



EFFLUENT VIOLATIONS IN THE U.S.

# Insights from 42 Years of NPDES Effluent Violations Data

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# Introduction

Effluent violations pose a significant threat to environmental and public health, as non-compliance with water discharge permits can result in the release of harmful pollutants into our waterways. This report provides an in-depth analysis of 42 years of effluent violation data from the National Pollutant Discharge Elimination System (NPDES), covering over four decades of compliance trends, industry-level insights, parameter-specific violations, and regional hotspots across the United States.

The goal of this report is to equip policymakers, environmental consultants, industry leaders, and advocacy organizations with actionable insights to better understand the scope, scale, and impact of effluent violations. For regulators and policymakers, the findings highlight critical areas for enforcement and resource allocation. For industries, the report sheds light on persistent compliance challenges, offering an opportunity to adopt proactive measures to improve performance. Advocacy groups and researchers can leverage these insights to advocate for stronger protections and smarter regulations.

## Why It Matters

Effluent violations directly affect the health of ecosystems, the safety of drinking water, and the economic vitality of communities reliant on clean water for agriculture, industry, and recreation. By understanding historical trends, identifying repeat offenders, and pinpointing geographic and industry-specific challenges, stakeholders can focus on targeted interventions to protect water resources.

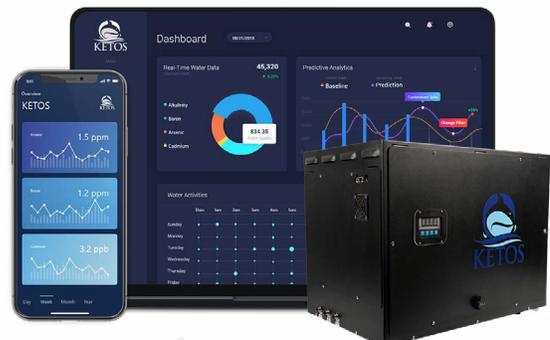


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## The Role of KETOS

KETOS offers an innovative solution to the persistent challenge of effluent violations by providing continuous, real-time water quality intelligence. With advanced automated monitoring systems, anomaly detection powered by AI, and seamless integration with industry-standard platforms, KETOS empowers facilities to detect and address compliance issues before they escalate. By enabling data-driven decision-making, KETOS helps industries meet regulatory standards, reduce the risk of costly violations, and safeguard the environment.

This report not only presents a retrospective analysis of NPDES data but also underscores the transformative potential of smart water quality monitoring in building a future of compliance, sustainability, and accountability.



# Dataset Overview

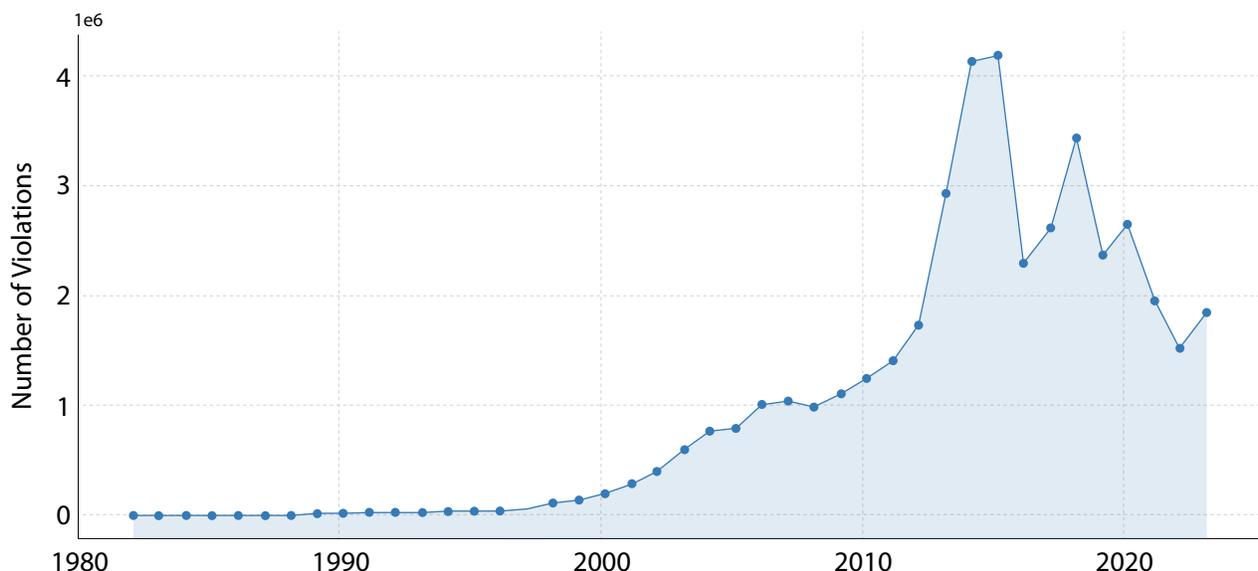
The NPDES Permit Effluent Violations dataset offers a comprehensive view of effluent violations data, spanning four decades of industrial and municipal activity. With its detailed records, this dataset serves as a vital resource for policymakers, industry leaders, and environmental consultants seeking to understand and address compliance challenges.

## Key Insights

- Total Violations:** The dataset documents a staggering 42.6 million unique violations, reflecting the scale of compliance issues across industries and regions.
- Time Coverage:** The dataset spans from 1982 to 2023, providing over four decades of data to analyze long-term trends in regulatory adherence and environmental impact.
- Unique Facilities:** The dataset encompasses 109,784 unique registry IDs, representing a broad spectrum of facilities, from small municipal plants to large industrial complexes.
- Permit Information:** It also contains 117,099 unique NPDES permits, highlighting the regulatory frameworks governing these facilities.
- Violations Over Time:** A time-series analysis shows fluctuations in the number of violations year over year. Understanding these trends helps stakeholders identify periods of significant non-compliance and evaluate the impact of policy changes over time.

The figure below identifies broad trends in the number of direct effluent violations over time. The number of violations steadily increased year over year before peaking and turning over in 2017. While earlier years (pre-2010) show less than 1000 direct effluent violations, it is possible that a lack of modern data management practices and reporting infrastructure led to fewer overall violations being reported in this period. We therefore limit our trend analysis in this report to the post-2010 period.

**Number of Unique Violations by Year (up to 2023)**



## Top Industries by Violations:

The industries with the highest number of violations offer valuable insights into sectors that require enhanced monitoring and compliance efforts.

NAICS Code	Industry Description	Violations
221320	Sewage Treatment Facilities	39,974,077
212111	Bituminous Coal and Lignite Surface Mining	2,212,919
531110	Lessors of Residential Buildings and Dwellings	1,782,979
221310	Water Supply and Irrigation Systems	349,988
212312	Crushed and Broken Limestone Mining and Quarrying	134,858
212321	Construction Sand and Gravel Mining	123,723
531190	Lessors of Other Real Estate Property	111,897
221210	Natural Gas Distribution	97,057
611110	Elementary and Secondary Schools	95,903



## Top Parameters Exceeded:

Violations associated with specific parameters highlight recurring compliance issues and their environmental implications.

Parameter Description	Violations
pH	4,755,980
Solids, Total Suspended	4,578,778
Flow, In Conduit or Through Treatment Plant	2,652,105
Iron, Total [as Fe]	1,883,412
Sulfate, Total [as SO <sub>4</sub> ]	1,672,472
Manganese, Total [as Mn]	1,670,844
Specific Conductance	1,635,332
Aluminum, Total [as Al]	1,546,086
Aluminum, Dissolved [as Al]	1,438,898
Solids, Total Dissolved	1,425,552

## Implications

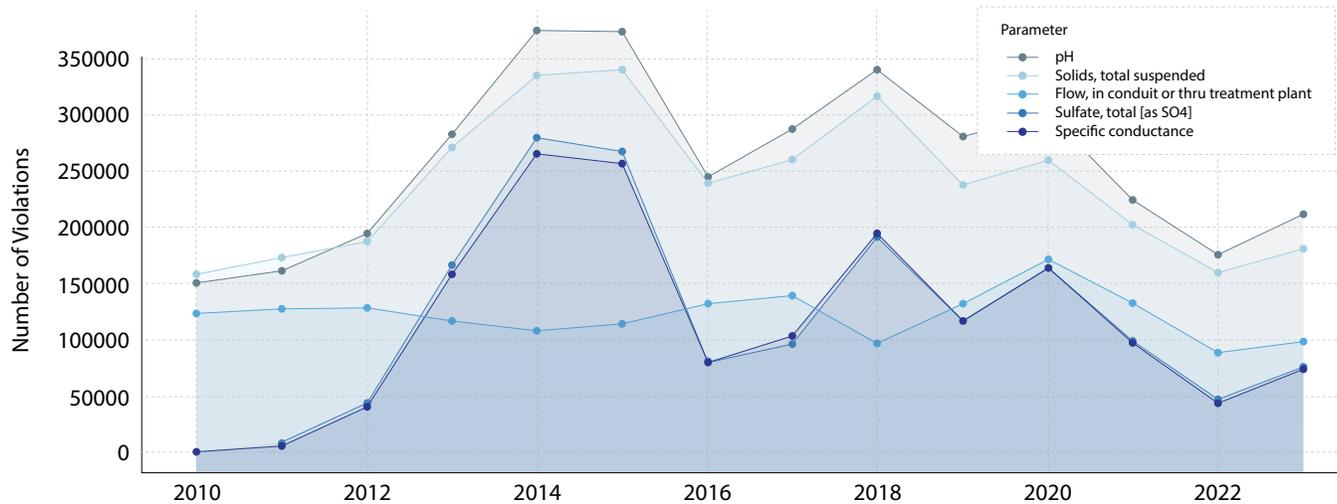
The dataset's breadth and depth provide unparalleled insights into compliance trends, enabling stakeholders to:

- Identify industries and regions requiring targeted regulatory focus.
- Prioritize efforts to address recurring violations in key parameters.
- Inform policy decisions to improve water quality standards over time.

