HEAL Report

Healthy air, healthier children

50 schools across the EU monitor air quality

Berlin, London, Madrid, Paris, Sofia, Warsaw

HEAL
HEALTH AND ENVIRONMENT ALLIANCE

About

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Disclaimer:

The report Healthy Air, Healthier Children - 50 schools across the EU monitor air quality, is a snapshot of indoor and outdoor air quality at 50 schools in six capitals in the EU, based on citizen science, with schools participating on the basis of interest. Therefore, this report is not a representative analysis of schools' indoor environments, nor did HEAL investigate actual health impacts of children in participating schools. Given the differences in each city (location, geographical conditions, state of the school buildings etc.) and differences in the intervals of measurement it is not possible to make comparisons between schools or cities. However, HEAL's citizen science monitoring demonstrates that ensuring clean air in school environments should be a priority for policy-makers, and that further monitoring should be undertaken.

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1.

Summary

The dangers of air pollution

In the EU, each year
air pollution causes
± 400,000
premature deaths
and hundreds of billions
of euros in health costs

Air pollution from energy production, transport, industry, agriculture and households is the number one environmental threat to health in Europe and globally[1]. The World Health Organization (WHO) recognises air pollution as a leading risk factor for major chronic diseases in adults, including heart and lung disease as well as cancer. It also states that no level of air pollution can be considered safe[2]. Each year, air pollution causes around 400,000 premature deaths and hundreds of billions of euros in health costs in the EU alone[3].

Breathing in air pollutants - particulate matter, for example, which are tiny particles much thinner than a human hair - can lead to changes in the body that damage health. Poor air quality is linked to chronic and acute respiratory diseases, such as bronchitis and the aggravation of asthma, heart disease and stroke. People already suffering from disease, those living in cities or who are economically deprived are particularly at risk from the harmful effects of polluted air[4].

In cities, emissions from cars, buses and lorries are a major contributor to poor air quality, in particular emissions of nitrogen dioxide (NO_2). NO_2 contributes to the formation of particulate matter with related health impacts, and is often considered an indicator for traffic-related air pollution. Studies have shown that NO_2 can lead to asthma and make health problems of asthmatic people worse. Researchers are also investigating a possible link between NO_2 and heart disease and diabetes[5].

Children and air pollution

Even more worrying is evidence of the toll it takes on children[6]. Children are exposed to air pollution in different ways to adults such as being closer to a vehicle exhaust. Exposure to air pollutants can increase the risk of a child developing asthma and the number and severity of asthma attacks, affect their learning abilities, as well as a child's heart, brain and nervous system development. Effects even affect the unborn child: pregnant women breathing unhealthy air can lead to children being born earlier, or with a lower birth weight, which increases the risk of disease decades later[7,4].

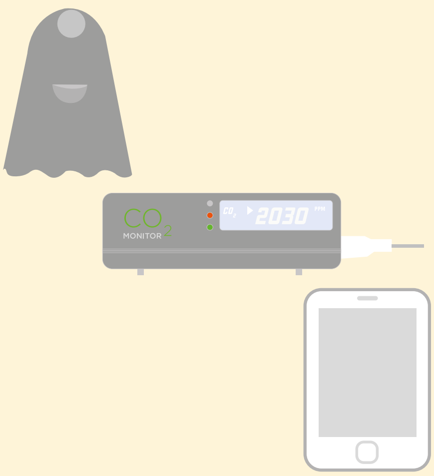
HEAL's project

To raise awareness of air pollution in school environments and how it affects children's health, **HEAL developed a citizen-science initiative to monitor indoor and outdoor air pollutants around primary schools in six capitals of the European Union – Berlin, London, Paris, Madrid, Sofia and Warsaw**. These cities and also the countries that they are located in currently fail to meet EU air quality standards. Berlin, Paris, London, Madrid have breached limits for nitrogen dioxide (NO_2); Spain is breaching both NO_2 and PM EU air standards; and Bulgaria and Poland have been found to breach EU air quality legislation for PM by the EU Court of Justice[8].

School environments have received less attention in both research and policy-making, which has largely focused on regulating outdoor air quality. At EU level, a comprehensive set of laws is in place to ensure good outdoor air quality and to cut emissions from the main pollution sources. The quality of inside air is significantly affected by outside air, as well as indoor factors[4]. People spend the majority of their time indoors, with children spending up to a third of their day at school, and yet no comparable framework exists for indoor environments.

During March, April and May 2019, 50 schools in these six cities participated in the initiative using low-cost monitoring devices to collect data on common air pollutants. NO_2 was monitored continuously for a period of three to four weeks and local partners visited each school to take a 20 minute measurement of the PM concentration in and around the schools and the CO_2 levels inside the classrooms.

Air quality monitoring



- Particulate Matter (PM) is the pollutant of greatest concern to health as tiny particles can enter the bloodstream. This project looked at both $PM_{2.5}$ and PM_{10}, the number indicating the size of the particles.
- Nitrogen Dioxide (NO_2). NO_2 is a pollutant often used to indicate air pollution from traffic, and it contributes to the formation of particulate matter. Studies also show it causes and aggravates asthma.
- Carbon Dioxide (CO_2) measured inside the classroom. CO_2 acts as an indicator of indoor air quality and ventilation. Inside CO_2 levels can rise high enough to cause drowsiness, affecting concentration and productivity[9].

In response to the public health threat that air pollution brings to those living in cities, more and more grassroots organisations and individuals are using low-cost devices to raise awareness of the need for clean air and to improve the knowledge of the exposure and vulnerability of different population groups. This local data can be useful to compare with data from official monitoring stations, or other collected data, and to bring home the message on the need for pollution reduction measures in communities.

This HEAL initiative is a contribution to this growing movement, providing a snapshot of air quality in and around schools in different cities, as well as recommendations for local authorities and school communities to discuss further. With the active participation of schools and children, this pilot initiative is one of the largest of its kind to use a coordinated, citizen science approach to measure both indoor and outdoor pollutants to date in Europe.

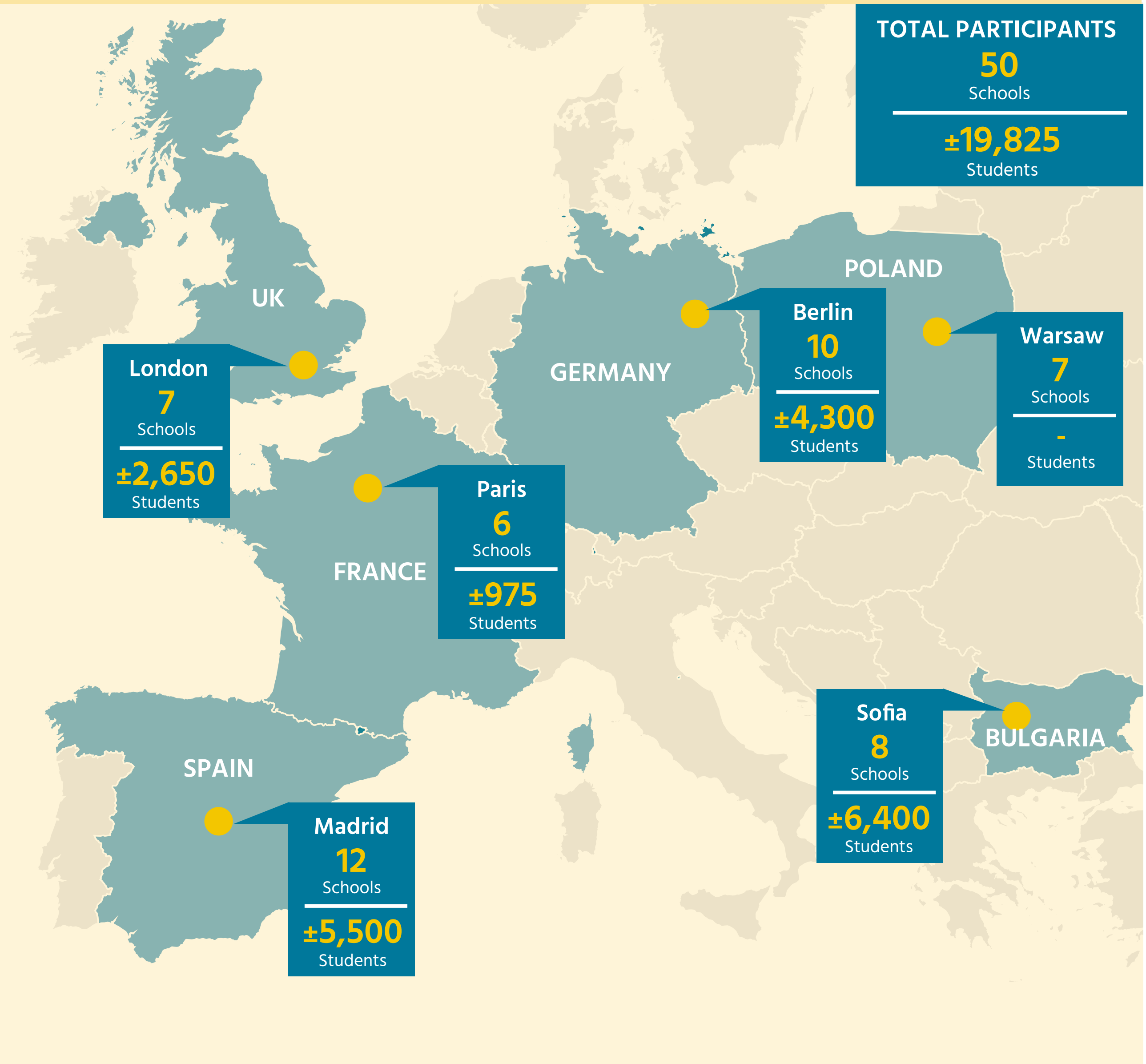
Findings of the HEAL snapshot – Indoor and outdoor monitoring at schools in six capital cities in Europe

