to discharge into the river and had not taken adequate precautions to prevent a spill.⁴¹ After this incident, West Virginia adopted legislation regulating above-ground storage tanks.

EPA has promulgated very detailed regulations under RCRA for hazardous waste disposal facilities. These include special precautions for facilities sited in a 100-year floodplain.⁴² Since rising seas and more intense storms mean that many more areas will have that level of flood risk, those areas will encompass many more facilities. Based on past experience, it is not clear that their operators will be taking the necessary precautions.⁴³

Clean Water Act. As enacted in 1972, the CWA requires EPA to “establish procedures, methods, and equipment and other requirements for equipment to prevent discharges of oil and hazardous substances.”⁴⁴ In 1973, EPA issued standards for the storage of oil.⁴⁵ The current regulations require oil storage facilities to have spill prevention control and countermeasure (SPCC) plans.⁴⁶ These plans are very elaborate and no doubt have greatly reduced the amount of oil that gets into the environment, but they are required only for oil. In 2015, several environmental groups sued EPA to compel it to issue similar regulations for hazardous substances, as the CWA requires. EPA agreed in a 2016 consent decree to begin a rulemaking to correct this gap, but the Trump Administration then concluded that new rules were not necessary.⁴⁷ The Joe Biden Administration has not indicated whether it will take a different position.

In 2019, the Natural Resources Defense Council and others sued EPA under a related provision of the CWA (added by the Oil Pollution Act of 1990 (OPA))⁴⁸ that required the president to issue regulations requiring owners or operators of certain onshore facilities to prepare plans “for responding, to the maximum extent practicable, to a worst case discharge, and to a substantial threat of such a discharge, of oil or a hazardous substance.”⁴⁹ The parties entered into a consent decree in March 2020 requiring EPA to propose regulations complying with this requirement within two years, and in March 2022, EPA issued its proposed rule on “Clean Water Act Hazardous Substance Worst Case Discharge Planning.”⁵⁰ EPA indicated that climate change could cause or worsen these worst-case events, and should be considered in the plans.

Even when SPCC plans are required, they often ignore the perils that climate change poses to tanks that hold large amounts of oil. In 2016, the Conservation Law Foundation sued ExxonMobil, alleging that its oil tank farm on the Mystic River near Boston is not prepared for storm surge or other possible impacts of climate change, in violation of the CWA and RCRA. The same group followed with similar suits against Gulf Oil and Shell Oil concerning different tank farms. These cases are in active litigation.⁵¹

Another kind of litigation—that under tort law—does little to induce greater care in protecting chemical facilities from climate risks. A damaging hurricane like Katrina or Harvey can cause multiple spills, leading to the intermingling of chemicals in a toxic soup and making it impossible to prove what facility caused what injury.⁵² Unless stronger standards are imposed, in many cases, plaintiffs will also have difficulty proving that the companies were negligent, which would be necessary for most of these suits to succeed.⁵³

Comprehensive Environmental Response, Compensation, and Liability Act. The best-known program for contaminated sites that are no longer active (as opposed to operating factories) is under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).⁵⁴ EPA places the worst sites on its National Priorities List; these are commonly called Superfund sites. These sites are

39. Judah Cohen et al., *Linking Arctic Variability and Change With Extreme Winter Weather in the United States*, 373 SCIENCE 1116 (2021).

40. 33 U.S.C. §§1251-1387, ELR STAT. FWPCA §§101-607.

41. U.S. CHEMICAL SAFETY AND HAZARD INVESTIGATION BOARD, INVESTIGATION REPORT: CHEMICAL SPILL CONTAMINATES PUBLIC WATER SUPPLY IN CHARLESTON, WEST VIRGINIA (2017); Press Release, U.S. Dept. of Justice, Freedom Industries and Former Freedom Industries Plant Manager Sentenced for Roles in Chemical Spill (Feb. 4, 2016), <https://www.justice.gov/usao-sdww/pr/freedom-industries-and-former-freedom-industries-plant-manager-sentenced-roles-chemical>.

42. 40 C.F.R. §264.18(b).

43. Timothy J. Flynn et al., *Implications of Sea Level Rise for Hazardous Waste Sites in Coastal Floodplains*, in GREENHOUSE EFFECTS AND SEA LEVEL RISE: A CHALLENGE FOR THIS GENERATION 271 (Michael C. Barth & James G. Titus eds., Springer 1984).

44. 33 U.S.C. §1321(j)(1)(C).

45. 38 Fed. Reg. 34165 (Dec. 11, 1973).

46. 33 C.F.R. §112.3.

47. U.S. EPA, *Final Action on Clean Water Act Hazardous Substances Spill Prevention*, <https://www.epa.gov/rulemaking-preventing-hazardous-substance-spills/final-action-clean-water-act-hazardous-substances> (last updated Sept. 20, 2022); Clean Water Act Hazardous Substances Spill Prevention, 84 Fed.

Reg. 46100 (Sept. 3, 2019), available at <https://www.govinfo.gov/content/pkg/FR-2019-09-03/pdf/2019-18706.pdf>; Noah M. Sachs, *Toxic Floodwaters: Strengthening the Chemical Safety Regime for the Climate Change Era*, 46 COLUM. J. ENV’T L. 73, 109-12 (2020).

48. 33 U.S.C. §§2701-2761, ELR STAT. OPA §§1001-7001.

49. 33 U.S.C. §1321(j)(5)(A)(i).

50. 87 Fed. Reg. 17890 (proposed Mar. 28, 2022), available at <https://www.regulations.gov/document/EPA-HQ-OLEM-2021-0585-0001>.

51. See Conservation L. Found. v. Exxon Mobil Corp., 3 F.4th 61, 51 ELR 20129 (1st Cir. 2021); Ruling and Order on Defendant’s Motion to Dismiss, Conservation L. Found. v. Shell Oil Co., No. Civ. 3:21CV00933, 2022 U.S. Dist. LEXIS 167377, 52 ELR 20111 (D. Conn. Sept. 16, 2022); Ruling and Order on Defendant’s Motion to Dismiss, Conservation L. Found. v. Gulf Oil Ltd. P’ship, No. 3:21-CV-00932 (SVN) (D. Conn. Sept. 29, 2022).

