HEALTH IMPACT RESULTING FROM
THE INTRODUCTION OF LOW-EMISSION ZONES

A COMPARATIVE INTERRUPTED TIME SERIES ANALYSIS OF A NATURAL EXPERIMENT
IN THREE BELGIAN CITIES USING INDIVIDUAL-LEVEL HEALTH OUTCOMES

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AIR QUALITY HAS IMPROVED, BUT THE MAJORITY OF BELGIANS ARE EXPOSED TO AIR POLLUTION LEVELS ABOVE WHO GUIDELINES

PM$_{2.5}$ in 2017

PM$_{2.5}$ in 2020

PM$_{2.5}$ in 2022

PM$_{2.5}$, $\mu$g/m$^3$

- 3.60 - 4.99
- 5 - 5.99
- 6 - 6.99
- 7 - 7.99
- 8 - 8.99
- 9 - 9.99
- 10 - 10.99
- 11 - 11.99
- 12 - 12.99
- 13 - 13.99
- 14 - 14.99
- 15 - 16.03

1.5% of members of Mutualités Libres meet WHO AQG (5µg/m$^3$)

Own visualisation and calculation by census tract and for individual members based on ATMO-Street air pollution data provided by Irceline.
STRONG EVIDENCE ABOUT THE IMPACT OF AIR POLLUTION ON HEALTH IN BELGIUM

Residential green space, air pollution, socioeconomic deprivation and cardiovascular medication sales in Belgium: a nationwide ecological study
Aerts et al. Science of the total environment, 2020

Association of air pollution and green space with all-cause general practitioner and emergency room visits: a cross-sectional study of young people and adults living in Belgium
Vranken et al. Environmental Research, 2023

Impact of short-term exposure to air pollution on natural mortality and vulnerable populations: a multi-city case-crossover analysis in Belgium
Demoury et al. Environmental Health, 2024

Short-term exposure to ambient air pollution and onset of work incapacity related to mental health conditions

In utero exposure to air pollutants and mitochondrial heteroplasmy in neonates
Cosemans et al. Environmental Science & Technology, 2023
REDUCING AIR POLLUTION LEVELS COULD PREVENT THOUSANDS OF DEATHS IN EUROPEAN CITIES EVERY YEAR (data for 2015)

ANTWERP

NO2 (ANNUAL MEAN)

RANKING POSITION

DEATHS THAT COULD BE AVOIDED

2/858

BRUSSELS

NO2 (ANNUAL MEAN)

RANKING POSITION

DEATHS THAT COULD BE AVOIDED

8/858
URBAN VEHICLE ACCESS REGULATIONS
TO IMPROVE ISSUES SUCH AS AIR QUALITY

- Low Emission Zone
- Urban Road Tolls
- Other Access Regulation
- Pollution Emergency
- Zero Emission Zone

https://urbanaccessregulations.eu/ (provided by Sadler Consultants Europe GmbH)
“LOW EMISSION ZONES MAY IMPROVE HEALTH OUTCOMES LINKED TO AIR POLLUTION”

- Systematic review of 8 STUDIES covering Low-Emission Zones in Germany, Japan and the UK
- 5 of 6 studies: reductions in CARDIOVASCULAR DISEASE subcategories
- 2 of 5 studies: improvements in RESPIRATORY OUTCOMES
- 2 German studies showed that HEALTH BENEFITS TENDED TO GROW OVER 3- AND 5-YEAR PERIODS
- 1 study in Japan detected IMPROVEMENTS IN LUNG CANCER RATES 6 TO 9 YEARS LATER

SOCIOECONOMIC POSITION, AIR POLLUTION AND BENEFITS FROM LEZ

ROME

Wealthy residents...

✓ are more likely to live in the city centre
✓ are exposed more than disadvantaged groups to higher air pollution concentrations
✓ because the LEZ targeted the central area of the city, they profited more

LONDON

More deprived areas...

