



DAB 16

U.S. Industrial Toxic Releases Analysis

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Submission Date: 25/11/2025



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1. INTRODUCTION

Industrial activities play a vital role in economic development, but they also contribute to the release of hazardous substances into the environment. Toxic chemical releases, whether to air, water, or land can pose significant risks to ecosystems, public health, and long-term sustainability. Understanding the scale, distribution, and trends of these releases is essential for informed environmental management and regulatory oversight.

Toxic chemicals are substances known to cause adverse effects on living organisms, including carcinogenicity, reproductive toxicity, and ecological harm. Common examples include heavy metals such as lead and mercury, and persistent, bioaccumulative, toxic (PBT) chemical.

Environmental monitoring and reporting systems, such as the Toxics Release Inventory (TRI), provide structured data to assess the quantity and type of chemicals released by industrial facilities. This information supports risk assessment, pollution prevention strategies, and community awareness.

2. PROBLEM STATEMENT

The **Toxic chemical released** in the **U.S.** demonstrate an **increase** by **6.2%** from **2020 to 2023** as reported in (Toxic Release Inventory) **TRI data**. This poses significant risks to ecosystems, public health, and long-term sustainability, increasing concerns about waste management pathway.

3. APPROACHES

3.1. Sectors and Facilities Trend

- What is the trend of total release quantity?
- How is the industrial sectors toxic releases contribution?
- How many reported facilities are in each sector? And how many are federal facility?

3.2. Regional Pattern

- How did total toxic releases change across the U.S. from 2020 to 2023?
- What is the top chemical class release in each state?

3.3. Releases Insights

- What is the pattern for each chemical class over the years?
- Did newly tracked chemicals (PFAS) show consistent growth in reporting since 2020?

3.4. Release Routes

- How much toxic chemicals released on-site versus off-site? And what is their pathway?

3.5. Reported Vs. Processed Quantities

- Is the manually reported quantities are close to the measured ones?

4. TARGET AUDIENCE

- U.S. State Environmental Agencies: State health & environmental protection offices
- EPA Administrator: Head of the U.S. Environmental Protection Agency
- Director of the EPA Toxics Release Inventory (TRI) Program

5. DATASET

This section of the report includes a detailed description of the data used in the analysis, including the data dictionary and data types. [1]

Column Name	Column Type	Column Description
YEAR	Integer	Calendar year in which the reported activities occurred.
TRIFID	Object	The unique TRI facility identification number assigned to each facility for TRI reporting purposes.
FRS ID	Float	Unique identification number assigned by EPA's Facility Registry Service (FRS) to the TRI facility.
FACILITY NAME	Object	Name of the reporting facility.
STREET ADDRESS	Object	Street address of the reporting facility.
CITY	Object	City in which the reporting facility is located.
COUNTY	Object	County in which the reporting facility is located.
STATE	Object	Two-letter state code of the reporting facility.
ZIP	Integer	ZIP code of the reporting facility.
BIA	Float	Three-letter Bureau of Indian Affairs (BIA) code indicating the tribe on whose land the reporting facility is located.
TRIBE	Object	Name of the tribe on whose land the reporting facility is located.
LATITUDE	Float	The latitude value that best represents the facility according to EPA's Facility Registry System (FRS).
LONGITUDE	Float	The longitude value that best represents the facility according to EPA's Facility Registry System (FRS).
HORIZONTAL DATUM	Object	The horizontal datum used in determining the latitude and longitude coordinates.

PARENT CO NAME	Object	Name of the corporation or other business entity that controls the reporting facility.
PARENT CO DB NUM	Object	Unique identification number assigned by Dun and Bradstreet to the parent company of the reporting facility.
STANDARDIZED PARENT COMPANY NAME	Object	A data field developed by EPA that is intended to best reflect the current ultimate U.S. parent company of the facility.
FOREIGN PARENT CO NAME	Object	Name of the foreign corporation that owns the facility if there is a higher-level parent company outside of the United States.
FOREIGN PARENT CO D&B NUM	Float	Unique identification number assigned by Dun and Bradstreet to the foreign parent company of the reporting facility, if one exists.
STND FOREIGN PARENT CO	Object	A data field developed by EPA that is intended to best reflect the current foreign parent company of the facility.
FEDERAL FACILITY IND	Object	Flag indicating whether the facility is federally owned and operated.
INDUSTRY SECTOR CODE	Integer	North American Industry Classification System (NAICS) code used to identify the facility's sector.
INDUSTRY SECTOR	Object	The industry or sector (e.g., Coal Mining, Metal Mining, Electrical Utilities, etc.) a facility belongs to. This categorization is primarily used to classify, analyze, and show industrial trends within TRI data.
PRIMARY SIC	Object	Primary 4-digit Standard Industrial Classification (SIC)

