Health Risk Maps of Air Pollution in Europe

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1. Air pollution is a major health burden in Europe, but it differs considerably by geography



400,000
premature deaths annually

Air pollution is currently the major environmental health risk in Europe, contributing to more than **400,000 premature deaths annually** according to the European Environment Agency (EEA).[1]

The number of premature deaths attributable to air pollution has decreased in recent decades, especially **due to EU regulation of emissions** from sectors such as road transport and the implementation of **national emission ceilings**.

National efforts to reduce emissions have also contributed to improvements in air quality. **The number of premature deaths due to air pollution is expected to decrease further** in the future due to continued EU and national regulation of emissions. However, **air pollution is expected to remain a substantial environmental health risk in Europe in the coming years**.

Estimates of premature deaths and other adverse health effects related to air pollution exposure at the European or national level can be hard to interpret for non-experts. **Health risk maps offer a way to illustrate the health impacts of air pollution in a more accessible way**, answering questions such as:

How does the health risk in my country compare to others?

How does the region where I live compare with other regions?

As part of the **MARCHES project, spatial health risk maps for Europe** have been developed, aiming to make such differences in health risks easier for citizens and policymakers to understand.

Fact box:

Easy-to-understand mapping of the health risk of air pollution

We have developed **simple indicators to communicate health risks associated with air pollution**, because understanding these risks is challenging for non-experts. These indicators target non-experts and illustrate the relative health risks of living in different countries, regions, and urban and rural areas.

The objective of the **spatial health risk map for Europe** is to communicate these health risks to citizens and policymakers by visualising relative risks across European countries and regions. The map provides easy-to-understand geographic indicators illustrating how health risks associated with air pollution vary between areas.

2. Quantifying the health burden of air pollution

The risk maps are based on output from the **integrated model system EVA** (Economic Valuation of Air Pollution)[2], which we use to calculate the health effects of air pollution. Air pollutant concentrations are based on model runs with the regional-scale chemistry-transport model DEHM (Danish Eulerian Hemispheric Model), which is set up with a geographical resolution of approximately 20 km x 20 km.

For Europe, the results are presented for administrative regions and show how the statistical health risks of air pollution differ spatially across individual countries and between countries.

As part of the MARCHES project, a health risk indicator that combines both **premature mortality and morbidity** was implemented into a single measure: the **disability-adjusted life year (DALY)**. DALYs represent the total health burden, and the health risk indicator is DALYs per 100,000 inhabitants.

For example, if an area has 1,000 DALYs per 100,000 inhabitants, this means that, overall, the population loses the equivalent of 1,000 years of healthy life. These lost healthy years are composed of people dying earlier than expected and from people living with illness or disability.

Using DALYs provides a more comprehensive measure of the health burden associated with air pollution than premature mortality alone, because this measure captures both the **loss of life due to premature death** and the **loss of healthy life associated with illness or disability**.



Fact box:

Disability-Adjusted Life Years (DALYs)

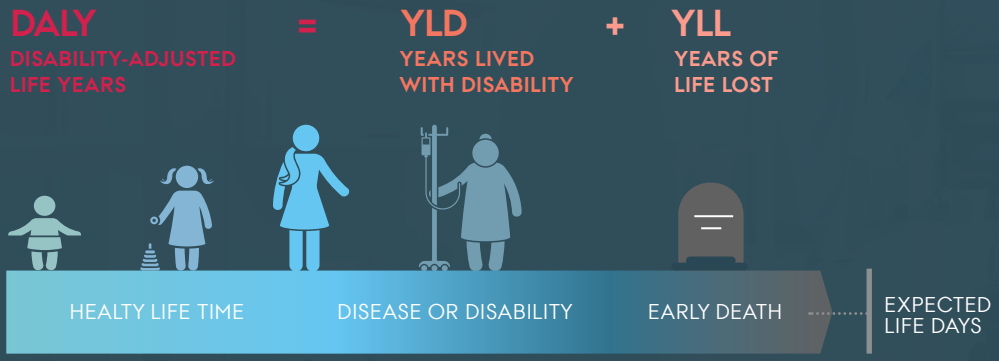
According to the World Health Organization (WHO), one DALY represents the **loss of the equivalent of one year of full health**.

