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Validating Non-Fatal Intentional Poisoning Incidents as a National Sentinel Indicator for Suicide Mortality Trends in Malaysia (2006–2021): A Mechanistic and Economic Impact Estimation

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Abstract

Background:

Suicide is a major public health concern in Malaysia. Relying solely on official mortality statistics often introduces significant reporting delays, hindering immediate public health response. In Malaysia, while the Suicide Mortality Rate (SMR) is the paramount metric for national health planning, official statistics suffer from a significant 1–2 year reporting lag, rendering prevention reactive. This study aimed to assess the utility of non-fatal intentional poisoning data—collected in near real-time by the National Poison Centre (NPC-USM)—as a sentinel indicator for tracking national distress and methodological shifts in suicide.

Methods:

A 16-year ecological and time-series analysis was conducted using data from the National Poison Centre (NPC) and the Department of Statistics Malaysia (DOSM). Spearman's correlation, Durbin-Watson statistics, and an Autoregressive Integrated Moving Average with Exogenous Predictor [ARIMAX (1,0,0)] model were utilized to address longitudinal autocorrelation. An economic impact estimation was formulated utilizing the official Malaysian Value of Statistical Life (VSL) proxy.

Results:

Time-series analysis revealed a complex decoupling between non-fatal poisoning and fatal suicide outcomes. Overall correlation was weak (r_s = 0.182), primarily due to a severe divergence occurring in the latter half of the study period. Between 2019 and the 2021 pandemic peak, non-fatal intentional poisoning attempts reported to the NPC plummeted by 29.2% (1,212 to 857 cases), whereas official DOSM suicide fatalities surged by 81.0%. The ARIMAX model (AIC = -1.12) and Durbin-Watson diagnostics (0.61) confirm this structural shift. Analysis of age group distribution revealed the 20–39 years demographic remains the strongest anchor (r_s = 0.826).

Conclusion:

The drastic decoupling of non-fatal poisoning and official mortality during the pandemic suggests an aggressive 'method substitution' toward higher-lethality means. The NPC data functions as a high-sensitivity sentinel not for parallel overall mortality, but for tracking acute behavioural shifts in method availability and lethality intent. Integrating real-time toxicovigilance into national psychiatric surveillance architectures presents a highly cost-effective paradigm for proactive public health intervention.

Background

Suicide and attempted suicide are critical public health crises demanding timely and effective intervention. In many jurisdictions, including Malaysia, official suicide mortality data (SMR) are sourced from police records and civil registration, often resulting in significant reporting delays, typically one to two years—due to investigation and verification processes [1–4]. This lag severely hampers the ability of public health authorities to implement rapid, data-driven prevention strategies during acute public health events.

In general, the functional role of the SMR is conventionally twofold: (1) to provide a retrospective, validated measure of national mental health failure (an audit function), and (2) to prospectively guide funding and interventions. The delay transforms the SMR into a purely historical indicator, forcing policymakers to allocate resources reactively, often addressing a crisis that peaked years earlier. This reactive, data-delayed approach is inherently inefficient, leading to misallocated funds, diluted program impact, and a higher overall societal cost.

To resolve this discontinuity between rapid emergency data and slow epidemiological data, this study examines non-fatal suicidal attempts, which occur closer to the time of distress [1], offering a vital, near real-time snapshot of evolving risk. The National Poison Centre (NPC) at Universiti Sains Malaysia (USM) collects granular, geo-referenced, and time-stamped data on intentional poisoning incidents as a by-product of its core life-saving consultation service [3, 5]. Poisoning, specifically, is a leading method for self-harm globally, particularly in Asia, often involving pesticides or common household substances [2, 6–9]. In Malaysia, the National Poison Centre (NPC) at Universiti Sains Malaysia (USM) serves as a key sentinel system, collecting data on all calls related to poisoning, including intentional (suicidal) incidents [3]. This study aims to address the temporal limitation of SMR data by:

1. Validating the statistical relationship between the NPC's non-fatal intentional poisoning Annual Incidence Rate (NPC AIR) and the published Age-Standardized SMR trends (2006–2021).
2. Identifying the most vulnerable age groups driving this correlation within the NPC data.
3. Applying advanced time-series modeling to account for longitudinal temporal dependencies.
4. Comparing the proportional changes in NPC cases versus official fatalities during the recent high-stress period of the COVID-19 pandemic to evaluate sentinel sensitivity during crises.

