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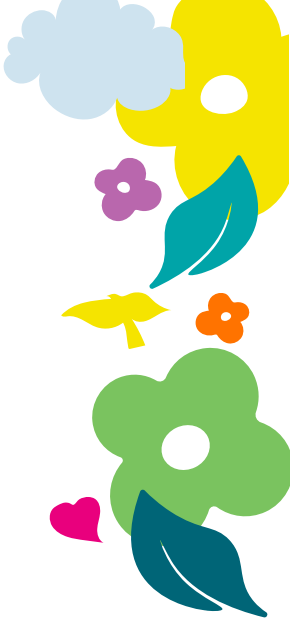

Protecting Europe's lungs in a changing climate: Addressing respiratory health impacts of air pollution and temperature changes

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climate-health cluster

SUMMARY

Respiratory diseases are a major cause of death in the EU. Climate change exacerbates respiratory health risks through rising temperatures and air pollution. To reduce this health burden, it is crucial to develop policies based on evidence about observed and expected impacts of climate change on respiratory health. This policy brief draws on a recent report from the EU climate-health research project TRIGGER to summarize the evidence on the adverse effects of air pollution and temperature changes on respiratory health in Europe. Special attention is given to vulnerable groups and socio-economic risk factors. We recommend a better integration of climate-health objectives into EU policies, implementation of a range of measures to reduce environment-related respiratory health risks, and ensuring equitable health outcomes.

KEY RECOMMENDATIONS

1. Better address climate-related respiratory health challenges in EU policies
2. Strengthen air quality regulations and health action planning for heat and cold
3. Expand early warning systems for air pollution and climate hazards
4. Ensure climate-resilient health infrastructure in urban planning and design
5. Support vulnerable groups
6. Promote research on respiratory health risks of climate change
7. Raise awareness and capacity building

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INTRODUCTION

The burden of respiratory diseases in Europe

Respiratory diseases encompass a range of illnesses affecting the lungs and airways, including acute infections (e.g., pneumonia and influenza), chronic diseases (e.g., chronic obstructive pulmonary disease (COPD) and asthma), as well as cancers of the respiratory tract. Together, respiratory diseases **represent a major health burden across the EU.** In 2021, respiratory diseases accounted for 324,300 deaths – 6.1% of all recorded fatalities – underscoring the urgency of effective interventions.[1]

Climate change: a growing driver of respiratory diseases

Climate change is a growing driver of respiratory health issues through changing environmental conditions and exacerbating harmful exposures. Rising temperatures have led to record-breaking heat and temperature extremes that have increased the number of deaths in Europe[2], in part due to respiratory issues.[3] Climate change also exacerbates air pollution, which contributes to 14% of premature deaths from chronic respiratory diseases in Europe.[3] For example, high temperatures and strong solar radiation favour the formation of ground-level ozone, an irritating gas that causes respiratory problems. Other climate-related exposures such as the spread of wildfire smoke, mineral dust and allergenic pollen, further compound the risks.[3,4] According to the European Environmental Agency, **environmental factors account for over a third (35%) of premature chronic respiratory deaths in Europe,** nearly equalling the impact of lifestyle factors such as smoking, alcohol use, physical inactivity, and unhealthy diets.[3]

The environmental burden of chronic respiratory deaths is higher in **Eastern** and **South-eastern Europe.**[3] These regions are home to many of Europe's most polluted cities, where coal is still used in industry, outdated power plants and residential heating.[5] Southern and Eastern Europe are also more exposed to wildfire-related air pollution[2] and exhibit greater socio-economic vulnerability compared to Northern and Western Europe.[6]

Current EU efforts and the need for action on environmental risks

Although the EU has several initiatives targeting respiratory diseases, such as the **Healthier Together Initiative** and the **EU4Health Programme 2021-2017,** **environmental risks tied to climate change remain largely unaddressed.**[3] Climate-related policies often overlook the link between climate change and respiratory health.[7] Developing comprehensive climate-health policies is essential to reduce the burden of respiratory disease, especially as Europe faces heightened vulnerability due to its aging and urbanizing population.[3] To ensure **equitable health outcomes,** policies should pay special attention to vulnerable groups and socioeconomic risk factors of respiratory diseases. The **EU Horizon Project TRIGGER** – a member of the European **Climate-Health Cluster** – aims to support evidence-based policymaking on climate-related respiratory health risks.