HEAL's citizen science monitoring found various unhealthy air quality concentrations in and outside classrooms where children spend the majority of their day. A detailed analysis of the results can be found in the respective city sections further in this report.

Common findings

- At all participating schools, NO_2 was detected inside the classrooms. As there were no sources of NO_2 in classrooms, these NO_2 levels can only come from outdoor air pollution, notably traffic.
- Concentrations of particulate matter varied, and for some schools were higher than what the World Health Organization recommends to protect health.
- The majority of the classrooms had CO_2 values above the recommended level of 1,000 parts per million (ppm), indicating an overall need for more ventilation.

Participating schools and number of represented students across Europe



City findings

BERLIN

In Berlin, ten primary schools participated, representing ± 4,300 pupils. NO_2 was detected in all classrooms where monitoring took place. The measurements indicate that outdoor air pollution travelled inside, as there was no indoor source of NO_2. The NO_2 values are averages and will likely have been higher during school hours and drop-off times.

LONDON

In London, seven primary schools participated, representing ± 2,650 pupils. In each classroom NO_2 concentrations were observed, indicating that outdoor NO_2 pollutants travelled indoors to classrooms, as there were no indoor sources of NO_2 in these classrooms. The NO_2 values are averages and will likely have been higher during school hours and drop-off times.

MADRID

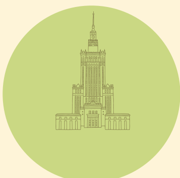
12 primary schools participated in the project in Madrid, encompassing ± 5,500 children. The observed NO_2 concentration averages for a month coming from traffic were generally high: at or just below the annual EU standards and WHO guidelines. The values measured are averages meaning that the concentration will probably have been significantly higher during certain parts of the day.

PARIS

In this capital, six schools joined the monitoring project, representing ± 975 children. At one school entrance the NO_2 concentration was 52 μg/m^3. The NO_2 values are averages and will likely have been higher during school hours and drop-off times. PM values varied and might have been influenced by construction works.

SOFIA

In Sofia, eight schools with ± 6,400 children joined the monitoring project. Particularly high concentrations of PM were observed at one school, 71 μg/m^3 at the entrance and 43 μg/m^3 inside the classroom and another school had a concentration of 45 μg/m^3 indoors.



WARSAW

Seven schools participated in Warsaw. The results of these measurements will be published in the autumn of 2019.

▶ CEIP Ignacio Zuloaga, Madrid, pupils use the CO_2 monitor. | © AEEA |

The results show that there were varying concentrations of unhealthy pollutants inside and outside classrooms.

The variation in the results can be explained by many factors, including proximity to busy roads and the season and characteristics of the building. Understanding how these interact is complex. However, the results do clearly demonstrate that outdoor pollutants enter school buildings and influence indoor air quality. Since there are no indoor sources of NO_2, the concentrations detected indicate the contamination of indoor air by traffic-related emissions.

It is important to highlight that the concentrations shared in this report do not remain steady throughout the day, or over the year, but vary as PM and NO_2 concentrations are influenced by traffic, the weather, use of heating, or ventilation. In order to determine the health risk to children, longer and continuous monitoring is needed.

The indoor environment cannot be separated from the outside world. The high values of CO_2 observed in a majority of the classrooms underlines the need for ventilation. To prevent drowsiness, loss of concentration, and decreased productivity, it is important to ventilate regularly. Yet, as long as the outdoor air is polluted, schools will struggle to achieve good indoor air quality. The outdoor air needs to be cleaned up, so that children can learn well and develop healthily.

▶ Citizen science monitoring - children help to set up monitoring tubes for nitrogen dioxide (NO_2) in the classroom | © HEAL |

2.

Context

Clean air has long been a priority in the EU, and EU legislation sets legally binding standards for a number of pollutants in the outside air[10,11, 1]. These EU standards are based on the WHO's recommendations, but for key pollutants they are less strict.

Unfortunately, most countries in the EU fail to keep to these standards, meaning air quality in numerous European cities remains poor[3]. The European Commission has recently taken six countries to the EU Court of Justice for failure to protect citizens, and Bulgaria and Poland have already been found in breach of EU air requirements[7].

Indoor air quality is influenced by the quality of the air outdoors - and it represents a monitoring gap that HEAL has identified, especially in regards to one of the most vulnerable groups of our society: children, who spend up to a third of their day at school, making indoor air quality a crucial determinant to their health. As studies demonstrate, children who spend long periods in unhealthy buildings are between one and a half to three times more prone to coughing and wheezing - symptoms of asthma and other respiratory conditions, than children in healthy indoor environments[12].

Buildings, climate change and people's health

Buildings, both residential and non-residential, are a crucial but often overlooked health determinant. Adults and children spend the majority of time – about 20 hours a day – indoors. Inadequate ventilation, poor indoor air quality, chemical contaminants from indoor or outdoor sources, temperature, traffic noise or poor lighting can influence people's health.

Direct health consequences can be respiratory and cardiovascular diseases, illness and deaths from temperature extremes and inadequate energy access; anxiety and depression when buildings can't provide a sense of safety; as well as discomfort from less than optimal lighting conditions or irritability from noise levels. Unhealthy buildings even result in a distinct medical condition, known as sick building syndrome (SBS).

Buildings, including schools, have increasingly been a focus of climate action: the building sector is responsible for a third of the EU's greenhouse gas emissions and consume 40% of total energy in the EU.

Almost all existing buildings could benefit from an upgrade in order to reduce their energy demand and make them more energy efficient. Schools can be at the forefront of such climate proofing and renovation could help solve ventilation problems

that were also detected in HEAL's project[13]. However, such energy efficiency renovations need to have health at its core.

HEAL's briefing 'Healthy Buildings, healthier people' lays out how the improvement of existing and new buildings are a priority in tackling climate change but equally a public health concern that requires respective social and equity priorities and that should therefore be of vital interest among policy-makers, the industry, and the public health community alike. The briefing highlights the positive impact that renovations combined with renewable energy and health considerations could make for planet and people.

Available in EN, DE, TR, NL, FR, ES, BG and PL.

[1] *Directive 2008/50/EC sets clear and binding objectives (limit values) and defines specific responsibilities for EU Member States to monitor, report on and manage air quality.*

Air quality standards and health recommendations

WHO's air quality guidelines for maximum concentrations of pollutants in the air are based on an extensive review of the science, and they are health-based, unlike the EU standards which are the result of a political compromise. The guidelines are important as they offer a reference tool for decision makers across the globe to set standards for key air pollutants which pose risks to our health. Following a recent review of the evidence which indicates negative health effects at lower concentrations, the WHO is in the process of updating the guidelines in 2019, and it is expected that at least the NO_2 guideline value will be stricter[6].

