

Changes in Fine Particulate Matter (PM_{2.5}) Levels in the United States: A Case Study of 1999 vs 2012

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Abstract

This study compares PM_{2.5} concentrations in the United States between 1999 and 2012 using national monitoring data. For clarity in descriptive trend estimation, analyses are restricted to valid measurements (observations with non-missing, non-negative PM_{2.5} values). We describe national and state-level distributions, quantify changes in central tendency and dispersion, and identify states with the largest improvements or deteriorations. Results show a clear downward shift in median PM_{2.5} between 1999 and 2012, with heterogeneous state-level patterns. We discuss implications for exposure assessment and highlight sensitivity checks to evaluate the impact of data exclusions.

Keywords: PM_{2.5}, air pollution, data quality, United States, environmental epidemiology

1. Introduction

Airborne fine particulate matter with aerodynamic diameter $\leq 2.5 \mu\text{m}$ (PM_{2.5}) is a well-established risk factor for cardiovascular and respiratory disease. Over the last two decades the United States has implemented a range of regulatory and technological interventions aimed at reducing emissions from industry, transportation, and power generation; monitoring networks have also expanded and evolved. Quantifying how PM_{2.5} distributions changed between 1999 and 2012 provides a useful overview of national progress and highlights spatial heterogeneity in exposure reductions.

This paper presents a descriptive comparison of PM_{2.5} data from two benchmark years (1999 and 2012). To focus the analysis on reliable measurements, we restrict analyses to valid observations (non-missing, non-negative PM_{2.5} values) and summarize changes at national and state levels. We present distributional comparisons (boxplots, densities), state-level trajectories, and maps, and we identify states with the largest percent changes. Where relevant, we flag limitations introduced by the data-cleaning choices and propose sensitivity checks.

1.1. Primary Objective

- Describe how PM_{2.5} levels changed between 1999 and 2012 at national and state levels using valid monitoring observations.

1.2. Research Questions

- Did median PM_{2.5} decline nationally from 1999 to 2012?
- Which states experienced the largest decreases or increases?
- Are changes geographically structured (regional patterns)?
- Do larger reductions occur where monitoring density changed?

1.3. Secondary Analyses

- Seasonal patterns: Compare monthly or seasonal distributions, if sufficient data are available.
- Robustness checks: (a) Include previously excluded negative values as NA (b) Exclude states with very few monitors and repeat key summaries

2. Methods

2.1. Data cleaning and selection

We combined the 1999 and 2012 monitoring datasets and parsed measurement dates to extract year and month. Observations with missing PM_{2.5} values or with negative PM_{2.5} values were excluded from the primary analysis; these exclusions are reported in Table X (number and percent removed). All subsequent analyses use the filtered dataset of valid observations. Sensitivity analyses that relax these exclusions (e.g. treating negative values as missing) are presented in the supplement.

After removing missing and negative PM_{2.5} entries, 1,308,884 valid observations remained (92.1 % of original N = 1,421,708); excluded counts are shown in Table 1. All subsequent analyses use these valid observations.

metric	value	percentage
total_rows	1421708	100 %
removed_missing	86350	6.074 %
removed_negative	26474	1.862 %
kept_rows	1308884	92.064 %

Table 1: Data cleaning summary (counts & % of total)

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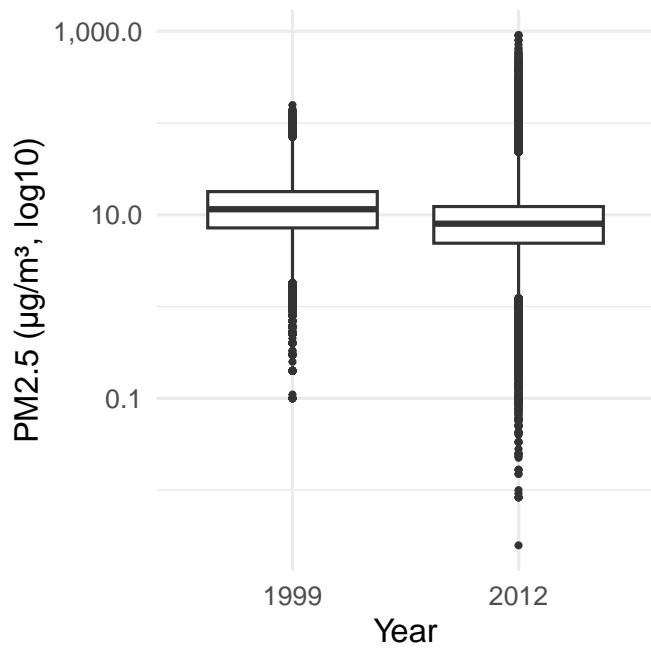


Figure 1: Distribution of PM_{2.5}: 1999 vs 2012

3. Results

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Year	n	Median PM	CI
1999	104204	11.50	[11.40, 11.54]
2012	1204680	7.90	[7.90, 8.00]

Table 2: Yearly medians and 95% bootstrap CIs

Statistic	Estimate	CI
Median difference	-3.60	[-3.60, -3.50]

Table 3: Median difference (2012 - 1999)

The national median PM_{2.5} decreased from 11.50 $\mu\text{g}/\text{m}^3$ in 1999 (95% bootstrap CI: [11.40, 11.54]) to 7.90 $\mu\text{g}/\text{m}^3$ in 2012 (95% bootstrap CI: [7.90, 8.00]). The bootstrap estimate of the median difference (2012 - 1999) is -3.6 $\mu\text{g}/\text{m}^3$ (95% CI: -3.6 to -3.5), indicating a statistically and practically meaningful decline in typical PM_{2.5} levels between the two years.

4. Discussion

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5. Conclusions

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References