Focus of this policy brief

This policy brief summarizes the current evidence on the adverse effects of two major climate-related environmental exposures on respiratory health in Europe – **air pollution** and **temperature changes** – building on a review of observational studies.[8] Special attention is given to the effects on **vulnerable groups** and the role of socio-economic factors. The **recommendations** derived aim to contribute to the development of comprehensive climate-health policies.

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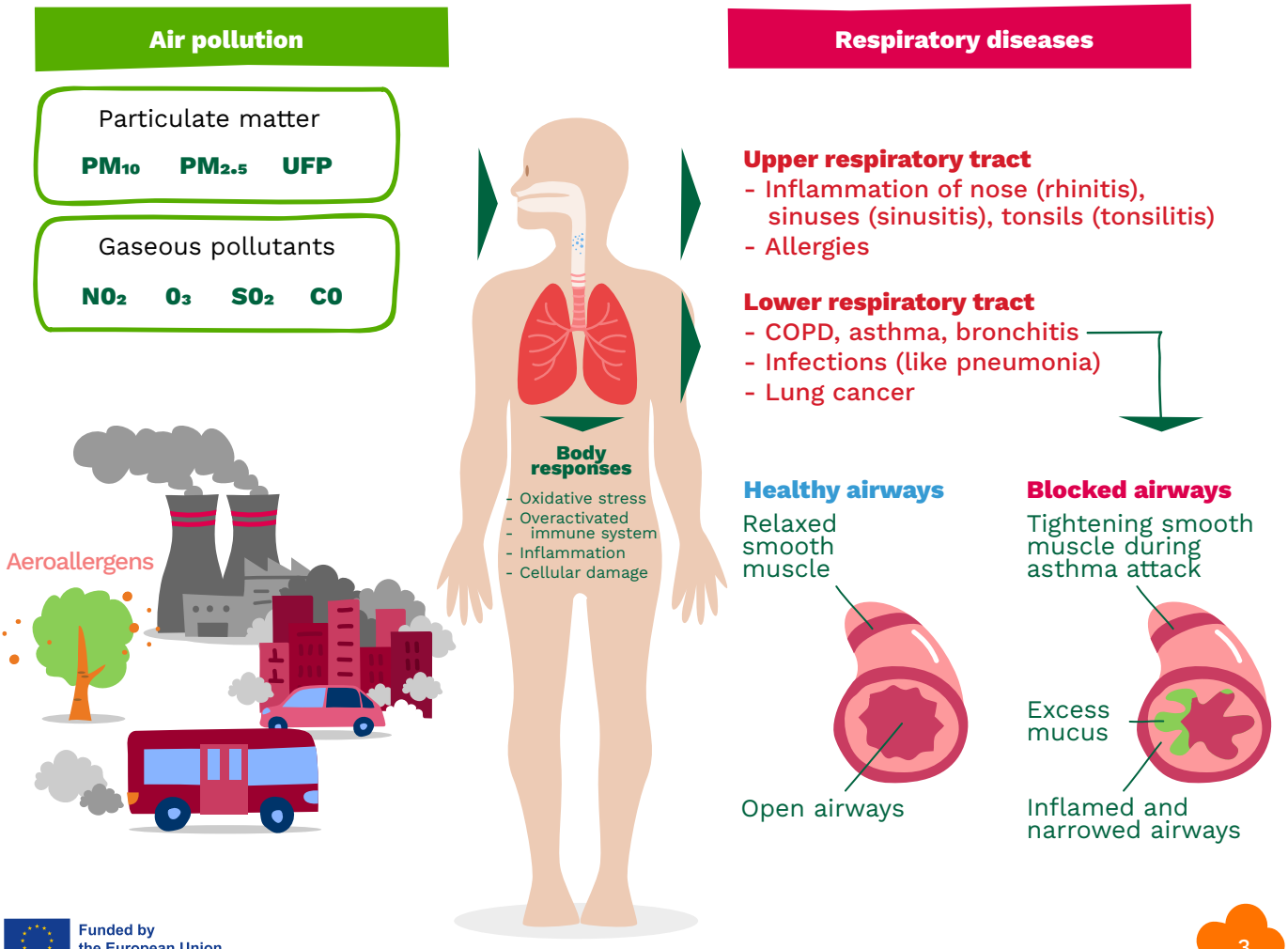
AIR POLLUTION AND RESPIRATORY HEALTH