52. Mary Fox et al., *Potential for Chemical Mixture Exposures and Health Risks in New Orleans Post-Hurricane Katrina*, 15 HUM. & ECOLOGICAL RISK ASSESSMENT 831 (2009), available at <https://www.tandfonline.com/doi/abs/10.1080/10807030903051309?journalCode=bher20>.

53. See generally Sachs, *supra* note 47.

54. 42 U.S.C. §§9601-9675, ELR STAT. CERCLA §§101-405.

disproportionately located in or near communities of color.⁵⁵ After listing, each site undergoes an elaborate process called the remedial investigation and feasibility study, leading to EPA's selection of a way to address the contamination, called a "remedy."

Some common remedies include digging up the material and hauling it to a licensed disposal site; leaving it in place and placing an impervious cover over it; or pumping out contaminated groundwater, treating it, and putting it back in the ground. Of the Superfund sites not on federal property, at least 60% (945 of 1,571) are in locations that under current conditions are vulnerable to flooding, storm surge, wildfires, or sea-level rise.⁵⁶ Even more sites will be at risk as climate conditions worsen.

Extreme storms do not necessarily release contaminants from Superfund sites. An EPA study of three 2017 hurricanes (Harvey, Irma, and Maria) found that 252 Superfund or similar sites were exposed to tropical force winds or higher and 63 experienced flooding, but only 16 reported minor damage.⁵⁷ One that was affected was the San Jacinto River Waste Pits, where Hurricane Harvey damaged a temporary protective cap on a pit of toxic sludge, exposing waste with high levels of dioxins and washing some of it downriver.⁵⁸ Hurricane Maria stirred up already high levels of polychlorinated biphenyls (PCBs) in Guánica Bay, Puerto Rico.⁵⁹

EPA has identified many ways that a changing climate can worsen the already toxic conditions at contaminated sites. For example, it can transport pollution offsite; mobilize formerly stable contaminants, especially those in sediments at the bottom of bodies of water; damage the often thin caps that cover contaminants that are left in place; and make contaminants more volatile with higher temperatures.⁶⁰ Climate change can also increase erosion, raise or lower groundwater levels, flood drainage systems beyond

their design conditions, and force soil vapor to migrate, further complicating Superfund remedies.⁶¹

In 2021, EPA suggested that its officials implementing CERCLA "should assess the vulnerability of a remedial action's components, including its associated site infrastructure and evaluate whether the long-term integrity of a selected remedy may be impaired by adverse effects of climate change," and that "intensities and frequencies of extreme weather events over a timeframe corresponding to a remedy's anticipated duration" should be considered.⁶² The remedies recently chosen for some sites do include protections against extreme flooding.⁶³

EPA has legal options if it finds that climate change has rendered a site remedy inadequate. CERCLA provides that if any contaminants remain at the site, EPA must review the remedial action at least every five years "to assure that human health and the environment are being protected," and if they are not, EPA must take action.⁶⁴ Most cleanups of Superfund sites are carried out through consent decrees with the potentially responsible parties, and EPA's model consent decree allows the Agency to compel further action at closed sites if required by the circumstances.⁶⁵ Therefore, if EPA concludes that the remedy at a Superfund site is vulnerable to climate change, it has considerable authority to require a change, though in practice it has seldom done so.⁶⁶ EPA could also go further and amend the regulation that governs the CERCLA cleanup process, called the National Contingency Plan, to require more systematic consideration of climate change when identifying sites to be listed as Superfund sites, selecting the remedy, and monitoring its effectiveness.⁶⁷

EPA is considering listing certain per- and polyfluoroalkyl substances chemicals as hazardous substances under

55. David E. Kramar, *A Spatially Informed Analysis of Environmental Justice: Analyzing the Effects of Gerrymandering and the Proximity of Minority Populations to U.S. Superfund Sites*, 11 ENV'T JUST. 29 (2018); JACOB CARTER & CASEY KALMAN, UNION OF CONCERNED SCIENTISTS, A TOXIC RELATIONSHIP: EXTREME COASTAL FLOODING AND SUPERFUND SITES 6-7 (2020); U.S. EPA, POPULATION SURROUNDING 1,857 SUPERFUND REMEDIAL SITES (2020), <https://www.epa.gov/sites/default/files/2015-09/documents/web-population-superfund-sites-9.28.15.pdf>.

56. GAO, SUPERFUND: EPA SHOULD TAKE ADDITIONAL ACTIONS TO MANAGE RISKS FROM CLIMATE CHANGE 18 (2019).

57. OFFICE OF LAND AND EMERGENCY MANAGEMENT, U.S. EPA, EVALUATION OF REMEDY RESILIENCE AT SUPERFUND NPL AND SAA SITES (2018), <https://www.epa.gov/sites/default/files/2019-02/documents/evaluation-of-remedy-resilience-at-superfund-npl-and-saa-sites.pdf>.

58. Kiah Collier, *EPA: Hurricane Harvey Compromised Cap on Toxic Waste Site*, TEX. TRIB. (Sept. 29, 2017), <https://www.texastribune.org/2017/09/29/epa-hurricane-harvey-compromised-caps-toxic-waste-site/>; David Hase-myer & Lise Olsen, *Battered, Flooded, and Submerged: Many Superfund Sites Are Dangerously Threatened by Climate Change*, INSIDE CLIMATE NEWS (Sept. 24, 2020), <https://insideclimatenews.org/news/24092020/climate-change-epa-superfund-sites-hurricanes-floods-fires-sea-level-rise/>.

59. Christopher Flavelle, *"Toxic Stew" Stirred Up by Disasters Poses Long-Term Danger, New Findings Show*, N.Y. TIMES (July 15, 2019), <https://www.ny-times.com/2019/07/15/climate/flooding-chemicals-health-research.html>.