		code. Note: SIC codes were reported by facilities from RY 1987 through 2005.
SIC 2	Float	Second 4-digit Standard Industrial Classification (SIC) code entered by facility.
SIC 3	Float	Third four-digit Standard Industrial Classification (SIC) code entered by facility.
SIC 4	Float	Fourth four-digit Standard Industrial Classification (SIC) code entered by facility.
SIC 5	Float	Fifth four-digit Standard Industrial Classification (SIC) code entered by facility.
SIC 6	Float	Six four-digit Standard Industrial Classification (SIC) code entered by facility.
PRIMARY NAICS	Integer	Primary 6-digit North American Standard Industry Classification System (NAICS) code.
NAICS 2	Float	Second 6-digit North American Standard Industry Classification System (NAICS) code entered by facility.
NAICS 3	Float	Third 6-digit North American Standard Industry Classification System (NAICS) code entered by facility.
NAICS 4	Float	Fourth 6-digit North American Standard Industry Classification System (NAICS) code entered by facility.
NAICS 5	Float	Fifth 6-digit North American Standard Industry Classification System (NAICS) code entered by facility.
NAICS 6	Float	Sixth 6-digit North American Standard Industry Classification System

		(NAICS) code entered by facility.
DOC_CTRL_NUM	Integer	Unique identification number assigned to each TRI form submission.
CHEMICAL	Object	Name of the chemical as listed on the TRI chemical list, or generic name, if the chemical is claimed as a trade secret.
ELEMENTAL METAL INCLUDED IND	Object	Flag indicating whether the facility submitted a combined reporting form for a metal compound and the corresponding elemental metal. TRI started collecting this data element beginning with RY 2018.
TRI CHEMICAL /COMPOUND ID	Object	TRI Chemical ID is an internal program number that uniquely identifies chemical or category codes (for compounds).
CAS NUMBER	Object	Unique numerical identifier assigned by the Chemical Abstracts Service to every chemical substance.
SRS ID	Float	The Substance Registry System (SRS) identification number.
CLEAN AIR ACT CHEMICAL	Object	Flag indicating whether the chemical is listed as a hazardous air pollutant under the Clean Air Act (CAA).
CLASSIFICATION	Object	Indicates the classification of the chemical. Chemicals can be classified as either a dioxin or dioxin-like compound, a Persistent, Bioaccumulative and Toxic chemical, or a general EPCRA Section 313 chemical.
METAL	Object	Flag indicating whether the chemical is a metal with TRI reporting restrictions.

METAL CATEGORY	Object	Category of metal. Values are either 1, 2, 3, or 4.
CARCINOGEN	Object	Flag indicating whether the chemical is classified as a carcinogen by the Occupational Safety and Health Administration (OSHA).
PBT	Object	Flag indicating a chemical as a persistent, bioaccumulative, toxic (PBT) chemical.
PFAS	Object	Flag identifying a chemical as a per- and polyfluoroalkyl substance (PFAS). PFAS chemicals were added to TRI in reporting year 2020.
FORM TYPE	Object	Indicates whether the facility submitted a Reporting Form R or Form A Certification Statement.
UNIT OF MEASURE	Object	Indicates the unit of measure used to quantify the chemical. Dioxin and dioxin-like compounds are reported in grams, while all other TRI chemicals are reported in pounds.
5.1 – FUGITIVE AIR	Float	An estimate of the total quantity of the toxic chemical released as fugitive air emissions at the reporting facility.
5.2 – STACK AIR	Float	An estimate of the total quantity of the chemical released as stack (point source) air emissions at the reporting facility.
5.3 – WATER	Float	An estimate of the total quantity of the chemical released on site as surface water discharges.
5.4 – UNDERGROUND	Float	An estimate of the total quantity of the chemical injected on site at the facility into underground injection wells.