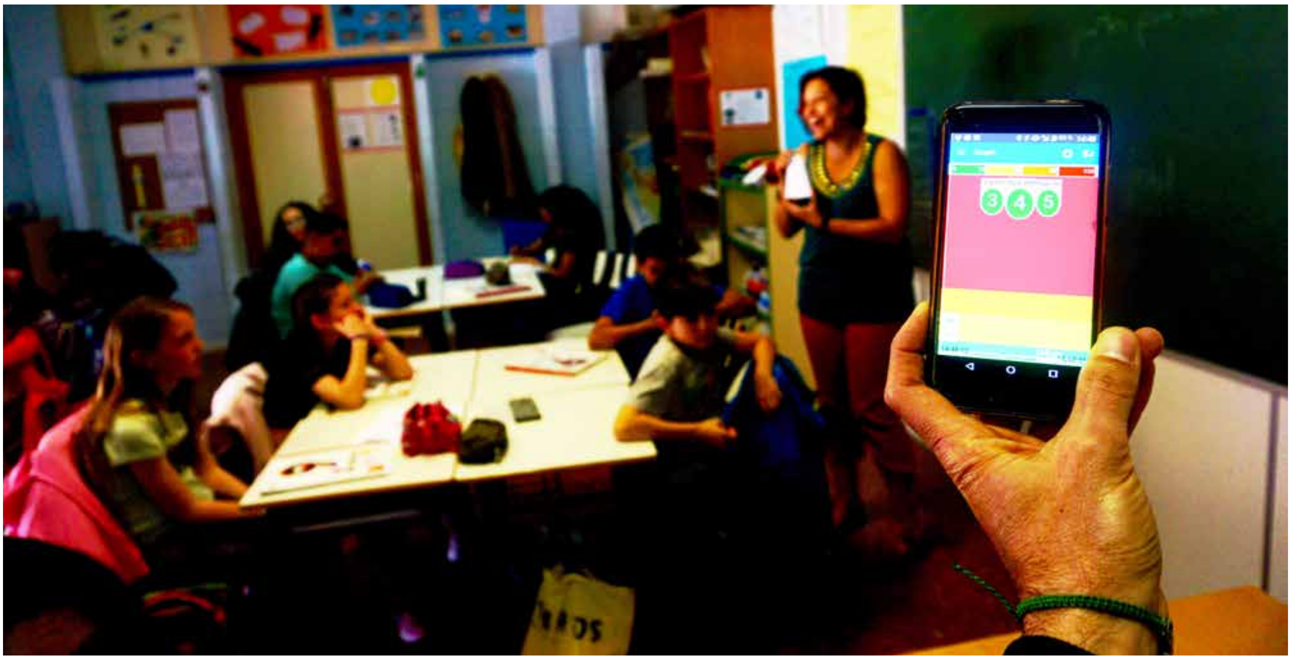
Regarding indoor air, the WHO has issued a set of recommendations for indoor sources[14]. At EU level, there are no indoor air quality standards, but the EU funded SINPHONIE project[15] which formulated guidelines and recommendations for better air quality in schools in Europe, proposed 1,000 ppm as a guideline for CO_2 concentrations in classrooms.

		EU Air Quality Directive	WHO Guidelines
Pollutant	Period	Concentration (limit value µg/m³)	Concentration (limit value µg/m³)
$PM_{2.5}$	24 Hours	-	25*
$PM_{2.5}$	Annual	25	10
PM_{10}	24 Hours	50**	50*
PM_{10}	Annual	40	20
NO_2	Hourly	200***	200
NO_2	Annual	40	40

* 99th percentile - 3 days/year

** not to be exceeded more than 35 days a year

*** not to be exceeded on more than 18 times a year



▶ Air monitoring device to measure particulate matter in and outside classrooms | © AEEA |

3.

How air pollution may harm your health

Brain

- Increased cerebrovascular ischemia
- Dementia

Blood

- Altered rheology
- Increased coagulability
- Translocated particles
- Peripheral thrombosis
- Reduced oxygen saturation

Cells

- Bladder cancer
- Skin cancer
- Obesity
- Diabetes

Lungs

- Inflammation
- Oxidative stress
- Accelerated progression and exacerbation of COPD
- Increased respiratory symptoms
- Effected pulmonary reflexes
- Reduced lung function
- Higher lung cancer risk

Heart

- Altered cardiac autonomic function
- Oxidative stress
- Increased dysrhythmic susceptibility
- Altered cardiac repolarisaion
- Increased myocardial ischemia

Children

- ADHD
- Pre-eclampsia of the pregnant mother
- Pre-term birth
- Reduced birth weight
- Pollutants can reach the placenta
- Increased asthma risk, and increased frequency of attacks for already asthmatic children

Vasculature

- Atherosclerosis, accelerated progression and destabilisation of plaques
- Endothelial dysfunction
- Vasoconstriction and hypertension

Health impacts result from both short and long-term, repeated exposure to air pollution. A recent review by the World Health Organisation (WHO) found that impacts can already occur at concentrations even lower than previously considered, and that the range of health impacts is larger than previously thought. For particulate matter there is no safe threshold.

Source: Adapted from APHEKOM project 2012; and Pope&Dockery 2006, as well as REVIHAAP 2013.

4.

Sources and health impact of pollutants

$PM_{2.5}$
PM_{10}

Particulate matter (PM): Small particles in the air, with the number indicating the size of the particles. PM_{10} is 10 micrometers or less, while $PM_{2.5}$ is 2.5 micrometers or less. When inhaled, the tiny particles travel into the bloodstream and cause harm to our lungs and heart. They can cause stroke and lead to premature death. New studies also link particulate matter with harm to the healthy development of children, and diseases such as obesity and Alzheimer's[7]. Recent research has found particles in the placenta. For particulate matter, no safe thresholds exist[7].

The major sources of $PM_{2.5}$ are the combustion of fossil fuels, vehicle exhaust, industrial production and power plants[16].

NO_2

Nitrogen oxide (NO_2) is part of a group of gases called Nitrogen oxides (NO_x), which can cause inflammation of the airways. They play a significant role in exacerbating asthma, pneumonia, bronchial symptoms and reduction in overall lung function. They can react in the atmosphere to form particulate matter[7]. NO_2 has been linked to reduced lung function growth in children and increased bronchitis symptoms of asthmatic children. In cities, the principal source of NO_2 is traffic.

CO_2

CO_2 is rarely regarded as a threat to health in indoor environments, but in buildings such as schools it can rise to levels high enough to cause drowsiness, affecting concentration and productivity[9]. In indoor environments, CO_2 is produced by the human body through breathing, therefore indoor air concentrations tend to be higher.

In schools, CO_2 measurements are used as a measure of indoor air quality and to calculate ventilation rates[9,15]. Ventilation is essential to indoor air quality as it dilutes the level of pollution. Poor ventilation rates inside schools, causing increased levels of CO_2 in classrooms, are common throughout Europe and are linked to asthma, dizziness, inability to concentrate, headaches, irritated throat amongst other symptoms[15].

5.

Methodology

Citizen science

Citizen science spans a range of levels of engagement and involvement of citizens in research, from becoming better informed about science, to gathering data[17]. This project used a citizens monitoring approach to involve teachers and children in and around primary schools, to provide monitoring data on the short and long term exposure to air pollutants. Citizen monitoring can contribute to the monitoring process as air pollutant levels can vary significantly over short distances and many measurement locations are needed to properly understand an area's air quality. Therefore extra measurements at different school buildings provide a much clearer understanding of the local air pollution and raise public awareness on the need for clean air, particularly for vulnerable groups such as children in schools. Citizen science should not replace official and long-term monitoring but be seen as a way to raise awareness and increase pressure on decision makers to act for clean air.