60. U.S. EPA, CLIMATE ADAPTATION ACTION PLAN 5-6 (2021); OFFICE OF SOLID WASTE AND EMERGENCY RESPONSE, U.S. EPA, CLIMATE CHANGE ADAPTATION IMPLEMENTATION PLAN 6 (2014); U.S. EPA, CLIMATE CHANGE ADAPTATION TECHNICAL FACT SHEET: CONTAMINATED SEDIMENT REMEDIES (2015).

61. INVESTIGATION AND REMEDY SELECTION FOCUS GROUP, ASSOCIATION OF STATE AND TERRITORIAL SOLID WASTE MANAGEMENT OFFICIALS, PLANNING FOR RESILIENCY AND SUSTAINABILITY IN A CHANGING CLIMATE 12-13, 18, 24-25 (2022), https://astswmo.org/files/Policies_and_Publications/CERCLA_and_Brownfields/2022-04-Planning-for-Resiliency-and-Sustainability-in-a-Changing-Climate.pdf; U.S. EPA, CLIMATE CHANGE ADAPTATION TECHNICAL FACT SHEET: GROUNDWATER REMEDIATION SYSTEMS (2013).

62. Memorandum from Larry Douchand, Director, Office of Superfund Remediation and Technology Innovation, U.S. EPA, to Regional Superfund National Program Managers, Regions 1-10, U.S. EPA, Consideration of Climate Resilience in the Superfund Cleanup Process for Non-Federal National Priorities List Sites (June 30, 2021), <https://semsubpub.epa.gov/work/HQ/100002993.pdf>. See also U.S. EPA, *Superfund Climate Resilience*, <https://www.epa.gov/superfund/superfund-climate-resilience> (last updated Oct. 27, 2022); Emily Russell, *Superfund and Climate Change: Lessons From Hurricane Sandy*, NAT. RES. & ENV'T, Winter 2014, at 3.

63. U.S. EPA, *American Cyanamid Superfund Site Reduces Climate Exposure*, <https://www.epa.gov/arc-x/american-cyanamid-superfund-site-reduces-climate-exposure> (last updated May 12, 2022).

64. 42 U.S.C. §9621(c).

65. Katrina Fischer Kuh, *Climate Change and CERCLA Remedies: Adaptation Strategies for Contaminated Sediment Sites*, 2 SEATTLE J. ENV'T L. 61, 75-76 (2012); Gregory E. Wannier, *Infrastructure, in THE LAW OF ADAPTATION TO CLIMATE CHANGE* 198 (Michael B. Gerrard & Katrina Fischer Kuh eds., American Bar Association 2012).

66. OZZY RODRIGUEZ, HARVARD LAW SCHOOL ENVIRONMENTAL AND ENERGY LAW PROGRAM, ADAPTING SUPERFUND REMEDIAL PLANS FOR CLIMATE CHANGE (2021), <https://eelp.law.harvard.edu/2021/03/adapting-superfund-remedial-plans-for-climate-change/>.

67. See Lindsey Dundas, *CERCLA: It's Time to Prioritize Climate Threats*, 91 U. COLO. L. REV. 283 (2020).

CERCLA. If it does so, that could require a new look at the selected remedies at many Superfund sites. This could provide a good occasion for also looking at the storm vulnerability of those sites.

States could secure more stringent cleanups of CERCLA sites by amending their coastal management plans under the federal Coastal Zone Management Act (CZMA)⁶⁸ to mandate more climate-resilient cleanups, making these requirements “applicable or relevant and appropriate requirements” that must be met in CERCLA cleanups.⁶⁹

II. Related Threats and Applicable Laws

Many hazardous liquids and gases are carried by pipelines. In 2022, the Pipeline and Hazardous Materials Safety Administration (PHMSA), part of the U.S. Department of Transportation, issued an advisory bulletin warning, stating:

[C]hanging weather patterns due to climate change, including increased rainfall and higher temperatures, may impact soil stability . . . [posing] a threat to the integrity of pipeline facilities if those threats are not identified and mitigated. Owners and operators should consider monitoring geological and environmental conditions, including changing weather patterns, in proximity to their facilities.⁷⁰

PHMSA documented numerous instances where earth movement had ruptured pipelines and caused the release of their often hazardous contents.⁷¹

One seldom-recognized risk arises if a site is downstream of a dam that is holding back a large volume of water. One investigation identified 81 dams in 24 states that, if they failed, could flood a major toxic waste site and potentially spread its contamination.⁷² The design of remedies at Superfund sites does not tend to consider this risk. Moreover, many dams are themselves holding back not only water, but also piles of contaminated sediment that have accumulated over the years; failure or removal of the dam would also release this contamination downstream.⁷³

For example, in 1973, a dam on the Hudson River was intentionally removed by its owner; a large quantity of sediment, heavily contaminated with PCBs from General Electric (GE) factories upstream, was washed downstream, the Hudson River became a Superfund site, and GE has spent about \$1.6 billion cleaning it up.⁷⁴ Around 1,700 dams have been identified in 44 states and Puerto Rico that are rated in poor or unsatisfactory condition and that could cause loss of life if they failed.⁷⁵ Moreover, these figures tend to reflect only the larger dams; there are around 2.5 million smaller “nonjurisdictional” dams, many of which may also be vulnerable to extreme weather events, and of those, an unknown number are holding back contaminated sediment.⁷⁶

Many dams and impoundments hold the ash that is generated in huge quantities by coal-fired power plants. About 185 pounds of coal ash are generated for each megawatt hour of electricity from a coal plant.⁷⁷ This ash, which often contains arsenic, mercury, chromium, and other contaminants,⁷⁸ is almost always kept in the open air without any cover. Many severe storms have washed over coal ash impoundments and swept the ash into nearby land or streams.⁷⁹ In December 2008, the dike holding up an impoundment of ash in Kingston, Tennessee, from Tennessee Valley Authority coal plants failed (not due to severe weather), releasing 5.4 million cubic yards of coal ash sludge; this led to a massive cleanup operation, and then to multiple lawsuits by nearby property owners, by workers who became sick performing the cleanup, and others.⁸⁰

Partly in reaction to this incident, in 2015, the Obama Administration issued regulations strengthening rules on the disposal of coal ash, but not listing it as a hazardous waste under RCRA, which might have required the

www.mercurynews.com/2015/11/04/state-warns-northern-california-dam-holding-back-arsenic-contaminated-tailings-may-collapse-this-winter/.

