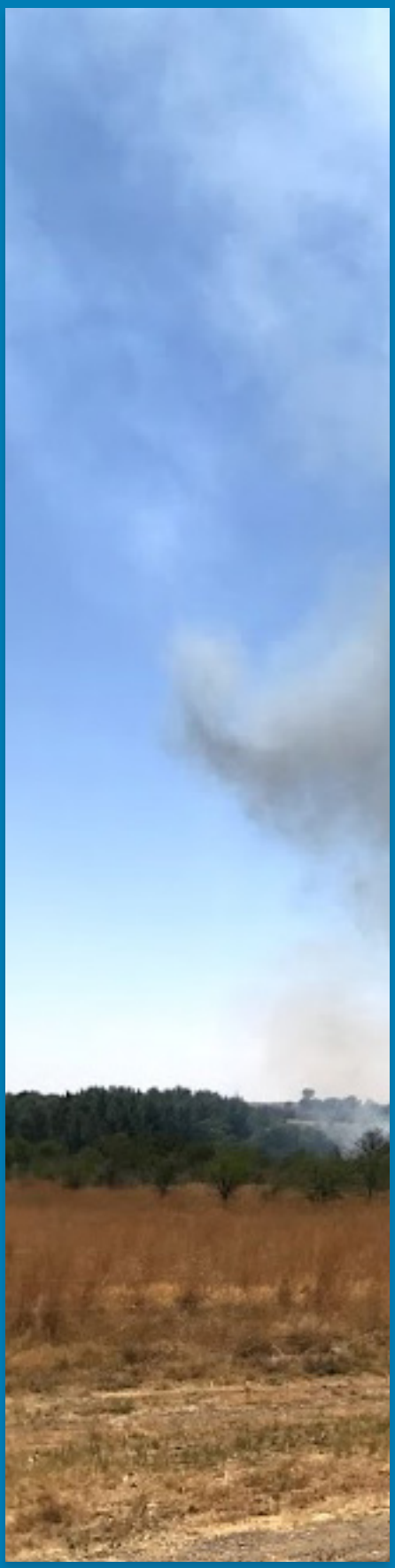

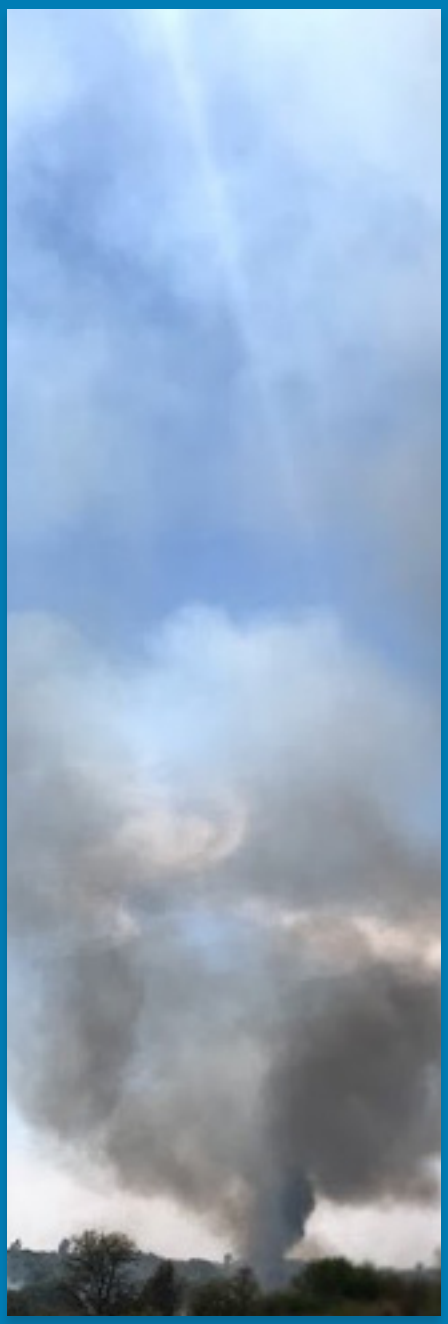

REPORT FOR POLICYMAKERS
13 JANUARY 2026

THE IMPACT OF AIR POLLUTION ON HUMAN HEALTH IN THE THREE AIR POLLUTION PRIORITY AREAS IN SOUTH AFRICA

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CLEAN AIR FUND

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Contents

EXECUTIVE SUMMARY

Introduction

This report presents the results of an in-depth epidemiological study conducted across the Highveld Priority Area (HPA), the Vaal Triangle Priority Area (VTPA), and the Waterberg-Bojanala Priority Area (WBPA) in South Africa, focusing on the association between ambient air pollution and mortality. By integrating data from 2005 to 2020, stratified by district, pollutant, and season, this study aims to provide robust, policy-relevant insights into the public health impacts of pollutants such as PM_{10} and SO_2.