Global Perspectives on Proxy Validity and Discordance.

The epidemiological utility of non-fatal self-harm as a sentinel for suicide mortality is characterized by significant regional heterogeneity, fuelling ongoing debate regarding attempt death discordance. In jurisdictions such as the United Kingdom and Taiwan, longitudinal surveillance of hospital-presenting self-harm has demonstrated high predictive validity for subsequent mortality trends, effectively bridging the data lag in official registries [10–12]. Conversely, the "Distinct Populations" hypothesis challenges this linearity, positing that "attempters" (often driven by dysregulated impulse or communication of distress) and "completers" (characterized by high intent and lethal planning) represent overlapping but phenomenologically distinct cohorts [13–14].

This discordance is particularly critical when analyzing method substitution; while restricting access to lethal pesticides in Sri Lanka and South Korea successfully reduced total suicide rates, similar interventions elsewhere have occasionally resulted in a shift toward hanging, thereby decoupling non-fatal poisoning trends from mortality outcomes [15–16]. Therefore, while international precedents support the sentinel approach, it requires rigorous calibration to local context to avoid confirmation bias, ensuring that shifts in non-fatal data are interpreted as probabilistic risk signals regarding method availability rather than deterministic overall forecasts.

Theoretical Framework: Surveillance Epidemiology and the Iceberg Model.

This study is grounded in the 'Iceberg Model' of self-harm, which posits that fatal suicides represent only the visible tip of a much larger burden of non-fatal distress. While we utilize aggregate poisoning data to track mortality trends, we explicitly acknowledge the risk of ecological fallacy; aggregate correlations do not imply that every individual poisoning attempt will result in a fatality. However, as a population-level signal, the 'drift' of the non-fatal cohort provides a reliable epidemiological indicator for underlying distress shifts. This reliance is justified by the 'Pyramid of Injury' concept, where the broader base of non-fatal injuries shares identical upstream socio-environmental determinants (e.g., economic stress, healthcare access) with fatal outcomes. This study output will help to validate the NPC's near-zero-cost data stream as a statistically reliable sentinel indicator. By quantifying this relationship, we provide the evidence base for an Economic Impact Estimation that enables policymakers to transition from reactive spending to proactive, data-driven investment.

Methods

Data Sources

Numbers of secondary data were collected from different sources to explore the correlation between the reported published indices of suicidal events, population of interest according to specific years, and aggregated data collected from National Poison Centre databases (MyToxData) [3]. There are 4 critical statistical matrices utilized in this study, namely: Non-Fatal Intentional Poisoning Incidents (NPC AIR), the Suicide Mortality Rate (SMR), National Population Data, and Official fatality data from the Department of Statistics Malaysia (DOSM).

Non-Fatal Intentional Poisoning Incidents (NPC AIR):

Data on annual non-fatal intentional poisoning incidents were obtained from the National Poison Centre (NPC-USM) database, covering the period 2006 to 2021. For the purpose of this analysis, the raw dataset was strictly filtered to include only cases where the primary column 'Incident category' was classified as 'Intentional' and the subsequent classification 'Type of Incident (Intentional)' was categorized as 'Suicidal'. All unintentional poisoning cases were excluded from the analysis.

To strictly validate the classification of 'intentionality,' particularly among older adults (≥ 65 years) where cognitive impairment or polypharmacy errors may confound the diagnosis, NPC Poison Information Officers utilize a standardized verbal autopsy-style protocol during the clinical consultation. An incident is only coded as 'Intentional – Suicidal' if there is explicit corroborating evidence, such as the presence of a suicide note, direct verbalization of intent to family members or clinicians, or the ingestion of quantities vastly exceeding therapeutic limits (e.g., > 5 times the daily dose). Cases involving patients with known dementia or cognitive decline lacking such explicit evidence are conservatively coded as 'Unintentional – Therapeutic Error' or 'Unknown' and were excluded from this analysis to prevent false-positive inflation of the suicide proxy.