Air pollution poses a significant risk to both human health and the global climate.[9] Air pollution refers to chemical, physical, or biological contaminants in the air that harm people and the environment. Air pollution is closely linked to climate change, as it shares many emission sources with greenhouse gases, including fossil fuel and biomass combustion for heating, power generation, transportation and industrial processes, as well as animal agriculture.[9] The latter emits ammonia, which can form particulate matter pollution, and greenhouse gases such as methane.[9,10] Some air pollutants are also potent greenhouse gases, such as black carbon smoke and ground-level ozone.[9] Rising temperatures, in turn, can worsen air pollution, for example by increasing the formation of ground-level ozone and the risk of wildfires.[11]

Impact of air pollution on respiratory health

Air pollution is a **major risk factor for respiratory diseases (Figure 1).** The respiratory tract and lungs are the first point of contact. Once inhaled, air pollution can trigger oxidative stress, overactivation of the immune system, inflammation, and cellular damage throughout the body.[8] Air pollution can irritate the lungs, inducing coughing, wheezing and shortness of breath; cause inflammation of the upper respiratory tract (e.g., nose, sinuses, tonsils); and contribute to allergies.[8] Furthermore, it can lead to diseases characterized by obstructed airways in the lower respiratory tract, including asthma, COPD and bronchitis (which is a key feature of COPD), and increase the risk of respiratory infections (e.g., pneumonia), lung cancer, and premature death.[8] Notable air pollutants include **particulate matter** (PM_{10}, $PM_{2.5}$ and ultrafine particles or UFP), **gaseous pollutants** (i.e., NO_2, O_3, SO_2 and CO), and **aeroallergens.**[12]

Figure 1 – Air pollution causes respiratory diseases[8]



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Particulate matter

Particulate matter (PM) are solid or liquid particles often classified by size (aerodynamic diameter):

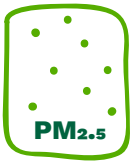
- PM_{10} refers to particles of ≤10 µm
- $PM_{2.5}$ refers to fine and ultrafine particles of ≤2.5 µm
- $PM_{0.1}$ refers to ultrafine particles (UFP) of ≤0.1 µm

These particles stem from various natural and human sources **(Table 1).**[9]

Impact on respiratory health:

- Short- and long-term PM exposure is linked to several respiratory health risks, with most evidence derived from research on PM_{10} and $PM_{2.5}$ pollution **(Table 1).**[8]
- $PM_{2.5}$ is the deadliest air pollutant: In 2022, $PM_{2.5}$ pollution above the WHO guideline level of 5 µg/m³ led to at least 239,000 deaths in the EU, primarily from cardiovascular issues, but also from **COPD** and **lung cancer**.[13] Long-term $PM_{2.5}$ exposure is further linked to the development of asthma, **pneumonia** and inflammation of the upper respiratory tract (e.g., **allergic rhinitis, sinusitis**).[8]
- Unlike $PM_{2.5}$ and PM_{10}, UFP are not regulated within the EU and available evidence on their health effects is more limited. However, **finer particles pose a greater health risk** as they can penetrate deeper into the lungs and reach other organs via the bloodstream.[8]

Table 1 – Sources of major pollutants and short- and long-term cardiovascular risks[8,9]

Particulate matter (PM)	Sources	Short-term risks (minutes, days)	Long-term risks (months, years)
	- Wind-blown dust - Traffic, mining - Agriculture (ammonia)[10] - Pollen, sea spray - $PM_{2.5}$ sources	- Lung irritation, reduced lung function - COPD hospitalizations - Asthma hospitalizations - Pneumonia hospitalizations	- COPD - Asthma - Pneumonia - Lung cancer
	- Fossil fuel combustion: traffic, industry, power generation - Chemical reactions in air - Black carbon from incomplete combustion of biomass from wildfires or burning wood, coal or fuel - Indoors: heating	- Same as PM_{10}	- Same as PM_{10} - Rhinitis - Sinusitis - Allergic rhinitis

Note. Respiratory health risks mentioned are based on available evidence and thus not conclusive.

