PROTECTING BENGALURU'S CHILDREN:
time to act for clean air around schools

HEAL HEALTH AND ENVIRONMENT ALLIANCE

THE GLOBAL CLIMATE & HEALTH ALLIANCE

IPA LEAD Child Health Emerging Leaders Program

Shishuka Childrens Specialty Hospital

About

This report is produced by the Global Climate and Health Alliance (GCHA) and Health and Environment Alliance (HEAL), as part of the work of the Healthy Air Coalition, Bengaluru and a global initiative for clean air in our cities in 2030, known as Unmask My City.

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This report includes data from Dr Reddy's recent study of air quality near schools in Bengaluru, undertaken as a member of the International Pediatric Association's IPA LEAD: Child Health Emerging Leaders Program. This novel, executive-style, global leadership development program for early career pediatricians is designed to increase leadership capacity and collaboration among the world's pediatric professional societies, with the goal of accelerating advances in child health at local, national and global levels.

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1 Executive summary

Air pollution is the largest environmental health risk worldwide, and also in India. There is a considerable body of evidence on the detrimental impacts of breathing in polluted air in the short and long term. Recent science has also highlighted the impact of poor air quality on the healthy development of children from the first point of exposure to air pollutants in utero, to disease in childhood and later life. While the overall awareness of the health threat of air pollution has grown, leading to policies and political support for clean air, this has not necessarily translated into a commitment to improving the quality of the air that children breathe, while commuting to school and at school, where they spend a significant amount of their time when not at home.

This report aims to shed light on air quality around schools in the city of Bengaluru, India. As an education hub, Bengaluru holds pride in having some of the best schools in the country. In recent months, concerns have grown among local health professionals about the possible impact of air pollution on children and young people. There has, however, been limited research carried out in this field and a lack of data to evaluate.

Led by Dr. Bharath Reddy, Director & Consultant Pediatric Pulmonologist, Shishuka Children's Speciality Hospital, we investigated almost 500,000 data points over a 14 months period (June 2019 – July 2020) around 270 schools in 18 districts of Bengaluru. The data were gathered through an independent network of air quality monitoring devices that had been set up by the Healthy Air Coalition Bengaluru in 2019. These gather real-time data on fine particles ($PM_{2.5}$, PM_{10}) and also provide for an air quality index (AQI), accessible to everyone.

Given that Bengaluru experienced a unique lockdown and consequent drop in pollution, the results are likely to be an underestimate.

This report proposes a series of recommendations, including prioritising good air quality around schools and ensuring compliance with Indian outdoor air quality standards, installing more monitors throughout the city to carry out routine monitoring, restricting heavy traffic around schools and introducing school road closures. A change in school hours in areas with heavy air pollution should also be considered, construction work during school hours should be avoided, and children and families should opt where possible to travel to and from school via less busy routes.

Doctors treating children with chronic lung problems, allergies and asthma, should consider air pollution in general and the air quality in the school environment specifically.

The analysis revealed the following:

According to World Health Organization recommendations, air quality in Bengaluru is unhealthy for children throughout the year, but especially from October to April. In December and January, particulate matter pollution even exceeded the Indian air quality standard, which is nearly double the US EPA standard. Children with chronic conditions like asthma are at a high risk of developing symptoms during this period, as the impact of cold weather on chronic respiratory conditions is further exacerbated by the poor air quality this time of the year.

During school hours, two-thirds of the areas studied had high daily concentrations of $PM_{2.5}$, above the US EPA standard (throughout the 14 months). Consequently, children may be breathing polluted air during their break time and in classrooms when windows are kept open.

Air quality was found to be especially poor during school departure times (3 to 5 PM).

2 Air pollution and health in Bengaluru

Bengaluru - an overlooked air pollution hotspot

Air pollution in India is a serious health issue. According to the World Health Organization (WHO) 13 out of the 20 most polluted cities in the world are located in India and one in eight deaths (12.5%) in the country is due to poor air quality [1].

A recent study in the Lancet on the economic impact of air pollution in India found even greater impact, showing that nearly 1.67 million deaths were attributable to air pollution in India in 2019, accounting for almost 20% of the total deaths in the country. The majority of these deaths were from ambient particulate matter pollution (0.98 million) and household air pollution (0.61 million). While the death rate due to household air pollution decreased by 64% from 1990 to 2019, the rate due to ambient particulate matter pollution increased by 115%. Lost output from premature deaths and morbidity attributable to air pollution accounted for economic losses of US$28.8 billion and $8 billion, respectively, in India in 2019. This total loss of $36.8 billion represents 1.36% of India's gross domestic product (GDP)[2].

"Improving air quality, both locally and globally, is key to sustainable development and to advancing "health for all." Children are especially vulnerable to the adverse health effects of air pollution, but have no control over environments where they live, learn and play. We have a duty to protect children from airborne toxins, because they can't protect themselves. Doing so requires political will, a multi-sector commitment to improving air quality, and sustained collaboration towards comprehensive solutions. It also requires better monitoring of levels and sources of air pollution, to inform efforts to minimize children's exposure."

Dr Linda Arnold, Director, IPA LEAD: Child Health Emerging Leaders Program & Associate Professor of Pediatrics and Emergency Medicine, Yale School of Medicine.

Whereas air pollution has been identified as a national problem and is frequently in the spotlight in the capital Delhi, it does not receive equal public nor policy attention across the country, particularly in southern cities such as Bengaluru. Karnataka has been estimated to have lost US$2113 million due to premature deaths and US$568 million in 2019 due to the effects of air pollution[3].

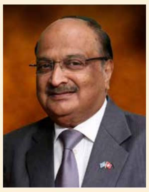
Bengaluru is one of India's largest cities, the IT capital of the country and a major economic and cultural hub. It is also one of the fastest growing cities in India and worldwide. With this rapid urbanisation came a series of pollution problems including a significant increase of vehicles and traffic[4], waste burning, a decline in green spaces and trees, as well as the release of dust from ongoing construction. The sources of air pollution in the city are mostly local.

Air quality is deteriorating, and ill-health is increasing

Doctors are concerned about an increase in cases of childhood asthma, upper respiratory infections, chronic pulmonary disease, as well as heart attacks in young people. Heart problems, in particular, have risen alarmingly in people younger than 40 years, according to doctors at the Jayadeva Institute of Cardiovascular Sciences and Lakeside Hospital.

Whereas systematic gatherings of data have been scarce and insufficient, cardiologists and pulmonologists are concerned that rising air pollution levels are a factor in the increase in disease burden among the city's population.

According to a 2018 study, the prevalence of asthma in people under 18, in Bengaluru has increased from 9% in 1979 to 29.5% in 1999. Similarly, allergic rhinitis has increased from 22.5% in 1994 to 40% in 2018. As part of this study, a survey in 12 schools with 6550 children showed higher asthma rates for children in schools in high traffic areas (19.34% compared to 11.15% in low traffic areas), and even higher rates in areas with both heavy traffic and a low socioeconomic status[5].



Allergic airway diseases are a major global epidemic, causing a tremendous psycho-socio-economic health care burden to society.