▶ Air beam monitor and NO_2 tubes to measure air pollutants. | © Sustrans |

Step I NO_2 diffusion tubes

NO2 was measured outside the school entrance and inside the schools' classrooms for three to four weeks using diffusion tubes which were provided to each participating school together with a project poster board. Project partners along with teachers and often the help of students installed the diffusion tubes. The measurements took place between mid-March and mid-April 2019 in Berlin, London, Madrid and Sofia. Paris and Warsaw measurements took place during May 2019.

▶ The low cost air monitor works with a light scattering method to measure fine particulate matter. | © AEEA |

Step II CO_2 and PM measurements

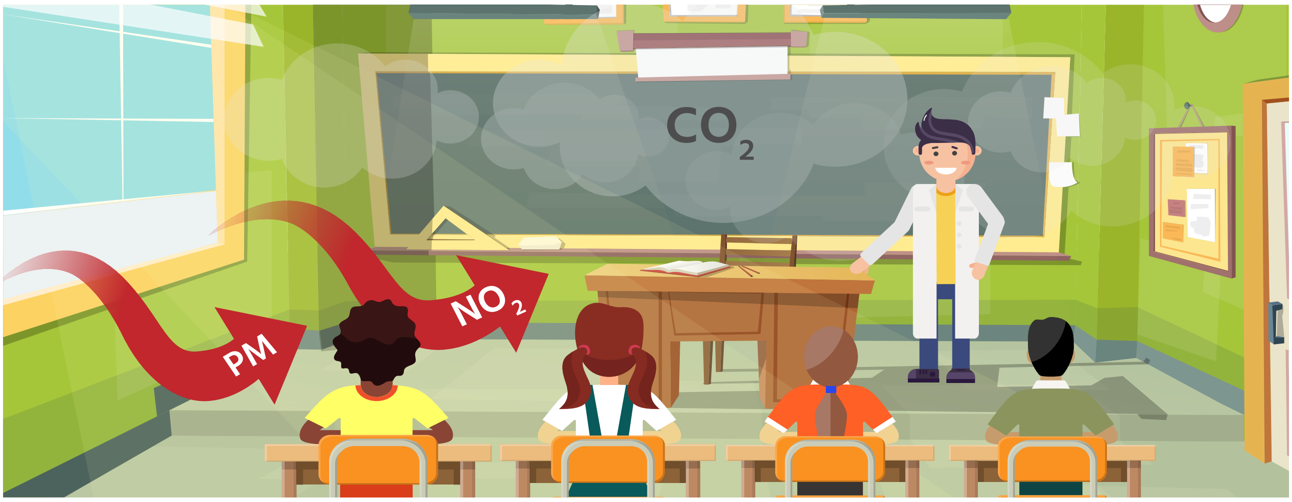
Each participating school was visited by a project representative, to explain the activity and then monitor PM and CO_2 concentrations for a period of ± 20 minutes.

PM values are optimally measured over a longer period to be able to establish an average annual concentration. The results of the PM reading in this project therefore only offer a snapshot of a day during the project and can not be generalised.

▶ A mini CO_2 monitor was used which contains a traffic light system for classifying the indoor CO_2 concentration. | © HEAL |

6.

Common findings



HEAL's monitoring confirmed that the quality of the indoor air is influenced by how polluted or clean the outdoor air is. Our monitoring showed that air quality in schools across Europe is poorer than it should be, and that it needs to be improved in order to protect children's health and to promote their ability to learn. Indoor air quality, together with outdoor air improvement should become a priority for policy-makers and the public - the two go hand in hand. This holds especially true for efforts to make school buildings more energy efficient.

Particulate Matter (PM)

The cities had varying levels of PM, taken at snapshot measurements over a 20 minute period, some higher than the guideline value the WHO recommends for 24 hours, both outside the school and inside the classroom. As WHO states that there are no safe level for PM, efforts should be made to identify and address the sources of pollution.

Nitrogen Dioxide (NO_2)

The monitoring detected NO_2 in all of the schools participating in the project. As there were no sources of NO_2 pollution in classrooms (such as fuel-burning stoves, tobacco use, gas-fired heating systems etc.[14]), these NO_2 levels can only come from outdoor air pollution, notably traffic.

It is important to note that the result values are averages, meaning that the NO_2 concentration will probably have been significantly higher during certain periods of the monitoring, most probably during the day when there is more traffic - and when lessons are taking place in schools. Data from official monitoring stations in Belgium showed that the concentration of NO_2 is significantly higher during school hours than measurements taken during evenings and weekends as there is more traffic during these times[18].

In several of the schools across the cities indoor NO_2 measurements were almost as high or higher than the outdoor NO_2 levels. This could be due to many external factors including building properties, weather and type of road the school is on, but it also indicates that children are exposed to levels of NO_2 inside the school buildings while in class, not just on their walk to school or in the playground. NO_2 is entering the indoor environment from outdoor pollution.

CO_2 and ventilation

CO_2 levels were consistently high in the majority of schools. In some cases 2-3x higher than the recommended indoor CO_2 guideline. In several cases, teachers explained that they do not regularly ventilate due to concerns about the outdoor air quality as well as the noise from traffic. Some schools showed concentrations of NO_2 that were similar to outside levels as well as a high concentration of CO_2. An explanation for this could be that if the classroom is ventilated in the morning before the children arrive, there is a risk that peak pollution from rush hour enters the classroom and contaminates the indoor air. If subsequently the rooms are not ventilated anymore, the CO_2 levels rise.

7.

Results

As in many German cities, the air quality in Berlin is worse than the levels necessary to protect health. The annual EU standard for NO_2 has been exceeded year after year and PM_{10} standards have not been complied with since 2009[19]. The city authority is currently considering which further measures are needed for the city's air quality action plan to reduce pollution[20] and will likely decide on a new clean air plan at the end on July 2019. While there has been success in cutting air pollution from industry, energy and heat generation, transport is now the main polluting sector. Berlin has introduced a low emission zone and provides incentives for sustainable transport modes[21].

Summary

Geographical location of the schools across Berlin

- Ten public primary schools in Berlin
- School population represented: ± 4,300 pupils
- All ten schools were in a busy location and covered the areas of Neukölln, Mitte, Tempelhof-Schöneberg, Steglitz-Zehlendorf, and Friedrichshain-Kreuzberg.

Results

In Berlin, the air quality in and around ten primary schools was measured. NO_2 concentrations were detected outdoors at all schools and surprisingly also inside the classroom.. Two schools' NO_2 results were actually higher inside the classroom than outdoors at the school entrance. As there should be no sources of NO_2 in the classroom, this indicates that NO_2 travelled from outside into the rooms where children spend a significant part of their day.

None of the ten schools had healthy levels of CO_2 when the measurements began, and one school had CO_2 levels over 3x the recommended levels. After opening the windows some classrooms reached values below 1,000 ppm however, not all schools were able to lower the CO_2 concentration. The schools informed the project team that due to safety measures, they were not allowed to fully open the windows preventing proper ventilation.

▶ NO_2 monitoring tubes outside a Berlin school | © HEAL |

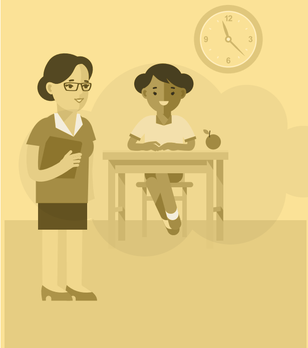
Schools	NO_2 outdoors (µg/m³) *Measured over a four-week period*	NO_2 indoors (µg/m³) *Measured over a four-week period*	$PM_{2.5}$ outdoors (µg/m³) *Measured over a single 20-minute period*	$PM_{2.5}$ indoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} outdoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} indoors (µg/m³) *Measured over a single 20-minute period*	CO_2 (ppm) *Maximum value measured over a single 20-minute period*
Berlin school 1	25	11	4	2	5	18	1300
Berlin school 2	20	22	14	16	24	31	1995
Berlin school 3	31	12	6	3	9	5	2220
Berlin school 4	6	13	3	4	4	6	2100
Berlin school 5	17	12	4	10	5	20	1800
Berlin school 6	19	7	6	3	6	9	2750
Berlin school 7	18	10	4	1	8	4	2400
Berlin school 8	13	5	5	18	5	40	>3000
Berlin school 9	18	7	14	13	22	21	1680
Berlin school 10	20	7	19	5	27	9	2630

Conclusions and Recommendations for Berlin

The results in Berlin clearly illustrate that indoor air quality is influenced by outdoor air pollution. Since there are no internal sources of NO_2 emissions inside the classrooms, the concentrations detected in the schools in Berlin have travelled from outdoors into the schools' interior where they can affect the health of the pupils. The high CO_2 concentrations show that it is necessary to improve ventilation as the levels observed were all far above healthy limits and therefore likely to negatively influence the learning performance of the children. However, when ventilating the classrooms by opening windows, the outdoor air quality and its potential to enter the classroom environment must be considered.