The three priority areas reflect regions of high industrial activity and emissions. The HPA includes Sedibeng and Gert Sibande, the VTPA comprises Nkangala and Fezile Dabi, and the WBPA includes Waterberg and Bojanala. These areas have been designated based on elevated pollutant concentrations and significant population exposure. The dataset includes weekly mortality counts, meteorological data, and air pollution concentrations, covering a broad range of temporal and spatial variation. This robust structure allows for the analysis of lagged effects of pollution exposure and the differentiation of risk patterns across seasons.

Key Findings

- Statistically significant associations were found between PM_{10}, SO_2, and mortality.
- Nkangala showed the highest risks in both spring and autumn. The elevated risks reflect seasonal exposure patterns likely driven by heating practices, regional meteorology, and pollution accumulation.
- Fezile Dabi similarly showed significant associations suggesting a persistent health burden from SO_2 and PM_{10} emissions during colder months, when pollutant dispersion is limited.
- Sedibeng presented consistently elevated risks, notably in winter and spring. These results underscore Sedibeng as a district of particular concern due to both elevated baseline exposure and significant population density.
- Gert Sibande, part of the HPA, exhibited more moderate but significant associations indicative of episodic but impactful pollution events.
- In Waterberg and Bojanala, the magnitude of association between air pollution and health was lower but still noteworthy.

Policy Implications

This study provides compelling evidence that ambient air pollution—specifically PM_{10} and SO_2—is significantly associated with increased weekly mortality across several South African districts, particularly in transitional seasons like spring and autumn. Importantly, these findings are consistent across both individual district analyses and meta-analytic aggregation.

The short lag between exposure and mortality suggests that acute public health interventions—such as real-time air quality alerts, emergency healthcare readiness, and targeted emissions control during high-risk seasons—could substantially mitigate health risks. For districts like Sedibeng and Nkangala, which show consistent multi-season risk, more sustained structural interventions are warranted, including air quality regulation enforcement, industrial emissions monitoring, and urban planning to reduce exposure.

Additionally, the significant results from the WBPA, although more moderate, underscore the importance of proactive policy even in regions with lower population densities, where vulnerable populations may be at risk.

The results support the value of a national early warning system based on air quality thresholds, tailored by season and pollutant type. Furthermore, the inclusion of lagged effects reinforces the need for continued exposure monitoring and temporal modelling in public health planning.

Conclusions

In conclusion, the study has uncovered important and statistically robust associations between air pollutants and mortality in South Africa. With consistent patterns of elevated risk for PM_{10} and SO_2 across multiple seasons and lag periods, particularly in HPA and VTPA, the case for urgent air quality management is clear.

These findings offer direct, data-driven guidance for national and local policymakers to design, implement, and evaluate air pollution mitigation strategies and public health safeguards. This evidence base also offers a strong justification for longitudinal monitoring, cross-sectoral collaboration, and integration of environmental health data into routine policy assessment frameworks.

INTRODUCTION

According to the World Health Organization, "air pollution is the single biggest environmental threat to human health, based on its notable contribution to disease burden" (WHO, 2021).[1] It is estimated that poor air quality causes nearly 800 000 premature deaths in Africa every year. South Africa's Constitution states in Section 24 that "everyone has the right to an environment that is not harmful to their health and well-being", which includes ambient air.

South Africa has legislation regulating air quality under the National Environmental Management: Air Quality Act 39 of 2004 (NEMAQA), as well as air quality standards (which may be legally enforced) that are based on health and are for the most common pollutants. South Africa also has a monitoring network of several air quality monitoring stations (125 in 2019) managed by the South African Weather Services. There are three air pollution priority areas in South Africa: Vaal Triangle Airshed (declared in 2006). The Highveld Priority Area (2007) and Waterberg-Bojanala (2015) (Figure 1). These air pollution areas were identified for special management across provinces and by National Government (i.e., the Department of Forestry, Fisheries and Environment).