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Gaseous pollutants

Gaseous pollutants are airborne chemicals that can easily diffuse and penetrate deep into the lungs. Prominent gaseous pollutants include **nitrogen dioxide (NO_2), ground-level ozone (O_3)*, sulphur dioxide (SO_2)** and **carbon monoxide (CO),** with the combustion of fossil fuels as a common source **(Table 2).**[9] NO_2 is an important precursor of PM pollution and ground-level ozone (O_3).[12]

Impact on respiratory health:

- Short- and long-term exposure to gaseous pollutants is linked to several respiratory health risks (Table 2), with long-term risks especially well-studied for **NO_2** in urban areas.
- Regarding **ground-level ozone (O_3)**, long-term exposure above the WHO guideline level of 60 µg/m³ led to at least 70,000 deaths in the EU in 2022, primarily due to **COPD.**[13]
- **Sulphur dioxide (SO_2)** can exacerbate **asthma** and trigger **bronchiectasis**, a lung condition characterized by a permanent widening of lung airways, mucus accumulation and coughing.
- **Carbon monoxide (CO)** inhibits the binding of oxygen in the blood, causing oxygen shortage (hypoxia) and potential respiratory failure. It can be fatal at high concentrations.

Table 2 – Sources of gaseous pollutants and short- and long-term respiratory risks[8,9]

Gaseous pollutants	Sources	Short-term risks (minutes, days)	Long-term risks (months, years)
NO_2	- Fossil fuel combustion: heating, traffic, industry, power generation - Indoors: fire places, gas stoves, ovens, furnaces	- Lung irritation, reduced lung function, asthma symptoms - Hospitalization due to pneumonia	- COPD[3] - Asthma[3] - Rhinitis - Sinusitis - Allergic rhinitis
O_3	- Ground-level ozone in smog is formed by sunlight that interacts with NOx, CO and volatile organic compounds (VOCs) from traffic and industry	- Lung irritation, reduced lung function, asthma symptoms - COPD hospitalizations - Pneumonia hospitalizations	- COPD[13]
SO_2	- Fossil fuel combustion: heating, industry, power generation - Disinfectants, refrigerants, reducing agents, bleach, food preservatives	- Lung irritation, reduced lung function, asthma symptoms - Asthma hospitalizations - Bronchiectasis	
CO	- Incomplete combustion of biomass from wildfires, burning organic fuels in fireplaces, stoves, furnaces - Motor vehicles	- Breathing difficulties, exhaustion, dizziness, and other flu-like symptoms - Suffocation/death at high exposure	

Note. Respiratory health risks mentioned are based on available evidence and thus not conclusive.

*Note that while ground-level (or tropospheric) ozone negatively impacts human health, stratospheric ozone in the upper atmosphere forms a protective layer shielding the earth from harmful UV radiation.

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Aeroallergens

Aeroallergens are airborne biological substances, such as pollen (from plants), mould spores (from fungi) and animal-derived substances (e.g., dust mites) that can cause allergic reactions.[14] Among these, pollen is the most significant outdoor aeroallergen.

Impact on respiratory health:

- Aeroallergens can irritate the airways, triggering or worsening allergic rhinitis, asthma symptoms, and other respiratory sensitivities.[8] Higher concentrations of aeroallergens and seasonal pollen peaks may increase the use of health services.[8]
- Pollen cause inflammation of airways because they contain protein-degrading enzymes that can degrade the lung's protective barriers. Long-term exposure to high pollen levels (e.g., farmers in fields) increases the risk of developing asthma or other chronic respiratory problems.[8]
- Air pollution may increase sensitivity to pollen and worsen symptoms in already allergic people.[8,11,15,16] Although more research is required[11,16], air pollution may increase the allergenic potential of pollen by damaging the airways, allowing inhaled allergens to reach immune cells, or by altering the protein surface of pollen grains.[15,16]

TEMPERATURE AND RESPIRATORY HEALTH

Temperature is another major climate-related exposure affecting respiratory health. Global warming increases the severity and frequency of heatwaves, with Europe being the fastest warming continent. This trend is also evident in the exceptional rise in temperatures during the cold season.[3] As a result, climate change could drive a shift from less cold-related to more heat-related disease and death in Europe. However, there is currently no evidence of a decline in cold-related deaths in Europe, and potential future declines are not expected to offset the increase in heat-related deaths.[3] Therefore, cold waves remain a serious public health concern in Europe, particularly among vulnerable groups.