The following recommendations should be implemented to counter the negative impacts of air pollution affecting the most vulnerable, such as young children:

1. **Make tackling air pollution in schools and other children's environments a political priority.**
2. **Discourage and restrict traffic and car idling around schools, for example through including schools in low emission zones or congestion charge areas and the encouragement of car sharing among parents, and use public transportation, walking and cycling.**
3. **Ensure regular ventilation of school classrooms, either through manual or mechanical ventilation, and determine the best times to ventilate when air pollution is low.**



LONDON

Reduce traffic pollution to clean up schools indoor environments

Air quality in London has been of concern for both the public and policymakers. In 2016, two million people in London breathed polluted air, of which 400,000 were children[22]. The UK has the highest prevalence of childhood asthma among all European countries[23].

London exceeds EU NO_2 air standards, with half of emissions coming from road traffic[24]. The borough of Lambeth, where the schools monitored in this project are located, is ranked as one of the worst polluted boroughs in the city[25].

Public Health England published a review of interventions to improve outdoor air quality and public health in 2019[26]. The Mayor of London commissioned an indoor air quality audit among 50 primary schools and a study which found that PM concentrations in most classrooms were above WHO guidelines. It also indicated that limiting CO_2 to between 600 and 1,000 ppm may improve cognitive performance of students[23].

In order to protect Londoner's health, a new Ultra Low Emission Zone came into effect in spring 2019, charging diesel and petrol vehicles if they fail to meet new emission standards. This zone is set to be expanded further in 2021[24].

Summary

Geographical location of the schools across Lambeth, London

- Seven public primary schools in Lambeth, London[2]
- School population represented: ± 2,650 pupils
- One school is exposed to a main central London road and has installed a green screen - a wall of plants - to better protect the playground from traffic. Two schools are set 50m back from main roads and have wildlife gardens surrounding the playground. Two schools are on quieter side roads with busy periods at drop-off time.

[2] *Participating schools were Hitherfield Primary School and Children's Centre, Allen Edward Primary School, Oasis Academy Johanna and Lark Hall Primary School, the other schools wished to remain anonymous.*

Results

Seven schools participated in the initiative in London. In each classroom, the results show NO_2 concentrations of at least 12 µg/m³ to up to 26 µg/m³. This is remarkable as there are no indoor sources of NO_2 in classrooms, meaning that outdoor NO_2 pollutants travelled indoors to classrooms. Outdoors the values ranged from 25 to 41 µg/m³. It is important to note that the results of the NO_2 monitoring are averages and will likely have been higher during school hours and drop-off times due to higher traffic volumes compared to evenings and weekends.

In all the classrooms the CO_2 concentrations were well above 1,000 ppm, ranging from 1,195 ppm to as high as 2,750 ppm. This indicates that there is a need for more ventilation. Ventilation is essential to indoor air quality as it dilutes the level of pollution. Poor ventilation rates inside schools may cause asthma, dizziness, inability to concentrate, headaches and irritated throat - amongst other symptoms[16].

Hitherfield Primary School Eco Group helped with the NO_2 monitoring. | © Sustrans |

Schools	NO_2 outdoors (µg/m³) *Measured over a four-week period*	NO_2 indoors (µg/m³) *Measured over a four-week period*	$PM_{2.5}$ outdoors (µg/m³) *Measured over a single 20-minute period*	$PM_{2.5}$ indoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} outdoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} indoors (µg/m³) *Measured over a single 20-minute period*	CO_2 (ppm) *Maximum value measured over a single 20-minute period*
London school 1*	26/36	26/36	2	3	2	4	2000
London school 2	25	15	5	1	6	1	1250
London school 3	29	17	17	5	25	6	2520
London school 4	29	20	3	2	3	3	2750
London school 5**	-	-	0	1	1	1	1645
London school 6*	12/35	12/35	2	0	1	3	1195
London school 7	30	17	1	1	1	1	1395

* Technical problem that prevented determining if value was outside or inside, both results are given. However, it is likely that the higher value was outdoors.
** Unfortunately, the tubes from school 5 were lost and are missing from the analysis.

Conclusions and Recommendations for London

The relatively high levels of NO_2 inside the classrooms in London show that air pollution travels indoors. Traffic related air pollution does not remain confined to the roads but enters places where children spend the majority of their time. Children at school should not be exposed to these levels of air pollution as they are especially vulnerable to its negative health effects since their bodies are still developing.

The high concentrations of CO_2 inside the classrooms show there is a need for ventilation. Yet as long as the outdoor air poses a risk to health, children are not protected while at school.

The following actions should be followed to reduce air pollution in London and protect health:

1. **School and local authorities should discourage and restrict traffic and car idling around schools, for example by implementing School Streets, where immediate streets around the school gates are closed to cars during the school run to reduce car emissions. Sustrans, the UK walking and cycling charity, has recently organised School Streets with 40 schools across the UK, to inspire action. Central governments are urged to give all councils the same powers the councils in London have to enforce School Streets.**

2. **Local authorities should establish free public transportation, powered by renewables and encourage walking and cycling. The UK government needs to show leadership by helping local authorities fund and deliver a network of walking and cycling routes to school so that every child is able to travel by foot or by bike to school safely and with confidence.**

3. **Further citizen science monitoring projects like the one performed in the seven schools in the Lambeth borough should be encouraged, to raise local awareness and engagement in tackling poor indoor and outdoor air quality. This is also an opportunity to teach children about the health effects of air pollution and what can be done to improve air quality.**

Yvonne Morris from Hitherfield Primary School and Children's Centre, one of the seven schools that actively participated in this monitoring project said: *"We take air quality very seriously in our school, as we want to provide the best environment we can for our children inside and outside the school. It was very interesting to monitor the pollution, particularly inside the school. Before we started the project, we didn't really know much about nitrogen dioxide, the fact it might travel into the buildings and how harmful that could be."*

MADRID

Traffic pollutes schools and threatens children's health

Spain has exceeded the EU air quality standards, especially in the cities of Madrid and Barcelona, and was threatened to be brought to court by the European Commission in 2017[27]. Madrid is one of the European regions most polluted capitals and traffic is responsible for around half of the emissions of NO_2 and PM. Diesel vehicles combined with frequent dry climate conditions contribute to high NO_2 levels.

Researchers have found that, based on air quality data, the amount of particles entering citizens' lungs while breathing is equivalent to smoking 2-3 cigarettes a day in some districts of Madrid[28]. In order to tackle the air pollution problem, the city of Madrid enforced a zero emissions zone in November 2018, called Madrid Central. Only zero emissions vehicles and residents have authorisation to drive in this area. It has been reported that this area has seen a 40% reduction in NO_2 since the introduction[29].

Summary

Geographical locations of the schools across Madrid

- 12 primary schools in Madrid[3]
- Covering ten out of 21 districts in Madrid, every social and economic status
- The centre of the city is fully represented, except for the districts of Retiro and Chamartín
- School population represented: ± 5,500 children and ± 300 children inside the participating classrooms
- Two schools were within 1km of a motorway, three other schools were surrounded by big streets and one near an A-road and one near a highway tunnel. The remaining four were not within 500m of a busy road or highway
- The majority of schools said that children mainly walked to school.

[3] Participating schools were CEIP Amador de los Ríos, CEIP Ignacio Zuloaga, CEIP Rufino Blanco, CEIP Ermita del Santo, CEIP San Ildefonso, CEIP Concepción Arenal, CEIP Eduardo Rojo, CEIP El Quijote, CEIP Esperanza the other schools wished to remain anonymous.