The main factors for their increase include losing our threshold of protection, a change in our food habits, a western lifestyle of living with poor cross ventilation and little sunlight, and a higher exposure to outdoor and indoor air pollution.

It is time to act to clean up the air that we breathe".

Prof. H Paramesh , Pediatric Pulmonologist and Environmentalist, Distinguished Professor Divecha Center for Climate Change, Indian Institute of Science, Bengauluru, and author of a study on prevalence of asthma in under 18 year olds.

"I was surprised to see an increase in heart attacks in younger people, without them having any of traditional risk factors such as hypertension, diabetes or obesity. With taking a closer look I found that many of these patients were either an auto or taxi driver from in and around Bengaluru. They are the worst hit as they are often stranded in bad traffic for long hours, and are exposed to high levels of pollution. We need to study this phenomenon in more detail"

Dr. Rahul Patil, Consultant Cardiologist and Head of Premature Coronary Artery Disease Division at the Jayadeva Institute of Cardiovascular Sciences and Research, Bengaluru, and author of the investigation into cardiovascular disease in under 40 year olds.

3 Air quality monitoring and clean air regulations

There is an official, government funded, network of monitoring stations in Bengaluru but they are not sufficient to cover a city of over 12 million inhabitants.

Currently, there are only 10 online [state-controlled] monitoring stations operating in real-time in the city, providing data on a 24/7 basis. Five of these went live in January 2018 and are located in Hebbal, Jayanagar, Kavika, NIMHANS, and Silk Board[6]. In addition to the online monitoring stations that measure $PM_{2.5}$ concentrations, the state pollution control board also has 14 manual monitoring stations which measure PM_{10} or the RSPM (Respirable Suspended Particulate Matter) on any two days in a week. In addition to the existing network, there is also a mobile van in place for any emergency measurements that may be needed.

Publicly accessible information on the results of the 10 online real-time monitoring stations, plus the ones that collect data from time to time, is provided through monthly summary reports[7].

These reports provide information on concentrations of PM_{10}, $PM_{2.5}$ and other pollutants, and also give an air quality index (AQI).

This index is based on daily averages of PM_{10}, $PM_{2.5}$ and other gas concentrations. It includes a range of pollutants, and uses the parameters of the US Environmental Protection Agency (EPA) and not the Indian Air quality standards.

The monitors of the independent air network were set up by the Healthy Air Coalition Bengaluru, which provided the data for this report.

Air pollutants and health

Outdoor and indoor air pollution is the largest environmental risk to health worldwide[8]. There is a comprehensive body of evidence demonstrating the many effects of short and long-term exposure to polluted air, and each year, hundreds of new studies are published.

The main air pollutants include:

PM_{10} / $PM_{2.5}$ — **Particulate Matter (PM):** These are particles of less than 10 and 2.5 microns in diameter. PM less than 10 microns are known as respirable suspended particulate matter (RSPM). $PM_{2.5}$ is of particular concern because it can travel deep into the lungs, enter the bloodstream and travel to other organs, even crossing the blood/brain barrier. PM and diesel exhaust have been classified as carcinogenic by WHO's International Agency for Research on Cancer (IARC).

NO_2 — **Nitrogen dioxide (NO_2):** Diesel cars are the major source of this pollutant, which also contributes to the formation of PM. The direct short and long term effects of NO_2 are currently under review by WHO.

O_3 — **Ozone:** This pollutant forms through a reaction with heat and sunlight.

The greatest health burden of air pollution is from premature death, cardiovascular and lung disease. Recent studies also show impacts on children's health (even in utero), and air pollution as a possible contributor to obesity and neuro-degenerative disease[9]. A new WHO review on the science is expected for 2021.

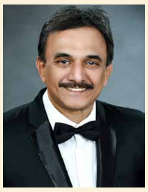
Clean air standards and health-based recommendations

India's Central Pollution Control Board (CPCB) has set regulatory standards for acceptable levels of air pollution. These are currently set at a much higher level than the WHO recommendations. One study by Urban Emissions suggests that Bengaluru's pollution levels are three times the WHO air quality recommendations[10].

Table 1 - Overview of selected $PM_{2.5}$ standards and recommendations

Particulate $Matter_{2.5}$ Standards	Indian Air Standard	WHO guideline recommendations	US EPA (Environmental Protection Agency) standards
Daily (24hr mean)	60 µg/m^3	25 µg/m^3	35 µg/m^3
Annual average	40 µg/m^3	10 µg/m^3	12 µg/m^3 (for primary PM) and 15 µg/m^3 (for secondary PM)

The above chart compares particulate matter $standards_{2.5}$ prescribed by the Indian Govt[11] compared to the World Health Organization[12] and US EPA recommendations (primary PM is formed directly from combustion processes, while secondary PM develops through chemical processes)[13]. The WHO recommendations for PM and other pollutants are based on an extensive review of accumulated scientific evidence by a large team of renowned international experts; they are purely health-based; the US EPA standards are also based on a scientific review and consultation with the Agency's independent scientific advisors. Indian standards have been set by the Central Pollution Control Board.



"Pollution is a serious concern of our times. Its effects on child health is increasingly becoming evident across the world. Doctors and professional medical bodies have a responsibility to help mitigate the negative impact of pollution by educating the community and creating awareness. Health care professionals must be trained in the effects of air pollution and its preventive strategies in conferences. It is also high time air pollution is included in the medical education syllabus. This encourages doctors to take up the cause of clean air for children from early on as doctors are important advocates for social change"

Dr Santosh Soans, Prof. & H.O.D., A. J. Institute of Medical Sciences, IPA LEAD Mentor & Ex-President Indian Academy of Pediatrics (IAP) (2018).

4 The health impacts of air pollution and particularly $PM_{2.5}$ pollution on children's health

Children are vulnerable to the effects of air pollution due to their outdoor play activity, breathing higher concentration of pollutants, more mouth breathing behaviour, higher minute ventilation, an ineffective nasal filtering capacity, and an underdeveloped detoxification and antioxidant defence system[14]. Hence, the effects of air pollution on children can be both acute and long-term, impacting a child's lungs, heart, brain and nervous system[15].

$PM_{2.5}$ has a particularly strong negative impact on children's health

In the last 60 years, a sharp increase in asthma prevalence was observed in a number of countries. The effect of poor air quality on childhood asthma and allergies is well described. Acute increases in air pollution play a significant role in flare-up of asthma in children[16]. More than 15% of all asthma flare-ups in children were found to be related to traffic-related air pollution (TRAP)[17], especially in those whose homes were close to roads with heavy vehicular traffic. Exposure to traffic-related air pollution in infancy has also been shown to be associated with a lower lung function at the age of 16 years[18], which has a potential to lead to asthma in the future and develop into chronic obstructive pulmonary disease (COPD)[19]. Hence early exposure to air pollution can sow the seeds of significant long-term illnesses such as asthma in children.

Bengaluru has seen an increase in the cases of asthma over recent years with an increase in urbanisation. A study of hospital based data showed an increase in the prevalence of asthma in Bengaluru from 9% in 1979 to 29.5% in 1999. The prevalence in urban Bengaluru was found to be higher at 16.6% in comparison to 5.5% in the rural area. Children exposed to heavy traffic, especially from the less affluent families, had a higher prevalence of asthma of nearly 31%[5].