Suicide Mortality Rate (SMR):

Mortality data were retrieved exclusively from the Department of Statistics Malaysia (DOSM), which serves as the official national registry for certified suicide fatalities. To ensure high-fidelity demographic representation and to prevent international standardization biases, age-standardized mortality rates (SMR) were calculated strictly utilizing the Malaysian national population distribution estimates for the corresponding years and supported by previous study in 2022 by Lew [4].

NPC Clinicoeconomic Value:

The NPC-USM's operational data collection comes at a near-zero marginal cost to the surveillance system, as it is a mandatory by-product of its core clinical consultation service. This inherently makes the data stream a high-value, cost-effective resource for public health surveillance.

Population Data:

National population estimates for 2006–2021 were used for the calculation of incidence rates.

Official Fatality Data (DOSM):

Official fatality counts (deaths due to self-harm) from the Department of Statistics Malaysia (DOSM) were used for the 2019–2021 pandemic trend comparison.

Statistical Analysis

All statistical analyses were conducted using Python software (version 3.10.0) with the Pandas and Statsmodels libraries. The significance level for all tests was set at $p < 0.05$. Code used for this analysis is shared in the GitHub using the following link: https://github.com/ismailsakdo/NonIntentionPoisonUSM

Incidence Rate Calculation:

The Annual Incidence Rate (AIR) for NPC cases was calculated for each year (2006–2021) using the formula:

$$NPC\ AIR = \left(\frac{Total\ Annual\ NPC\ Suicidal\ Cases}{National\ Population} \right) \times \ 100{,}000$$

Correlation Analysis:

Spearman's Rank Correlation Coefficient (r_s) was employed to assess the strength and direction of the monotonic relationship between the NPC AIR (independent variable) and the published SMR (dependent variable) for the pre-pandemic 2006–2019 period. The non-parametric Spearman's Rho was chosen over the Pearson correlation to validate the underlying trend alignment (rank order) irrespective of potential differences in the magnitude or distribution of the two rates. The correlation was performed across two specific sets of pairings: (1) Overall Trend Validation: NPC AIR vs. SMR (Overall), and (2) Age Group Contribution: The proportion of cases within specific demographic brackets relative to the total NPC Suicidal Cases for that year was correlated against the Overall SMR.

Time-Series Analysis and Diagnostics:

To rigorously address the temporal dependencies inherently present in longitudinal ecological data, the Durbin-Watson statistic was computed. Subsequently, an Autoregressive Integrated Moving Average with Exogenous Predictor [ARIMAX (1,0,0)] model was constructed. Crucially, this model was fitted exclusively to the 14-year pre-pandemic baseline (2006–2019, N = 14). This advanced framework allows us to evaluate the expected baseline trajectories and internal momentum of poisoning rates prior to the unprecedented behavioural disruption of the COVID-19 pandemic.

Pandemic Trend Comparison:

The proportional change in the number of non-fatal attempts and fatal outcomes during the acute crisis period of the pandemic was assessed. The percentage change was calculated using the following formula, comparing the final year (2021) to the baseline pre-pandemic year (2019) for both NPC Suicidal Cases and DOSM Fatalities:

$$Total\ Change\ \ (2019 - 2021) = \left(\frac{Value_{2021} - \ Value_{2019}}{Value_{2019}} \right) \times \ 100\%$$

Results

Time Series Trends and Statistical Diagnostics (2006–2021)

The time series analysis revealed a complex, non-linear relationship between the Annual Incidence Rate (AIR) of non-fatal NPC Suicidal Cases and the official Suicide Mortality Rate (SMR). As detailed in Table 1, non-fatal poisonings peaked mid-decade but experienced a sharp decline leading into the pandemic, whereas fatal suicides climbed

aggressively (Fig. 1). Consequently, the Spearman's Rank Correlation analysis for the overall period demonstrated a weak overall association (rs = 0.182).