Results

12 primary schools participated in the project in Madrid. The NO_2 concentration in and around the schools was generally high during the weeks of the monitoring. At one school close to heavy traffic, the NO_2 value at the school entrance was 43 μg/m³. This monthly average is higher than the annual EU and WHO air quality standards. Since the values measured are averages, the NO_2 concentration will probably have been significantly higher during certain periods of the monitoring. During the night and the weekends there will have been lower concentrations as there is less traffic during these times. Three other schools had NO_2 measurements at the school entrances between 34 and 39 μg/m³. It is likely that at these schools the NO_2 concentration also exceeded 40 μg/m³ during school hours. Indoors, NO_2 concentrations as high as 35 μg/m³ were observed, indicating that outdoor air pollutants enter the school building and the classroom.

The CO_2 monitoring in the classrooms showed that only one classroom had a concentration below 1,000 ppm. Two classrooms even had concentrations higher than 3,000 ppm, out of the range of the measuring device. Discussions with the teachers indicated that ventilation is often a dilemma as street air quality is poor and there are also energy efficiency considerations, for example losing heat in winter and keeping cool in summer.

School children hang up the NO_2 monitoring tubes at CEIP Ignacio Zuloaga | © AEEA |

Schools	NO_2 outdoors (μg/m³) *Measured over a four-week period*	NO_2 indoors (μg/m³) *Measured over a four-week period*	$PM_{2.5}$ outdoors (μg/m³) *Measured over a single 20-minute period*	$PM_{2.5}$ indoors (μg/m³) *Measured over a single 20-minute period*	PM_{10} outdoors (μg/m³) *Measured over a single 20-minute period*	PM_{10} indoors (μg/m³) *Measured over a single 20-minute period*	CO_2 (ppm) *Maximum value measured over a single 20-minute period*
Madrid school 1*	-	-	5	4	6	6	1395
Madrid school 2	43	33	12	3	16	3	1540
Madrid school 3	21	10	3	2	3	3	>3000
Madrid school 4	27	18	13	4	17	5	1515
Madrid school 5	39	15	5	1	6	2	1835
Madrid school 6	29	21	5	5	6	7	1800
Madrid school 7	20	30	8	2	10	3	950
Madrid school 8	34	35	6	4	7	4	1385
Madrid school 9	26	17	3	2	4	3	1840
Madrid school 10	37	22	6	2	7	2	1800
Madrid school 11	26	18	3	9	4	11	2000
Madrid school 12	26	27	5	3	3	7	>3000

* Unfortunately, the NO_2 tubes of Madrid school 1 were lost and are missing from the analysis.

Conclusions and Recommendations for Madrid

The high values of NO_2 at the schools in Madrid underline the traffic-related air pollution issue in the city. These results show that traffic related pollution does not exclusively impact outdoor air but also influences the air quality indoors, where children who are more vulnerable to the negative health impacts, go to learn and play.

In order to tackle air pollution and have clean, healthy air, the following recommendations should be implemented in Madrid:

1. **Make tackling air pollution in schools and other children's environments a political priority.**
2. **Maintain and expand the Madrid Central low traffic area in the centre of the city.**
3. **Create a safe and extensive network of cycling lanes as demanded by civil society, such as the 2021 project[4].**

Walter Post, teacher at from CEIP Ignacio Zuloaga, one of the 12 schools who actively participated in this monitoring project said:
"Not even classrooms, where boys and girls spend part of their lives, are free of air pollution caused by human activities. It is necessary, imperative, to protect them, protect ourselves, and live in healthy environments."

[4] *For more information see website of Pedalibre: https://pedalibre.org/2018/11/26/por-una-red-ciclista-para-2021/*

PARIS

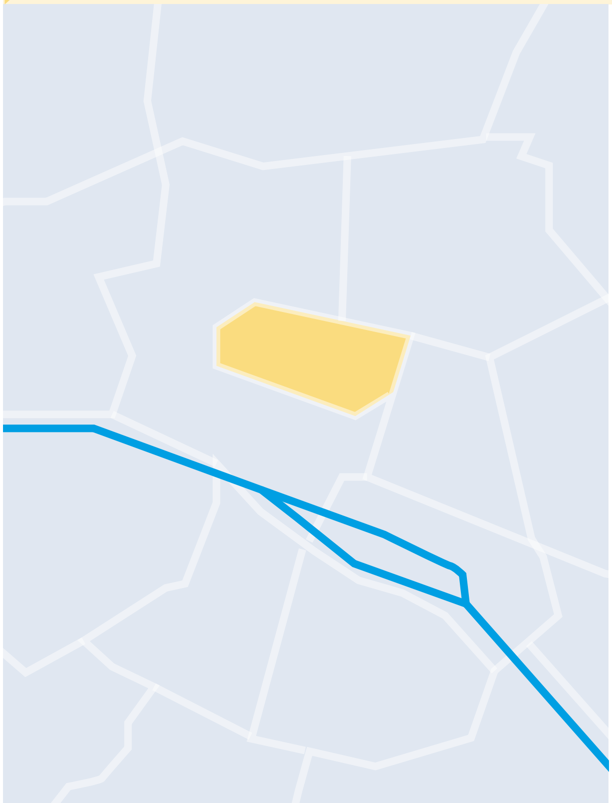
Further action on cutting traffic is needed for healthy schools

One of Europe's largest cities, Paris, exceeds the EU limit value for both NO_2 and PM. Long-term exposure to poor air quality has been associated with around 55,000 premature deaths in France annually[30]. Road transport accounts for the majority of primary emissions of both NO_2 and PM (73% NO_x and 42% PM_{10}) in Paris[30]. The mayor of Paris has made clean air a priority, and plans to reduce the number of cars in the city by half, and pedestrianisation of the capital is planned in addition to a ban of diesel vehicles by 2024. All vehicles in Paris are required to display an anti-pollution sticker under the Crit'Air scheme in an effort to improve air quality in the city[31]. Emergency measures are put in place during pollution episodes including free public transport, speed restrictions and the ban of heavy duty vehicles.

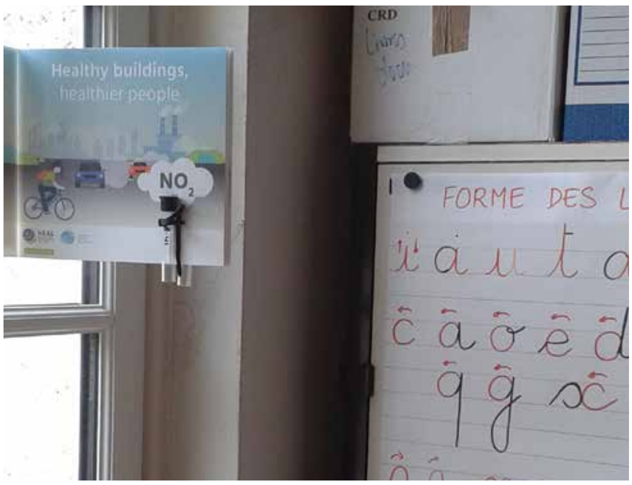
A recent study led by the French association Respire created an inventory of the air pollution near schools in Île-de-France, the Paris region, at crèches, schools, colleges and high schools. Of the 12,520 schools analysed 682 were exposed to air pollution levels exceeding NO_2 annual standards guidelines[32]. Additionally, studies in French schools across six French cities found that poor air quality in classrooms, predominantly $PM_{2.5}$ and NO_2, was linked to an increased prevalence in asthma in children in the past year[33].

Summary

- Six nursery and primary schools
- School population represented: ± 975 children
- Most children are not dropped off by car but come to school by foot, bike, metro or bus
- Schools located in the centre of Paris
- Measurements taken in May 2019.



Geographical location of the schools across Paris



NO_2 monitoring in a school in Paris

Results

Six schools participated in the monitoring initiative in Paris. The NO_2 concentration at the school entrance of Paris school 2 was exceptionally high at 52 µg/m³. The annual EU and WHO air quality standard is 40 µg/m³. The values measured are averages and the NO_2 concentration will probably have been higher during certain periods of the monitoring, increasing the risk of negative health effects. Indoors the NO_2 concentrations ranged from 17 to 27 µg/m³. At Paris school 3 the NO_2 concentration at the school entrance was 32 µg/m³ which is a relatively high value because the school is located near a park and surrounded by pedestrianised and calm streets.