5.4.1 – UNDERGROUND CLASS I	Float	An estimate of the total quantity of the chemical injected on site at the facility into Class I wells.
5.4.2 – UNDERGROUND CLASS II-V	Float	An estimate of the total quantity of the chemical injected on site at the facility into Class II-V wells.
5.5.1 – LANDFILLS	Float	An estimate of the total quantity of the chemical released to landfills at the facility.
5.5.1A – RCRA C LANDFILLS	Float	An estimate of the total quantity of the chemical released to RCRA Subtitle C landfills at the facility.
5.5.1B – OTHER LANDFILLS	Float	An estimate of the total quantity of the chemical released to other on-site (non-RCRA Subtitle C) landfills.
5.5.2 – LAND TREATMENT	Float	An estimate of the quantity of the chemical disposed of through land treatment/application farming at the facility.
5.5.3 – SURFACE IMPOUNDMENT	Float	An estimate of the total quantity of the chemical released into surface impoundments at the facility.
5.5.3A – RCRA SURFACE IMPOUNDMENT	Float	An estimate of the total quantity of the chemical released into RCRA Subtitle C surface impoundments at the facility.
5.5.3B – OTHER SURFACE IMPOUNDMENT	Float	An estimate of the total quantity of the chemical released into other (non-RCRA Subtitle C) surface impoundments at the facility. This field was added in RY 2003.
5.5.4 – OTHER DISPOSAL	Float	An estimate of the total quantity of the chemical released to other disposal units (other than landfills,

		land treatment, and surface impoundments) at the facility.
ON-SITE RELEASE TOTAL	Float	Total quantity of the chemical released to the air, water, and land at the facility.
6.1 – POTW – TRANSFERS FOR RELEASE	Float	The total quantity of the chemical reported as transferred off site to a POTW for release or disposal.
POTW – TOTAL TRANSFERS	Float	The total quantity of the chemical reported as transferred off site to a POTW for further treatment.
6.2 – M10	Float	The total quantity of the chemical reported as transferred off site for disposal using code “M10: Storage Only.”
6.2 – M41	Float	The total quantity of a metal or metal compound reported as transferred off site for solidification/stabilization using disposal transfer code “M41: Solidification/Stabilization - Metals and Metal Category Compounds Only.”
6.2 – M62	Float	The total quantity of a metal or metal compound reported as transferred off site for wastewater treatment not at POTWs using disposal transfer code M62: “Wastewater Treatment (Excluding POTWs) – Metals and Metal Compounds Only.”
6.2 – M40 METAL	Float	Total quantity of the chemical reported as transferred off site for disposal using the code “M40: Solidification/Stabilization” when the chemical is a type 1 metal (Row #45, METAL CATEGORY = 1) or the chemical is Vanadium (Fume

		or Dust) or Vanadium (Except when contained in an alloy).
6.2 – M61 METAL	Float	Total quantity of the chemical reported as transferred off site for disposal using the code “M61: Wastewater Treatment (Excluding POTWs)” when the chemical is a type 1 metal (Row #45: METAL CATEGORY = 1) or the chemical is Vanadium (Fume or Dust) or Vanadium (Except when contained in an alloy).
6.2 – M71	Float	The total quantity of the chemical reported as transferred off site for disposal using the code “M71: Underground Injection.”
6.2 – M81	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M81: Underground Injection to Class I Wells.” This field was added in RY 2003.
6.2 – M82	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M82: Underground Injection to Class IIV Wells.” This field was added in RY 2003.
6.2 – M72	Float	The total quantity of the chemical reported as transferred off site for disposal using the code “M72: Landfills/Disposal Surface Impoundments.”
6.2 – M63	Float	The total quantity of the chemical reported as transferred off site for disposal using the code “M63: Surface Impoundment.”
6.2 – M66	Float	Total quantity of the chemical reported as transferred off site for disposal using code

		“M66: RCRA Subtitle C Surface Impoundments.”
6.2 – M67	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M67: Other Surface Impoundments.”
6.2 – M64	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M64: Other Landfills.” This field was added in RY 2002.
6.2 – M65	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M65: RCRA Subtitle C Landfills.”
6.2 – M73	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M73: Land Treatment.”
6.2 – M79	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M79: Other Land Disposal.”
6.2 – M90	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M90: Other Off-Site Management.”
6.2 – M94	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M94: Transfer to Waste Broker for Disposal.”
6.2 – M99	Float	Total quantity of the chemical reported as transferred off site for disposal using code “M99: Unknown.”
OFF-SITE RELEASE TOTAL	Float	Total quantity of the toxic chemical reported as transferred to off-site locations for release or disposal. Sum of rows #66 + (#69 through #87).