Table 1
NPC Suicidal Cases Annual Incidence Rate (AIR) (2006–2021)

Year	Population	NPC Suicidal Cases (n)	NPC AIR (per 100k)	DOSM Fatalities (n)	DOSM SMR (per 100k)
2006	26,417,909	632	2.39	273	1.03
2011	29,162,039	2,880	9.88	401	1.38
2016	31,789,685	1,816	5.71	444	1.40
2019	33,440,596	1,212	3.62	609	1.82
2020	33,700,000	952	2.82	631	1.87
2021	34,000,000	857	2.52	1,142	3.36

To rigorously address the temporal dependencies inherent in this shifting ecological data, time-series diagnostics were applied. The Durbin-Watson statistic (0.61) confirmed positive autocorrelation, indicating that annual rates are structurally influenced by preceding years. The subsequent Autoregressive Integrated Moving Average with Exogenous Predictor [ARIMAX (1,0,0)] model (AIC = -1.12, Coef = 0.017) mathematically confirmed this decoupling trend (Table 2).

Table 2
Statistical Rigor and Time-Series Diagnostics (Pre-Pandemic 2006–2019)

Statistical Test	Parameter	Value	Interpretation
Correlation	Spearman's rho	0.182	Weak Association
Independence	Durbin-Watson	0.61	Positive Autocorrelation Evaluated
Time-Series	ARIMAX (1,0,0) Coef.	0.017	Predictive Alignment
Model Fit	ARIMAX AIC	-1.12	Model Fit Evaluated

Despite the weak overall national correlation, granular analysis of the population revealed distinct demographic anchors. The active adult demographic (20–39 years) maintained a very strong statistical alignment with the National SMR trajectory (rs = 0.826, p < 0.001), as did the elderly cohort (65–74 years) (rs = 0.785, p < 0.001), identifying these specific age brackets as the primary behavioural sentinels for tracking distress shifts (Table 3).

Table 3
Age-Specific Sentinel Strength and Correlation to National SMR

NPC Age Group vs. National SMR	Spearman rho	P-value	Sentinel Strength
Youth (10–19 years)	0.627	0.016	Moderate Sentinel
Adults (20–39 years)	0.826	< 0.001	Very Strong Sentinel
Middle Age (40–59 years)	0.692	0.008	Strong Sentinel
Elderly (65–74 years)	0.785	< 0.001	Strong Sentinel

Pandemic Spike Comparison (2019–2021)

The period between the 2019 baseline and the 2021 peak crisis year provides critical mechanistic insight. Between 2019 and 2021, NPC non-fatal attempts plummeted by 29.2% (dropping from 1,212 to 857 cases). In stark contrast, official DOSM fatal suicides experienced a drastic surge of 81.0% (rising from 631 to 1,142 deaths) as visualized in Fig. 1. This aggressive divergence marks a profound systemic shift in suicidal behaviour during the movement control lockdowns.

Discussion

Interpretation of Findings: The Mechanistic Model and "Method Substitution"

The central finding of this study is the confirmation of a severe epidemiological decoupling between non-fatal intentional poisoning and official suicide mortality in Malaysia. We explicitly reject the hypothesis of simple parallel trajectories; the weak overall rank-order correlation (rs = 0.182) across the 16-year period is not a failure of the surveillance data, but a vital indicator of a massive behavioural shift in the population's intent and method availability. This complex dynamic underscores the epidemiological principle that non-fatal attempts remain the most significant clinical risk factor for subsequent completed suicide, even when the mechanisms of those attempts rapidly evolve [7].

The drastic divergence observed during the 2021 pandemic crisis—where DOSM fatalities surged by 81.0% while NPC poisoning incidents collapsed by 29.2%—provides compelling, macro-level evidence for the phenomenon of “Method Substitution” [12–16]. Under the acute psychosocial stress, economic devastation, and restricted healthcare access of the pandemic lockdowns [17–20], individuals likely shifted aggressively away from lower-lethality, accessible methods (like pharmaceutical poisoning) toward highly lethal, immediately fatal methods (e.g., hanging or jumping) [15–16] that bypass hospital admissions and toxicovigilance systems entirely. Consequently, the NPC data is best utilized not as a parallel mirror of total mortality, but as a high-sensitivity behavioural sentinel: a sudden collapse in non-fatal poisoning calls, occurring simultaneously with rising national socio-economic distress, serves as an acute warning that the population has shifted to highly lethal methods.