"As a Pediatric Pulmonologist I consult children with asthma and allergic rhinitis on a daily basis.

Many of these children have flare-ups of asthma when exposed to indoor and outdoor air pollution.

I took up the cause of clean air in Bengaluru city to ensure that our children are protected from the effects of air pollution. "

Dr K.R.Bharath Kumar Reddy, Director & Consultant Pediatric Pulmonologist, Shishuka Children's Speciality Hospital, and lead investigator for this report.

Exposure to polluted air with higher levels of $PM_{2.5}$, nitrogen dioxide (NO_2) and ozone (O_3) has also been shown to increase the chance of developing acute lower respiratory tract infections and pneumonia in children[20]. Children exposed to higher levels of $PM_{2.5}$ and environmental tobacco smoke also have a higher prevalence of allergic rhinitis and recurrent ear infections (otitis media) which could lead to hearing loss[21].

Increasing evidence has come to show an association between childhood obesity and exposure to air pollution. Higher exposure to traffic-related air pollution earlier in life was linked with weight gain at a much faster rate in children, resulting in obesity by 10 years of life[22]. Confounders also need to be considered such as concurrent poor diet and higher stress levels associated with living in poorer areas with higher air pollution. $PM_{2.5}$ further plays a key role in the development of neuroinflammation and neurodegeneration in children and has been linked to Alzheimer's disease later in life[23].

Air pollution exposure leaves its mark on the unborn child. Developing babies who are exposed to air pollution during the prenatal period may experience adverse health outcomes as they mature and throughout childhood. There is some evidence that exposure to air pollution during pregnancy can predispose the offspring to cardiovascular disease later in life[24] as well as a lower lung capacity. Research indicates air pollutants reach the developing fetus via the placenta[25]. A study of an Indian cohort of 1285 pregnant women in the Southern region Tamil Nadu, one of India's 28 states, found that a 10 $\mu g/m^3$ increase in exposure to $PM_{2.5}$ during pregnancy was associated with a decrease in birth weight of 4 g and a 2% increase in the prevalence of low birth weight[26].

Several studies also looked at the impact of increased air pollutant concentrations on infant mortality and found that infant and post-neonatal mortality increased with each 10 $\mu g/m^3$ short-term exposure increase in $PM_{2.5}$. This held true even when concentrations were below national air quality standards, as was the case in a study done in Japan[27].

Unfortunately, more of these effects were seen in children from low and middle-income countries (LMIC). Notably, 98% of all children under 5 years of age in these countries are exposed to levels of fine particulate matter ($PM_{2.5}$) higher than the WHO air quality guideline recommended levels[24]. The annual mean levels of $PM_{2.5}$ in the African, South-East Asian and Western Pacific WHO regions was 5-10 times greater than the WHO guideline limit.

5 Rationale for this study: Investigating air quality at schools

Globally, in 2016 UNICEF reported that around 300 million children live in areas where air is hazardous[28].

All over the world, children spend a significant proportion of their day at school. A significant amount of time is spent during travel to and from school as well. Hence, it can be said that the air that children breathe on their way to school, during school hours (as pollution travels inside from outside) and on their return route from school can pose a significant impact on their health.

Protecting children of school age from air pollution requires a combination of taking action to address pollution from the root causes and minimising their exposure to the emissions. Organizations such as the US Environmental Protection Agency (USEPA) and the British Lung Foundation have issued guidance to schools on how to reduce exposure to pollutants in the air[29].

However, in many cases the extent of the air pollution problem at schools is unclear.

In response to local health concerns and the stark increase in health conditions among children and young people, increasingly affected by the city's air pollution crisis, as well as the lack of research in the field of children's health and air pollution in Bengaluru, this assessment aims to to evaluate whether the air quality in Bengaluru was a health risk to schoolchildren during the months June 2019 to July 2020.

Monitoring air quality in and around schools - response to growing concerns

Around the world, concerns about air pollution on children have led to the installation of networks of air quality monitors near schools to get baseline data on pollution to which children may be exposed, including agency-led efforts, academic research, as well as citizen-led efforts.

The European Environment Agency (EEA) and the European Network of the Heads of Environmental Protection Agencies (EPAs), for example, launched an initiative to monitor air quality around schools in Europe[30]. In a study from Barcelona air quality was monitored in 39 urban schools to evaluate the effects of exposure to traffic related air pollutants in schoolchildren[31]. A series of measures were proposed to improve air quality in urban schools. An investigation by HEAL monitoring 50 schools in 6 EU capitals found that air quality must be improved in order to protect children's health and ensure optimal learning[32]. In the UK, the National Education Union has issued a guidance scheme for air quality around schools (see Annex 10.6). Closing roads around schools to traffic at pick up and drop off times has cut nitrogen dioxide (No_2) levels by up to 23 percent, research published by the London mayor`s office has revealed[33].

Citizen science in Bengaluru

Apart from the official data provided by the Karnataka State Pollution Control Board (KSPCB), at least five other organisations have installed monitors, including the Healthy Air Coalition air quality monitoring network, as well as citizen science monitoring projects[34].

An example comes from 2018 from a report published by Climate Trends and Citizen Matters, highlighting the huge gaps in air quality information in Bengaluru[6]. Using mobile devices, the groups monitored air quality over a 7 day period, for peak times at 7 selected transport intersections. The seven arterial routes had a common starting point: Jayanagar/Banashankari touching Marathahalli, Silk Board, Electronic City, White Field, Uttarahalli, MG Road and Mekhri Circle.

The results were not directly comparable to official monitoring data, as the time frame was shorter. However, the averages observed over the four-hour auto rides, carried out in two parts, consistently generated averages above 200 ųg/m^3 $PM_{2.5}$. The WHO recommendation for the daily average of $PM_{2.5}$ is 25 ųg/m^3. Poor air quality levels persisted for several hours every day owing to traffic congestion.

6 Methodology of the Study

The data for this investigation was gathered through an independent monitoring network that the Healthy Air Coalition, through the support of HEAL and GCHA has set up in the city in 28 major locations. These were set up especially at, or near, places frequented by vulnerable groups, including community health centers. The monitors are calibrated on an ongoing basis with one monitor co-located with an official, regulatory monitor. Data were recorded in real-time on a continuous basis for 24 hours a day.

For the schools analysis, data from 18 monitors were randomly chosen to avoid any bias in selection of the monitor data.

In total, 482,708 data points were analysed to determine the air quality during school going hours. Areas were further classified into different zones based on the levels of $PM_{2.5}$ and PM_{10}. Zones were further ranked into those with best air quality during school hours to the worst values.

In total, air quality around 270 schools was investigated.

Data were extracted from the monitors at 15 minute intervals for a duration of 14 months from June 2019 to July 2020. Data were sorted into 2 recorded parameters - $PM_{2.5}$ and PM_{10} of which $PM_{2.5}$ was further analysed and described in detail.