# Violation Trends by Parameter

We investigated historical trends in the number of violations by parameter in the NPDES permit violations dataset. The trend analysis was limited to years 2010 to 2023 due to the limited availability of violations data prior to and after this time period, either due to technical reasons (limited reliable data reporting capabilities) or due to partial data availability (post March 2024).

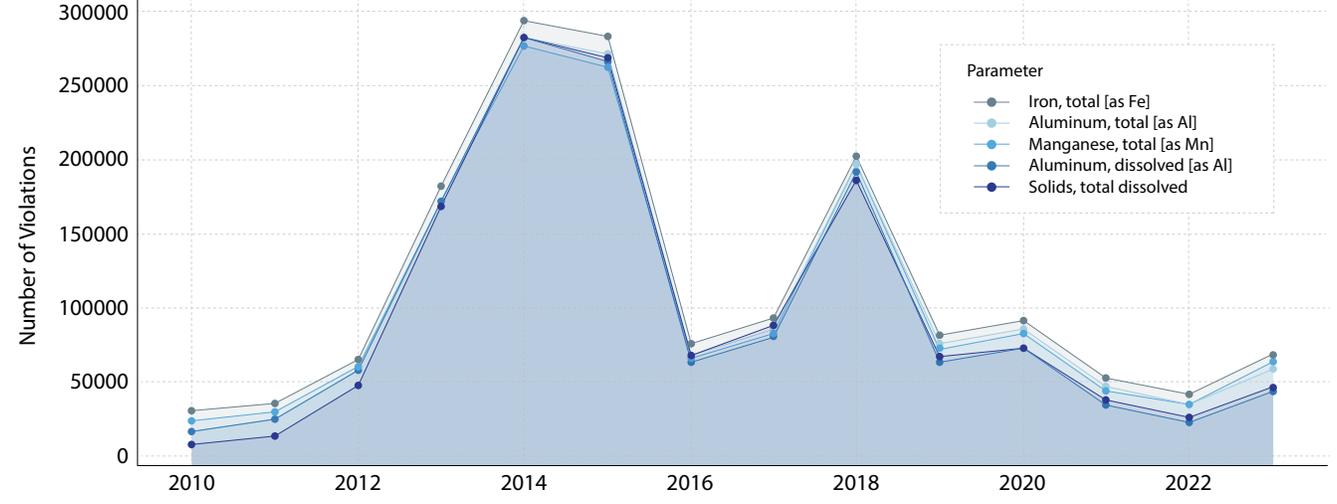
**Top 5 Parameters by Violations Over Time (2010-2023)**



The top 10 parameters by number of violations (identified in the previous section) show a similar overall historical trend (to the trend reported in the previous chapter). All parameter violations peak into the mid-2010s before reducing significantly over the next 7 to 8 years.

While the cause of this uniform reduction in the number of violations is unknown, we can rule out a lack of suitable reporting infrastructure and data gathering as reasons for this reduction (we have chosen to perform the analysis from 2010 onwards for reasons mentioned previously).

**Next 5 Parameters by Violations Over Time (2010-2023)**

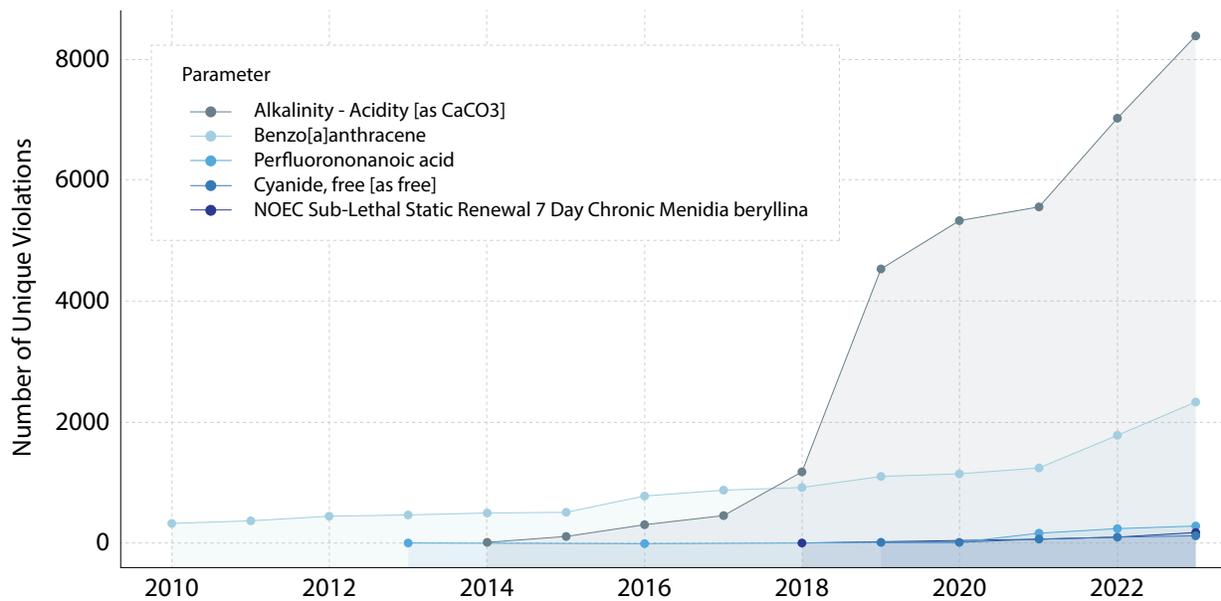


We also investigated if there were other parameters outside of the top 10 by violations that did not confirm the broad trend. Of particular interest were parameters that either showed monotonically increasing (continuous worsening) or decreasing (continuous improvement) trends.

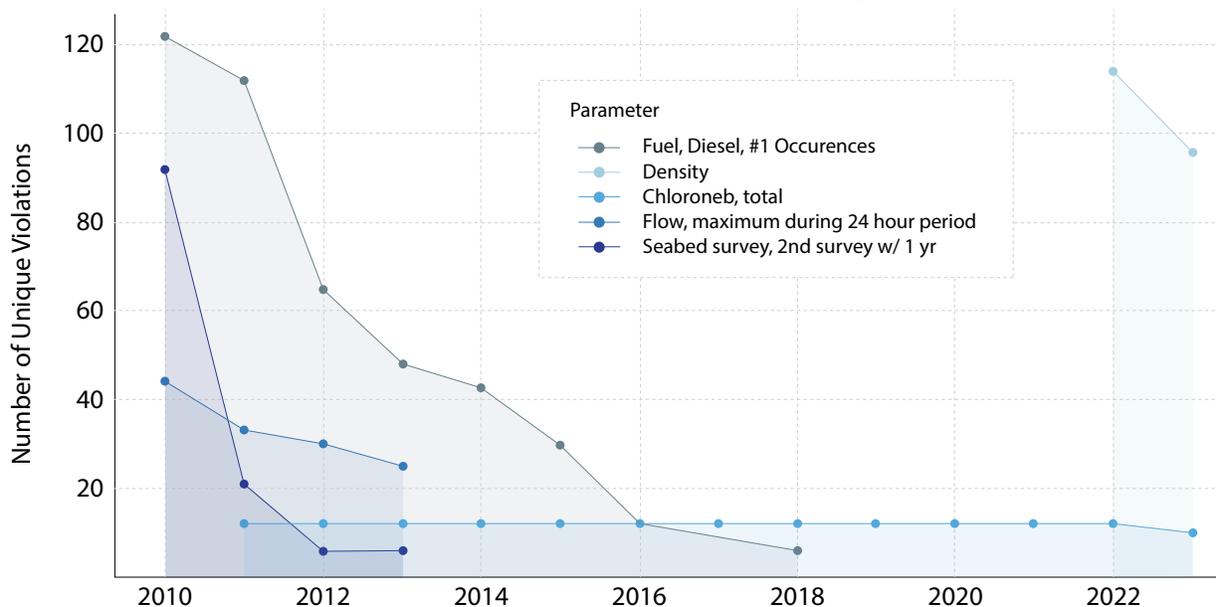
Among the parameters with a monotonically increasing trend, Alkalinity showed a significant increase in the decade spanning 2013-2023. Even though the total number of violations in Alkalinity is currently far below that for the top 10 parameters, the continuous and rapid increase in the number of violations is a cause for concern.