68. 16 U.S.C. §§1451-1466, ELR STAT. CZMA §§302-319.

69. Grace Pezzeminti, *Keeping Superfund Sites Above Water: Using State Coastal Management Plans to Prevent Storm Event Hazardous Waste Releases*, 13 GEO. WASH. J. ENERGY & ENV'T L. 142 (2022).

70. Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Earth Movement and Other Geological Hazards, 87 Fed. Reg. 33576 (June 2, 2022).

71. *Id.* at 33577.

72. James Dinneen & Alexander Kennedy, *Below Aging U.S. Dams, a Potential Toxic Calamity*, SALON (June 12, 2021), https://www.salon.com/2021/06/12/below-aging-us-dams-a-potential-toxic-calamity_partner/.

73. Michael Scott, *Gorge Dam's Toxic Stew Is Cuyahoga River's Biggest Barrier to Continued Improvement*, CLEV. PLAIN DEALER (June 16, 2019), <https://www.cleveland.com/news/2019/06/gorge-dams-toxic-stew-is-cuyahoga-rivers-biggest-barrier-to-continued-improvement.html>; Jeff Hull, *At Toxic Montana Dam, a River Now Runs Through It*, REUTERS (Mar. 28, 2008), <https://www.reuters.com/article/us-dam/at-toxic-montana-dam-a-river-now-runs-through-it-idUSN2834669620080329>; Associated Press, *State Warns Northern California Dam Holding Back Arsenic-Contaminated Tailings May Collapse This Winter*, MERCURY NEWS (Nov. 4, 2015), <https://>

74. GE, *How We Got Here*, <https://hudsonredging.com/about> (last visited Dec. 18, 2022); Jesse McKinley, *G.E. Spent Years Cleaning Up the Hudson. Was It Enough?*, N.Y. TIMES (Sept. 8, 2016), <https://www.nytimes.com/2016/09/09/nyregion/general-electric-pcb-hudson-river.html>.

75. David A. Lieb et al., *At Least 1,680 Dams Across the U.S. Pose Potential Risk*, ASSOCIATED PRESS (Nov. 11, 2019), <https://apnews.com/article/ne-state-wire-us-news-ap-top-news-sc-state-wire-dams-f5f09a300d394900a1a88362238dbf77>.

76. Peter K. Brewitt & Chelsea L.M. Colwyn, *Little Dams, Big Problems: The Legal and Policy Issues of Nonjurisdictional Dams*, 7 WIRES WATER e1393 (2020), <https://doi.org/10.1002/wat2.1393>.

77. Bill Nussey, *Straight Facts on the Environmental Impact of Coal: CO₂ Emissions, Pollution, Land, and Water*, FREEING ENERGY (June 5, 2020), <https://www.freeingenergy.com/environmental-impact-coal-water-co2-so2-mercury-pollution/>.

78. AMRIKA DEONARINE ET AL., U.S. GEOLOGIC SURVEY, TRACE ELEMENTS IN COAL ASH (2015).

79. Gavin Bade, *Hurricane Florence Triggers Coal Ash Spill, Cuts Power to Millions*, UTIL. DIVE (Sept. 17, 2018), <https://www.utilitydive.com/news/hurricane-florence-triggers-coal-ash-spill-cuts-power-to-millions/532491/>; James Bruggers, *In Hurricane Florence's Path: Giant Toxic Coal Ash Piles*, INSIDE CLIMATE NEWS (Sept. 12, 2018), <https://insideclimatenews.org/news/12092018/toxic-coal-ash-ponds-hurricane-florence-flood-collapse-risk-north-carolina-virginia/>; Zack Colman, *The Toxic Waste Threat That Climate Change Is Making Worse*, POLITICO (Aug. 26, 2019), <https://www.politico.com/story/2019/08/26/toxic-waste-climate-change-worse-1672998>.

80. *See* Adkisson v. Jacobs Eng'g Grp., 35 F.4th 421 (6th Cir. 2022); *Mays v. Tennessee Valley Auth.*, 699 F. Supp. 2d 991, 40 ELR 20103 (E.D. Tenn. 2010).

impoundments to be lined at the bottom and covered on top. The Trump Administration attempted to weaken those rules, but those efforts were struck down in court.⁸¹ In August 2022, Earthjustice brought a lawsuit against EPA seeking stronger rules on coal ash.⁸² According to Earthjustice, 172 coal ash impoundments fall within Federal Emergency Management Agency 100-year floodplains.⁸³

Flooding also afflicts another subject of outdoor disposal—hog waste. Especially in North Carolina, a major locus of the U.S. hog industry with around eight million hogs, the waste from concentrated animal feeding operations (CAFOs) is flushed into uncovered and unlined lagoons (as they are called) where bacteria partially break it down. Then, it is sprayed onto cropland, causing horrific odors and serious health problems for those living nearby, who are disproportionately African American.⁸⁴ Hurricanes have flooded these lagoons, spreading the foul mix over large areas and drowning thousands or tens of thousands of hogs and millions of chickens, which are then landfilled or incinerated.⁸⁵

These lagoons are regulated at the state rather than the federal level, and North Carolina, at least, has been notoriously lax. In 2000, Smithfield Foods, the world's leading pork producer, entered into an agreement with the North Carolina attorney general to fund a research program to find more environmentally sound methods of handling hog waste, but the results were modest.⁸⁶ In 2018, Smith-

field announced plans to cover most of its hog lagoons to protect them from rain and to capture the methane gas the waste generates for sale to generate energy (though that creates its own environmental problems).⁸⁷ Smithfield is owned by a Chinese company, and a considerable amount of pork is exported from North Carolina to China, where some of the environmental regulations of this industry are (surprisingly) tighter.⁸⁸ After years of complaints, in 2022, EPA launched a civil rights investigation into whether North Carolina's regulation of aspects of these operations involve environmental racism.⁸⁹

Another important kind of waste is municipal solid waste (MSW)—household garbage. In the United States, about one-half of it—146 million tons a year—goes to landfills.⁹⁰ There are now about 1,900 MSW landfills operating in the continental United States, and many more that are no longer operating (usually because they are full).⁹¹ A significant portion of these are located near a shoreline or river, or in a floodplain. One study found that in Florida, about 1,099 landfills (active or inactive) are within the present 100-year coastal flood zone, and this number will rise considerably as that zone expands.⁹²

Unlike hazardous waste landfills, MSW landfills are subject to few federal rules and are mostly under state or local control. Until the enactment of RCRA in 1976 and EPA's adoption of its implementing regulations in 1980, there was little legal distinction between hazardous waste and MSW, and much of what we now think of as hazardous waste went to MSW landfills. That was lawful unless local public health laws provided otherwise.