The highest concentrations of particulate matter were measured at Paris school 5 and Paris school 6. Close to these two schools construction works took place, which might have influenced the higher PM values.

Schools	NO_2 outdoors (µg/m³) *Measured over a four-week period*	NO_2 indoors (µg/m³) *Measured over a four-week period*	$PM_{2.5}$ outdoors (µg/m³) *Measured over a single 20-minute period*	$PM_{2.5}$ indoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} outdoors (µg/m³) *Measured over a single 20-minute period*	PM_{10} indoors (µg/m³) *Measured over a single 20-minute period*	CO_2 (ppm) *Maximum value measured over a single 20-minute period*
Paris school 1	33	21	12	7	17	9	584
Paris school 2	52	27	8	2	10	5	1525
Paris school 3	32	17	20	9	28	13	1075
Paris school 4	26	20	4	3	5	5	1785
Paris school 5	30	19	25	10	35	15	686
Paris school 6	36	24	23	7	37	10	1062

Conclusions and Recommendations for Paris

The air quality at Paris school 2 was very poor during the period the NO_2 concentrations were measured. It is likely that a big boulevard next to the school entrance impacted this result. Even at Paris school 3 the air pollution was relatively high, even though it was less affected by busy roads. It is essential to increase monitoring of air pollution in order to raise awareness of the problem and improve the understanding of children's exposure, while at the same time implementing measures.

The majority of the pupils in the participating schools were not brought to school by car. It is extremely difficult for schools and parents to address air pollution themselves. Air pollution should be tackled as a whole in order to protect the health of the most vulnerable. Decision makers on local, national, and international level should make clean air a priority because as long as the outdoor air poses a risk to health, children are not protected while at school.

The key recommendations for Paris are:

1. **Support the expansion of regulatory and citizen science air quality monitoring in schools.**
2. **The Paris mayor and school authorities should look to discourage and restrict traffic and car idling around schools, for example by including schools in low emission zones or congestion charge areas and promote free public transport.**
3. **Highlight the health evidence to teach citizens about the negative impacts of air quality, which in turn can contribute to more awareness on the benefits of cleaner air and climate action for greater public health gains.**
4. **Increase knowledge and raise awareness about the impact of construction works on air quality and its health effects in and around schools.**

SOFIA

Elevated particulate matter pollution

Sofia is one of the most polluted cities in the EU, in a country with high health impacts from air pollution[34]. Especially in winters Sofia has struggled with poor air quality. In December 2018, citizens of the city were called to avoid using their cars to limit particulate matter concentrations. However, traffic is just one of the sources of air pollution, fuel-fired heating and coal power generation have been major sources as well[35]. In 2015, $PM_{2.5}$ and PM_{10} concentrations exceeded the WHO recommended concentrations[36] and in 2017, Bulgaria was found in breach of EU legislation for PM_{10} levels[37].

Summary

- Eight primary schools in Sofia[5]
- School population represented: ± 6,400 pupils
- Located in 8 of the 24 different districts of the Sofia municipality.

▶ Geographical location of the schools across Sofia

▶ School lesson on the citizen monitoring project. | © Association Air for Health |

[5] *Participating schools were 26 SU "Yordan Iovkov", 75 OU "Todor Kableshkov", Telelcomunication school, and NPMG, the other schools wished to remain anonymous.*

Results

On three occasions the $PM_{2.5}$ value was higher during the 20-minute monitoring period than the hourly WHO guideline for $PM_{2.5}$. A particularly high concentration of 71 µg/m³ was observed at the entrance of one school with a concentration of 43 µg/m³ inside the classroom and another school had a level of 45 µg/m³ indoors.

In Sofia, the NO_2 concentrations in and around eight schools were monitored. Two schools had values of 30 and 32 µg/m³ respectively at the school entrance and another school had an average concentration of 30 µg/m³ inside the classroom compared to 22 µg/m³ outside indicating that outside air pollution can and does enter into the indoor environment where children spend their day. Since the values that were measured are averages, the NO_2 concentration will probably have been significantly higher during certain periods of the monitoring as there will have been lower concentrations at night and at the weekends when there is less traffic.

The CO_2 levels measured in the classrooms in the participating schools in Sofia were generally lower than in other cities. Yet still in three classrooms the concentration was above 1,000 ppm. The teacher in the classroom with the highest level of CO_2 indicated that although they can open the windows fully, they rarely do so because the classroom faces a boulevard with a lot of traffic.

Schools	NO_2 outdoors (µg/m³) *Measured over a four- week period*	NO_2 indoors (µg/m³) *Measured over a four- week period*	$PM_{2.5}$ outdoors (µg/m³) *Measured over a single 20-minute period*	$PM_{2.5}$ indoors (µg/m³) *Measured over a single 20-minute period*	CO_2 (ppm) *Maximum value measured over a single 20-minute period*
Sofia school 1	17	10	10	19	527
Sofia school 2	17	9	12	10	658
Sofia school 3	22	30	71	43	1440
Sofia school 4	16	23	14	18	980
Sofia school 5	32	14	11	13	1512
Sofia school 6	30	19	15	13	972
Sofia school 7	22	19	17	24	1142
Sofia school 8	17	7	18	45	210

Conclusions and Recommendations for Sofia

As WHO states that there are no safe level for PM, efforts should be made to identify and address the sources of pollution. PM can have serious negative health effects such as leading to heart and respiratory diseases and new studies indicate that PM can increase chances of developing Alzheimer's and obesity. Differences in the measured levels reinforce the need for local monitoring at school locations.

The key recommendations for Sofia are:

1. **Make tackling air pollution in schools and other children's environments a national priority and encourage interactions between civil-society and governments focusing on the urban and green planning of school neighbourhoods.**
2. **Support the expansion of regulatory and citizen science air quality monitoring in schools with relevant indicators, such as NO_2, PM, CO_2, VOCs, noise, etc.**
3. **Advocate for the inclusion of more targeted air pollution education in the curriculum for primary schools.**

WARSAW

Poland breaks air pollution laws by exceeding annual EU limits of particulate matter (PM_{10})[38]. In 2016, as many as 33 Polish cities were among the 50 most polluted cities in the EU, according to the WHO urban air quality database for average annual levels of $PM_{2.5}$.[39] Road traffic is the most significant source of harmful NO_x emissions in Poland's capital, Warsaw[36]. Every day over one billion cars commute to and out of Warsaw. There are severe traffic jams and numerous congested roads. In 2015, there were 649 cars for every 1,000 Warsaw citizens, making the Polish capital one of the most congested cities of the EU[40].

A study has in Silesian kindergartens in Southern Poland monitored indoor air quality over 24-hours including NO_2 and $PM_{2.5}$. The results indicated that in urban kindergartens, all air pollutants originated from outdoor air[39].

This section will be updated in autumn 2019

8.

Recommendations

In order to provide school environments where children can learn, play and grow up healthily breathing clean air, HEAL recommends:

For EU and national decision makers

European and national decision-makers can create the conditions for children to thrive in environments with good air quality inside and outside their classrooms and buildings. They should:

1. Ensure compliance with EU outdoor air quality standards and ultimately work towards the WHO recommendations
2. Make tackling indoor air pollution a political priority
3. Support the expansion of regulatory and citizen science air quality monitoring in schools
4. Include health considerations in efforts to reduce buildings' climate footprint, as part of the renovation of school buildings under the national long-term renovation strategies (LTRS), the implementation of the EU Energy Performance of Buildings Directive (EPBD) and other climate measures. This will ensure schools become frontrunners for energy efficiency and health improvements across Europe.

For local authorities and schools

1. Inform parents, teachers and the public on why good indoor and outdoor air quality is important for children, which measures are being taken at schools, e.g. by organising information sessions as part of the curriculum
2. Discourage and restrict traffic and car idling around schools, e.g. through including schools in low emission zones or congestion charge areas, encouraging car sharing among parents, and designating a school staff member to check on clean air measures
3. Promote active mobility for children's journeys to school, and support the necessary infrastructure changes financially, e.g. green school routes, bicycle hire schemes, e-buses, parking for bicycles
4. Establish free public transportation, powered by renewables
5. Ensure regular ventilation of school classrooms, either through manual or mechanical ventilation, and determine best times to ventilate at times when air pollution is low
6. Plan constructions in periods when no pupils are at school or move the pupils to a temporary alternate location to protect them from pollution coming from renovation activities.