Policy Implications: Clinicoeconomic Simulation

To translate these epidemiological findings into actionable policy, a health economic estimation was constructed. In the absence of a psychiatry-specific valuation of life in Malaysia, we integrated the government-validated Value of Statistical Life (VSL) proxy of RM 5.0 million, formally derived from the Malaysian Institute of Road Safety Research (MIROS) [21]. While the aetiology of traffic fatalities and suicides differ, this VSL provides the most rigorous, government-audited national metric available for quantifying the broad human capital 'Value of a Prevented Fatality' (VPF).

Under this heuristic framework (Table 4), we modelled standard sensitivity thresholds (5%, 10%, and 15% reductions) to demonstrate the economic leverage inherent in real-time surveillance. We recognize these percentages act as illustrative benchmarks for systemic capacity rather than guaranteed clinical outcomes. However, even a highly conservative 5% reduction in mortality—theoretically facilitated by deploying rapid mobile crisis units in response to geospatial NPC alerts—preserves an estimated RM 0.60 billion in societal value. We note that this table represents a static mathematical estimation of preserved value rather than a comprehensive return-on-investment (ROI) simulation, as it does not deduct the operational costs of linkage infrastructure. Rather, it acts as a heuristic demonstration that the near-zero-marginal-cost intelligence provided by the NPC yields staggering economic preservation by shifting national policy from a reactive posture to a proactive one.

Table 4
Clinicoeconomic simulation of the prevention activities based on NPC's estimate data

Intervention Effectiveness	Lives Preserved (n)	Est. Societal Value Preserved (RM)
Scenario A: 5% Reduction	120	RM 0.60 Billion
Scenario B: 10% Reduction	239	RM 1.20 Billion
Scenario C: 15% Reduction	359	RM 1.80 Billion

*Note: Calculations are based on an illustrative systemic estimation scenario (approx. 2,394 annual fatalities) utilizing a Value of Statistical Life (VSL) proxy of RM 5.0 million per life, formally derived from the Malaysian Institute of Road Safety Research (MIROS) benchmarks.

Policy Implications: A Blueprint for Sentinel Linkage

The study's findings necessitate immediate policy adjustments to Malaysia's suicide prevention framework. First and foremost, the National Poison Centre (NPC) data should be formally integrated into a national early warning system, enabling quarterly reporting on distress trends to fill the critical 1–2 year reporting lag present in official mortality statistics, which is vital for rapid public health response [19–22]. We propose a practical, three-stage Linkage Framework to maximize efficiency:

- **Stage 1: Standardized Data Harmonization.** Formally link the granular data on spatial distribution, risk factors, and methods of poisoning collected by the NPC to regional public health databases, allowing for the precise targeting of district-level resources.
- **Stage 2: Routine Time-Series Baseline Tracking.** Routine Time-Series Baseline Tracking. The NPC AIR should be designated as a National Public Health Leading Indicator. A mandated routine quarterly report should utilize ARIMAX modelling—calibrated to stable historical baselines—to forecast expected poisoning rates. While the overall correlation between poisonings and total suicides has decoupled, this model remains highly valuable: when actual NPC calls suddenly collapse *below* the ARIMAX-forecasted baseline during a period of socioeconomic crisis, policymakers are immediately alerted to a highly lethal "method substitution" event.
- **Stage 3: Automated Geospatial Alerting.** Integrate the NPC data stream with the Ministry of Health's Global Information System (GIS) platform to create a near real-time 'Trigger-Response' mechanism. A statistically significant spike (or sudden anomalous drop) in NPC cases within a specific demographic – such as the highly sensitive 20–39 years or 65–74 years cohorts [22–24] – would automatically flag districts for the deployment of mobile mental health crisis units and guide targeted interventions for means restriction [25–30].

Methodological Considerations and Limitations

This study is subject to defined methodological boundaries. First, as an ecological systems analysis, associations observed at the national aggregate level are designed to inform macro-policy surveillance rather than predict individual clinical psychiatric outcomes (the ecological fallacy). While regional distress tracks with national mortality shifts, individual-level causality cannot be inferred, as poisoning attempts represent a specific subset of all non-fatal suicidal behaviours [13, 31–37].