6.2 – M20	Float	Total quantity of the chemical reported as transferred off site for recycling using the code “M20: Solvents/Organics Recovery.”
6.2 – M24	Float	Total quantity of the chemical reported as transferred off site for recycling using the code “M24: Metals Recovery.”
6.2 – M26	Float	Total quantity of the chemical reported as transferred off site for recycling using the code “M26: Other Reuse or Recovery.”
6.2 – M28	Float	Total quantity of the chemical reported as transferred off site for recycling using the code “M28: Acid Regeneration.”
6.2 – M93	Float	Total quantity of the chemical reported as transferred off site to recycling using the code “M93: Transfer to Waste Broker - Recycling.”
OFF-SITE RECYCLED TOTAL	Float	Total quantity of the toxic chemical reported as transferred to off-site locations for recycling. Sum of rows #89 through #93.
6.2 – M56	Float	Total quantity of the chemical reported as transferred off site to energy recovery using the code “M56: Energy Recovery.”
6.2 – M92	Float	Total quantity of the chemical reported as transferred off site to energy recovery using the code “M92: Transfer to Waste Broker - Energy Recovery.”
OFF-SITE ENERGY RECOVERY TOTAL	Float	Total quantity of the toxic chemical reported as transferred to off-site locations for energy recovery. Sum of rows #95 and #96.
6.2 – M40 NON-METAL	Float	Total quantity of the non-metal chemical reported as transferred off site for

		<p>treatment using the code “M40: Solidification/Stabilization.” A chemical is considered a non-metal when it is NOT a type 1 metal (Row #45, METAL CATEGORY \neq 1) and the chemical is NOT Vanadium (Fume or Dust) and NOT Vanadium (Except when contained in an alloy).</p>
6.2 – M50	Float	Total quantity of the chemical reported as transferred off site for treatment using the code “M50: Incineration/Thermal Treatment.”
6.2 – M54	Float	Total quantity of the chemical reported as transferred off site for treatment using the code “M54: Incineration/Insignificant Fuel Value.”
6.2 – M61 NON-METAL	Float	Total quantity of the chemical reported as transferred off site to treatment using the code M61: “Wastewater Treatment (Excluding POTWs).” A chemical is considered a non-metal when it is NOT a type 1 metal (Row #45, METAL CATEGORY \neq 1) and the chemical is NOT Vanadium (Fume or Dust) and NOT Vanadium (Except when contained in an alloy).
6.2 – M69	Float	Total quantity of the chemical reported as transferred off site for treatment using the code “M69: Other Waste Treatment.”
6.2 – M95	Float	Total quantity of the chemical reported as transferred off site for treatment using the code “M95: Transfer to Waste Broker - Waste Treatment.”

OFF-SITE TREATED TOTAL	Float	Total quantity of the chemical reported as transferred off site for treatment. The sum of rows #67 + (#98 through #103).
6.2 – UNCLASSIFIED	Float	Total quantity of the chemical reported as transfer off-site as unclassified. This includes chemicals reported using code “M91: Transfers to Waste Broker” and other transfers that did not contain a specific transfer code.
6.2 – TOTAL TRANSFER	Float	Total quantity of the chemical reported as transferred off site. Sum of rows #88, #94, #97 and #104.
TOTAL RELEASES	Float	The total on- and off-site releases from sections 5 and 6 of the Form R. The value for this field equals On-site Release Total (row #65) + Off-site Release Total (row #88).
8.1 - RELEASES	Float	Amount of total on- and off-site releases as reported in Section 8, Source Reduction and Recycling Activities / Pollution Prevention.
8.1A – ON-SITE CONTAINED RELEASES	Float	Total quantity of on-site disposal to Class I underground injection wells, RCRA Subtitle C landfills and other landfills.
8.1B – ON-SITE OTHER RELEASES	Float	Other on-site disposal or release amounts not covered in section 8.1A of the reporting form.
8.1C – OFF-SITE CONTAINED RELEASES	Float	Total quantity of off-site disposal to Class I underground injection wells, RCRA Subtitle C landfills and other landfills.
8.1D – OFF-SITE OTHER RELEASES	Float	Other off-site disposal or release amounts not covered in Section 8.1 of the reporting