✓ have higher air pollution concentrations
✓ experienced greater air pollution reductions and mortality benefits compared to the least deprived areas

Note: contradicting findings have also emerged likely resulting from different levels of analyses and deprivation measures, see Verbeek & Hinckx, 2022.

THERE ARE 3 LOW-EMISSION ZONES IN BELGIUM

- **ANTWERP LEZ**
  - LEZ since 2017
  - stricter regulations in 2020

- **BRUSSELS LEZ**
  - LEZ since 2018
  - stricter regulations in 2019, 2020 and 2022

- **GHENT LEZ**
  - LEZ since 2020
Study objectives

I. Evolution of **AIR QUALITY** since the implementation of the LEZs, compared to other cities

II. Differential exposure to air pollution according to **SOCIOECONOMIC POSITION**, and the evolution thereof since the implementation of the LEZ

III. **HEALTH IMPACT** of the implementation of the LEZs, compared to other cities
The study population comprises 175,691 MEMBERS of the Independent Health Insurance Funds (~2.2 million members) LIVING AT THE SAME ADDRESS DURING THE STUDY PERIOD (01-01-2014 TO 31-12-2023) within either the 3 LEZ or 17 control cities.
I. IMPROVEMENT OF AIR QUALITY IN THE LEZ CITIES, COMPARED TO CONTROL CITIES
Air quality measures include average annual concentrations of \( \text{PM}_{2.5}, \text{PM}_{10}, \text{NO}_2 \) AND BC FOR 2016-2022, and are CALCULATED FOR ALL INCLUDED INDIVIDUAL MEMBERS from ATMO-Street data provided by the Belgian Interregional Environment Agency.

Note: average annual concentrations for the pollutants were ALSO CALCULATED FOR THE FULL GEOGRAPHICAL AREA for the 3 LEZs and 17 control cities – findings did not statistically significantly differ from findings based on the concentrations calculated for our members.

*Modelled data used in this study originate from ATMO-Street, an integrated model chain that models air quality at high resolution.*
Random coefficient model approach, with **BASELINE** as covariate

(sensitivity analysis: baseline*year)

**ANTWERP COMPARED WITH FLEMISH CONTROL CITIES** since LEZ was implemented in 2017 and no pre-LEZ ATMO-Street data for Wallonia available in 2016 (so no baseline available)

**BRUSSELS COMPARED WITH FLEMISH AND WALLOON CONTROL CITIES**

**GHENT NOT EVALUATED**, for now, as LEZ implementation coincided with COVID-19, and few post-measures are available
FINDINGS: AIR POLLUTION OVER TIME FOR LEZ AND CONTROL CITIES

<table>
<thead>
<tr>
<th></th>
<th>Antwerp LEZ</th>
<th>Brussels LEZ</th>
<th>Ghent LEZ</th>
<th>Control-FLA</th>
<th>Control-WAL</th>
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<tbody>
<tr>
<td>BC, NO₂</td>
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<tr>
<td>pre-LEZ (2016)</td>
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<td>LEZ (2022)</td>
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<td>change 2017-2022</td>
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(pre-)LEZ worse than control  
(pre-)LEZ better than control  
Larger improvement in LEZ than in control
## FINDINGS: AIR POLLUTION OVER TIME FOR LEZ AND CONTROL CITIES

<table>
<thead>
<tr>
<th>City</th>
<th>Year comparison</th>
<th>PM$_{10}$</th>
<th>PM$_{2.5}$</th>
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<tbody>
<tr>
<td>Antwerp LEZ</td>
<td>pre-LEZ (2016) vs LEZ (2022)</td>
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II. SOCIOECONOMIC POSITION &

( THE EVOLUTION OF ) EXPOSURE TO AIR POLLUTION
Measure of deprivation: **BELGIAN INDICES OF MULTIPLE DEPRIVATION (BIMD) DECILES** (for the year 2011), with a focus on **BRUSSELS**