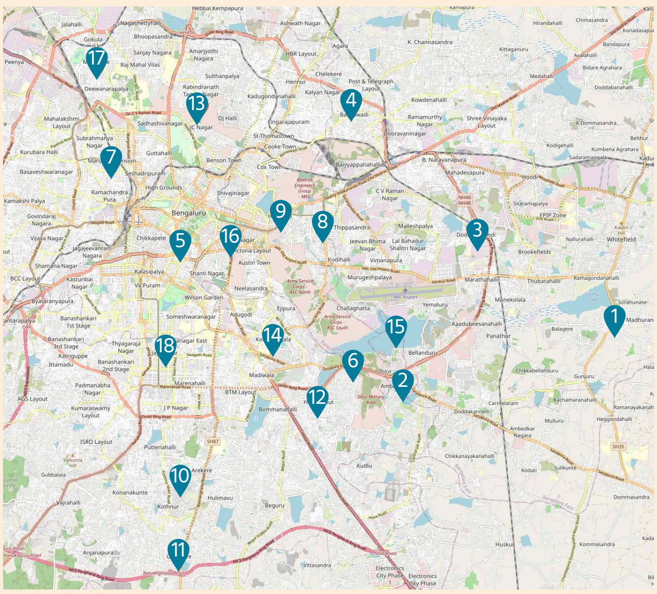
The monthly mean with standard deviation of $PM_{2.5}$ was calculated and compared to determine seasonal changes in air quality. Mean of hourly data was calculated to determine $PM_{2.5}$ levels for each of the 24 hours in a day. Further a mean value of hourly data over 14 months was calculated for each of the 18 areas.

Mean values of $PM_{2.5}$ at school arrival (6AM to 10AM), during school (8AM to 4PM) and school departure (2PM to 6PM) for 5 weekdays (Monday to Friday) were plotted to compare with 24 hour data. Similar data were extracted for the same timings on the weekend (Saturday and Sunday). A comparison of means between the weekdays versus weekend values was done using the student t-test.

To analyse the change of air quality during the lockdown imposed during the start of the COVID19 pandemic, we divided the assessed time periods into 3 - Pre-lockdown, Lockdown and Post-lockdown. The 45 days from February 8th to March 24th 2020 was taken as the pre-lockdown period, the 45 days from March 25th to May 8th 2020 as lockdown period, and the 45 days from May 9th to June 23rd 2020 as post-lockdown period.

Data of $PM_{2.5}$ divided into these 3 periods were averaged, analysed and compared. Humidity and temperature values also measured by the monitors were used to account for any influence of these on air quality recordings.

Figure 1 - Overview of the 18 areas studied in Benglauru



Areas include:

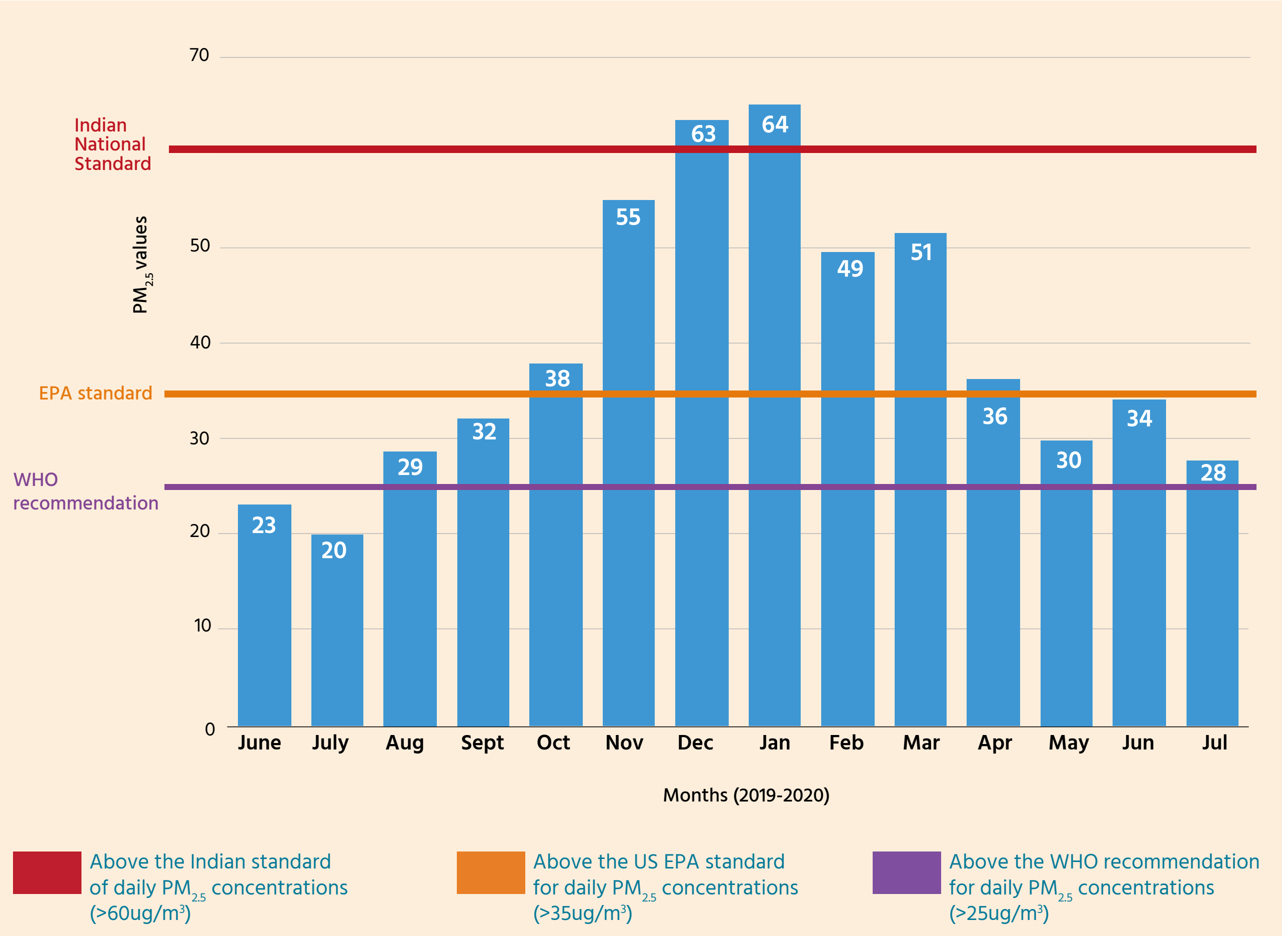
1. Varthur
2. Springfield
3. Doddanekundi
4. Kalyannagar
5. Corporation Circle
6. Sarjapur
7. Srirampura
8. Indiranagar
9. Ulsoor
10. MS Ramaiah City
11. Gottigere (IIM-B)
12. HSR Layout
13. JC Road
14. Koramangala
15. Bellandur
16. Brigade Road
17. Mathikere
18. Jayanagar

7 Results and discussion

7.1. Air Quality through the year in Bengaluru

$PM_{2.5}$ was found to be significantly increased from the months of November 2019 to March 2020, in all recorded areas uniformly. Subsequently, the values declined from March to July 2020. This could be attributed to the imposition of a lockdown in the city due to the COVID-19 pandemic in the month of March 2020.