These landfills were often sited in low-lying areas, and most of them lacked such modern systems as leachate collection, methane capture, and impervious liners at the bottom and caps on top. When it rained, the water seeped through, picked up contaminants from the waste, and leaked nasty liquid into the groundwater below or the nearby streams. After the enactment of CERCLA in 1980,

81. *Utility Solid Waste Activities Grp. v. Environmental Prot. Agency*, 901 F.3d 414, 48 ELR 20151 (D.C. Cir. 2018); KATHERINE CLEMENTS, HARVARD LAW SCHOOL ENVIRONMENTAL AND ENERGY LAW PROGRAM, *THE COAL ASH RULE TRILOGY SPANNING OBAMA, TRUMP, AND THE D.C. CIRCUIT* (2020), <http://eelp.law.harvard.edu/wp-content/uploads/Coal-Ash-Rule-Triology-Clements.pdf>.

82. *Statewide Org. for Cmty. Empowerment v. Environmental Prot. Agency*, No. 1:22-cv-02562 (D.D.C. filed Aug. 25, 2022), https://earthjustice.org/sites/default/files/files/2022-08-25_complaint.pdf. See also ENVIRONMENTAL INTEGRITY PROJECT & EARTHJUSTICE, *POISONOUS COVERUP: THE WIDESPREAD FAILURE OF THE POWER INDUSTRY TO CLEAN UP COAL ASH DUMPS* (2022).

83. Joshua Irvine, *Rising Waters, Sinking Feeling: From the Great Lakes to the Ohio River, Climate Change Puts Coal Ash Impoundments at Risk*, GREAT LAKES NOW (Aug. 26, 2022), <https://www.greatlakesnow.org/2022/08/climate-change-puts-coal-ash-impoundments-at-risk/>.

84. Julia Kravchenko et al., *Mortality and Health Outcomes in North Carolina Communities Located in Close Proximity to Hog Concentrated Animal Feeding Operations*, 79 N.C. MED. J. 278 (2018).

85. Kendra Pierre-Louis, *Lagoons of Pig Waste Are Overflowing After Florence. Yes, That's as Nasty as It Sounds*, N.Y. TIMES (Sept. 19, 2018), <https://www.nytimes.com/2018/09/19/climate/florence-hog-farms.html>; *Hurricane Florence: Carolina Pig Waste Lagoons Overflow*, BBC (Sept. 19, 2018), <https://www.bbc.com/news/world-us-canada-45578485>; Jennifer Lu, *During a Hurricane, Where Does All the Pig Poop Go? Into Your Water*, POPULAR SCI. (Sept. 25, 2018), <https://www.popsci.com/hurricane-flood-pig-poop/>; Michael Graff, *Millions of Dead Chickens and Pigs Found in Hurricane Floods*, GUARDIAN (Sept. 22, 2018), <https://www.theguardian.com/environment/2018/sep/21/hurricane-florence-flooding-north-carolina>; Kelli Bender, *3.4 Million Chickens, Thousands of Pigs Dead in North Carolina Following Hurricane Florence*, PEOPLE (Sept. 19, 2018), <https://people.com/pets/3-million-chickens-thousands-of-pigs-dead-hurricane-florence/>; Jedediah Purdy, *The Unequal Distribution of Catastrophe in North Carolina*, NEW YORKER (Sept. 18, 2018), <https://www.newyorker.com/news/our-columnists/the-unequal-distribution-of-catastrophe-in-north-carolina>.

86. D. Lee Miller & Ryke Longest, *Reconciling Environmental Justice With Climate Change Mitigation: A Case Study of NC Swine CAFOs*, 21 VT. J. ENV'T L. 523 (2020); Talia Buford, *A Hog Waste Agreement Lacked Teeth, and Some North Carolinians Say They're Left to Suffer*, PROPUBLICA (Nov. 23, 2018),

<https://www.propublica.org/article/a-hog-waste-agreement-lacked-teeth-and-some-north-carolinians-say-left-to-suffer>.

87. Greg Barnes, *Smithfield Announces Plans to Cover Hog Lagoons, Produce Renewable Energy*, NC HEALTH NEWS (Oct. 29, 2018), <https://www.northcarolinahealthnews.org/2018/10/29/plans-to-cover-hog-lagoons/>; Michael Sainato & Chelsea Skojec, *The North Carolina Hog Industry's Answer to Pollution: A \$500m Pipeline Project*, GUARDIAN (Dec. 11, 2020), <https://www.theguardian.com/us-news/2020/dec/11/north-carolina-hog-industry-lagoons-pipeline>.

88. Doug Bock Clark, *Why Is China Treating North Carolina Like the Developing World?*, ROLLING STONE (Mar. 19, 2018), <https://www.rollingstone.com/politics/politics-news/why-is-china-treating-north-carolina-like-the-developing-world-122892/>; CORBAN ADDISON, *WASTELANDS: THE TRUE STORY OF FARM COUNTRY ON TRIAL* 64-67 (2022).

89. Aman Azhar, *EPA to Probe Whether North Carolina's Permitting of Biogas From Swine Feeding Operations Violates Civil Rights of Nearby Neighborhoods*, INSIDE CLIMATE NEWS (Jan. 25, 2022), <https://insideclimatenews.org/news/25012022/epa-north-carolina-cafo-biogas-permit/>.