DALYs for a disease or health condition are the sum of **years of life lost due to premature mortality (YLLs)** and the **years of healthy life lost due to disability** (YLDs).[3]

Disability weights for how different diseases affect the health-related quality of life have been identified in large-scale surveys among citizens by the Global Burden of Disease project [4] and implemented into the EVA model system.

Different health conditions have different impacts on quality of life. For example, asthma is estimated to reduce quality of life by around 4.5%, while cancer has a much greater impact, estimated at around 26.5%. To illustrate how this is reflected in DALYs, four years lived with cancer would correspond to approximately one year of healthy life lost (one DALY).

For example, 1,000 DALYs per 100,000 inhabitants could mean that, among 100,000 people, the health impact is equivalent to losing 1,000 years of healthy life: around 700 years could be due to people dying earlier than expected and around 300 years could be due to people living with illness or disability.



EVA model system

The **EVA model** system integrates **air pollution data from atmospheric models** - accounting for atmospheric dispersion, deposition, and chemical transformation - with population data (density and age distribution) to estimate human exposures.

It then uses formulas that **link pollution exposure to health risks** according to local health status, estimating the occurrence of early deaths and various chronic diseases to be expected statistically **(Figure 1)**.

Finally, these **health impacts are monetised** using valuation methods.

The EVA model system estimates both **premature mortality and morbidity associated with air pollution**.

• **A premature death** from air pollution is a death that occurs earlier than expected because exposure to air pollutants increased the risk of fatal disease. A finding of the MARCHES project, based on Andersen (2017)[5] is that, on average, a premature death of an EU citizen corresponds to approximately **11 years of life lost**.

• **Morbidity** refers to the incidence of illness and disease, as opposed to mortality, which refers only to death. In the context of air pollution, morbidity includes a wide range of health conditions caused or worsened by exposure to air pollution.

THE EVA MODEL SYSTEM INCLUDES THE FOLLOWING HEALTH IMPACTS:

- ACUTE MYOCARDIAL INFARCTION
- STROKE
- HYPERTENSION
- CARDIOVASCULAR HOSPITAL ADMISSIONS

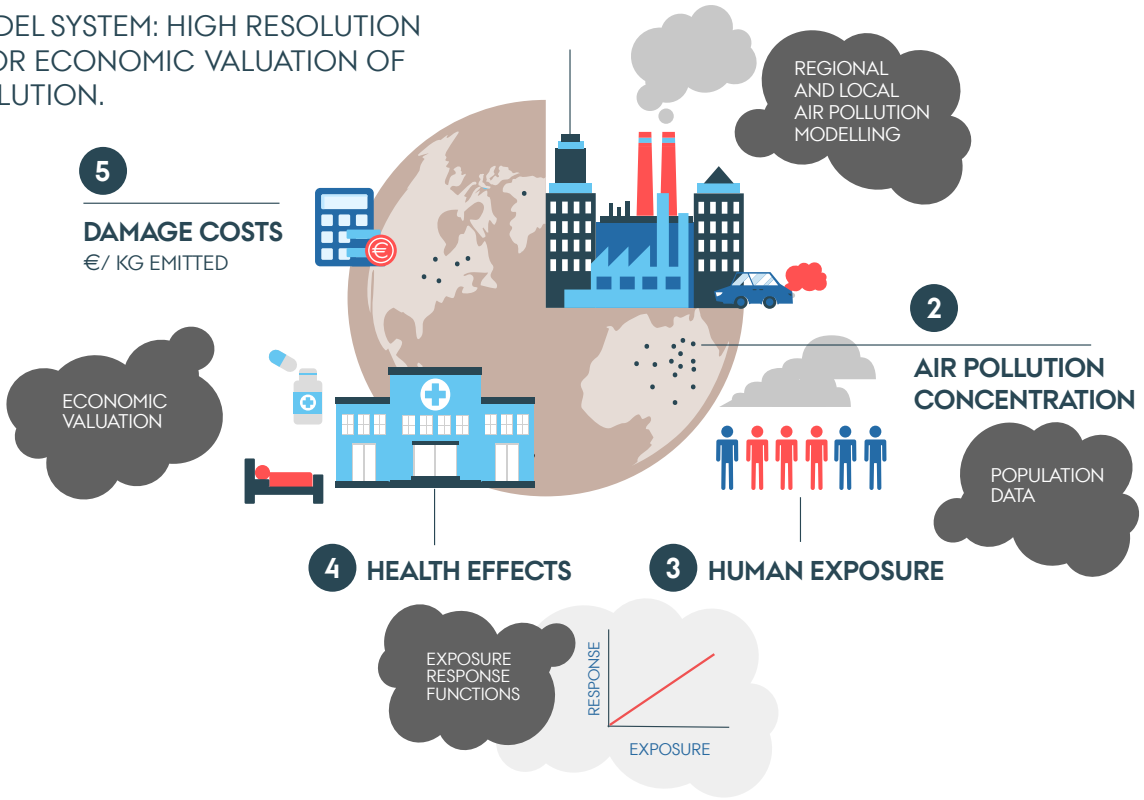
- ACUTE LOWER RESPIRATORY INFECTIONS
- ASTHMA (ADULT/CHILDHOOD)
- CHRONIC OBSTRUCTIVE PULMONARY DISEASE (COPD)
- LUNG CANCER