Table 2 - Monthly average values of $PM_{2.5}$ in Bengaluru from June 2019 to July 2020



The monthly average $PM_{2.5}$ concentrations are above the WHO recommendations for daily (>25µg/m³) and annual concentrations (>10µg/m³), and above the US EPA standard for 24 hour concentrations (>35µg/m³) between the months of October to April. A notable increase is seen during the months of December 2019 and January 2020 when the $PM_{2.5}$ values cross the Indian National clean air standard (>60µg/m³), which is known to be 'unhealthy for sensitive groups'. The annual mean of $PM_{2.5}$ was noted to be 40.7 ug/m³ which is much above the WHO recommendation for an annual concentration of 10 ug/m³.

Table 3 - Monthly average distribution of $PM_{2.5}$ in Bengaluru city from June 2019 - July 2020

Month	Average $PM_{2.5}$ (ug/m^3)
2019	
June	23
July	20
August	29
September	32
October	38
November	55
December	63
2020	
January	64
February	49
March	51
April	36
May	30
June	34
July	28

- Above the Indian standard of daily $PM_{2.5}$ concentrations (>60ug/m³)
- Above the US EPA standard for daily $PM_{2.5}$ concentrations (>35ug/m³)
- Above the WHO recommendation for daily $PM_{2.5}$ concentrations (>25ug/m³)

Annual $PM_{2.5}$ concentration in Bengaluru: - 40.7 mcg/m³

Why is this happening?

The reason for this seasonal change in air quality parameters could be explained by a change in climatic conditions. Atmospheric and weather conditions impact the levels of air pollution. Colder and denser air settles lower and moves slower than warm air. These seasonal variations, with poor air quality during winter months, have been demonstrated in the northern cities such as Delhi. They have always been attributed to the crop burning seen exclusively during this time in the neighbouring states of Haryana and Punjab. Although Bengaluru has been relatively protected from the effects of crop burning, we demonstrate a similar trend of worsening air quality during the winter months of 2019/20 in the city.

Why is this important to note?

This study indicates that children were exposed to higher levels of particulate matter during the months of November 2019 to April 2020 in Bengaluru, particularly in December and January. Children with underlying chronic respiratory conditions, allergies and asthma are at a high risk of developing symptoms and flare-ups during this period. The impact of the cold weather on chronic respiratory conditions is further worsened by the poor air quality that was noted during this time of the year.

However, when judged on the health based recommendations of WHO, air quality is poor all year round in Bengaluru city.

7.2. Air Quality during school hours

During school going hours, nearly 83% (15/18) areas had $PM_{2.5}$ values above the WHO recommendations for daily concentrations and 50% (9/18) areas demonstrating values above the EPA daily standard. Areas with poor $PM_{2.5}$ values, as per EPA standards, were MS Ramaiah City Layout, Gottigere, HSR Layout, JC Road, Koramangala, Bellandur, Brigade road, Mathikere and Jayanagar. Jayanagar was seen to have disproportionately abnormal values of $PM_{2.5}$ during school hours. Whether this is attributed solely to particulate matter generation or is an artefact in the data needs to be further studied. Mathikere was one area found to have values close to the maximum limit recommended by Indian National standards.

All areas were above the annual WHO recommendation and US EPA standard for $PM_{2.5}$, all year round.

112 schools (primary and secondary) with 39,780 students are present in the areas which had a $PM_{2.5}$ value above the US EPA daily standard of 35 ug/m^3.

Table 4 - Ranking of areas on Average $PM_{2.5}$ values during school hours

Location	Average values of $PM_{2.5}$ (ug/m^3)
Vartur	18
Springfield	20
Doddanekundi	24
Kalyannagar	29
Corporation Circle	29
Sarjapur	29
Srirampura	31
Indiranagar	31
Ulsoor	31
MS Ramaiah City	35
Gottigere (IIM-B)	36
HSR Layout	36
JC Road	37
Koramangala	38
Bellandur	38
Brigade Road	40
Mathikere	58
Jayanagar	167

Above the Indian standard of daily $PM_{2.5}$ concentrations ($>60ug/m^3$)

Above the US EPA standard for daily $PM_{2.5}$ concentrations ($>35ug/m^3$)

Above the WHO recommendation for daily $PM_{2.5}$ concentrations ($>25ug/m^3$)

"Air pollution is a poison that makes children susceptible to severe and uncontrollable asthma. It is a precursor of lifelong impairment of lung health and reduction of life span. Schools must be strong advocates against this menace in all possible ways."

Dr Jagadish Chinnappa, President, Indian Academy of Pediatrics (IAP) National Respiratory chapter.

7.3. Air Quality during school arrival and departure time

We studied the air quality parameters in the 18 areas in Bengaluru during school arrival time (morning hours) and school departure time (evening hours). In Bengaluru city, school arrival time is commonly between 7AM to 9AM and school departure between 3pm to 5pm. Hence we studied air quality one hour prior and one hour after between 6AM to 10AM and 2PM to 6PM.

During school arrival time, the overall average values of $PM_{2.5}$, for all 18 areas were relatively favourable between 7am to 9am as measured against the Indian daily standard. Only 1 area, Jayanagar showed $PM_{2.5}$ values above Indian National standards between 6am to 9am.

However, 77% of the areas, were above the WHO recommended daily values.

Between 6am to 7am, 44% of areas crossed the permissible EPA values. Similar findings were seen when tracking the levels of PM_{10} in these areas between 6am to 7am. Between 7am to 9am, only 2 areas, Mathikere and Jayanagar had $PM_{2.5}$ values above the US EPA daily standard.

It is speculated that this is related to the heavy vehicular traffic which passes through the city during the night up to the early morning hours. Heavy vehicular traffic including trucks and transport vehicles are known to contribute significantly to particulate matter in the atmosphere which persists in the air due to the colder weather in the morning hours.

During school departure time, 94.4% (17/18) studied areas had $PM_{2.5}$ concentrations above the WHO recommended daily values between 3pm to 5pm.

83.3% (15/18) areas showed values of $PM_{2.5}$ above the EPA values between 3pm to 5pm.

Two areas, Jayanagar and Mathikere showed $PM_{2.5}$ values above Indian National standards between 3pm to 5pm.

This means that the air quality during school departure was found to be unfavourable for sensitive groups in all these areas. We further noted that even at 2pm, the air quality remained relatively poor, negating the possibility of reducing exposure by advancing school departure.