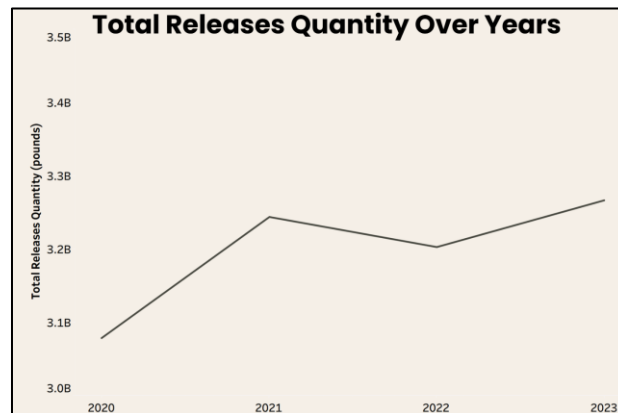
		form. Note: Beginning in RY 2003, the total releases in Section 8 of the Form R were broken up into four subcategories (rows #109-#112).
8.2 – ENERGY RECOVERY ON SITE	Float	The total quantity of the toxic chemical burned on site for energy recovery.
8.3 – ENERGY RECOVERY OFF SITE	Float	The total quantity of the toxic chemical sent off site to be burned for energy recovery.
8.4 – RECYCLING ON SITE	Float	The total quantity of the toxic chemical recycled on site at the facility
8.5 – RECYCLING OFF SITE	Float	The total quantity of the toxic chemical sent off site for recycling.
8.6 – TREATMENT ON SITE	Float	The total quantity of the toxic chemical treated on site at the facility.
8.7 – TREATMENT OFF SITE	Float	The total quantity of the toxic chemical sent off site for treatment (including transfers to POTWs).
PRODUCTION WASTE (8.1 – 8.7)	Float	The total quantity of production-related waste containing the chemical. This is the sum of the quantities in Section 8.1 through 8.7 of the Form R (rows #109 through #118).
8.8 – ONE-TIME RELEASE	Float	The total quantity of the chemical released into the environment or transferred off site due to events not associated with routine production processes.
PROD_RATIO_OR_ACTIVITY	Object	Indicates whether the value reported in Section 8.9 (see row #122) is a production ratio value or an activity index value.
8.9 – PRODUCTION RATIO	Float	The ratio of production or activity in the reporting year

		divided by production or activity in the previous year.
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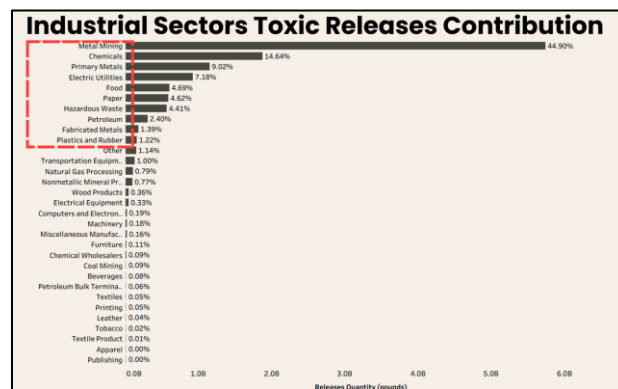
6. DATA HANDLING

For detailed information about data handling, refer to Jupyter notebook.

7. ANALYSIS AND FINDINGS

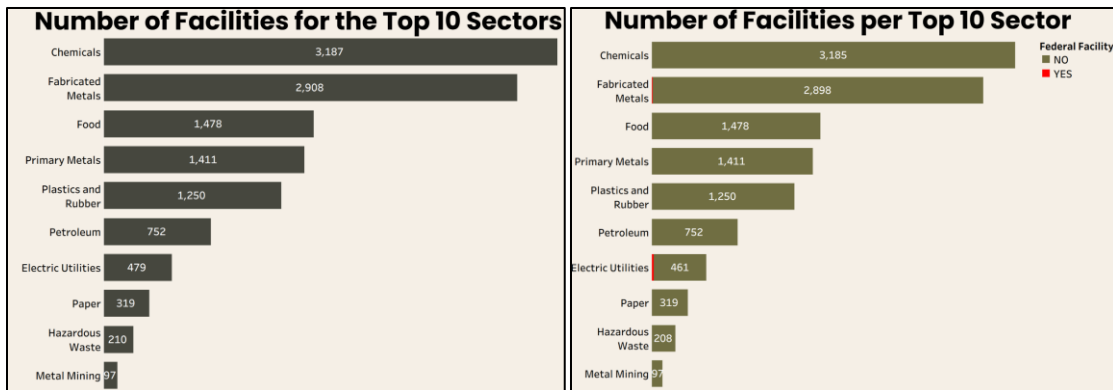


The toxic chemicals release in the U.S. increased by 6.2% over the studied time period. As it started as 3.1 B in 2020 and reached 3.3B in 2023.