- DEMENTIA
- AUTISM

- RESTRICTED ACTIVITY DAYS
- WORK LOSS DAYS
- DIABETES (TYPE 2)

FIGURE 1

EVA MODEL SYSTEM: HIGH RESOLUTION TOOL FOR ECONOMIC VALUATION OF AIR POLLUTION.



3. Key findings

Spatial distribution of the most hazardous pollutants

The EVA model system includes the pollutants:

- fine particulate matter ($PM_{2.5}$) **(Figure 2)**
- ozone (O_3)
- nitrogen dioxide (NO_2)
- sulfur dioxide (SO_2)

Almost all premature deaths and morbidity outcomes estimated by the EVA model system are attributable to $PM_{2.5}$, although O_3 and NO_2 also contribute to the health burden.

The **contribution from SO_2 has been almost negligible** in recent years due to the low concentration levels following large emission reductions during the last decades.

The spatial distribution of the total premature deaths and morbidity cases therefore **depends primarily on the spatial distribution of $PM_{2.5}$ concentrations and the population density (Figure 3)**.

However, the age distribution and life expectancy of the population also influence the estimated health burden.

The EVA model assumes that $PM_{2.5}$ can affect health even at low concentrations, with no "no-effect" threshold. **Of the total health burden estimated in DALYs, approximately 70% is attributable to premature mortality and 30% to illness and disability**.

FIGURE 2

ANNUAL MEAN $PM_{2.5}$ CONCENTRATIONS IN 2022 BY ADMINISTRATIVE REGION (µg/m³).