Table 5 - $PM_{2.5}$ values during School arrival (6AM to 10 AM) and School departure time (2PM to 6PM)

	School Arrival Time					School Departure Time				
Location	6AM	7AM	8AM	9AM	10AM	2PM	3PM	4PM	5PM	6PM
Vartur	20	17	16	15	14	23	22	21	20	19
Springfield	21	20	18	28	17	26	26	25	23	24
Doddanekundi	24	22	21	19	19	34	32	31	32	32
Kalyannagar	30	27	26	24	24	36	37	36	36	36
Corporation circle	35	31	28	25	24	35	37	38	37	37
Sarjapur	30	27	25	24	23	33	36	36	36	36
Srirampura	32	30	38	37	35	42	37	37	36	36
Indiranagar	33	30	27	25	25	38	42	40	37	36
Ulsoor	30	28	26	25	25	38	41	41	40	41
MS Ramaiah City Layout	34	32	30	31	31	41	43	43	43	44
Gottigere (IIM-B)	40	36	33	32	30	39	41	41	40	41
HSR Layout	35	36	30	29	29	49	49	46	44	45
JC Road	45	40	37	36	34	40	42	42	41	40
Koramangala	38	34	31	29	31	41	42	42	40	40
Bellandur	36	32	31	29	28	57	54	50	49	49
Brigade Road	41	38	34	31	30	54	55	54	51	51
Mathikere	48	46	47	44	40	95	70	59	39	34
Jayanagar	108	135	122	112	97	238	110	245	178	188

Above the Indian standard of daily $PM_{2.5}$ concentrations (>60ug/m^3)

Above the US EPA standard for daily $PM_{2.5}$ concentrations (>35ug/m^3)

Above the WHO recommendation for daily $PM_{2.5}$ concentrations (>25ug/m^3)

Is the poor air quality contributed by school going vehicular traffic alone?

Considering the high levels of $PM_{2.5}$ in many areas during school arrival, and more so during school departure time, the question on whether this is primarily contributed by school going traffic does arise. If indeed the high levels of $PM_{2.5}$ during school departure are due to the vehicles going to and from schools, then we would be able to target strategies specifically towards this group.

To obtain an answer to this question, we compared the air quality parameters during weekdays (Monday to Friday) and the weekend (Saturday & Sunday) during the same hours of school arrival (7am to 9am), school departure (3pm to 5pm) and school-going hours (9am to 4pm).

Table 6 - Comparison of Average $PM_{2.5}$ on weekdays and weekends across all areas studied

	6AM to 10AM (School Arrival)	2PM to 6PM (School Departure)	School hours (8AM to 4PM)
Weekday (Monday to Friday)	32	45	38
Weekend (Saturday & Sunday)	33	45	39
Average $PM_{2.5}$ across all 18 areas studied in Bangaluru	32	45	38

Above the Indian standard of daily $PM_{2.5}$ concentrations (>60ug/m^3)

Above the US EPA standard for daily $PM_{2.5}$ concentrations (>35ug/m^3)

Above the WHO recommendation for daily $PM_{2.5}$ concentrations (>25ug/m^3)

We noted there was no significant change between the weekend and weekday in the values of $PM_{2.5}$ during school arrival, school departure and school going hours.

On the other hand, the values were found to be slightly higher on the weekend when compared to the weekday during these hours. This helps us speculate that school going vehicular traffic did not contribute solely to the poor air quality which was noted during these hours on the weekdays. Further research in this area is needed.

"This study helps us to understand the air quality during school opening and closing hours. Schools now have some data which can be useful in planning the school timings.

Simple measures like restriction of heavy traffic in school zones especially during school hours will help reduce students' exposure to $PM_{2.5}$. We educators must also open dialogues with our parents and children on the health effects of air pollution. "

Dr Tristha Ramamurthy, Doctor of Education EdD (King's College London), Founder, Ekya Schools, Bengaluru.

7.4 Effects of reducing vehicular traffic in Bengaluru as part of lockdown

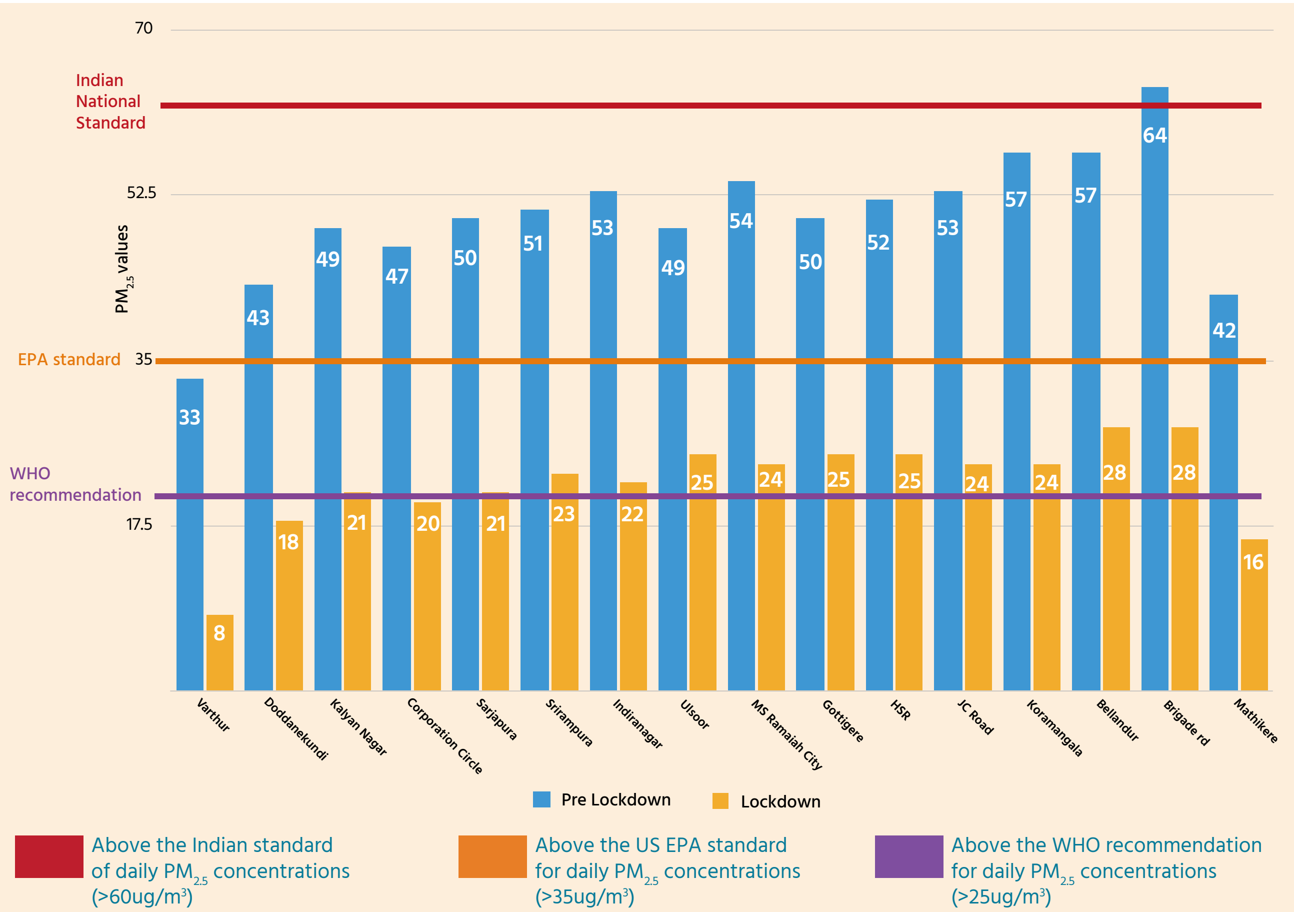
There is an increasing need to improve the air quality around schools in Bangalore as demonstrated by the high and unhealthy levels of $PM_{2.5}$ in the areas we have studied. However, the question always remains on how much of an impact would it make on existing air quality, if vehicular traffic in these areas were reduced. An answer to this question would help Governmental organisations to implement appropriate strategies around schools. We further studied the effect of reducing vehicular traffic on air quality in Bangalore.