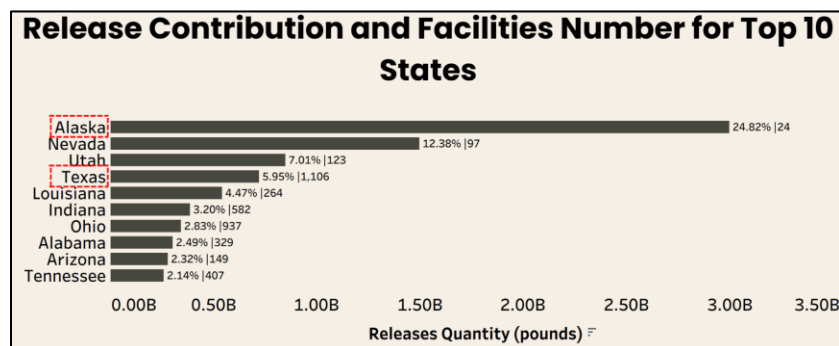
A small number of sectors dominate the TRI burden, suggesting that targeted interventions could yield significant reductions.

The top ten sectors they are highlighted in red, collectively account for over 94% of total releases with Metal Mining in the first place with approximately 45% contribution.

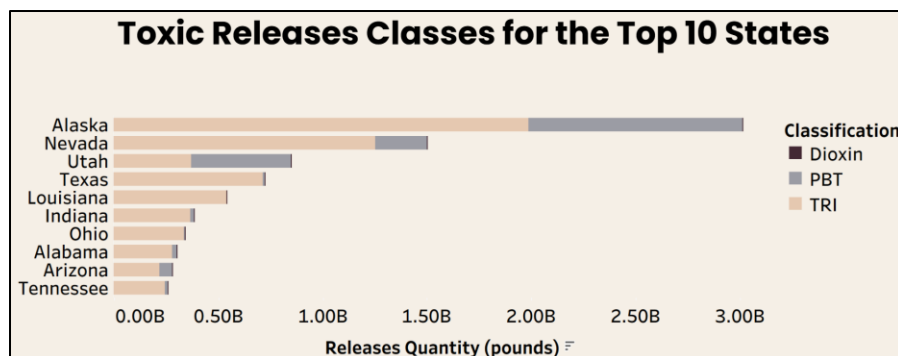


High facility count does not indicate high release volume as sectors like Chemicals and Fabricated Metals have many facilities but lower per facility release intensity compared to Metal Mining.

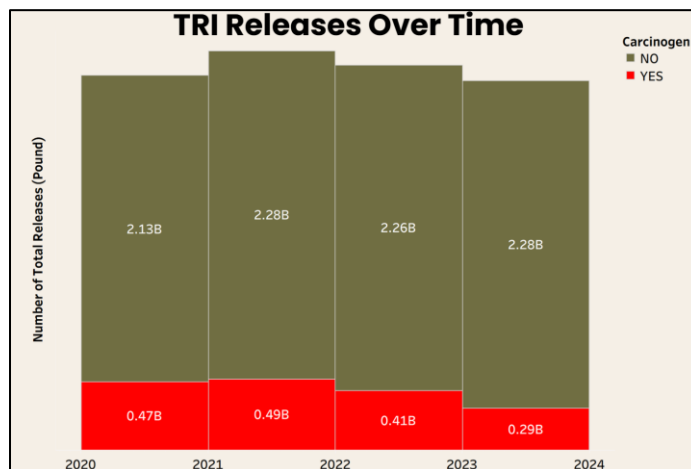
Federal oversight is limited. Most toxic releases originate from non-federal facilities, suggesting that state level regulation and private sector compliance are critical.



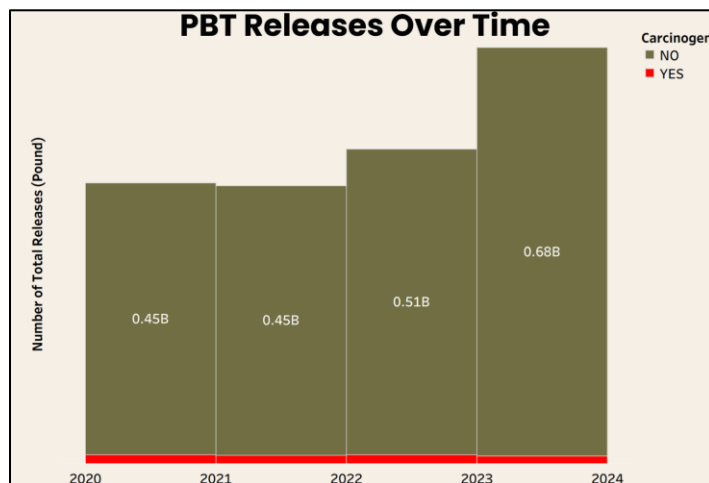
Alaska leads with nearly 25% of total releases approximately 3B pounds, with the lowest number of facilities. Hence, the main reason behind the quantity released is the production processes and their undesired byproducts. Alaska's low population density [2] means fewer people are directly exposed, but the ecological impact is significant. On the other hand, Texas ranks four in release percentage around 6%, however it has the highest number of facilities. It is worth to mention the Texas has large population size [2], therefore the pollution prevention strategies and community level risk assessments must be more tide.