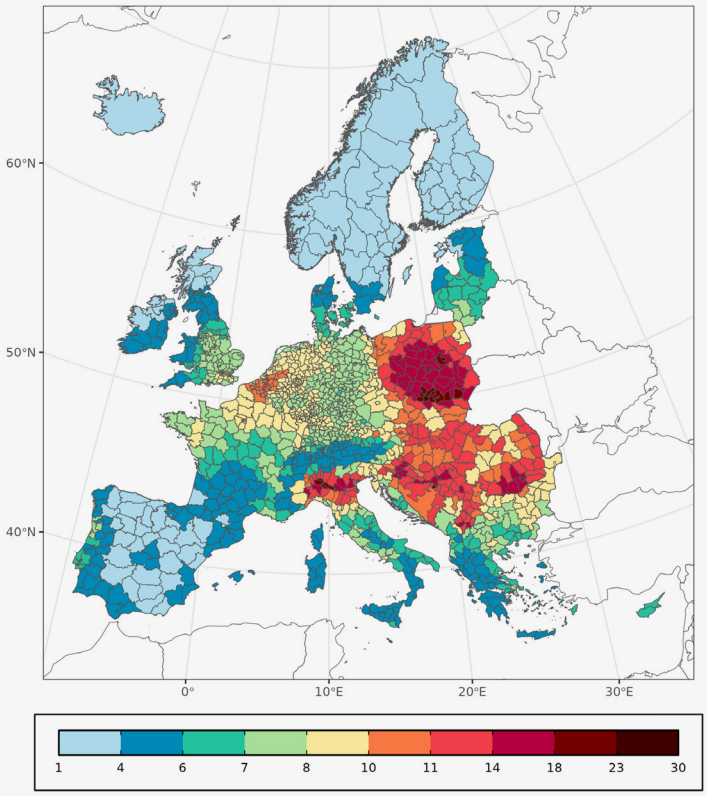
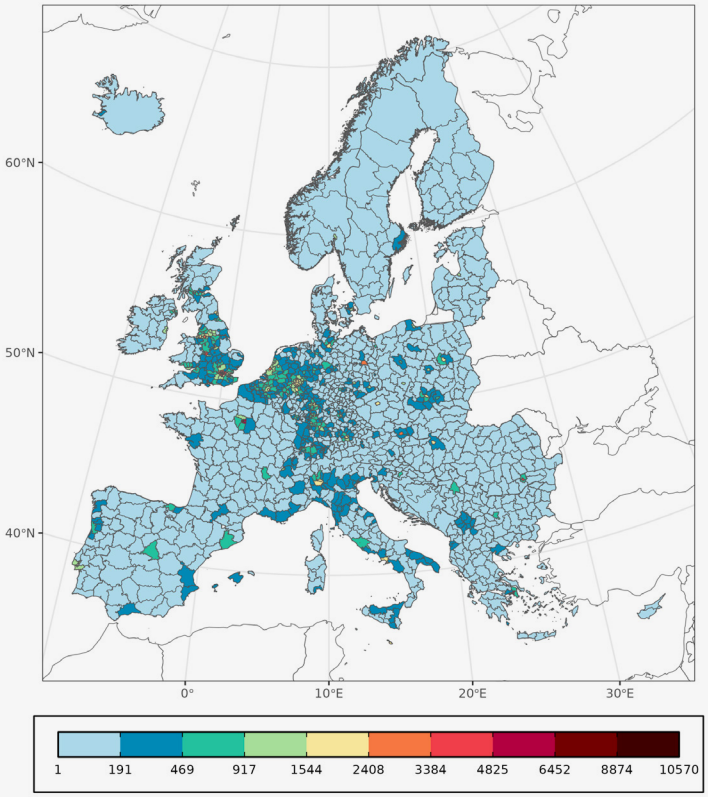