We fortunately had the opportunity of a reduction in vehicular traffic and other contributing factors to air pollution during the Nationwide lockdown which happened in the city for the COVID19 pandemic. This posed an opportunity for us to study the changes in air quality during the lockdown period when the Government had imposed restrictions on vehicular movements across the city. This could be equated to the changes that we could probably find on decreasing vehicular traffic in the city around schools.

We divided the time periods into 3 periods - Pre-lockdown, Lockdown and Post-lockdown. 45 days between February 8th to March 24th 2020 was taken as the pre-lockdown period, 45 days between March 25th to May 8th 2020 as lockdown period and 45 days post between May 9th to June 23rd 2020 as post-lockdown period. Data was divided into these 3 periods and the average values recorded for $PM_{2.5}$ and PM_{10} were analysed and compared.

We demonstrate in our study a significant drop in $PM_{2.5}$ in all areas from the pre-lockdown to lockdown period. Similarly a significant drop in $PM_{2.5}$ was also seen from the pre-lockdown to post-lockdown periods. The % drop in $PM_{2.5}$ from pre-lockdown to lockdown period ranged from 11% to 34% in different areas. The % drop in $PM_{2.5}$ from pre-lockdown to post-lockdown ranged form 36% to 56%. We thus demonstrate that significant changes in Air quality with drop in $PM_{2.5}$ can be achieved by reduction in vehicular traffics, construction work and other contributing sources of air pollution.

Table 7 - Change in $PM_{2.5}$ concentrations from pre-lockdown to lockdown



Limitations of this analysis and future research needed

This report is only an initial investigation into air quality around Bengaluru schools.

Limitations include:

The lockdown from March - May 2020 was unprecedented and led to a reduction in air pollution unlike in other years. It is therefore not clear if the high pollution observed in winter 2019/20 continued well into the spring, or if it is in general lower before monsoon.

It is also not possible to make any calculation of the health effects of poor air quality in children in Bengaluru, to determine the burden on the healthcare system in addition to individual suffering.

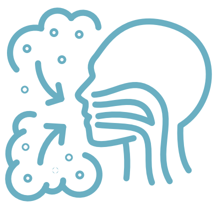
3Km

The monitors were placed at a distance ranging from 250m through 3km from different schools in the area. Some studies have considered a range of 50-100m. Hence more accurate values can be obtained if monitors are placed on school premises.

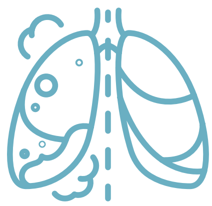
Which future research is needed

More research and scientific work is needed in the field of air pollution and its impact on child health in India. The future holds promise in improving the air quality for our children as more data is generated and strategies to reduce air pollution are implemented accordingly. Key areas for additional research:

Air quality measurements within schools (both indoor and outdoor) need to be measured.



The correlation between the prevalence of asthma and allergic rhinitis in areas of poor air quality needs to be studied.



The lung capacity of children studying in schools in areas where air quality is poor needs to be evaluated.

The development of biomarkers for the impact of air pollution in children would help enable physicians to perform simple tests to evaluate the exposure to $PM_{2.5}$ and ozone in children with asthma.

8 Recommendations

As a city of high popularity with major growth and as India's IT capital, Bengaluru holds great potential to pave the way for green, healthy cities in what is now the world's most polluted country. Currently, however, pollution levels in the city are harmful to health, and a threat especially to children in the city.

Here is what needs to happen to prevent further ill-health for current and future generations:

FOR POLICY-MAKERS

- Prioritise achieving clean air in the school environment and other places where children spend time.
- Ensure compliance with Indian outdoor air quality standards, with the aim to achieve WHO air quality recommendations by 2030.
- Increase the number of air quality monitors across the city.
- Invest in clean and green infrastructure changes, e.g. electric vehicles and cycling lanes.
- Allow new schools to be established only at a distance from the main roads and in areas with good air quality.
- Establish an alert system for areas with poor air quality, and consider pollution reduction measures for these areas such as:
  > Restricting heavy vehicular traffic around school areas.
  > Closing school roads to regular traffic.
  > Restricting factory and industrial activity around schools.
  > If construction work needs to be done near or at school, it should be scheduled during non-school hours.

FOR SCHOOL LEVEL LEADERSHIP & PARENT ORGANISATIONS

- Increase awareness on air quality and its impact on health among parents, children, teachers, and the general public.
- Encourage car-pooling, use of school buses, cycles and public transport to travel to school.
- Consider shifting school arrival time and departure time based on the changes in air quality in the area.
- Children must avoid travelling to school through busy roads and business hubs with poor air quality.
- Invest in improvement of the quality of ventilation in classrooms.
- Greening of the school and its surrounding must be encouraged.
- Parent organisations could create local clean air groups, and work together with existing initiatives such as clean air community groups, or the "bicycle mayor" (who leads an initiative which aims to increase safe cycling in Bengaluru).
- During period of poor air quality, additional measures must be taken to reduce exposure to air pollutants such as:
  - > Wearing a mask during travel to school.
  - > Closing the school road.
  - > Closing windows of classrooms during high pollution hours.

FOR HEALTH PROFESSIONALS

Many health professional organizations throughout the world are focusing increasingly on the adverse health impacts of air pollution on children. While further research is needed in a number of areas, the scientific evidence is already robust and sufficient for taking clear, concrete steps now to reduce the exposure of children to air pollution.

Doctors and other health professionals should:

- Share their expertise at an organizational and individual capacity on the health impact of air pollution on children.
- Advise parents on the effects of air pollution in the school and home environment and the measures that can be taken to prevent exposure.
- For children with existing respiratory problems, physicians must take a detailed environmental history with regard to the different sources of pollution exposure.
- Health professionals should engage school and parent organisations and community groups to advocate for clean air.
- Consult and advise city authorities about projects impacting the city's air quality and environmental health.

9 Annex

10.1. Number of Schools and Students in the areas studied

As per the District Information System for Education (DISE) data of 2011-12, there are 4818 schools in Bengaluru city, with 1946 in Bengaluru North and 2872 in Bengaluru South districts. The schools are categorised as primary, upper primary, secondary and higher secondary schools. They include schools which are private unaided or public schools under the department of education.