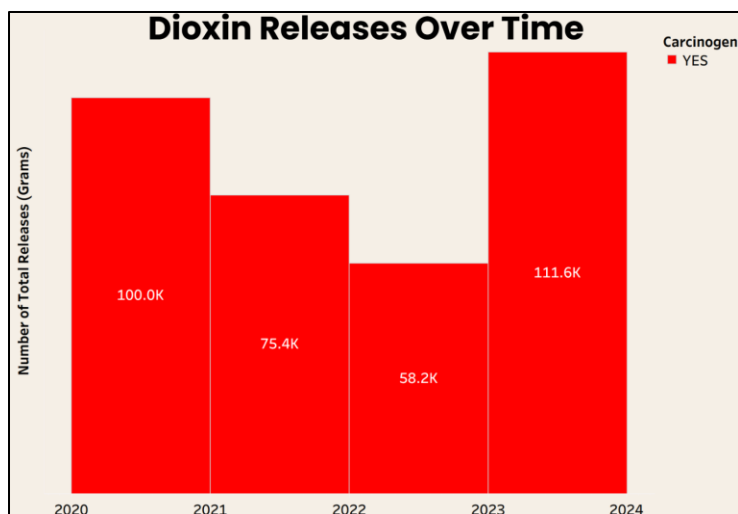
All three chemical classes (TRI, PBT, and Dioxin) are present across all top 10 states, indicating widespread diversity in toxic releases. However, the TRI class consistently dominates in every state. This is expected, as the TRI category encompasses a large number of listed chemicals making it the broadest and most frequently reported class in the inventory.



The annual total toxic releases reported under the Toxics Release Inventory (TRI), segmented by carcinogenic and non-carcinogenic substances shows that the total releases remain relatively stable, fluctuating between 2.61B and 2.57B. While Carcinogenic releases have declined from 0.47B in 2020 to 0.29B in 2023. Non-carcinogenic releases have increased, suggesting a shift in chemical usage or improved substitution practices.

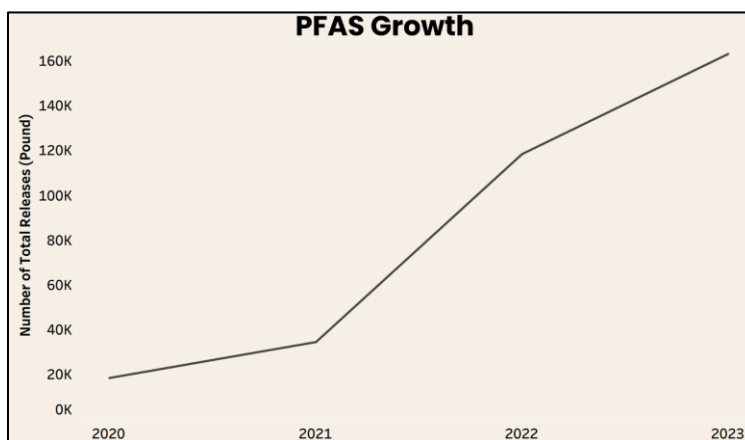


PBT Releases are increasing steadily over time mainly due to expansion of this class as the EPA added more PBT chemicals to the TRI list and lowered reporting thresholds, making previously unreported releases now visible.

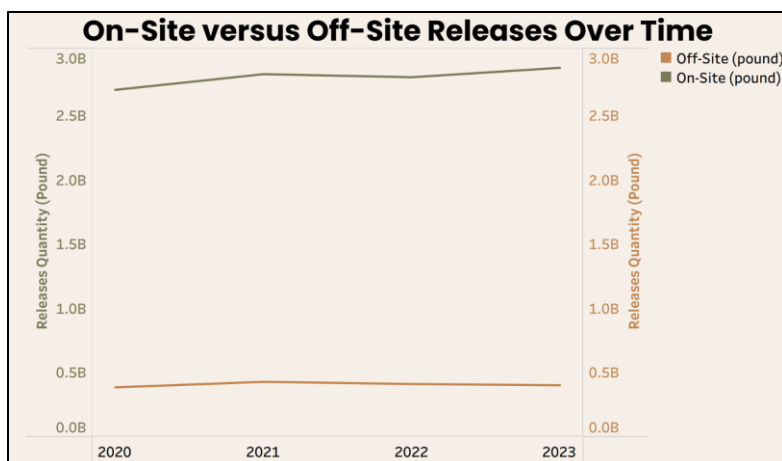


The decline in dioxin releases from 2021 to 2022 aligns with pandemic-related reductions in industrial activity. However, the sharp rebound in 2023 highlights the environmental consequences of resumed operations and deferred controls.