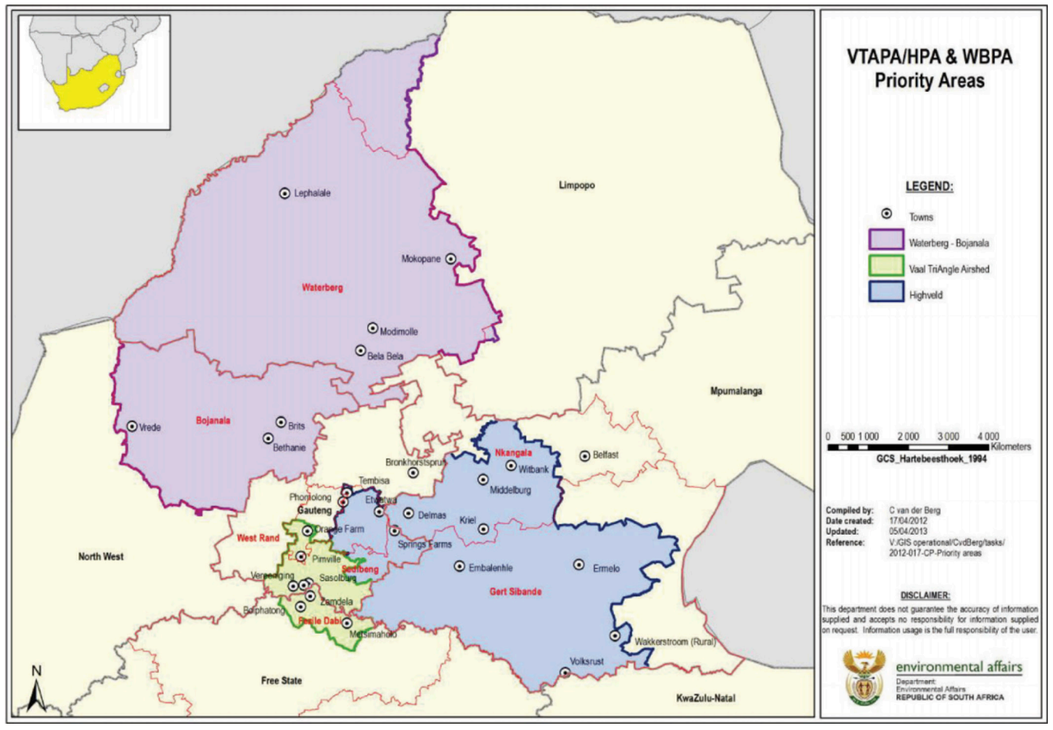


Figure 1. Location of the Air Pollution Priority Areas in South Africa.

While some studies have been conducted on the air pollution concentrations in the priority areas, and some studies have considered the health impacts, there has been no comprehensive assessment of long-term trends in air pollution in relation to mortality and morbidity in the three air pollution priority areas. In a recent review of air pollution and health in the Waterberg-Bojanala Priority Areas, less than ten studies were identified that considered air quality and health impacts (Wernecke et al., 2023).2 Moreover, most of the studies that have been done used a cross-sectional approach to assess air pollution-related health impacts through questionnaire surveys and self-report. No similar reviews on air pollution and health are available for the other two priority areas (this study fills this gap too).

Given this lack of evidence, the SAMRC (Environment and Health Research Unit) proposes a research study (outline in Figure 2) to understand the impacts of air pollution on human health focusing on the geographical areas of priority in terms of air quality management, namely the three air pollution priority areas. This epidemiological study applies a retrospective longitudinal methodology, together with a case crossover analysis as a sensitivity study stratified by seasons. The health effects included the all-cause mortality datasets from Stats SA and morbidity data from Department of Health Information System (DHIS). The morbidity data included Pneumonia under 5 and new cases of TB related hospital admissions. The DoH provided the morbidity data and SASTATS provided the morbidity datasets. The timeframe was from 1997 to 2023.