Among parameters with decreasing or relatively stable trends, we saw significant, continuous improvement in the reported data on diesel fuel emissions in effluents.

**Top 5 Parameters with Monotonically Increasing Trends (2010-2023)**



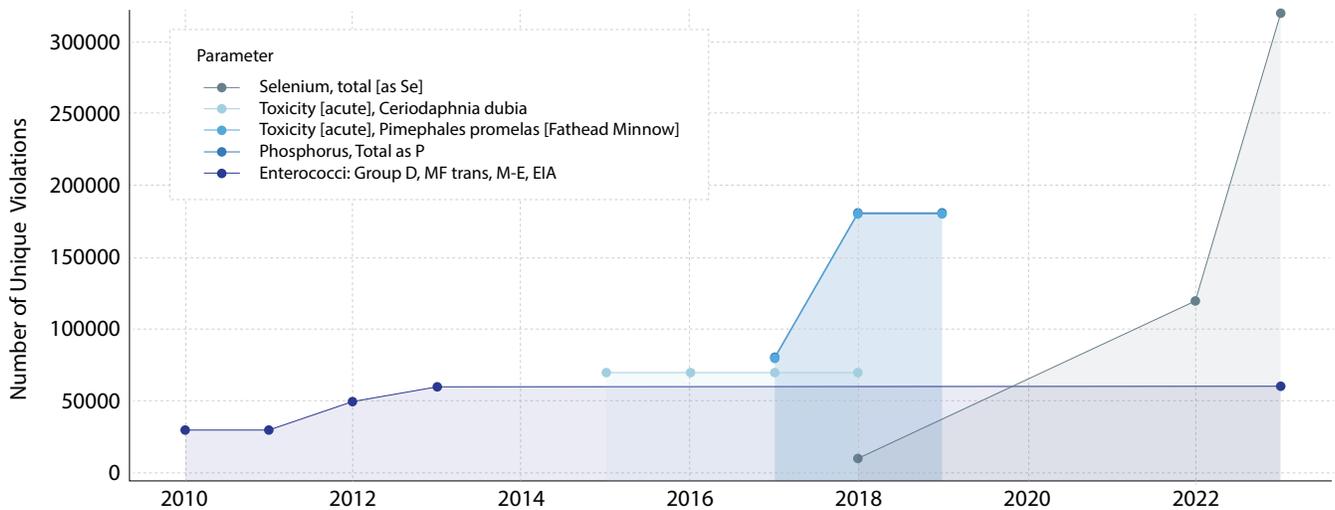
**Top 5 Parameters with Monotonically Decreasing Trends (2010-2023)**



From a public water quality perspective, the desired trend in effluent contaminant violations is a monotonic decrease toward zero violations. Since the dataset contains a mixture of types of violations involving actual effluent limit violations, reporting violations, schedule violations and so on, we repeated the trend analysis on parameters that only had effluent discharge limit violations. This analysis did not reliably find parameters (other than Selenium) that showed either significant, continuous improvement or significant worsening.

Since Selenium data is available for only three years and the absolute number of violations is rather small in comparison to other parameters, we suggest a cautious approach to drawing broad conclusions from this dataset.

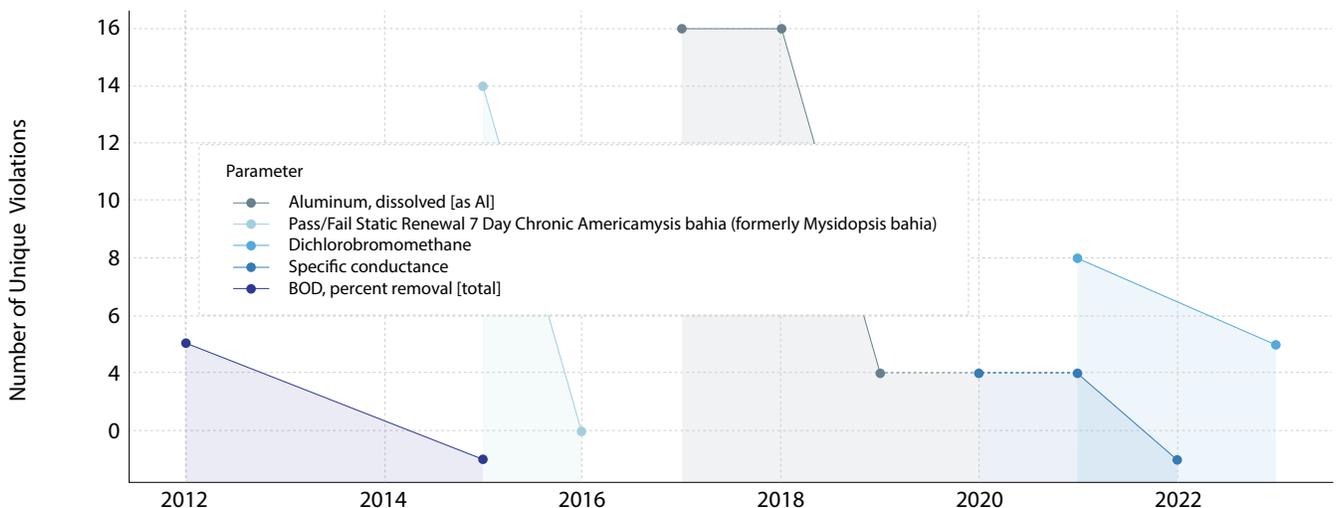
**Top 5 Monotonically Increasing Parameters (EFF) (2010-2023)**



Overall, while the trend analysis on parameters shows a marked reduction in the number of violations post-2014, the overall number is still firmly above historical norms (where data is available).

Reducing the overall number of effluent violations is a combined effort between monitoring agencies and effluent producers. The adoption of continuous, real-time water quality intelligence tools such as KETOS SHIELD should greatly improve visibility into effluent contaminant levels and help avoid effluent violations.

**Top 5 Monotonically Increasing Parameters (EFF) (2010-2023)**

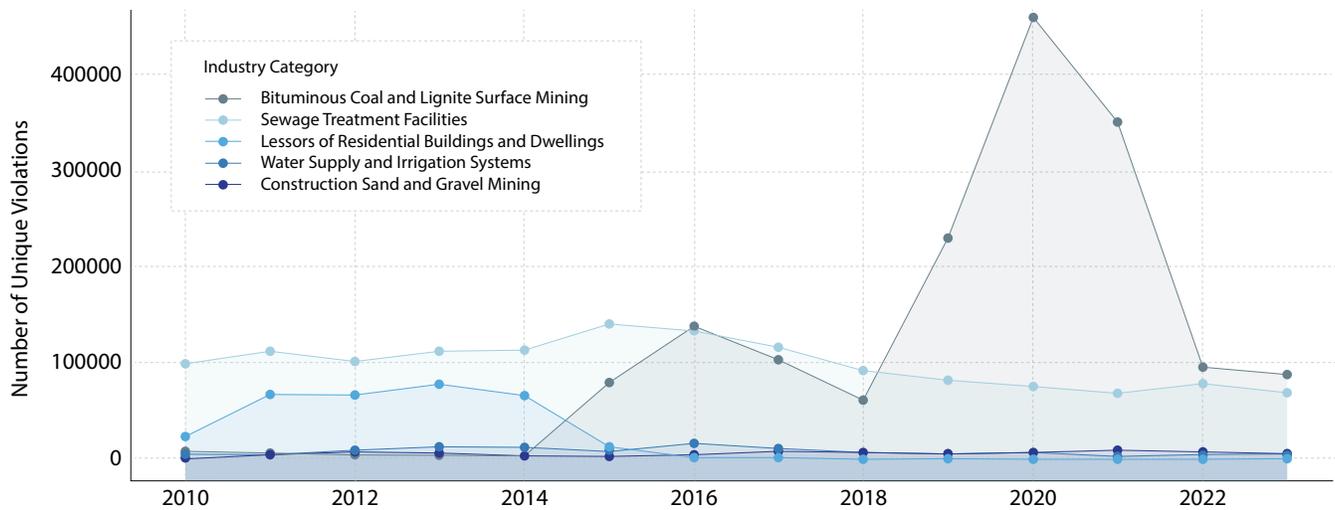


# Violation Trends by Industry Category

This section of the report delves into the compliance behavior of key industrial categories over time, focusing on their effluent violations. By analyzing these trends, stakeholders can identify industries with persistent compliance issues, evaluate the effectiveness of regulations, and prioritize enforcement efforts. This section examines both the volume of violations and their temporal evolution, shedding light on industries that either exhibit improvements in compliance or require targeted interventions due to recurring or worsening violations.