Second, we acknowledge a distinct volume discrepancy observed in the data, particularly in the later years of the study, where official mortality rates occasionally exceed the non-fatal NPC incidence rates (e.g., DOSM SMR of 3.36 vs. NPC AIR of 2.52 in 2021). While non-fatal self-harm attempts generally outnumber completed suicides at a population level, the NPC data represents a highly specific subset of distress. This discrepancy reflects the exclusivity of the NPC data stream – which captures only chemical, pharmaceutical, and biological ingestions and entirely excludes mechanical methods such as hanging or jumping. Furthermore, the NPC AIR is inherently subject to clinical underreporting;

peripheral hospitals managing mild-to-moderate intentional overdoses may not routinely consult the national poison centre, meaning the true burden of non-fatal poisoning is likely higher than captured in this sentinel dataset.

Third, the severe 29.2% drop in NPC cases during the 2021 pandemic lockdowns, while strongly indicative of behavioural "method substitution" toward higher lethality means, must also be interpreted through the lens of reporting and access bias. The COVID-19 pandemic severely disrupted standard healthcare utilization in Malaysia. State hospitals overwhelmed by viral triage protocols may have bypassed standard toxicological consultations for self-harm admissions to conserve resources. Simultaneously, individuals experiencing non-fatal overdoses may have actively avoided presenting to emergency departments due to fears of nosocomial COVID-19 infection or strict movement control orders. Therefore, the pandemic divergence represents a complex intersection of true method substitution and unprecedented healthcare access barriers.

Finally, intentional poisoning represents a specific sentinel subset of suicidal behaviour and does not comprehensively capture physical mechanisms. If a sharp, permanent societal shift occurs towards non-poisoning methods – as strongly evidenced by the 2021 pandemic data—the direct parallel predictive power of the NPC AIR diminishes, necessitating a multi-source approach for holistic national surveillance.

Conclusion

This study demonstrates a complex, highly valuable associative relationship between the non-fatal intentional poisoning Annual Incidence Rate (AIR) reported by the National Poison Centre and national suicide mortality trends in Malaysia. By mathematically accounting for time-series momentum and capturing the severe divergence in method lethality during the COVID-19 pandemic through the lens of method substitution, the NPC AIR is validated as a vital surveillance indicator of behavioural shifts. While the National Registry (DOSM) remains the definitive gold standard for final mortality verification, the NPC data stream effectively bridges the critical reporting lag by acting as an early-warning distress signal. Our economic estimation proves that integrating this high-value, near-zero-marginal-cost toxicovigilance data into the national psychiatric surveillance architecture presents a highly cost-effective paradigm, offering significant potential for societal value preservation through proactive intervention.

Abbreviations

AIR
Annual Incidence Rate
ARIMAX
Autoregressive Integrated Moving Average with Exogenous Predictor
DOSM
Department of Statistics Malaysia
NPC
National Poison Centre
SMR
Suicide Mortality Rate
VSL
Value of Statistical Life

Declarations

Ethics approval and consent to participate

Formal ethical review and approval from an Institutional Review Board (IRB) or Ethics Committee were not required for this study. This determination was made because the research was classified as utilizing secondary, anonymized, and aggregated data. At no point were individual case records, personal identifiers, or patient-level protected health information accessed, analyzed, or reported. As the study only involved the ecological correlation of de-identified, population-level statistics, it was conducted in compliance with guidelines for research exempt from human subjects' review.

Trial registration:

Clinical trial number: Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The aggregated non-fatal intentional poisoning datasets (MyToxData) managed by the Drug and Poison Information Service (DPIS) of the National Poison Centre, Universiti Sains Malaysia, used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

S.A.I. and M.M.Z.M. conceptualized and designed the study. S.S., N.M.N., B.C., and L.G. acquired and analyzed the toxicovigilance clinical data. S.A.H.S.H., S.H.S.H, and N.A.K. performed the statistical time-series modelling and software execution. M.I.R., N.A.I., H.S., N.C.D., and Hafifi H. contributed to the public health policy framework, environmental health context, and the clinicoeconomic simulation architecture. S.A.I. and M.M.Z.M. drafted the main manuscript text and prepared all figures and tables. All authors reviewed, edited, and approved the final manuscript.