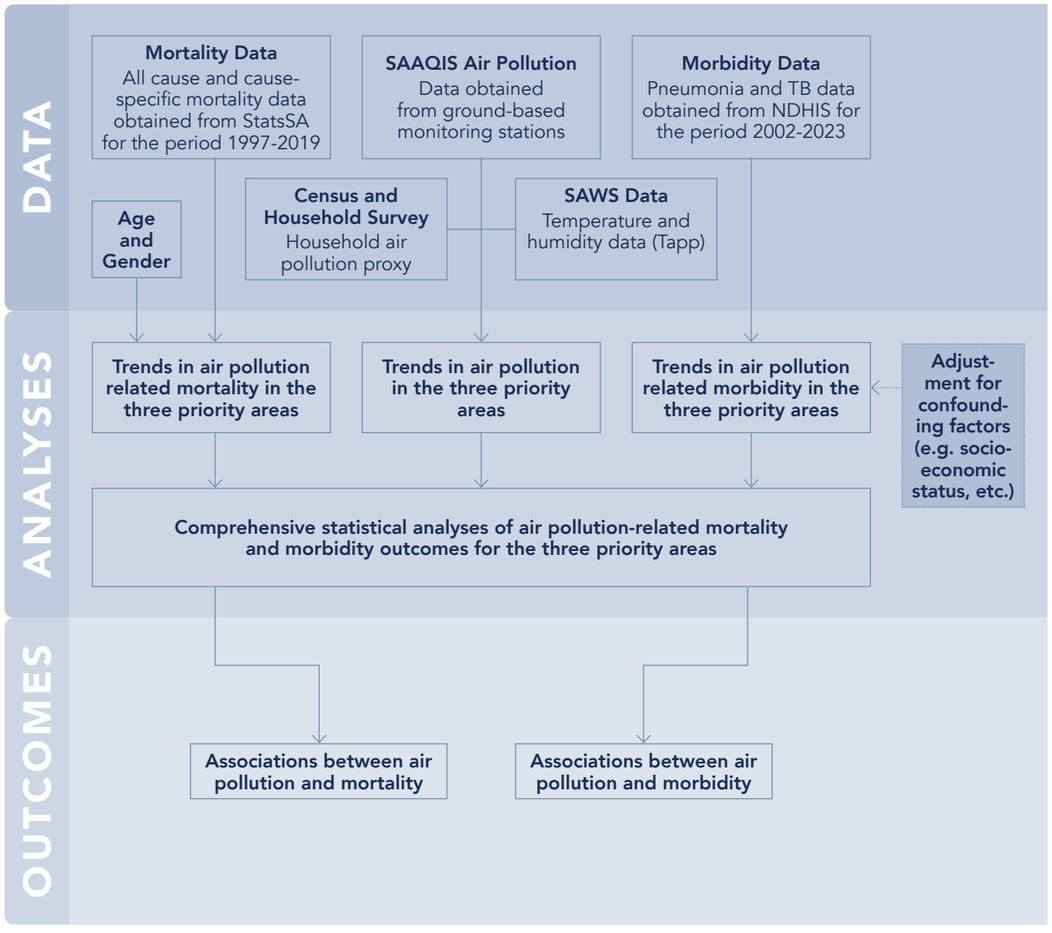


Figure 2. Flowchart illustrating the data, analyses and outcomes of the proposed research study.

BACKGROUND AND CONTEXT

The Clean Air Fund (CAF) is launching activities related to reducing air pollution in South Africa. The South African Strategy has a focal point on integrated policy pathways assessment for air pollution, climate and impact on health, including evidence on the health (and economic) impacts of air pollution. To achieve these goals, the Clean Air Fund requires a comprehensive account of the air pollution-related health impacts in the three air pollution priority areas in South Africa. This project presents a research study to fill this gap.

The study aligns to the objectives of the National Department of Health's National Air Quality and Health Steering Committee and will feed into their Five-Year Air Quality and Health Strategic Plan for South Africa. The goal of the National Strategy is to generate evidence on the health and wellbeing of South Africans in relation to air pollution exposure, and this proposed study will do that for the priority areas in South Africa. The South African Medical Research Council (SAMRC) serves on the National Air Quality and Health Steering Committee.