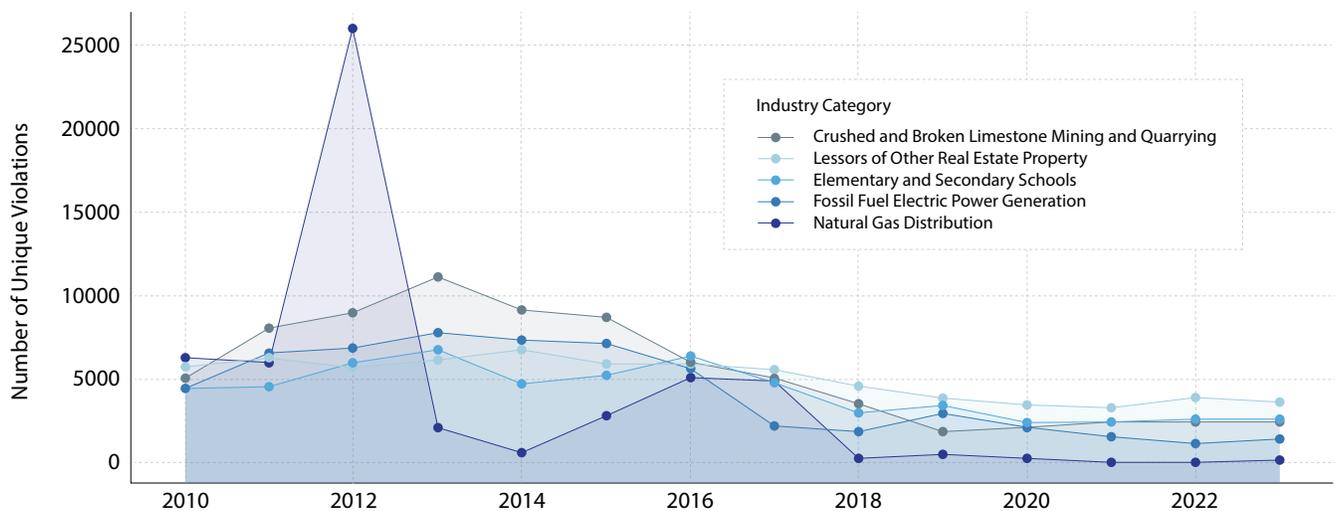
First, we analyzed trends in the total number of violations by industry type. The following two graphs show the top 10 industry categories ranked by total number of NPDES violations.

**Top 5 Industry Categories by NPDES Effluent Violations Over Time (2010-2023)**



The industry categories shown in this pair of graphs highlight a mix of persistent and fluctuating compliance issues. While some industries, like mining, have shown improvement, others, like sewage treatment, continue to face significant challenges.

**Next 5 Industry Categories by NPDES Effluent Violations Over Time (2010-2023)**



While the number of violations is an important metric to monitor, it's also important to monitor the severity of these violations when they do occur. This analysis initially revealed some interesting categories, as shown below.

Industry Category	Unique Violations	Median Exceedance Percentage
Parking Lots and Garages	47	2147483650
Apple Orchards	3	99999
Skiing Facilities	78	19750
Administration of Public Health Programs	12	8991
Motor and Generator Manufacturing	101	8584
Major Household Appliance Manufacturing	57	5991
Real Estate Credit	3	4900
Continuing Care Retirement Communities	218	3036
Drinking Places (Alcoholic Beverages)	153	2426
Geothermal Electric Power Generation	6	2100

While significant deviations from permitted effluent limits always deserve attention, from a public health and water quality perspective, it is better to focus on the most frequent and most impactful types of effluent violations.

To do this, we filtered out those industry categories with fewer than 10,000 overall violations to get the following table.

Industry Category	Number of Violations	Median Exceedance Percentage
Lessors of Residential Buildings and Dwellings	20,616	167
Water Supply and Irrigation Systems	16,607	122
Gasoline Stations with Convenience Stores	12,603	113
Land Subdivision	25,464	106
Elementary and Secondary Schools	29,037	105
Lessors of Other Real Estate Property	24,311	100
None	2,200,918	85
Sewage Treatment Facilities	478,649	67

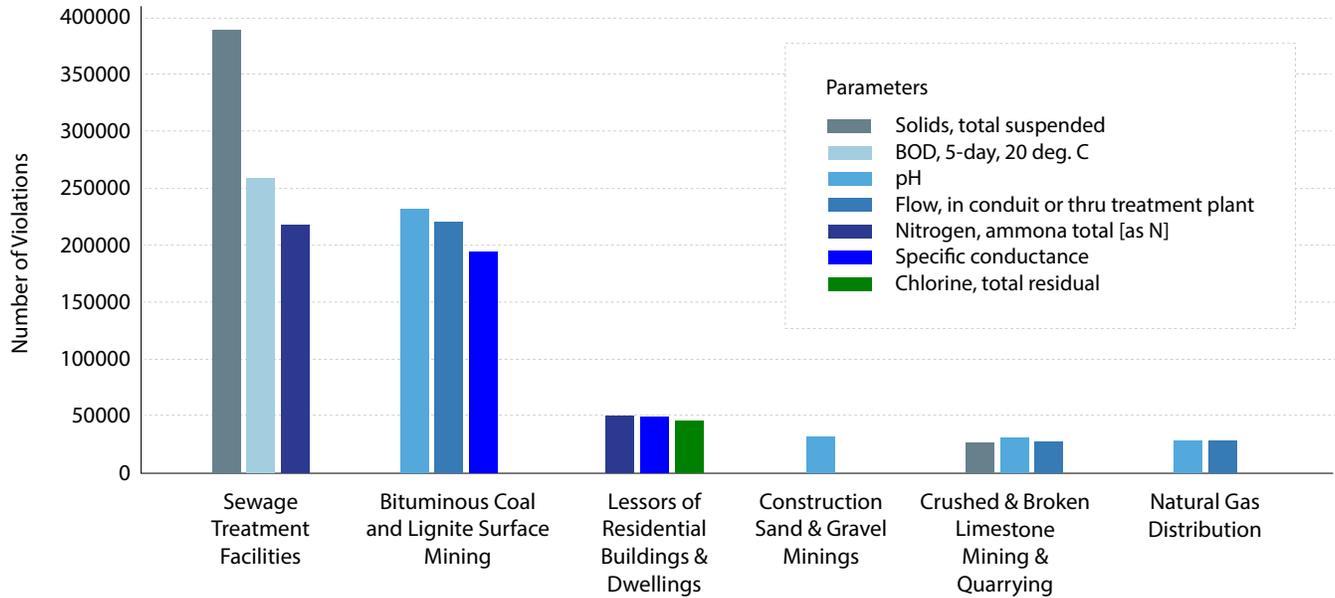
Sewage Treatment Facilities, the largest identified category ('None' implies no specific industry category), has a median limit exceedance of 67%. Water Supply and Irrigation systems are even higher at 122%, i.e. typically more than double the limit.

Given the volumes of water released yearly into public waters by these two industry categories, the findings are a profound cause of worry from a public water quality perspective.

Next, we analyzed the top parameters in violation for the top five industry categories by number of violations. The most frequently occurring parameter across the top 5 industry categories is pH, followed by Nitrogen.