Impact of heat on respiratory health

- **High temperatures lead to more hospitalizations and deaths from respiratory diseases.**[17]
  - Extreme heat worsens respiratory symptoms among people with pre-existing lung conditions such as COPD, asthma, and lung cancer.[11]
  - Increased coughing, wheezing and shortness of breath can lead to a greater need for rescue medication, healthcare visits and hospitalizations.[11]

- **Hot and humid air form an additional burden.**
  - Hot, muggy air is hard to breathe even for healthy people, increasing respiration rate, thermal discomfort and stress on the lungs.[11,18]
  - People who suffer from asthma and allergies are especially vulnerable.[11]

- **Exercising becomes more difficult.**
  - Outdoor activities such as walking, jogging and cycling in hot weather increase respiratory distress, especially in people with respiratory disease.[11]

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Impact of cold on respiratory health

- **Cold temperatures also increase hospitalizations and deaths from respiratory diseases.**
  - Cold air constricts the airways, triggering coughing, wheezing, and shortness of breath, especially in people with pre-existing lung conditions such as COPD and asthma.[3,19]
  - In Europe, 11% of chronic respiratory deaths and nearly 20% of lower respiratory infection deaths are linked to cold exposure.[3]

- **Cold increases the risk of respiratory infections.**
  - Cold temperatures can suppress the immune system, increasing susceptibility to bacterial and viral infections. Increased indoor crowding further promotes disease transmission.
  - Extreme variability in daily temperatures as well as changes in seasonal temperatures may also increase susceptibility.[20,21] For example, warmer winters are usually followed by more severe influenza epidemics in the next season.[21]

- **Cold temperatures can trap air pollution.**
  - In winter, a layer of dense cold air in the atmosphere can trap air pollution near the surface. Cold temperatures and air pollution often interact to worsen respiratory health and increase respiratory infections.[8,19]

INTERPLAY BETWEEN RISING TEMPERATURES AND AIR POLLUTION UNDER CLIMATE CHANGE

Climate change can interact with air pollution to exacerbate respiratory diseases:

Climate change increases the frequency and severity of heatwaves. Breathing polluted air during hot weather raises the risk of serious respiratory problems, hospitalizations, and deaths.[22]

Rising temperatures can worsen air pollution by causing more extreme weather events, prolonged droughts and regionally or temporarily reduced precipitation. These weather conditions not only **reduce air clearance**[3,14], but also increase the risk of **dust storms** and **wildfires**, exposing local communities to massive air pollution (e.g., PM, SO_2).[3,11,23] Hot temperatures also increase the formation of ground-level ozone.[11,23]

Climate change can magnify the respiratory health impacts of pollen:

- Warmer temperatures and **prolonged plant growing seasons** boost pollen production and prolong exposure, including highly allergenic species such as birch and ragweed.[3]
- Climate change allows **allergenic plant species** to **spread to new regions,** as seen with ragweed moving northward in Europe.[3]
- **Extreme weather events, thunderstorms** and **changes in humidity** can increase the concentration of pollen and allergens in the air during the pollen season.[3]

Extreme weather events like storms and floods can **increase the spread of respiratory infections** due to viruses and bacterial pneumonia.[23]

Climate-related disasters, such as floods and wildfires, **can also disrupt healthcare services,** making it harder for patients with respiratory conditions to access medical care.

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VULNERABLE GROUPS

Some groups are at higher risk of respiratory issues from air pollution and sub-optimal temperatures:

Children's lungs and airways are still developing and they are more exposed to air pollutants, allergens and infectious agents because of their lower height and greater outdoor activity.[8,24] Children living near major roads or polluted areas are more likely to develop asthma, allergies or infections like respiratory syncytial virus (RSV) and pneumonia.[8] Children are also less effective in regulating their body temperature and thus more vulnerable to heat and cold.[8]

Older people face age-related declines in lung function and higher sensitivity to pollutants, temperature changes and respiratory infections.[8,25] Pre-existing health problems (e.g., COPD and cardiovascular disease) are also more common.[8,23] Exposure to PM and ozone pollution increases the risk of hospitalization for COPD, asthma and pneumonia in older adults.[25] Both hot and cold extremes affect COPD cases.[8]