STUDY OBJECTIVES AND METHODS

The study assessed short-term effects of air pollutants ($PM_{2.5}$, PM_{10}, NO_2, SO_2, and O_3) on mortality and morbidity between 2005 and 2020. Using an adapted distributed lag non-linear model and case-crossover designs, researchers examined health risks with weekly mortality and morbidity data. This innovative approach allowed analysis despite incomplete datasets, providing reliable evidence in resource-constrained settings.

KEY FINDINGS

1	2	3	4	5
$PM_{2.5}$ and NO_2 exposure are consistently associated with higher mortality and morbidity, particularly respiratory deaths and tuberculosis-related outcomes.	**A 10 µg/m³ increase in $PM_{2.5}$ was linked to a 14–19% higher mortality risk.**	**NO_2 exposure was strongly related to pneumonia and respiratory deaths.**	**SO_2 and O_3 also showed significant associations in certain districts and seasons, particularly in winter.**	**Children, youth, and older adults remain the most vulnerable groups.**

HEALTH IMPACTS IN PRIORITY AREAS

Highveld Priority Area (HPA): Highest levels of $PM_{2.5}$ and NO_2, especially in winter, linked to elevated respiratory deaths.

Vaal Triangle Airshed (VTAPA): Strong associations between $PM_{2.5}$ and tuberculosis mortality, and consistent SO_2 impacts from industrial activity.

Waterberg-Bojanala Priority Area (WBPA): Elevated SO_2 and O_3 risks, linked to coal and smelting industries. Health risks persist despite lower population density.

The figure below show the statistically significant ($p < 0.001$) result of a pollutant per season across all Districts within the three priority areas for total new cases of pneumonia < ages of 5 years ranked by the top ten for district and season.

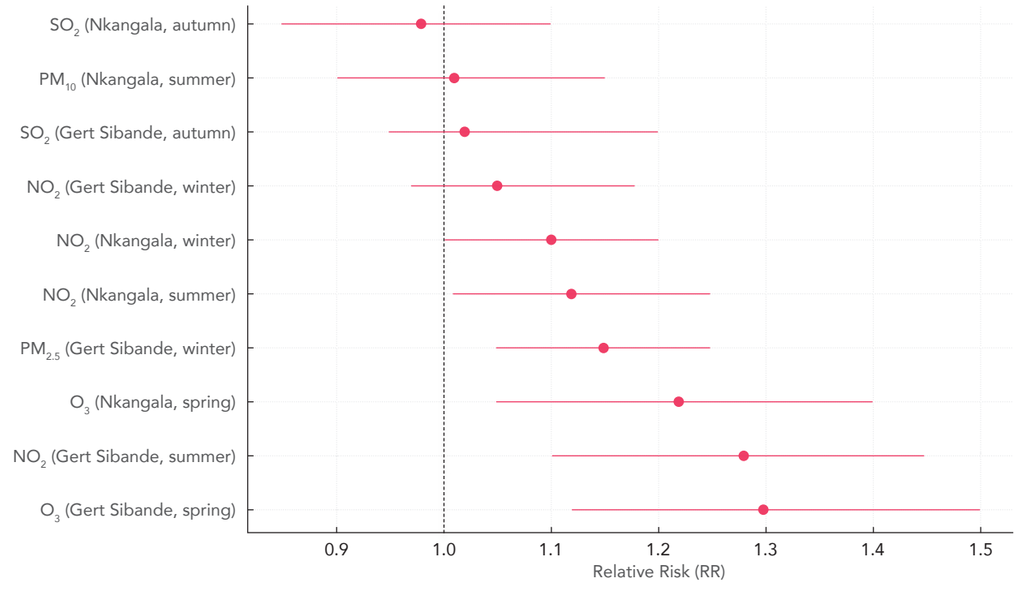


Figure 3. Top 10 Statistically Significant RR > 1 (O Lower > 1)

In the figure, all the relative risks, except for Nkangala (autumn, SO_2) show an increased risk for pneumonia in children under 5 years of age associated with a exposure to a specific pollutant. The highest relative risk of 1.3 was for Gert Sibane for O_3 exposure in spring. This can be understood as a three times greater risk for children under 5 years exposed to ozone experiencing pneumonia compared to unexposed children.

POLICY IMPLICATIONS

The findings highlight the urgent need for stronger enforcement of air quality standards and targeted interventions in Priority Areas.