90. U.S. EPA, *National Overview: Facts and Figures on Materials, Wastes, and Recycling*, <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials> (last updated Dec. 3, 2022).

91. U.S. EPA, *Municipal Solid Waste Landfills*, <https://www.epa.gov/landfills/municipal-solid-waste-landfills> (last updated Apr. 25, 2022).

92. Robert J. Nicholls, *Coastal Landfills and Rising Sea Levels: A Challenge for the 21st Century*, 8 FRONTIERS MARINE SCI. 1, 14 (2021).

many of them became Superfund sites. Today, more than 250 of the landfills that received both hazardous waste and MSW are on the National Priorities List—about 23% of all sites on that list.⁹³

These landfills were not sited or designed with sea-level rise or extreme flooding in mind, and their often primitive engineering means they are vulnerable to extreme weather. They are typically covered with soil and vegetation, and unless they are well maintained, the soil can erode or be washed away, exposing the waste. Rising groundwater—especially if salty—can eat away at whatever liners are there.⁹⁴ If near the shore, some long-buried waste is uncovered and carried away by the waves; this “zombie garbage,” as it has been called, adds to the plastics in the ocean.⁹⁵ Some landfills are so buoyant that if the groundwater below them rises and is not continually pumped out (into perpetuity, one presumes), they can creep upward, breaking their covers, liners, and piping.⁹⁶

So far, the discussion has concerned how climate change affects waste that exists anyway. But the storms and wildfires that are worsened by climate change can themselves create very large volumes of waste: the debris left behind. The destroyed buildings, toppled trees, and everything else will block roads and cause health and safety hazards, and need to be quickly removed.

Hurricane Harvey created about 25 million cubic yards of debris, which is two-thirds of the total amount of MSW that Houston would ordinarily generate in a year.⁹⁷ The usual systems could not handle that surge of waste. The state suspended many of its rules for waste handling and disposal, set up 228 temporary debris management sites, allowed 25 landfills to exceed their permit limits, burned vegetative debris in special incinerators, and used employees and contractors to haul tens of thousands of loads in

trucks.⁹⁸ Hurricane Katrina generated about four times that much debris, and its removal and disposal cost \$3.7 billion.⁹⁹ Wildfires create similar mounds of debris (though, of course, they have been pre-incinerated),¹⁰⁰ and depending on what they burn can spew dangerous levels of toxins into the air.¹⁰¹

The orderly and lawful demolition of a building involves the careful removal of asbestos-containing material, the draining of ozone-depleting substances from refrigerators, and the special handling and disposal of other hazardous materials. After a disaster, these niceties may not be possible; EPA and other agencies grant emergency exemptions or look the other way, and the landfills where the debris is taken may become laden with yet more toxic material.¹⁰² The debris often goes to old unlined landfills that had been closed but are reactivated for this purpose. In many places, these landfills are disproportionately located in disadvantaged communities.¹⁰³

III. How Should the Law Change to Cope With 4°C?

The environment does not care whether a chemical that has gotten into the air, water, or land is a waste or a product, or whether it was released while in storage or in transport, or accidentally or deliberately. But the law cares. The environmental statutes and regulations were written at different times and in response to different concerns or incidents, and they reflect interest group lobbying. The result is an often bewildering patchwork of requirements where the care with which a substance is handled depends on arcane regulatory distinctions that bear little relation to the actual environmental or health risk involved. Because RCRA covers only “waste,” the U.S. Court of Appeals for the District of Columbia (D.C.) Circuit famously spoke of its “mind-

93. FindLaw, *Municipal Superfund Liability*, <https://corporate.findlaw.com/library/municipal-superfund-liability.html> (last updated Mar. 26, 2008).

94. Flynn et al., *supra* note 43; Xunchang Fei et al., *Climate Change Affects Land-Disposed Waste*, 11 NATURE CLIMATE CHANGE 1004 (2021); Stephen Stock et al., *Toxins Long Buried May Surface as Groundwater Rises*, NBC BAY AREA (Nov. 5, 2021), <https://www.nbcbayarea.com/investigations/toxins-long-buried-may-surface-as-groundwater-rises/2718842/>.

95. Michael Allen, *The Future Is Full of Zombie Garbage*, HAKAI MAG. (Dec. 15, 2021), <https://hakaimagazine.com/news/the-future-is-full-of-zombie-garbage/>; Tarek Bazley, *Climate Change Erosion Feeding Deep Ocean Trash Dump*, AL JAZEERA (Apr. 15, 2019), <https://www.aljazeera.com/news/2019/4/15/climate-change-erosion-feeding-deep-ocean-trash-dump>.

96. OFFICE OF RESEARCH AND DEVELOPMENT, U.S. EPA, VULNERABILITY OF WASTE INFRASTRUCTURE TO CLIMATE INDUCED IMPACTS IN COASTAL COMMUNITIES 30 (2019).

97. *Hearing Before the Subcomm. on Superfund, Waste Mgmt. & Regul. Oversight of the S. Comm. on Env't & Pub. Works*, 115th Cong. 2 (2017) (testimony of Bryan W. Shaw, Chairman, Texas Commission on Environmental Quality), https://www.epw.senate.gov/public/_cache/files/5/a/5ab74817-e4b0-4faa-bf51-918ff4d522d0/9AF7983F9000B93EB511829185A16E74.shaw-testimony-12.06.2017.pdf [hereinafter Testimony of Bryan W. Shaw]. One cubic yard of uncompacted MSW weighs about 225 pounds. See NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES, VOLUME-TO-WEIGHT CONVERSION FACTORS, <https://www.des.nh.gov/sites/g/files/ehbemt341/files/documents/vol-to-weight-conversion.pdf>. Houston generates about 4.3 million tons of MSW per year. See DAVID S. YANKE, NEW-GEN STRATEGIES AND SOLUTION, A MUNICIPAL SOLID WASTE GENERATION AND DIVERSION FORECAST FOR THE CITY OF HOUSTON 9 (2019), https://houstontx.gov/solidwaste/longrange/pdf/2019_4_25.pdf. That works out to 38.27 million cubic yards.