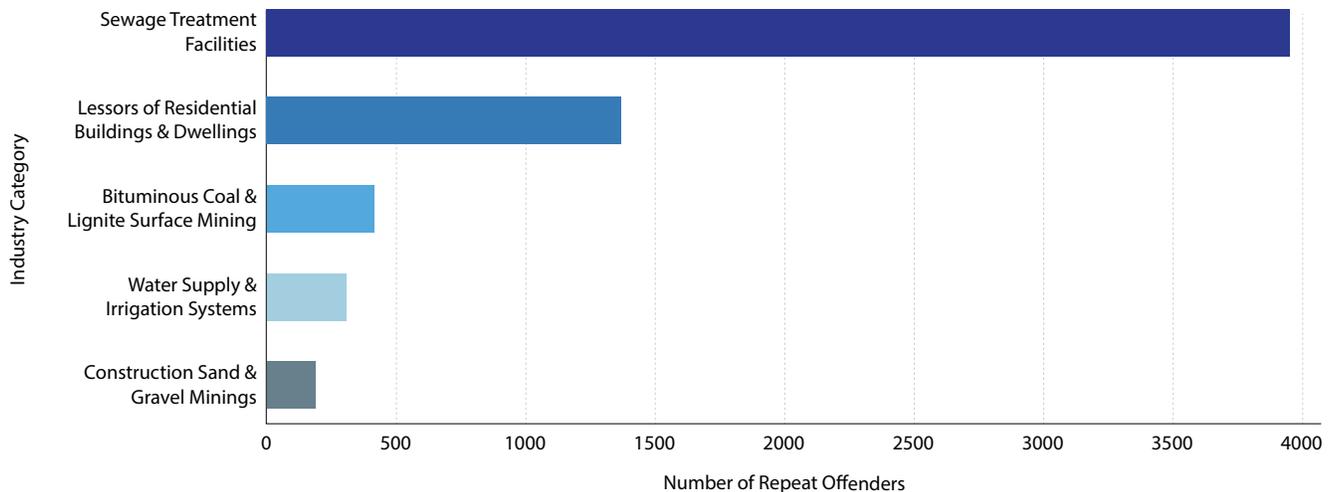
While pH is relatively easy to monitor, it is possible that a lack of continuous, real-time monitoring along with alerts for threshold violations is leading to repeated pH violations. Our experience helping industrial customers has also confirmed this finding. For example, most industrial customers with Nitrogen discharge permits have found it difficult to maintain Nitrogen levels below permit levels without the help of continuous monitoring with solutions such as KETOS SHIELD, which is consistent with the finding of Nitrogen being implicated in violations across industries.

### Effluent Violations by Parameter for Top Industry Categories



The industry categories with the highest numbers of violations predictably have the highest number of repeat violators. We define repeat violators as single facilities that have greater than 100 unique violations.

### Top 5 Industry Categories by Repeat Offenders



Unsurprisingly, Sewage Treatment Facilities were again at the top of the list of repeat offenders with almost 4000 facilities having greater than 100 permit violations.

The industry category trend analysis conducted in this section highlights the importance of tailoring compliance efforts to the unique challenges of each industry. While some industries demonstrate improvements, others reveal persistent issues that necessitate ongoing oversight and intervention. This analysis provides a foundation for identifying key focus areas in regulatory enforcement and industry support.

## Violation Trends by Geography

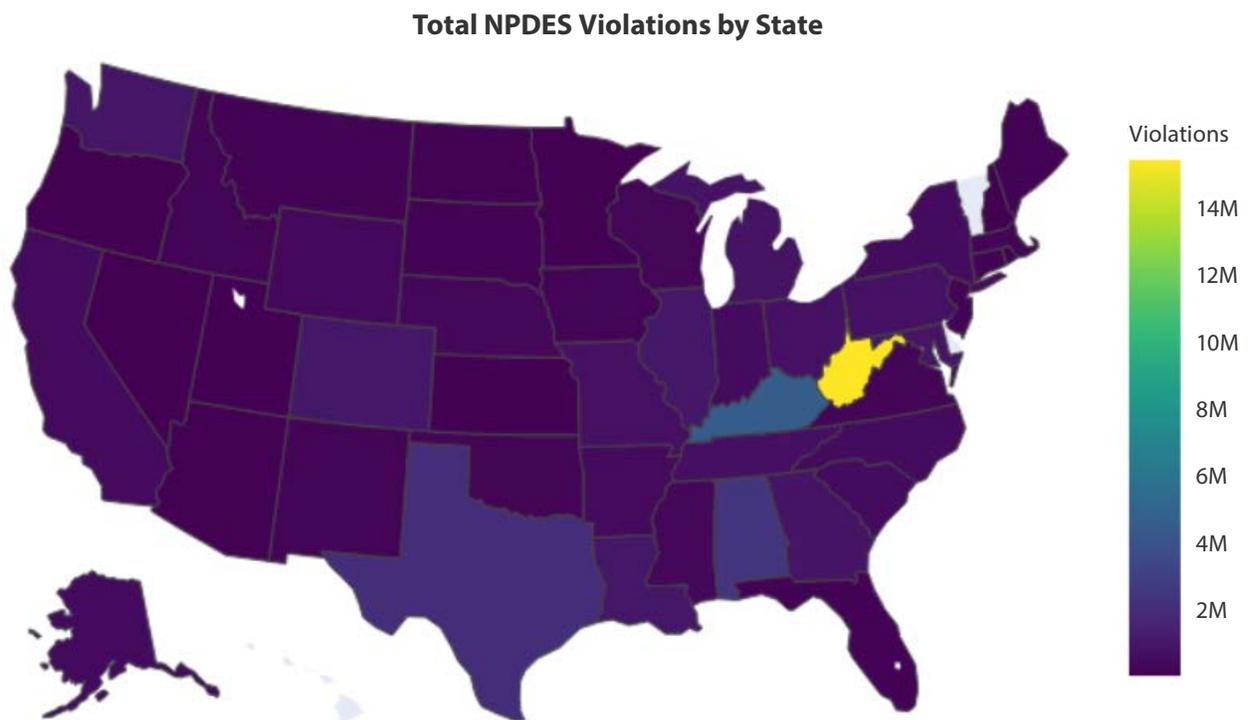
Understanding the geographical distribution of effluent violations is critical for identifying compliance hotspots and tailoring regulatory interventions. By mapping violations across regions, policymakers and enforcement agencies can focus their resources on areas with persistent non-compliance, while industries operating in those regions can prioritize investments in mitigation measures.

In this section, we perform hotspot analysis to visualize regions with the highest concentrations of violations. This analysis is conducted for:

1. **Overall violations** to capture the broader compliance landscape.
2. **Specific parameters (e.g., pH)** to highlight targeted environmental risks.
3. **A key industry category (e.g., Sewage Treatment Facilities)** to assess sector-specific compliance challenges.

Such insights not only provide a granular view of compliance patterns but also serve as a foundation for location-based environmental policies.

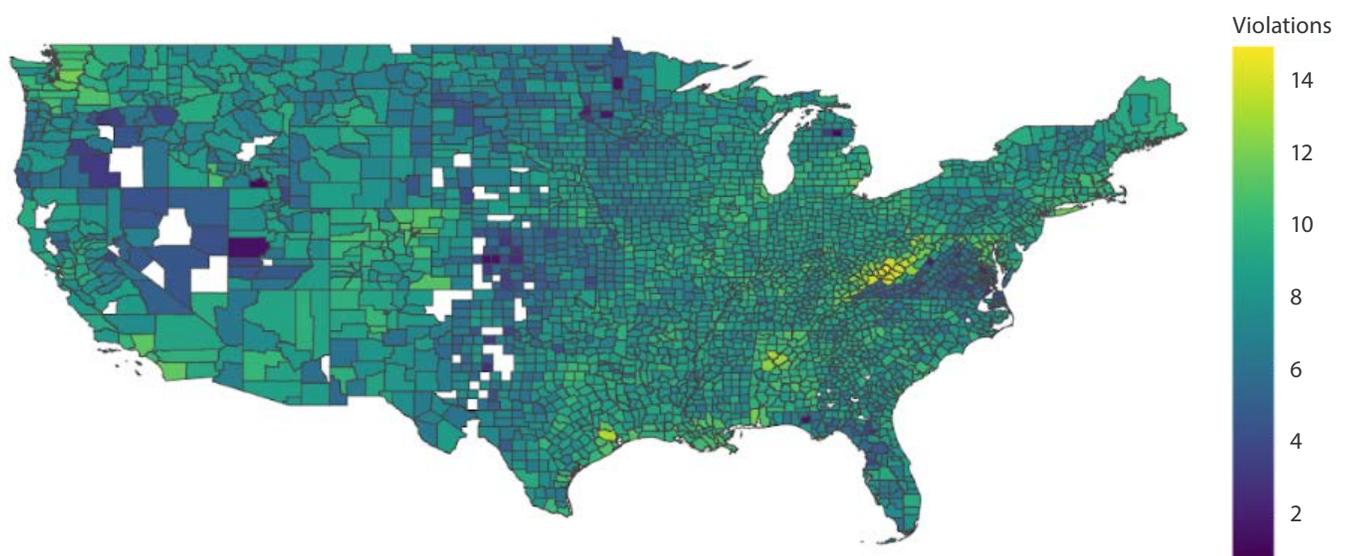
The simplest possible aggregation that can be made to understand geographical trends in NPDES violations is on a state level. To do this, we counted all the unique NPDES violations for each state and plotted it on a heatmap as shown below.