Women are more vulnerable to respiratory problems from environmental stressors than men due to differences in body structure, such as smaller lungs and airways.[8] Air pollution can worsen COPD, especially in women, and climate change may intensify symptoms due to increased exposure to heatwaves, PM and wildfire smoke.[3,8] Women living near roads may be more susceptible to impaired lung function, while high pollen levels and extreme temperatures further increase their vulnerability. Women also have a reduced ability to sweat, making it harder to cool down in hot weather.[8]

Pregnant women are more prone to respiratory diseases like asthma and allergic rhinitis because of hormonal and immunological changes. Pregnant women with asthma face higher risks of complications such as preterm birth, low birth weight and stillbirths.[11] Extreme heat and air pollution can worsen asthma.[8] Air pollution can also trigger (allergic) rhinitis[8], which may contribute to sleep apnoea and preeclampsia.[26]

Outdoor workers are directly exposed to heat, cold, and air pollution.[27] Extreme temperatures may increase respiratory distress and exposure to hazardous chemicals and vector-borne diseases.[27] Prolonged ozone and PM exposure are linked to respiratory diseases and allergic reactions.[27] Moreover, exposure to airborne allergens (e.g., pollen) can exacerbate allergic reactions and asthma.[27]

People with disabilities may be less able to cope with disruptions in healthcare access and with extreme weather events, such as finding shelter or staying hydrated during heatwaves.[28] However, vulnerability depends on the severity of the disability and the level of social support that is received.[28] People with respiratory insufficiency are especially vulnerable to heatwaves.[28] **Pre-existing respiratory conditions** such as COPD, asthma and allergies also increase vulnerability. Clinical risk factors include obesity, diabetes, immunodeficiency and rheumatoid arthritis.[3]

People with lower socioeconomic status (SES) are more likely to live in urban areas with heavy traffic and limited green space, which tend to have higher air pollution and heat risks.[8,11] Living near high-traffic areas (e.g., highways) is a significant risk factor for pneumonia and persistent asthma with ongoing symptoms.[8] Poorly insulated homes and lack of (proper) heating, cooling or air purification increase respiratory health risks.[11] A limited access to healthcare services and a lack of health literacy can also increase risks, leading to a vicious cycle that increases health inequality.[11]

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RECOMMENDATIONS

The following policy recommendations outline an integrated approach to protecting respiratory health in the face of increasing climate change impacts in Europe.

1. Better address climate-related respiratory health challenges in EU policies

- **Embed cardiovascular health into EU Green Deal policies** such as the Climate Law and the Zero Pollution Action Plan to ensure that respiratory health risks from climate change are adequately addressed.[7] Likewise, respiratory health risks should be covered more consistently in national adaptation strategies in Europe.[29]

- **Strengthen the European Health Union by integrating environmental stressors and climate adaptation in EU health policy.** The EU Global Health Strategy (2022) highlights the need for better coordination and integration of EU and Member States policies in the context of climate change.

2. Strengthen air quality regulations and health action planning for heat and cold

- **Align EU air quality regulations** for key pollutants ($PM_{2.5}$, PM_{10}, NO_2, O_3, SO_2, CO) with WHO guidelines and follow WHO's good practices to reduce UFP pollution.[8,12] These recommendations support the EU's ambition to speed up the transition to clean energy and climate neutrality.

- **Improve international collaboration** and capacity building to reduce transboundary pollution.[8]

- **Strengthen pollen monitoring systems** to better assess the impact of pollen exposure on respiratory health, as current indirect methods such as the skin prick test are limited.[8] Clear standards and thresholds for aeroallergens are also needed to enhance health protection.[8]

- **Expand and evaluate heat-health action plans** at national, regional and local levels. Over a quarter of European countries lack these plans, which may negatively impact their preparedness to heat. Existing action plans need to be evaluated for effectiveness and revised.[30]

- **Develop cold-health action plans** to reduce cold-related deaths by incorporating real-time monitoring and early warning systems, timely public and medical advice, protections for vulnerable populations, improved urban planning and prepared health and social care systems. Align with energy poverty initiatives, such as the EU Social Climate Fund and Renovation Wave.

3. Expand early warning systems for air pollution and climate hazards

- **Implement real-time air pollution warning systems** that provide mobile alerts, public health advisories, and urban digital displays in high-pollution areas.

- **Strengthen early warning systems** for heatwaves, cold spells, aeroallergens and other climate hazards to help at-risk populations prepare and protect themselves.

- **Support the UN Early Warnings for All initiative** by expanding access to climate and air pollution alerts, emergency preparedness programs, and community-based risk communication strategies.