98. Testimony of Bryan W. Shaw, *supra* note 97, at 3; REBUILD TEXAS, EYE OF THE STORM: REPORT OF THE GOVERNOR'S COMMISSION TO REBUILD TEXAS 72-73 (2018).

99. U.S. EPA, PLANNING FOR NATURAL DISASTER DEBRIS 1 (2019).

100. Emily C. Dooley, *Hauling Away California Fire Rubble to Take a Year, Cost Billions*, BLOOMBERG (Dec. 7, 2018), <https://news.bloomberglaw.com/environment-and-energy/hauling-away-california-fire-rubble-to-take-a-year-cost-billions>; Sarah Maslin Nir, *In California, Houses Burned, So Did the Toxic Chemicals They Contained*, N.Y. TIMES (Nov. 29, 2018), <https://www.nytimes.com/2018/11/29/us/california-fire-chemicals.html>; Dale Kasler, *“Toxic-Laden Stuff.” Will Anyone Take the Camp Fire Debris From Paradise?*, SACRAMENTO BEE (Dec. 31, 2018), <https://www.sacbee.com/news/california/fires/article223763895.html>.

101. Matt Vasilogambros, *Proliferating Wildfires Poison Public Health Across the Country*, PEW (Oct. 17, 2022), <https://www.pewtrusts.org/en/research-and-analysis/blogs/stateline/2022/10/17/proliferating-wildfires-poison-public-health-across-the-country>; Press Release, California Air Resources Board, New Analysis Shows Spikes of Metal Contaminants, Including Lead, in 2018 Camp Fire Wildfire Smoke (July 12, 2021), <https://ww2.arb.ca.gov/news/new-analysis-shows-spikes-metal-contaminants-including-lead-2018-camp-fire-wildfire-smoke>; Rosana Aguilera et al., *Wildfire Smoke Impacts Respiratory Health More Than Fine Particles From Other Sources: Observational Evidence From Southern California*, 12 NATURE COMM'NS 1493 (2021), available at <https://www.nature.com/articles/s41467-021-21708-0>.

102. U.S. EPA, *supra* note 99; Michael B. Gerrard, *Emergency Exemptions From Environmental Laws After Disasters*, 20 NAT. RES. & ENV'T 10 (2006).

103. ROBERT R.M. VERCHICK, FACING CATASTROPHE: ENVIRONMENTAL ACTION FOR A POST-KATRINA WORLD 134-35 (2010).

numbering journey through RCRA” in determining whether a certain kind of slag was a waste.¹⁰⁴

Because RCRA’s jurisdiction is limited to waste and oil, its regulations’ extremely detailed command-and-control rules only apply narrowly. EPCRA covers products as well as wastes, but it only requires planning and disclosure; it does not have substantive regulatory requirements. The Hazardous Materials Transportation Act covers a broad array of substances, and does have substantive requirements, but it only applies to transport-related activities. CERCLA also applies to many materials (but excludes petroleum) and imposes substantive rules, but only for the cleanup process. The Toxic Substances Control Act (TSCA),¹⁰⁵ despite its broad-sounding name, applies mainly to chemicals that are newly introduced into commerce, with a limited look back at old ones.

The regulations in place have great complexity. EPA’s regulations under RCRA, CERCLA, EPCRA, and TSCA take up five volumes of fine print in the *Code of Federal Regulations*; the U.S. Department of Transportation’s regulations under the Hazardous Materials Transportation Act are another two volumes. However, the regulations were all written during a 1°C world. Some of them attempt to prepare for the sorts of extreme events that occur during a one-degree world, such as flash floods that quickly subside.

But none envisions a 3°C or 4°C world, whose day-to-day may resemble today’s extremes; and it is challenging to find even rough depictions of an extreme day in such a world (at least outside of the growing genre of “Cli-Fi”—climate fiction—and its post-apocalyptic visions). The most sophisticated of today’s engineered landfill designs will not work if the landfill is entirely under water or is engulfed in flames. Systems that depend on a continuous flow of water have problems if the rivers have run dry.

As discussed above, EPA could do more with its existing statutory authorities to reduce the spread of hazardous materials caused by extreme weather events. It could revise the National Contingency Plan under CERCLA, strengthen the regulation of coal ash under RCRA, expand the requirements for spill prevention and countermeasure plans under the CWA and the OPA, and make greater use of §112(r) of the CAA, all to explicitly require greater precautions against floods, storms, and wildfires. But this would only take us so far.

The current system with idiosyncratically different legal requirements applying to very similar activities is dysfunctional if we are heading toward a 4°C world. If the objective is to keep harmful chemicals out of the environment, it should not matter whether they are wastes or products. They should be subject to the same kinds of command-and-control rules based on their physical properties. (For some kinds of installations, technology standards may be best; for others, performance standards.) The facilities handling these chemicals should be able to withstand the con-

ditions reasonably likely to occur (flooding, heat, etc.) at the end of their useful lives.

Flood maps that reflect the latest projections of future flooding should be utilized when siting and designing new facilities. Such maps should be used in the reviews of proposed projects that are subject to the National Environmental Policy Act (NEPA)¹⁰⁶ or its state equivalents. EPA’s Risk Management Program Rule and OSHA’s Process Safety Management Standard both require that facility siting be considered,¹⁰⁷ and EPA’s 2022 proposed revisions called for more care in siting facilities, though the focus was on proximity to residential communities rather than site vulnerability to extreme weather events.¹⁰⁸

The situation for *existing* facilities is considerably different. It is one thing to site, design, and build a new facility to withstand future conditions; it is another thing entirely to retrofit a facility that is already in operation (or maybe closed long ago, but has left waste behind). Sometimes sensitive equipment can be raised or protective walls can be built, but often it is not physically possible or economically feasible to protect these places fully.