FIGURE 3

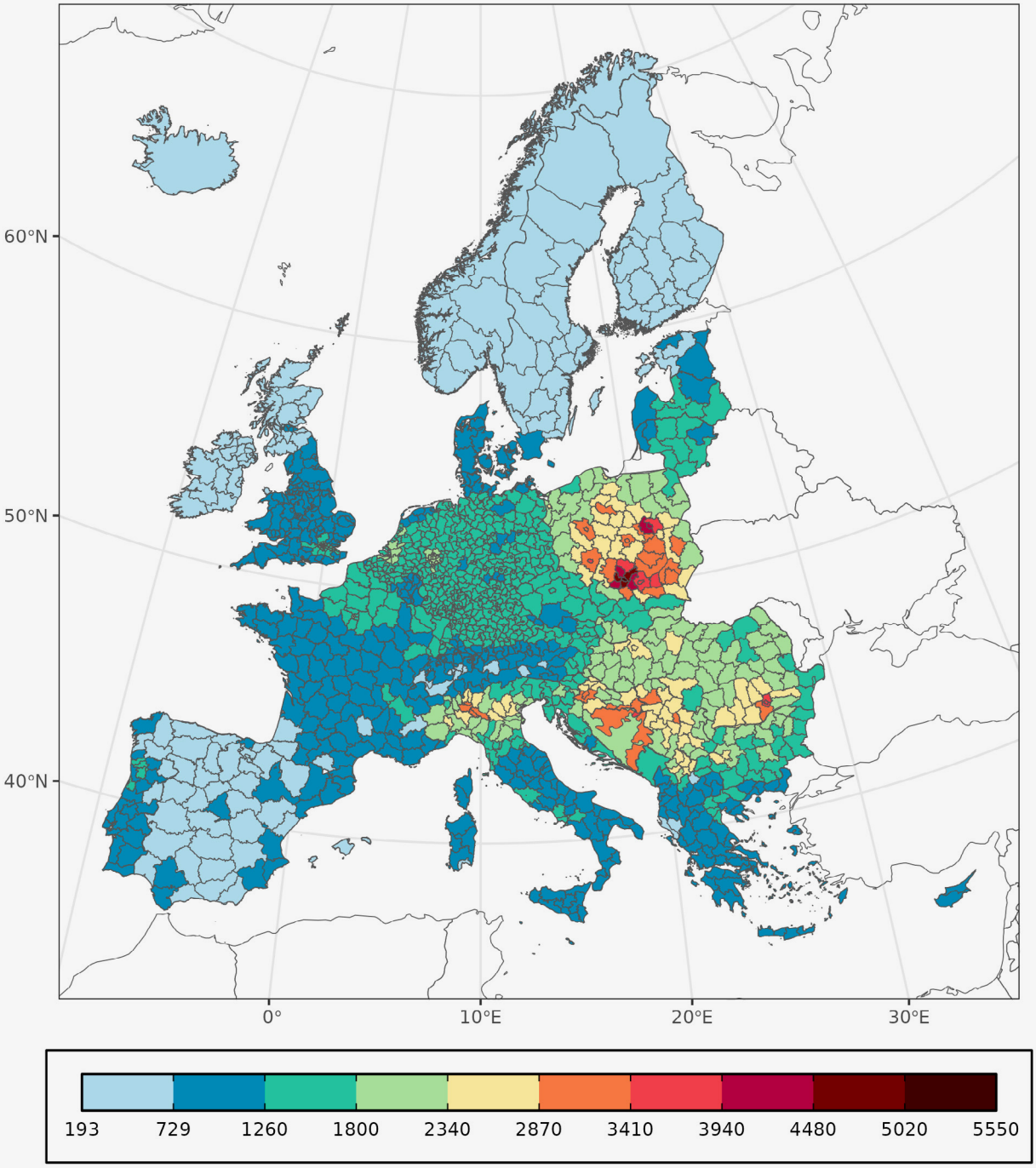
POPULATION DENSITY IN 2022 BY ADMINISTRATIVE REGION (Inhabitants/km²).



Health risk map of air pollution based on DALYs

The spatial distribution of DALYs per 100,000 inhabitants largely follows the spatial distribution of $PM_{2.5}$ concentrations, as $PM_{2.5}$ is the main contributor to the estimated health burden.

FIGURE 4
DALYS PER 100,000 INHABITANTS BY ADMINISTRATIVE REGION.



DALYs per 100,000 inhabitants allow health risks to be compared across areas with different population sizes.

The DALY map in **Figure 4** shows how some countries and regions are much more negatively impacted by air pollution than others.

For example, most of the **Nordic countries** is in the range of approximately **200 to 900 DALYs per 100,000 inhabitants**, whereas the highest values, found particularly in parts of **Eastern Europe**, reach about **5,500 DALYs per 100,000 inhabitants**.

NORDIC COUNTRIES
200-900 DALYS/100,000 INHABITANTS

EASTERN EUROPE
5,500 DALYS/100,000 INHABITANTS

ESTIMATED HEALTH BURDEN PER 100,000 INHABITANTS DUE TO AIR POLLUTION

5-28

TIMES HIGHER IN EASTERN EUROPE

This means that the estimated health burden per 100,000 inhabitants is approximately **5 to 28 times higher in the areas with the highest values compared to most of the Nordic countries**.