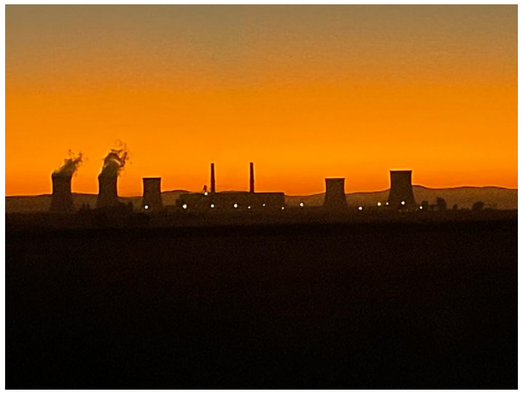
Wintertime pollution peaks underscore the role of energy policy and household fuel use.

The health risks identified also suggest the need for integrating air pollution mitigation into tuberculosis, pneumonia, and non-communicable disease strategies.

RECOMMENDATIONS

We propose six recommendations as follows:

1. **Strengthening enforcement of National Ambient Air Quality Standards in Priority Areas.**
2. **Expand air quality monitoring networks and improve data transparency.**
3. **Invest in cleaner energy alternatives and household energy transitions.**
4. **Establish early warning systems for air pollution episodes.**
5. **Integrate pollution reduction into health system preparedness, particularly for TB and respiratory care.**
6. **Conduct regular health impact assessments to inform adaptive policymaking.**



LIMITATIONS AND DATA GAPS

Data gaps in monitoring and health surveillance remain a major challenge.

Meteorological data were not consistently included, which may influence seasonal patterns. Despite these limitations, triangulation across multiple models and regions provides robust findings.

Expanding surveillance and integrating environmental and health data systems would strengthen future assessments.

CONCLUSION

Air pollution is a significant but preventable health risk in South Africa's Priority Areas. The evidence from this study demonstrates strong, consistent associations between pollutant exposure and mortality, particularly from respiratory diseases and tuberculosis. Addressing these risks requires coordinated action across environment, health, and energy sectors.

Policy action now can reduce premature deaths, improve health equity, and align with South Africa's climate and development goals.

BIBLIOGRAPHY

1. World Health Organization. WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organisation; 2021.

2. Wernecke B, Naidoo NP, Wright CY. Establishing a baseline of published air pollution and health research studies in the Waterberg-Bojanala Priority Area. Clean Air Journal. 2023; 33(1):1-12.

3. Achilleos S, Kioumourtzoglou M-A, Wu C-D, Schwartz JD, Koutrakis P, Papatheodorou SI. Acute effects of fine particulate matter constituents on mortality: A systematic review and meta-regression analysis. Environment international. 2017; 109:89-100.

4. Adeola FO. Global impact of chemicals and toxic substances on human health and the environment. Handbook of Global Health. 2020:1-30.

5. Cesaroni G, Badaloni C, Gariazzo C, Stafoggia M, Sozzi R, Davoli M, et al. Long-term exposure to urban air pollution and mortality in a cohort of more than a million adults in Rome. Environmental health perspectives. 2013; 121(3):324-31.

6. Gasparrini A. A tutorial on the case time series design for small-area analysis. BMC medical research methodology. 2022; 22(1):129.

7. Dominici F, Zigler C. Best Practices for Gauging Evidence of Causality in Air Pollution Epidemiology. American Journal of Epidemiology. 2017; 186(12):1303-9. doi:10.1093/aje/kwx307

8. Huang Y-L, Batterman S. Residence location as a measure of environmental exposure: a review of air pollution epidemiology studies. Journal of Exposure Science & Environmental Epidemiology. 2000; 10(1):66-85.

9. Bhaskaran K, Gasparrini A, Hajat S, Smeeth L, Armstrong B. Time series regression studies in environmental epidemiology. International journal of epidemiology. 2013; 42(4):1187-95.

10. Katsouyanni K, Schwartz J, Spix C, Touloumi G, Zmirou D, Zanobetti A, et al. Short term effects of air pollution on health: a European approach using epidemiologic time series data: the APHEA protocol. Journal of Epidemiology & Community Health. 1996; 50(Suppl 1):S12-S8.

11. Gasparrini A, Armstrong B. Reducing and meta-analysing estimates from distributed lag non-linear models. BMC Medical Research Methodology. 2013; 13(1):1. doi:10.1186/1471-2288-13-1