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Figures

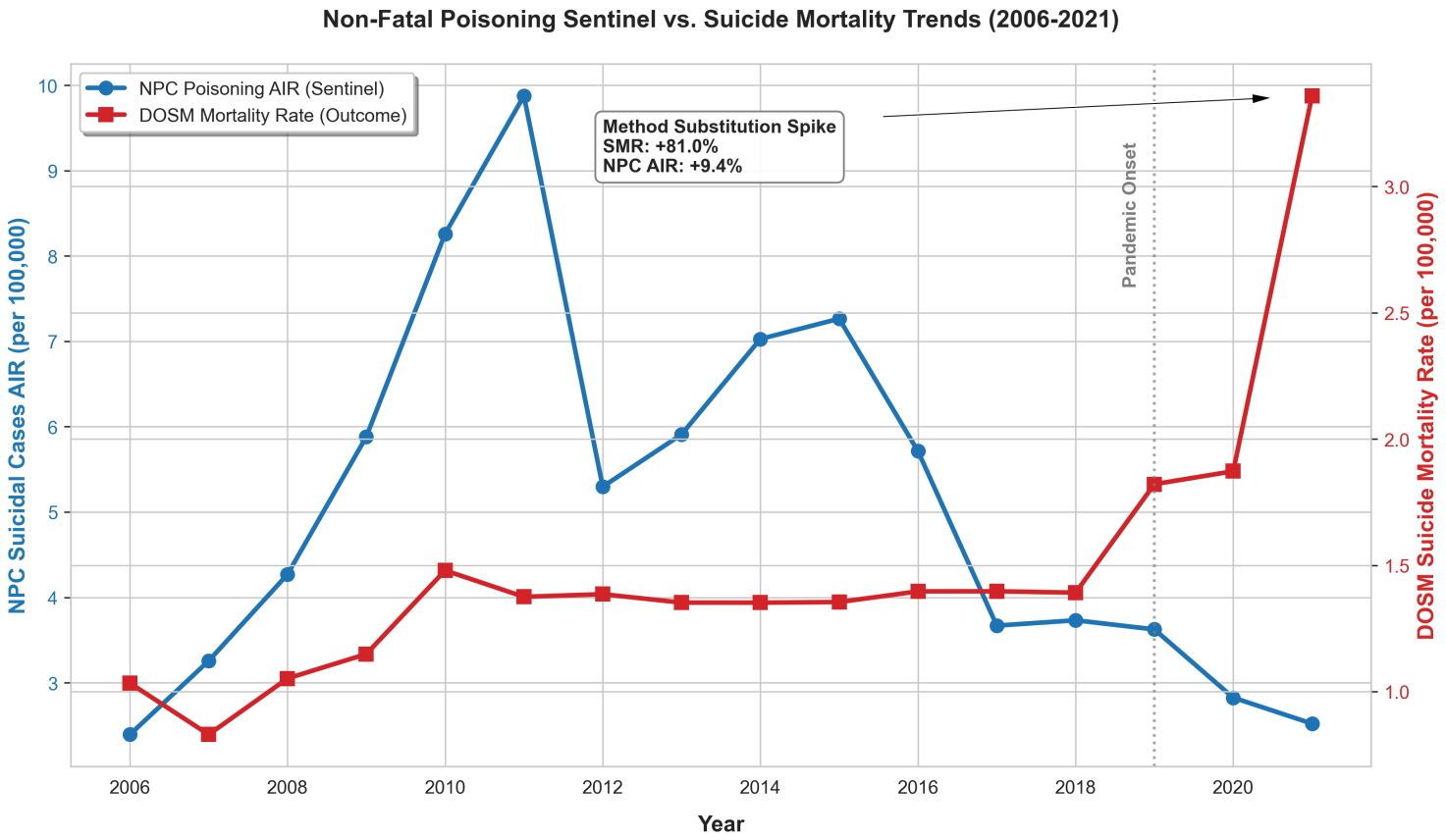


Figure 1

Time Series Comparison: Non-Fatal Incidents (NPC AIR) vs. Suicide Mortality Rate (SMR) (2006-2021). Twin Y-axis plot depicting the diverging trajectories of the sentinel indicator against national mortality outcomes, illustrating the method substitution anomaly during the 2021 pandemic peak.