For parents

1. Share your ideas with teachers and school authorities on how the air quality situation in and around schools can be improved
2. Consider how to limit your own air pollution footprint, e.g. by using public transportation, walking or cycling to school, or car sharing
3. Encourage schools to work against car idling and to create clean air zones
4. Share information on how good air quality in schools can be achieved with other parents, and join forces
5. Join a local clean air group or community action network.

For health professionals, patient groups and the health sector

1. Advise school authorities on the most promising clean air measures in schools and other children environments and share best practices with other countries
2. Increase health and medical organisational and individual capacity to engage in debates on the health impacts and costs of air pollution in schools
3. Highlight the evidence and use materials from the World Health Organization (WHO), such as BreatheLife[6] to learn about air quality in your city, which in turn can contribute to more awareness on the benefits of cleaner air and climate action for greater public health gains and a quicker energy transition
4. As health ministries, participate and provide input in the development and implementation of clean air activities and plans, as well as energy and climate policies
5. Raise awareness on the importance of indoor environments for health.

The European Environment Agency (EEA) launched a citizen science initiative, CleanAir@School, to monitor nitrogen dioxide (NO_2) around European schools using low-cost devices in May 2019. The project aims to educate children and parents about the health effects of air pollution. It will also explore how data collected by citizens might complement official air quality data. Participating environmental protection agencies are Belgium, Sweden, Ireland, Malta, Estonia, Netherlands, Spain, United Kingdom, and Italy[41].

[6] *Learn more about the BreatheLife campaign at https://breathelife2030.org/*

9.

Annex

In Berlin, HEAL's Health and Climate Change Coordinator, Focal Point for Healthy Buildings and Energy Poverty, Vijoleta Gordeljevic coordinated the selection of the schools and the monitoring of the air quality in and around them from HEAL Germany.

In London, HEAL's local partner Sustrans coordinated the selection of the schools and the monitoring of the air quality. Sustrans also provided important insight into the local situation. Sustrans is the UK charity making it easier for people to walk and cycle. Sustrans connects people and places, creates liveable neighbourhoods, transforms the school run and delivers a happier, healthier commute. www.sustrans.org.uk

In Madrid, HEAL's local partner Asociación Española de Educación Ambiental (AEEA) coordinated the selection of the schools and the monitoring of the air quality in and around them. They provided important insights into the local situation. AEEA is an open, scientific, non-profit association, formed by 200 individuals, associations, companies and institutions working in the field of environmental education. It aims to promote education as the key to ensure Sustainable Development and to improve the quality of life.

In Paris, HEAL's member organisation, France Nature Environnement (FNE), coordinated the selection of the schools and the monitoring of the air quality in and around them. FNE is the French federation of associations for the protection of nature and the environment. It acts as a spokesperson for a movement of 3500 associations, grouped in 64 member organizations, present throughout France, in mainland France and overseas.

In Sofia, HEAL's member organisation, Association Air for Health, coordinated the selection of the schools and the monitoring of the air quality in and around them. They provided important insights into the local situation. Association Air for Health is a Bulgarian NGO with the specific goal of increasing awareness in Bulgaria around the topic of air pollution, and more specifically engage the medical community as an ambassador for this communication. Air for Health as a local partner of HEAL successfully implemented the Unmask My City campaign for Sofia. They are also actively working with medical and municipal stakeholders to jointly achieve higher recognition of air pollution as a public health priority.

In Warsaw, HEAL's local partner was consultant Ewa Pietras. She coordinated the selection of the schools and the monitoring of the air quality. Weronika Michalak, Director, HEAL Poland, provided us with important information on the local situation.

School selection and lessons on air quality

Local partners in three of the cities - Madrid, Sofia, London, utilised their networks and chose 12, ten and seven schools to participate in the air quality monitoring. In Berlin, schools applied for the project through a local news outlet and ten were selected. In Warsaw and Paris schools meeting the selection criteria were approached with seven and six participating respectively.

Schools were selected following these criteria:

- Primary schools with children's age ranging between 6-11
- Willing and able to install the necessary measurement devices and have the participating class be visited by project staff
- A natural ventilation process in place, meaning no ventilation of classrooms via a mechanical process but solely through the opening of windows
- Located in urban areas but with varying proximity to busy roads.

Given that schools were selected based on interest to participate, school engagement has been high overall. In Berlin, Madrid, London and Sofia, visits by local partners to the schools have been accompanied by a short lecture to students on air pollution, its impacts and the monitoring tools used in their classroom.

▶ Hitherfield Primary School and Children's Centre, London, pupils engaged in the project in the school playground. | © Sustrans |

Detailed air monitoring process

The air monitoring exercises consisted of a two-step process.

Step I

NO_2 was measured using diffusion tubes. Buro Blauw, a Netherlands-based engineering firm specialised in air quality, provided the tubes and analysed them. Two diffusion tubes per measuring location were used in order to capture NO_2 concentrations. Measuring NO_2 via such tubes is a cost-effective and widely used method.

Each participating school received a total of four tubes, two to be hung inside a classroom and two to be hung outside the schools main entrance facing the street. Each tube had a distinct code assigned to it which allowed us to identify which tubes have been used at what school. The tubes were opened at the underside and installed correctly which was confirmed either by the project's local partners or alternatively, by photographs. Each tube hung for a minimum of 3 weeks and a maximum of 4 weeks depending on city and school preferences, collecting NO_2 particles from the air around it.

Several studies from different countries prove that the diffuse method in the open air is comparable to the constant monitoring equipment based on chemiluminescent (the reference method). All monitoring was performed in equivalent to the European norm NEN-EN-16339. Buro Blauw is accredited for important operations according to the norm NEN-EN-ISO/IEC170251. Besides that Buro Blauw is accredited for NO_2 analyses of Palmes tubes and is a member of the Vereniging Kwaliteit Luchtmetingen (VKL).

Step II

Each participating school agreed to be visited by a project representative, usually the local partner, to have two additional measures taken during one day.

Particulate Matter (PM)

This project used the AirBeam 1 and Airbeam 2 in order to measure the $PM_{2.5}$ and PM_{10} values. The AirBeam 1 is an earlier version and only captured $PM_{2.5}$ values. The AirBeam 1 was used in Sofia. The AirBeam uses a light scattering method to measure fine particulate matter. Air is drawn through a sensing chamber wherein light from a laser scatters off particles in the airstream. This light scatter is registered by a detector and converted into a measurement that estimates the number of particles in the air.

The Airbeams were obtained by HEAL from the HabitatMap Project. HabitatMap is a non-profit environmental health justice organization whose goal is to raise awareness about the impact the environment has on human health.

Each school was visited during one day by the respective local project partner who spent on average 20 minutes in both the classroom and in front of the school's main entrance to take PM concentrations via the Airbeam device. The results were immediately displayed in the Aircasting App, which is the program needed to use the AirBeam. The results were noted down by each project partner as well as saved in the App and later transmitted to HEAL.

The average concentration obtained during this 20 minute period is noted in this report. Optimally PM values are measured over weeks or months to be able to establish a yearly average concentration. The results of the PM reading in this project therefore only offer a snapshot of a day and can not be generalised.

Carbon Dioxide (CO_2)

The CO_2 concentration in the classroom was measured at the same time. A mini CO_2 monitor by TFA Dostmann was used to detect the level of CO_2. The monitor contains a traffic light system for classifying the indoor CO_2 concentration and a display via which the values can be read off as they are being captured.

10.

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The Health and Environment Alliance (HEAL) is the leading not-for-profit organisation addressing how the environment affects human health in the European Union (EU) and beyond. HEAL works to shape laws and policies that promote planetary and human health and protect those most affected by pollution, and raise awareness on the benefits of environmental action for health.

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As an alliance, HEAL brings independent and expert evidence from the health community to EU and global decision-making processes to inspire disease prevention and to promote a toxic-free, low-carbon, fair and healthy future.

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