However, for facilities subject to CAA §112(r), the plans prepared in accordance with EPA’s August 2022 proposal would go a long way toward at least requiring companies to consider climate risks in their facility operations. A particularly important measure to protect facilities that handle dangerous chemicals is enhancing the resilience of the electric power supply, coupled with emergency generators that can withstand extreme weather and have ample fuel supplies, since loss of power has become a common cause of chemical releases, and extreme weather is leading to more power outages.¹⁰⁹

As noted above, CAA §112(r) gives facilities a “general duty” to minimize hazards. EPA has interpreted this “to generally require owners and operators to adhere to recognized industry practices and standards in addition to any applicable government regulations.”¹¹⁰ If the organizations that set industry standards, such as the American Institute of Chemical Engineers and the American Society of Mechanical Engineers, were to establish standards that required consideration of future sea-level rise and other climate-related events in facility siting and operations, that would have important legal and practical effect.

One important step would be to create a nationwide inventory of the existing chemical and waste facilities and contaminated sites that are vulnerable to flooding under likely future climate conditions. (Ideally, the inventory would also reflect future wildfire conditions, but for these the mapping is far less advanced.) Then, decisions need to

104. *American Mining Cong. v. Environmental Prot. Agency*, 824 F.2d 1177, 1189, 17 ELR 21064 (D.C. Cir. 1987).

105. 15 U.S.C. §§2601-2692, ELR STAT. TSCA §§2-412.

106. 42 U.S.C. §§4321-4370h, ELR STAT. NEPA §§2-209.

107. 29 C.F.R. §1910.119(e)(3)(v); 40 C.F.R. §68.67(c)(5).

108. *Accidental Release Prevention Requirements: Risk Management Programs Under the Clean Air Act; Safer Communities by Chemical Accident Prevention*, 87 Fed. Reg. 53556, 53571-74 (Aug. 31, 2022).

109. *Id.* at 53570.

110. *Order Denying a Petition for Objection to Permit, In re Hazlehurst Wood Pellets, LLC*, Petition No. IV-202-0-5, at 13 (EPA Dec. 31, 2020), <https://www.epa.gov/sites/default/files/2021-01/documents/hazlehurstorder2020.pdf>.

be made about priorities. Different facilities will have different probabilities of flooding, and different health and environmental consequences if they do flood. They also have capacities to pay for improvements ranging from considerable (for some currently operating facilities) to zero (for many and probably most closed facilities).

Difficult choices will be needed in setting priorities, beyond just the calculation of risks, hazards, and costs (complex as those may be). That is particularly the case with CERCLA, the law that imposes the most stringent cleanup requirements. A common rationale in choosing CERCLA remedies is to avoid even a small health risk to people who, some day in the future, may drink water from under the site, or to children who someday may play in the dirt there.¹¹¹

But it makes little sense to spend large sums of money (especially public money) cleaning up sites for future residents of places that will become uninhabitable as a result of climate change. It is true that contaminants from these sites may leak out and cause some environmental damage, but in a 4°C world, the chemicals carried in the water from the globe's flooded waste and industrial sites could make those from many U.S. Superfund sites seem trivial. (To be fair, I have seen no study about this.) Scarce resources should be directed to actions that would have the greatest benefit.

Some have suggested that the waste in landfills that will be flooded should be moved to other locations.¹¹² However, digging up buried waste poses dangers to the construction workers; it can cause some of the waste to become airborne and enter nearby communities; and hauling it by trucks to new disposal locations will, statistically, cause a certain number of fatal accidents. Several studies have found that

these risks can exceed, perhaps by orders of magnitude, the risks to the site neighbors of the contamination staying in place.¹¹³ Moreover, finding a new place for the material is likely to be extraordinarily difficult. It is hard enough to find disposal locations for waste that was generated nearby; persuading a community to accept someone else's trash (or ramming it down their throats) is even harder.

The massive containment areas for coal ash are typically owned or controlled by the electric utilities that used them, and these utilities should be responsible for covering them in a way that protects them from flooding. Likewise, the lagoons with hog waste should be protected from flooding, and the large pork companies that sold the meat from these operations should pay for all of this. Unlike CERCLA, where the wastes are often underground, the coal ash and hog waste are very vulnerable to flooding that could cause considerable harm.

It would be wonderful if society stopped generating the wastes that require disposal. The phaseout of coal as a source of electricity—an essential part of any decarbonization strategy—will stop the generation of coal ash. Though recycling and composting will moderate the amount of MSW, trends do not indicate major progress in eliminating it.¹¹⁴ Generation of RCRA hazardous waste has been about flat for the past two decades.¹¹⁵ Nor is there a marked downward trend in pork consumption.¹¹⁶

Under any scenario, large amounts of hazardous and noxious substances will continue to be created every day. Dealing with them, and with those that already exist, will be a great challenge as we approach a 4°C (or even a 2°C) world; we are not even doing it adequately in our current 1.2°C world.

111. Michael B. Gerrard, *Demons and Angels in Hazardous Waste Regulation: Are Justice, Efficiency, and Democracy Reconcilable?*, 92 Nw. U. L. REV. 706 (1998).

112. See Dave Lindorff, *Coastal Landfills Are No Match for Rising Seas*, NATION (July 26, 2021), <https://www.thenation.com/article/environment/coastal-landfill-climate-change/>; Press Release, White House Media LLC, Landfills Are an Important and Ignored Danger for Coastal Waters (Aug. 4, 2021), https://www.einnews.com/pr_news/548069824/landfills-are-an-impending-and-ignored-danger-for-coastal-waters.

113. See Michael B. Gerrard, *Safety Hazards in Hazardous Waste Remediation*, N.Y. L.J., July 26, 2002, at 3.

114. See figure “Municipal Solid Waste Management, 1960-2018” at U.S. EPA, *National Overview: Facts and Figures on Materials, Wastes, and Recycling*, <https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials> (last updated Dec. 3, 2022).

115. Deeba Yavrom, *An Overview of Hazardous Waste Generation*, U.S. EPA (Apr. 28, 2021), <https://rcrapublic.epa.gov/rcra-public-web/action/posts/2>.

116. Caroline Christen, *Meat Consumption in the U.S. Is Growing at an Alarming Rate*, SENTIENT MEDIA (Mar. 17, 2021), <https://sentientmedia.org/meat-consumption-in-the-us/>.