DALYs per 100,000 inhabitants are a suitable indicator for illustrating the spatial health risk of air pollution, as **they integrate premature mortality and morbidity into a single indicator**. However, DALYs can be difficult for non-experts to interpret, highlighting the potential value of developing simpler indicators to communicate the spatial distribution of health risks to air pollution.

The index is specific to the geographic domain in this case Europe and can't be compared with other regions of the world. It is also specific to the year it is calculated. The spatial distribution can be compared with an index from other year but the development can't as the index is always between 0% and 100% for all years.

Simple relative indicators of health risk based on DALYs

In the MARCHES project, we developed and assessed **easy-to-understand indicators** to communicate the spatial health burden of air pollution to non-experts. The indicators are designed to illustrate relative differences in health risks between countries and regions.

In consultation with stakeholders, we identified **the best easy-to-understand indicator to be a risk index ranges from 0% to 100%**, with 100% representing the area in Europe with the highest health burden and 0% the lowest health burden, expressed in DALYs per 100,000 inhabitants. The risk index, ranging from 0% to 100%, is shown in **Figure 5**.

LOWEST HEALTH RISK

HIGHEST HEALTH RISK

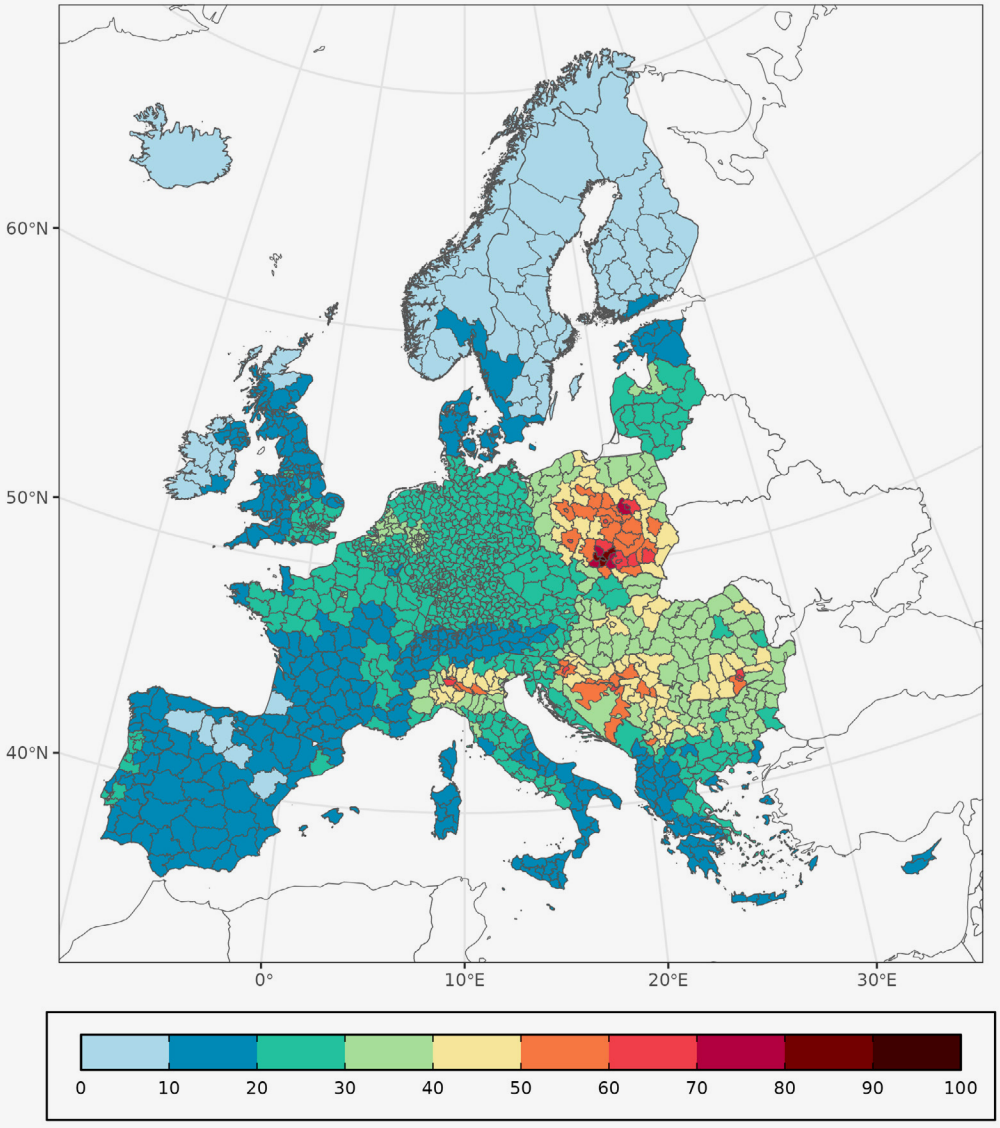
0% 100%

For example, if the health risk index is 80% in a location, this indicates that the DALYs per 100,000 inhabitants in that area are 80% of the value in the European area with the highest estimated health burden, or 20% lower than the highest value.

The index is specific to the geographic domain in this case Europe and can't be compared with other regions of the world. It is also specific to the year it is calculated. The spatial distribution can be compared with an index from other years but the development can't as the index is always between 0% and 100% for all years.

FIGURE 5

RISK INDEX BETWEEN 0% AND 100% (100% IS MAX) BASED ON DALYS PER 100,000 INHABITANTS.



4. Conclusions

Developing health risk maps of air pollution for member states

Finding ways to communicate the health risks associated with air pollution in an easy-to-understand way to non-experts is challenging.

Maps of health burden associated with air pollution presented as an index, offer an intuitive **illustration of the relative health risk associated with exposure to air pollution across different countries, regions, and urban and rural areas**.

Such maps may be easier for non-experts to grasp than statistical figures like e.g. the number of premature deaths in a country.

The **Ambient Air Quality Directive (2024/2881)**[6] requires Member States to inform the public about the past and present state of air quality, to provide short-term forecasts, including information and warning alerts, and to provide information about the Air Quality Index.