A stunning insight from this simple analysis is the overwhelming number of NPDES violations in the state of West Virginia compared to other states. Seven other states - KY, TX, LA, WA, AL, CO, IL - have a total number of NPDES effluent violations in excess of 1 million over the time period of this analysis.

For a more granular analysis, we can resolve violations data down to a county level and identify problematic counties. Since the order of magnitude of the number of violations varies greatly from one county to another, we chose to plot this on a log scale to illustrate these differences more clearly. The analysis shows significant violations in Appalachian counties and counties in Louisiana, Arkansas, Texas, Washington, New Mexico, Colorado and California.

**Log of Total NPDES Violations by County**

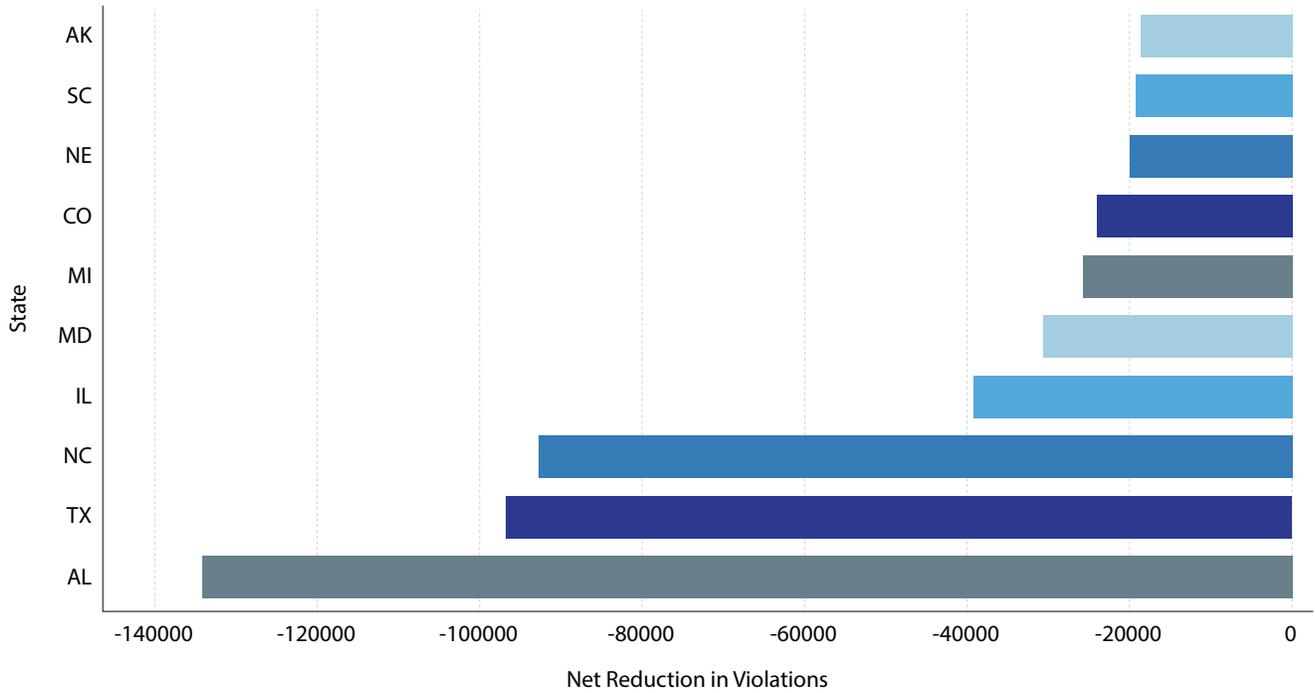


Next, we performed a regional trend analysis to see if any states showed strong improvements or worsening of their violation trends over time. The simplest analysis of this type that can be performed is subtracting the net violations in 2023 from 2010 and finding the top 10 states with improved (i.e. fewer violations in 2023 than 2010) or worse historical violation performance.

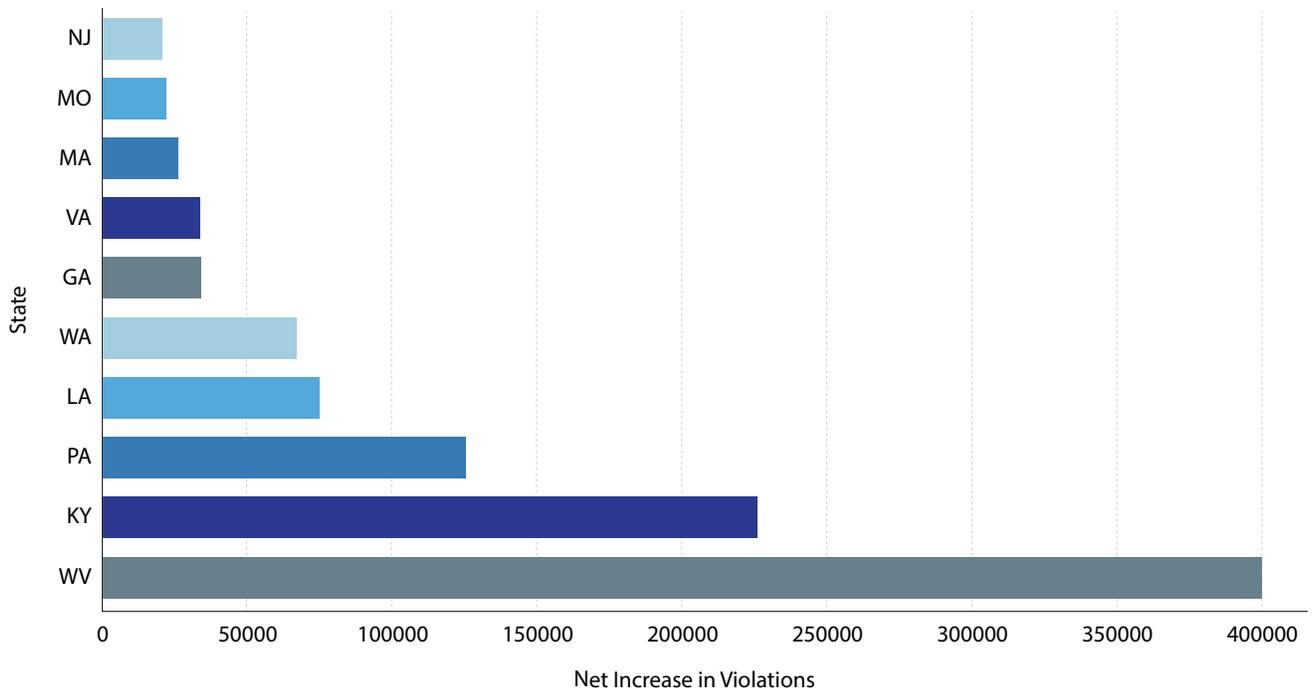
The results of this analysis are shown below. Alabama, Texas and North Carolina saw a significant reduction in overall violations while West Virginia, Kentucky and Pennsylvania saw a significant increase.

From an initial accounting of the distribution of regional violations, it appears that the Appalachian states seem to consistently feature on the list of worst performers in terms of effluent violations. Since mining is an industry that is responsible for a significant amount of economic activity in the Appalachian states, we decided to examine the overall violation trends in this industry in specific states as a major contributor to overall violations.