- BIMD (income, employment, education, housing) without the health deprivation domain
- BIMD deciles were categorized as 1 – Most deprived (n=263), 2 (n=146), 3 (n=112), 4 (n=75), ≥5 – Least deprived (n=94), for a total of 690 census tracts

- Random coefficient model approach, with **BASELINE** as covariate

(sensitivity analysis: baseline*year)

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**Otatova et al. Measuring small-area level deprivation in Belgium: The Belgian Index of Multiple Deprivation. Spat Spatiotemporal Epidemiol, 2023**
FINDINGS: DIFFERENTIAL EVOLUTION OF AIR POLLUTION WITHIN LEZ ACCORDING TO SOCIOECONOMIC STATUS (IN BRUSSELS)
Controlling for the pre-LEZ value (in 2017), there is a **STATISTICALLY SIGNIFICANT DIFFERENCE IN THE CHANGE IN BC AND NO$_2$ over time across BIMD deciles**. For BC there is a systematically slower decrease with lesser deprivation, while for NO$_2$, there is a slower decrease for BIMD decile $\geq 5$ → **MORE DEPRIVATION = MORE RAPID DECREASE**.

Controlling for the pre-LEZ value (in 2017), there is **NO STATISTICALLY SIGNIFICANT DIFFERENCE IN THE CHANGE IN PM$_{10}$ AND PM$_{2.5}$ over time across BIMD deciles**.

Exposure to these pollutants remains **STATISTICALLY SIGNIFICANTLY HIGHER IN MORE DEPRIVED BIMD DECILES**.
III. HEALTH IMPACT FROM THE INTRODUCTION OF LEZs
Repeated measurements, equally spaced by year, were created for:

✓ Number of all-cause IN-HOURS/OUT-OF-HOURS GENERAL PRACTITIONER VISITS
✓ Number of all-cause EMERGENCY ROOM VISITS
✓ Chronic (≥90 DDD) use of drugs: DIABETES (A10A & A10B)
    ● CARDIOVASCULAR DISEASE (C01 C02 C03 C07 C08 C09)
    ● OBSTRUCTIVE AIRWAY DISEASES (R03)
    ● ANTIDEPRESSANTS (N06A)
    ● ANTITHROMBOTIC AGENTS (B01)
PROPENSITY MATCHING TO BALANCE MEMBERS LIVING IN LEZ AND CONTROL CITIES

BELGIAN INDICES OF MULTIPLE DEPRIVATION

BIMD deciles combine information from 6 domains: income, employment, education, housing, health and crime

Data for 2011

TREE COVER

High Resolution Layers from the Copernicus Land Monitoring Service Dominant Leaf Type and Grassland 10 × 10 m raster data

Data for 2018

URBAN/RURAL

Having a population density of more or less than 600 inhabitants/km² at the level of the census tract, respectively

Data for 2014

Individual-level characteristics included in the analysis are AGE, GENDER, and NATIONALITY
✓ Generalized Estimating Equations (GEE) to account for repeated outcome measures

✓ Negative binomial GEE to the count outcomes

✓ Binary logistic GEE to the binary outcomes

✓ Estimation and testing on the event probability scale

✓ Subgroup analyses by age categories and BIMD

* The curve may take a different shape e.g. a slope change following a lag
CONCLUSION

✓ Air pollution concentrations in Belgium STILL LARGELY EXCEED WHO AQG LEVELS

✓ Compared to control cities, BC, NO$_2$, PM$_{10}$ and PM$_{2.5}$ SHOWED A LARGER DECREASE IN ANTWERP AND BRUSSELS SINCE THE IMPLEMENTATION OF THE LEZ

✓ In Brussels, MORE DEPRIVED NEIGHBOURHOODS BEAR THE HEAVIEST BURDEN, but for NO$_2$ and BC more deprived neighbourhoods BENEFITED MOST since the implementation of the LEZ