Although there is currently no formal requirement for Members States to communicate the health risk associated with air pollution, either through statistics or maps, providing information on its health impacts can help make air pollution more understandable, illustrate the scale and distribution of its health risk, and highlight the potential health benefits of reducing exposure. The approach developed in this project addresses this gap by providing an intuitive, accessible way to communicate the health risk of air pollution through maps and an index.



Overall recommendations:

- Member States may consider **developing health risk maps for air pollution at a higher geographical resolution**, potentially at the scale of a few kilometres, to inform the public on a website about the regional differences in air-pollution-related health burdens, and between urban and rural areas.
- A health risk map may also support policymakers in the **identification of geographical inequalities** in health risk of different areas in support of air quality policies that address these inequalities.
- The **disability-adjusted life year (DALY) metric is a promising indicator for health risk**, with the advantage of integrating years lost due to premature mortality and morbidity into a single indicator. This indicator is also suitable for monitoring changes over time, as a reduction in air pollution would result in lower DALYs.
- **A health risk index ranging from 0% to 100%**, where 100% represents the area with the highest estimated health risk based on DALYs per 100,000 inhabitants, **may be a suitable way to communicate relative differences in health risks to non-experts**, with a focus on communicating the relative differences between different areas.

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Health Risk Maps of Air Pollution in Europe

MARCHES Project

The Horizon Europe MARCHES (Methodologies for Assessing the Real Cost to Health of Environmental Stressors) project aims to advance methodological rigor and consistency in accounting for the welfare economic health costs of pollution, based on systematic reviews of health effects.

It aims to calculate the impact of nitrates in drinking water and of air pollutants (which include ammonia from fertilizers) on public health and to quantify the economic benefits of reducing emissions and exposures.

Establishing updated exposure-response functions is essential for accurately estimating the societal costs of pollution and highlighting the societal value of implementing mitigation measures.

This was demonstrated in case studies where MARCHES partners with public authorities in six countries (Czechia, Denmark, Estonia, Kosovo, Spain, and Sweden). Learn more about the research and activities of the MARCHES project here: https://projects.au.dk/MARCHES

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