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4. Support vulnerable groups

- **Provide targeted support for vulnerable groups** (e.g., children, the elderly, outdoor workers, women, people with disabilities or low socioeconomic status), such as climate adaptation tools in schools, elderly homes, care centres, and workplaces, and timely public health information.[8]

- **Improve healthcare access** for people with disabilities and marginalized communities.

- **Engage local communities in urban design decisions** (e.g., urban greening projects, low-emission zones) to ensure social equity in climate-health adaptation.[8]

5. Ensure climate-resilient health infrastructure in urban planning and design

- **Transform healthcare systems** to substantially decrease greenhouse gas emissions and increase preparedness against climate stressors to protect vulnerable groups.[11,31]

- **Retrofit buildings to improve energy efficiency and resilience to climate stressors** by adding insulation, replacing inefficient heating and cooling systems and improving ventilation and air purification/filtering to mitigate climate-related respiratory health risks.[31]

- **Expand walking and cycling infrastructure and introduce low-emission, low-traffic, and car-free zones** to encourage active, low-carbon transportation.[11,31] Compact city models (e.g., Barcelona's Superblocks, Paris' 15-minute city), where essential services are within walking and cycling distance, can support physical health while reducing car dependency and pollution.[31]

- **Expand green infrastructure** such as urban forests, green roofs, and parks to enhance air quality, mitigate urban heat and promote health by encouraging physical activity and social interaction.[31] Carefully monitor and select species planted in green spaces to ensure low allergy impact.[11]

- **Promote healthy, balanced, plant-rich diets in public institutions,** including hospitals, to reduce emissions and air pollution from agriculture, and to support health.[11]

- **Support entrepreneurs** who produce products and services with climate-health co-benefits, and make co-beneficial consumer choices accessible and affordable.

6. Promote research on cardiovascular health risks of climate change

- **Prioritize research on vulnerable populations,** including people with low socio-economic status (e.g., migrants, low-income communities), as these groups are often underrepresented.[8] Socio-economic factors should be properly considered **to ensure inclusive scientific evidence** on climate-related health risks **and enable the development of targeted interventions.**[8] States in the (south)east of Europe are more vulnerable to environmentally induced respiratory disease, yet high-quality studies are relatively scarce. More research is also needed to compare the vulnerability of **urban versus rural populations,** as most studies focus on urban areas.[8]

- **Promote "multi-exposure" research** to acquire a more comprehensive understanding on how multiple environmental exposures (e.g., air pollution, suboptimal temperatures) simultaneously affect respiratory health.[8] Current research often focuses on single exposures.

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- **Develop a standardized framework at the EU level** for analysing climate change and health to enable cross-study comparisons.[8] A coordinated, international effort is needed to standardize exposure definitions and a list of confounders in data collection.[8] The use of standardized personal wearables and agent-based modelling can also improve exposure assessments by capturing real-time individual-level data and reducing bias from indirect exposure proxies.[8]

- **Assess the impact of policy interventions.** Support research on the effectiveness of climate adaptation strategies, such as urban cooling measures and air quality improvements, in reducing respiratory health risks.[8]

7. Raise awareness and capacity building

- **Launch public education campaigns** on respiratory health risks of air pollution, aeroallergens and temperature extremes and on protective measures (e.g., staying hydrated, filtering the air, avoiding exercise during pollution peaks or temperature extremes).[7,11] Encourage climate change mitigation strategies with health co-benefits.[31]

- **Train health professionals** to recognize and address climate-related respiratory health risks through specialized education.[11] Equip them with skills to educate the public and vulnerable groups on prevention and adaptation strategies.[11]

CONCLUSIONS

Respiratory diseases remain a major health burden in Europe, exacerbated by air pollution and temperature changes within the context of climate change. To reduce these environmental risks, the EU and its member states need to integrate climate-related respiratory health challenges in EU and national policies, strengthen air quality regulations and health-action plans for heat and cold, expand early warning systems, and invest in climate-resilient infrastructure. Targeted interventions for vulnerable groups and increased research, awareness-raising and capacity-building are crucial for ensuring equitable health outcomes. An integrated approach to climate-health policymaking will help mitigate climate-related respiratory health risks and protect public health across Europe. Clinical studies and stakeholder engagement activities within TRIGGER will help to further refine policy recommendations.

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