**Top 10 States with Positive Compliance Trends (2010-2023)**

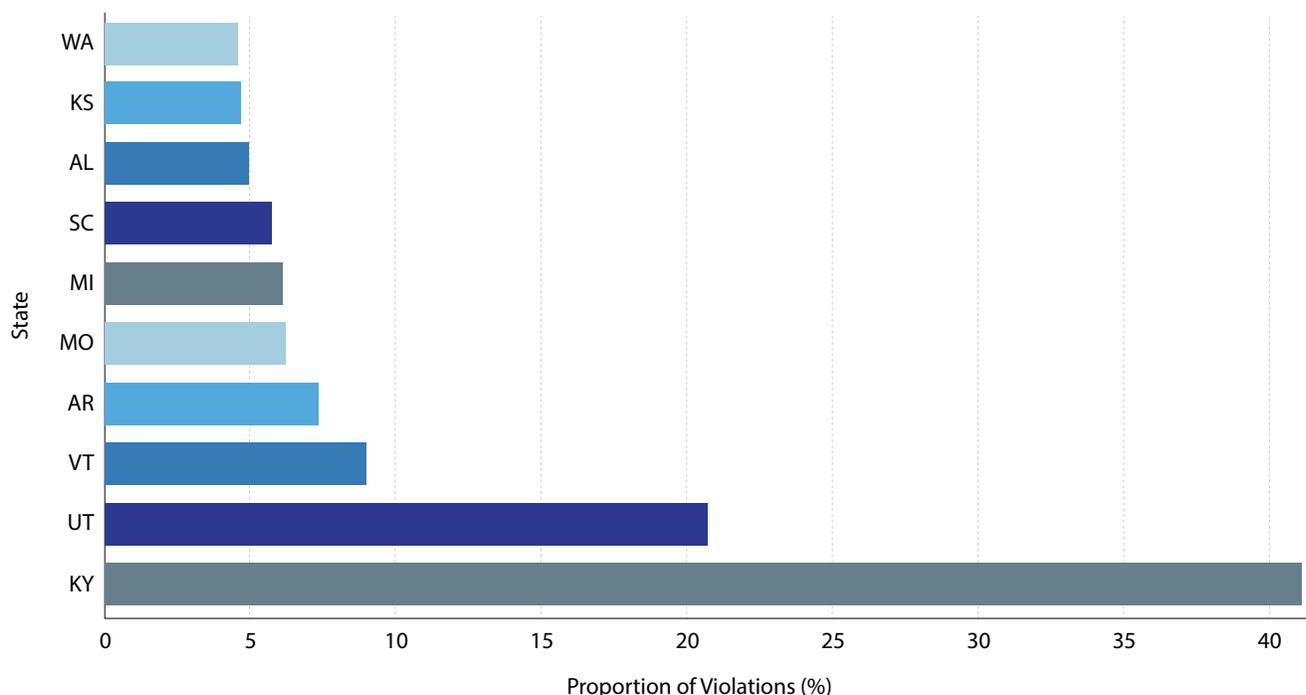


**Top 10 States with Negative Compliance Trends (2010-2023)**



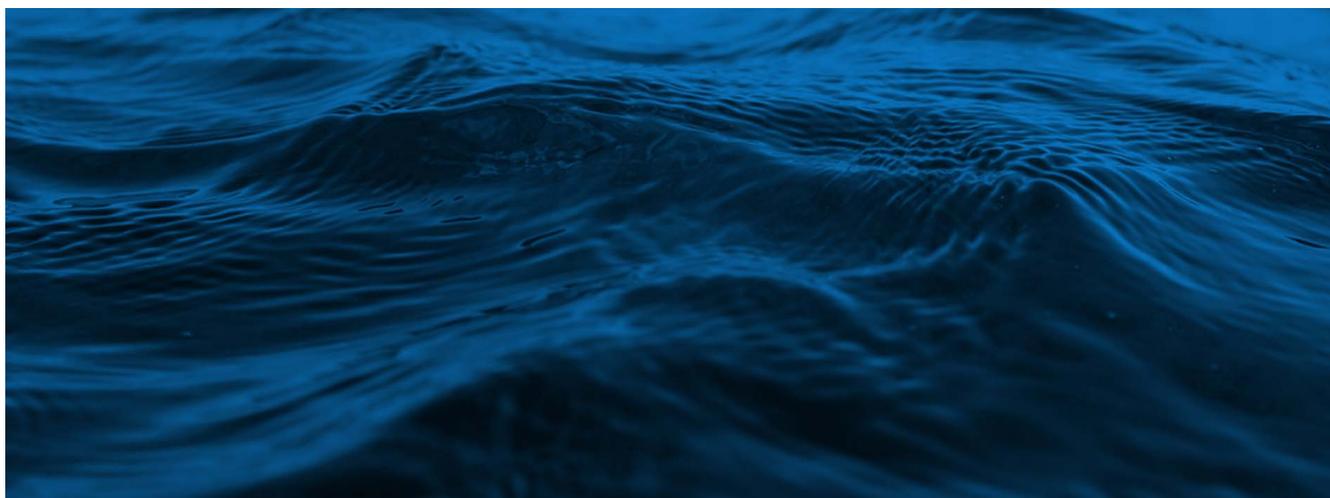
The state with the highest proportion of mining violations is Kentucky, where close to 40% of the violations come from the Mining industry. A notable unexpected omission in this list is West Virginia. Upon closer inspection, we found that the Industry Category classification (naics\_code) was not supplied in the original dataset for all 15 million effluent violation records in West Virginia.

### Top 10 States by Proportion of Violations Related to Mining



We then extended this analysis to find the top industry category by total number of violations for each state. Most states have Sewage and Water related facilities as the main contributor to NPDES violations. States with nearly 100% of the data from one industry category appear to have such a large proportion from a single contributing industry due to the mislabeling/lack of labeling problem mentioned previously.

Several states (LA, CA, etc) have a large number of facilities for which Industry Category (naics\_code) has not been labeled in the NPDES dataset. Consequently, we consider our analysis of the regional distribution of industry categories as only partially complete. As more data is received from the EPA, our analysis on this specific topic will reflect this and become more complete.

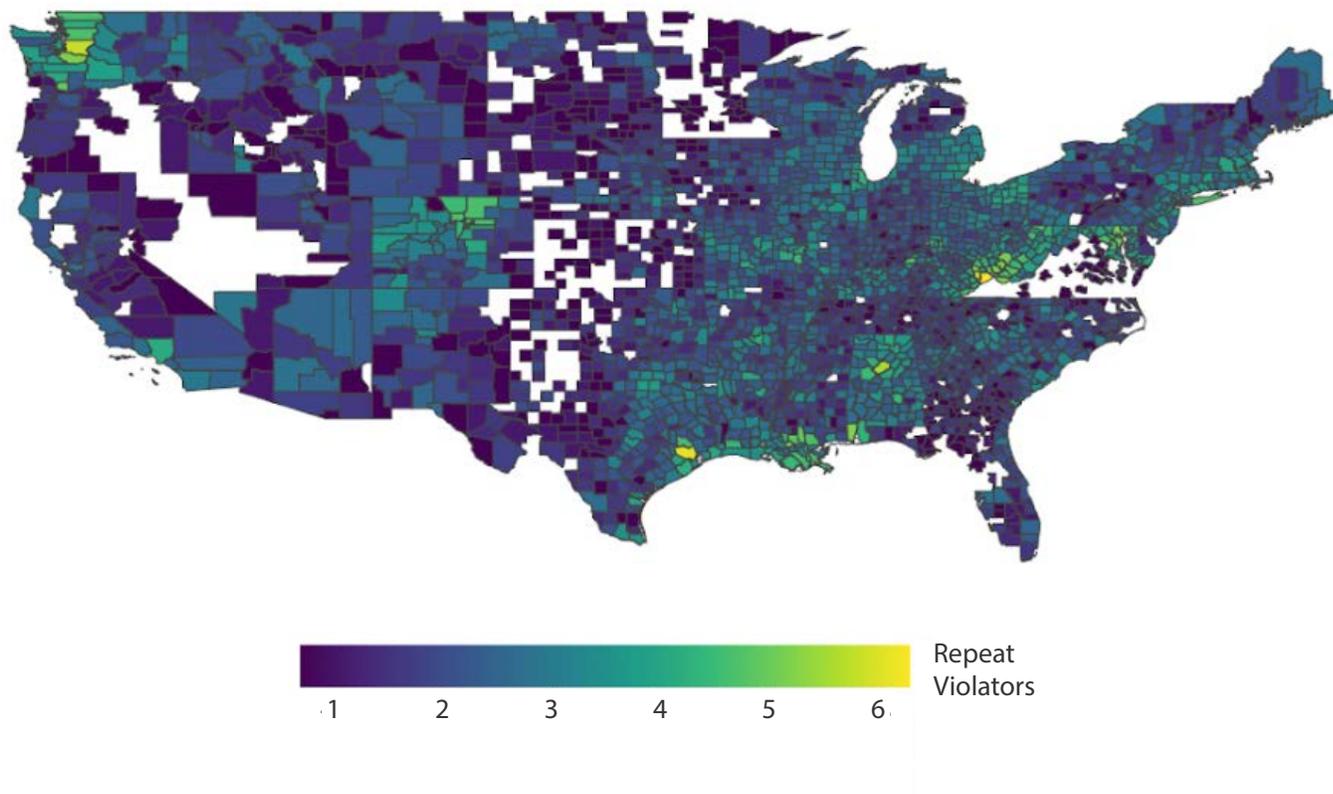


State Name	Top Contributing Industry	Percentage Contribution (%)
Louisiana	Plastics, Foil, and Coated Paper Bag Manufacturing	99.99
Ohio	Water Supply and Irrigation Systems	99.99
Illinois	Port and Harbor Operations	99.98
Maryland	Sewage Treatment Facilities	99.97
Texas	Water Supply and Irrigation Systems	99.79
Colorado	Water Supply and Irrigation Systems	99.60
California	Sewage Treatment Facilities	99.19
Wyoming	Water Supply and Irrigation Systems	99.01
North Carolina	Sewage Treatment Facilities	98.89
Nebraska	Sewage Treatment Facilities	98.04
New Mexico	Sewage Treatment Facilities	97.91
New Hampshire	Sewage Treatment Facilities	96.27
New York	Zoos and Botanical Gardens	94.66
Pennsylvania	Wood Preservation	94.27
Hawaii	Water and Sewer Line and Related Structures Construction	93.85
Wisconsin	Sewage Treatment Facilities	92.76
Arizona	Water Supply and Irrigation Systems	90.94