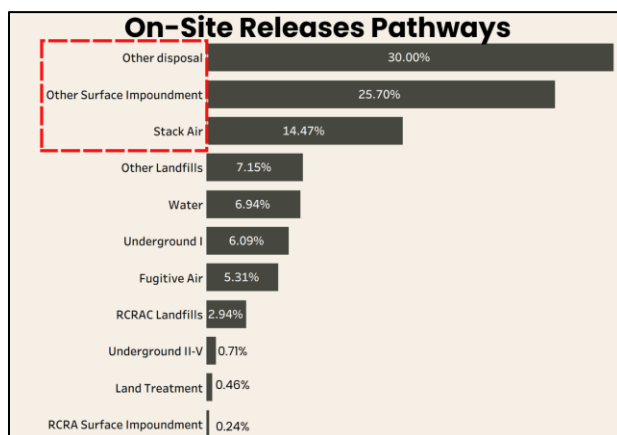
Dioxins are carcinogenic and persistent, so even small increases can have long-term health and ecological impacts.



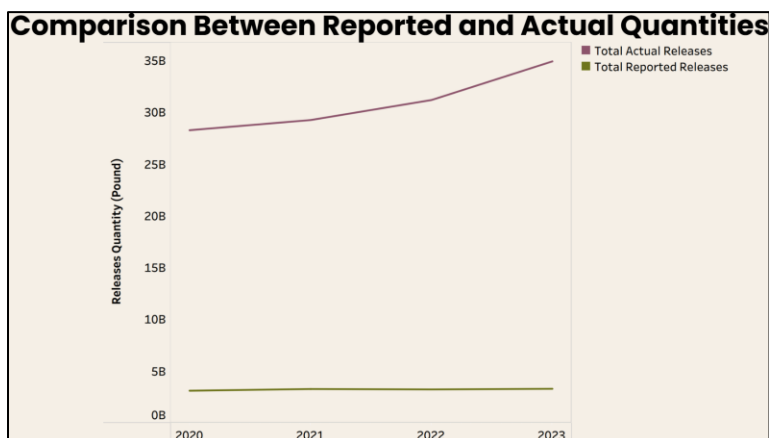
PFAS are persistent, bioaccumulative, and toxic, meaning even small releases can have long-term environmental and health consequences. This type of chemicals were added to the Toxics Release Inventory (TRI) starting in 2020 under the National Defense Authorization Act (NDAA). Initially, only a limited number of PFAS compounds were listed. In 2023, the EPA removed the de minimis exemption, requiring facilities to report PFAS even if present in small concentrations within mixtures. This significantly increased reported volumes.



The comparison between the quantity of toxic releases managed directly at the facility (on-site) versus those transferred elsewhere for treatment or disposal (off-site) from 2020 to 2023 reveal that on-site releases consistently dominate in volume. Which highlights the importance of strengthening on-site pollution control technologies, as they now represent the primary pathway for toxic chemical handling in the U.S. industrial landscape.



The data shows that three pathways for on-site toxic releases dominate, accounting for over 70% of all on-site releases. This reflect the significant contribution to environmental exposure.



While actual releases show a steady increase, reported releases remain flat and significantly lower, revealing a persistent gap between what facilities disclose and what is estimated or detected.

8. RECOMMENDATIONS

- Target high release states for oversight.
- Adopt Cleaner processing technologies for Metal Mining.
- Tighten the controls on manual releases reporting.
- Promote pollution prevention: PFAS-free formulations.

9. LIMITATIONS AND ASSUMPTIONS

- Self-reported data which can lead to underreporting.
- Incomplete coverage as TRI only includes facilities that meet specific employee count, industry type, and chemical threshold criteria.
- No Direct Exposure or Risk Metrics.

10. REFERENCES

[1] [TRI Basic Data Files: Calendar Years 1987-Present | US EPA](#)

[2] [State Population by Characteristics: 2020-2024](#)