This report considered the following number of schools and students:

Table 8 - Number of Schools and Students in areas studied

Area	Number of Schools	Total number of students
Vartur	18	5,267
Springfield	17	4,567
Doddanekundi	12	3,201
Kalyannagar	16	4,203
Corporation Circle	8	1,890
Sarjapur	10	2,546
Srirampura	29	6,759
Indiranagar	29	6,269
Ulsoor	19	3,434
MS Ramaiah City	17	5,665
Gottigere (IIM-B)	8	3,240
HSR Layout	11	4,564
JC Road	10	3,546
Koramangala	10	4,560
Bellandur	9	3,450
Brigade Road	12	6,543
Mathikere	17	3,709
Jayanagar	18	4,503
TOTAL	270	77,916

10.2 Population of children in Bengaluru city as per 2011/12 census

Table 9 - Population of children (0-19 years) in Bengaluru city as per 2011-12 census

	Male	Female	Total
0-4 years	340,232	321,653	661,885
5-9 years	327,003	308,185	635,188
10-14 years	328,467	309,698	638,165
15-19 years	346,522	328,273	674,795
TOTAL	1,342,224	1,267,809	2,610,003

10.3. Government air monitoring in Bengaluru

Currently, there are only 10 online monitoring stations operating in real-time in the city, providing continuous data. Five of these stations started operating in January 2018 and are located in Hebbal, Jayanagar, Kavika, NIMHANS, and Silk Board.

In addition, the state pollution control board has 14 manual monitoring stations which measure PM10 or the RSPM (Respirable Suspended Particulate Matter) on any two days in a week. There is also a mobile van in place for any emergency measurements that may be needed.

Information on the results of the 10 online real-time monitoring stations, plus the ones that collect data from time to time, is provided through monthly summary reports. These reports provide information on concentrations of PM_{10}, $PM_{2.5}$, other pollutants, and generate an air quality index. Possible health impacts are described for each scale.

In the official monitoring bulletins the number of monitoring sites is given as 21, as both the real-time monitors as well as the sites with occasional monitoring are counted. However, only 10 of these actually record continuous data.

It was indicated by researchers of the Urbanemissions that "at least 41 continuous air monitoring stations [were required] to statistically, spatially, and temporally, represent the mix of sources and range of pollution in the city". This suggests there are not enough monitors in place in Bengaluru to make a robust assessment of air pollution.

Furthermore, the installed stations do not measure air quality at people's breathing height and therefore do not provide information about pollution hotspots and individual exposure levels.

10.4. The Health Air Coalition's network for air monitoring

The Healthy Air Coalition aims to provide accessible, high quality air pollution data to the public, policy-makers and health experts, to assess the health burden of air pollution in the city and use that information to drive specific measures for improving Bengaluru's air.

Thirty stationary monitoring devices were installed across Bengaluru in March/April 2019, with the first 15 monitors installed and generating data available to the public by April 5, 2019. The Coalition is committed to maintaining these monitors for at least a year, so that by the end of the monitoring period health experts can carry out a robust comparative analysis of annual average concentrations against WHO recommendations and Indian standards, in addition to assessing daily concentrations.

The location of the monitors was chosen in collaboration with health members of the coalition, especially health experts at St. John's Research Institute. For the list of monitoring sites, see below.

Monitoring devices in use by the coalition

The network of 28 monitoring stations is a fixed system with monitors provided by Clarity Air Monitoring Solutions. These fixed sensors provide real-time measurements of two key air pollutants: particulate matter ($PM_{2.5}$) and Nitrogen dioxide (NO_2), as well as Temperature (T) and Relative Humidity (RH), data which are necessary to provide properly calibrated data. Real time data collected by each sensor is made available to the public via openmap.clarity.io and www.healthyaircoalition.org

The system uses 'smart calibration' to compare the results of the devices with local environmental parameters and government-operated regulatory monitoring devices, as well as machine learning algorithms to improve aggregate data estimations over different areas of the city.

10.5. Location of monitors across Bengaluru

LINK TO ACCESSING DATA: https://openmap.clarity.io/?viewport=12.946895,77.6152781,11.5

No	Location	RFID
1	Brigade Road	ANFLVMRB
2	Mathikere	AKKMZZTM
3	MS Ramaiah City	ADYYP61M
4	Koramangala	ADRMGGNB
5	Bannerghatta Road	AGSDMHMM
6	BBMP Head Office, Corporation Circle	AN86LJRX
7	Indiranagar	AVVXRF39
8	Doddakannelli, Sarjapur	A61RWNQK
9	Ulsoor	A8VYQKP6
10	Doddanekundi	A9GDZF8D
11	Springfield Society	AT627RHW
12	Banashankari	AX4JNS3T
13	Jayachamarajendra Road	AD6LV2QQ
14	NR COLONY - Basavanagudi	AP0MS6MH
15	Srirampura I	A86YTG4T
16	Bethany's High School, Koramangala	A58C681B
17	Jayanagar	AHTXGMB9
18	Electronic City	AYBF6SX1
19	Kalyan Nagar	AZRY538Z
20	Varthur	AVFB4XYG
21	Bannerghatta Road, Gottigere, IIM-B	AZDWPFBW
22	White Field	ATQDTDDB
24	Bellandur	AFWB2LRV
25	Jayaprakash Narayan Nagara	ABPXXL9K
26	BTM Layout	AKSWN1KT
27	HSR Layout	AC3PFTGK

10.6. The UK's guidance scheme and policy measures to reduce air pollution around schools

In the UK air pollution guidance for schools and colleges is provided by the National Education Union[35] and National Institute for Health and Care Excellence (NICE)[36]. On clean air zones, for example, NICE recommends the following:

- include restrictions or charges on certain classes of vehicle;
- support zero- and low-emission travel (including active travel);
- include targets to progressively reduce pollutant levels below EU limits and aim to meet World Health Organization air quality guidelines;
- aim to reduce exposure to air pollution across the whole zone rather than focusing on air pollution hotspots;
- work across local authority boundaries to address regional air pollution and prevent migration of traffic and emissions to other communities, resulting in areas of poor air quality.

In a recent survey of parents by ClientEarth and the British Lung Foundation, 60 per cent were worried about the impacts of air pollution on their children's health and supported traffic exclusion zones around schools while 13 per cent opposed the idea[37]. Government alerts for schools on high day pollution days were supported by 70 per cent of those surveyed along with guidance on how to minimise exposure to air pollution on the school run. The London Mayor's office has developed a cleaner air for primary schools toolkit[38]. This provides tools for schools and parents to identify areas of poor air quality around schools and is used to:

- promote pupil understanding of the causes and impacts of air pollution;
- engage staff, pupils and parents/carers with ways to improve air quality;
- provide ideas for creating school travel plans which maximise air quality benefits;
- set out a 12 week timeline of activities to maximise its benefits.

The most sustainable solution is to reduce air pollution to safer levels throughout towns and cities, not just around schools.

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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.

HEAL's over 90 member organisations include international, European, national and local groups of health professionals, not-for-profit health insurers, patients, citizens, women, youth, and environmental experts representing over 200 million people across the 53 countries of the WHO European Region.

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.

HEAL's EU Transparency Register Number: 00723343929-96
Contact: info@env-health.org

The Global Climate and Health Alliance (GCHA) is the leading global convenor of health professional and health civil society organizations addressing climate change. We are a consortium of health and development organisations from around the world united by a shared vision of an equitable, sustainable future, in which the health impacts of climate change are minimized, and the health co-benefits of climate change mitigation are maximised. GCHA works to elevate the influential voice of the health community in policy making to address the climate crisis.

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