State Name	Top Contributing Industry	Percentage Contribution (%)
Rhode Island	Site Preparation Contractors	89.19
Massachusetts	Water Supply and Irrigation Systems	83.82
Montana	Water and Sewer Line and Related Structures Construction	82.95
Oregon	Sewage Treatment Facilities	81.71
Virginia	Wood Preservation	80.88
New Jersey	Wired Telecommunications Carriers	79.32
Indiana	Wood Kitchen Cabinet and Countertop Manufacturing	79.23
South Carolina	Water and Sewer Line and Related Structures Construction	77.55
Georgia	Water and Sewer Line and Related Structures Construction	43.97
Nevada	Water and Sewer Line and Related Structures Construction	41.32
Florida	Zoos and Botanical Gardens	40.69
Mississippi	Wood Preservation	40.60
Kentucky	Zoos and Botanical Gardens	39.53
Utah	Water and Sewer Line and Related Structures Construction	37.97
Michigan	Water Supply and Irrigation Systems	33.93

We also analyzed the distribution of repeat offender facilities (facilities with more than 100 NPDES violations) by county to see if any interesting patterns exist.

### Log of Repeat NPDES Violators by County

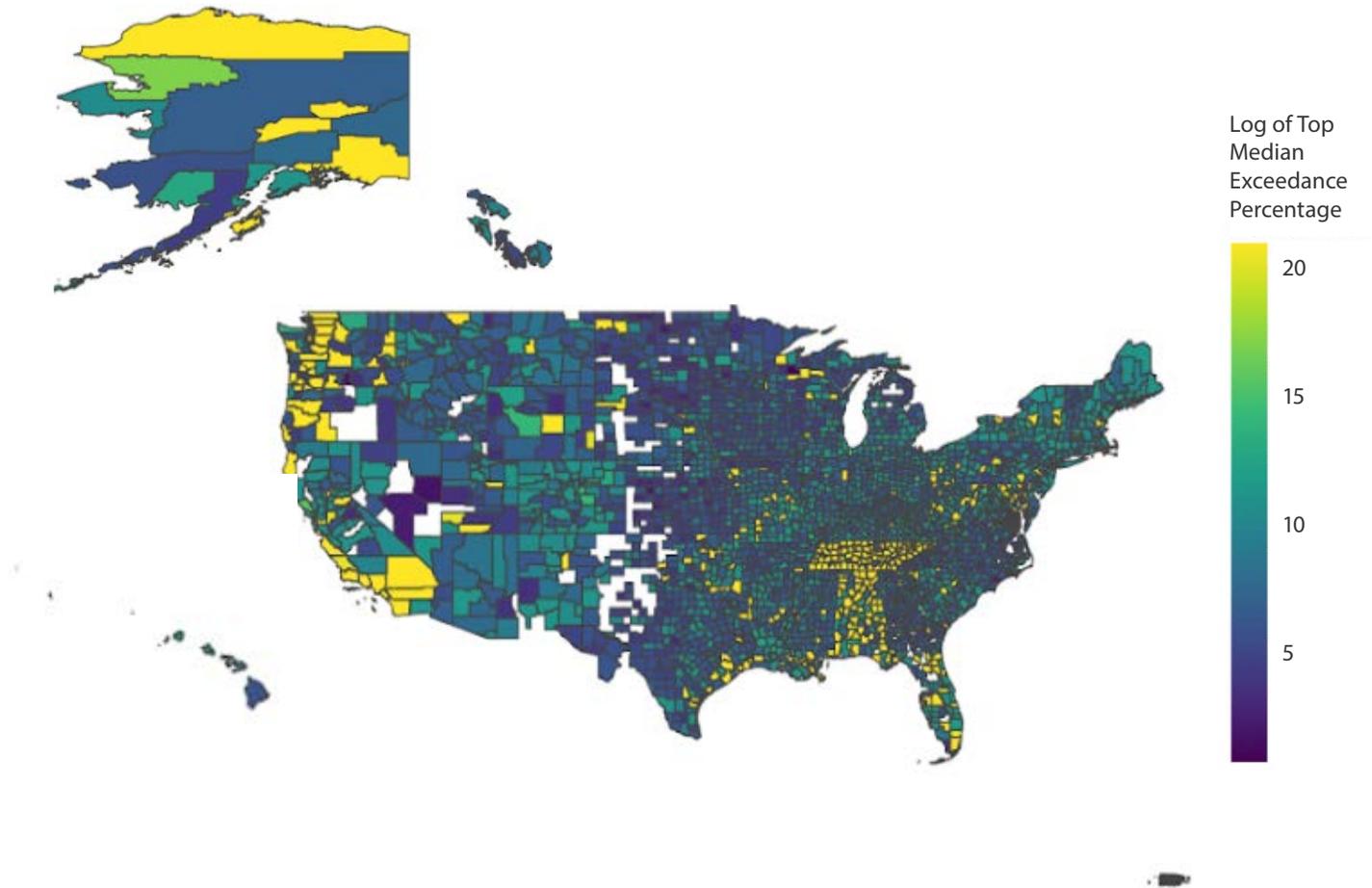


Similar to the distribution of facilities with violations, counties in Texas, Louisiana, Washington and Kentucky are part of the top 20-30 counties having facilities with greater than 100 violations. Counties shaded white were counties for which this information is not available or for which no facility had repeat offenders.

While the distribution of repeat offender facilities is interesting, we also wanted to see if we could find patterns in the severity of the violations by county. For this, we first computed the parameter that was most severely in violation, on average, per county. We then plotted the log of this exceedance percentage on a county map.

This map is far more revealing than the previous analyses since it tells us precisely which type of severe violation typically occurs in each county. While we have attempted to capture this information in a 2D map, the true power of this analysis can be seen only through a detailed interactive map. We will make this map freely available to readers of the full report.

## Log of Repeat NPDES Violators by County



A number of such useful geographical analyses can be performed with access to the underlying dataset. While we have aimed to provide readers of this report with insights that we felt weren't adequately represented in the literature on this topic, we believe that readers working in policy, marketing, and environmental research can benefit from a detailed analysis of this report.

As part of our own internal research, KETOS has also performed an analysis that dives deeper into each of these categories mentioned above. We encourage interested readers to inquire more about our proprietary research by contacting us at [prism\\_support@ketos.co](mailto:prism_support@ketos.co).

## Conclusion

The analysis of 42 years of NPDES effluent violation data provides critical insights into compliance trends, regional hotspots, industry challenges, and the severity of environmental risks. Despite significant improvements in some areas, such as reductions in violations for key parameters and industries, the data reveals persistent challenges requiring immediate intervention.

1. **Geographic Hotspots:** Appalachian states, particularly West Virginia and Kentucky, continue to feature prominently in effluent violations, driven in part by the mining industry. Counties in Texas, Louisiana, and Washington also exhibit high concentrations of repeat offenders, underscoring a need for targeted regulatory action.
2. **Industry Trends:** Sewage Treatment Facilities and Water Supply Systems remain the most significant contributors to violations, with severe median exceedance percentages. Industries such as Mining and Agriculture further complicate compliance in certain regions.
3. **Parameter-Specific Challenges:** Parameters like pH and Nitrogen consistently appear as major sources of violations. Emerging issues, such as rising Alkalinity violations, highlight areas requiring further research and monitoring.
4. **Severity of Violations:** Mapping the most severe exceedance percentages at the county level uncovers localized environmental risks that are often masked in broader regional or industry-level trends.

## Opportunities for Actions

Efforts to reduce violations must combine proactive regulation, targeted enforcement, and technological adoption. For policymakers, this report highlights regions and industries most in need of regulatory focus. For industry leaders, investing in advanced monitoring solutions like **KETOS SHIELD** can drive compliance improvements through real-time water quality intelligence, automated anomaly detection, and timely interventions.

By leveraging data-driven insights and embracing continuous monitoring solutions, stakeholders can collectively work toward a future with fewer effluent violations, improved water quality, and sustainable environmental stewardship.

We encourage readers to begin their journey to NPDES compliance by learning more about KETOS' comprehensive water quality intelligence solutions. KETOS SHIELD, our flagship product, is used by prominent companies in industries as diverse as mining, agriculture and municipal wastewater treatment to monitor for 40+ water quality parameters at zero capital expenditure. To learn more, contact us at [info@ketos.co](mailto:info@ketos.co) or visit <https://ketos.co/shield>.

