Investigating the air quality surrounding new schools in England: polluted playgrounds and school buildings are a source of avoidable harm

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ABSTRACT

Objective To assess levels of pollutants at the sites of new schools and whether pupils are likely to be protected from associated risks.

Setting Air pollution causes damage to children's health by increasing respiratory tract infection rates, asthma exacerbations, allergies and childhood cancers. Further effects include poorer neurocognitive outcomes and multisystemic illness in adulthood.

Design We obtained a list of all 187 proposed new schools in England from 2017 to 2025 and found locations for 147 of them. We assessed air quality against WHO air quality targets and the air quality percentile of the location relative to pollution levels across the UK. We review relevant legislation and guidance.

Results Our analysis found 86% of new schools (126/147) exceeded all three WHO targets, and every location exceeded at least one. Nationally, 76% (112/147) of sites were in the 60th or greater pollution percentile. Within London, the median pollution percentile was the 90th, with a minimum of 76th and maximum of 99th (IQR=83 rd to 94th).

Conclusion The guidance for school proposals does not include any requirement to assess air quality at the identified site. Building regulations also fail to consider how widespread poor air quality is, and significantly underestimates the levels of major air pollutants surrounding schools. Therefore it is unlikely that adequate action to reduce pupil and staff exposure is undertaken.

We argue that air quality assessment should be mandatory at the proposal and planning stage of any new school building and that national guidance and legislation urgently needs to be updated.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Air pollution is detrimental to children's health and has long-term effects on adult health.
⇒ Air pollution targets have been reduced as harm has been proven at lower levels than previously thought.
⇒ It is already known that many areas of England have poor air quality.

WHAT THIS STUDY ADDS

⇒ This study contextualises and highlights alarmingly poor air quality surrounding new schools approved and proposed to open in England.
⇒ This study provides descriptive data and visualisation of annual air quality breaches of WHO Air Quality Guidelines (AQG) targets surrounding new schools in England.
⇒ This study analyses existing new school proposal and opening guidelines, including building regulations omitting statutory or mandatory recommendations to ameliorate poor air quality.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ In terms of the opening and planning of new schools this study could impact policy and guidelines to include monitoring and expert guidance if AQG targets are breached.

INTRODUCTION

Children's right to clean air as part of a healthy environment is enshrined in the UN Convention on the Rights of the Child. The latest WHO Global Air Quality Guidelines (AQG) published in 2021 estimated that air pollution is responsible for nearly 7 million premature deaths annually.[1] The 2021 WHO Global AQG gives numerical targets for annual exposure to six pollutants: PM2.5, PM10, NO2, O3, SO2 and CO2, listed in table 1. These targets are defined as 'the lowest exposure level of an air pollutant above which … there is an increase in adverse health effects'. The 2021 guideline significantly revised the 2005 standards, with annual PM2.5 reduced by 50%, PM10 by 25%, NO2 by 75% and introduced six new targets. These changes were informed by a meta-analysis of evidence regarding the adverse effects of air pollution.[2] An analysis by City Hall (The Mayor of London Assembly) in 2021 estimated that more than 3.1 million children in England are attending schools in areas with unsafe levels of air pollution, exceeding WHO guideline targets for PM2.5.[3]

Increased research has allowed a better understanding of the biological mechanisms by which inhaled air pollutants cause cellular and tissue damage. It is proposed that inhaled particulates enter the airway, accumulate in cells, and cause epigenetic changes, protein aggregation, mitochondrial impairment and arteriosclerosis.[4 5]

Children are more susceptible to the harmful effects of pollutants as their developing tissues are undergoing rapid changes, paired with less developed anti-oxidant defence systems to respond to stress.[6 7] This is exacerbated by a higher minute

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Table 1 WHO AQG targets for pollutants and data for new school sites

Pollutant (unit)	WHO AQG target for annual exposure	Median annual exposure at new school site (IQR)	Number of new school sites breaching target (%)
PM2.5 (mcg/m3)	5	10.94 (9.95, 11.53)	147 (100)
PM10 (mcg/m3)	15	17.40 (16.18, 18.16)	130 (88)
NO2 (mcg/m3)	10	17.73 (14.27, 23.89)	137 (93)
Not included in our analysis	WHO ACG Target (duration)		
O3 (mcg/m3)	100 (8 hour*)		
SO2 (mcg/m2)	40 (24 hour*)		
CO (mg/m3)	4 (24 hour*)		

* 99th percentile i.e. 3-4 exceedance days per year.
CO, carbon monoxide; NO2, nitrogen dioxide; O3, ozone; PM10, particulate matter than is 10 micrometers or less in diameter; PM2.5, particulate matter that is 2.5 micrometers or less in diameter.

ventilation rate, and low stature, meaning they walk at the level of traffic fumes and higher concentrations of pollutants.[8]

The acute effects on children include higher incidence of asthma, worsening of symptoms and frequency of asthma exacerbations in those already diagnosed, increased sensitivity to allergens, shortness of breath, nose and throat irritation, more frequent and severe respiratory tract infections, and pneumonia.[5–7 9 10]

Long-term effects from air pollution include reduced lung function,[6] intrauterine growth restriction (IUGR) and low birth weight,[1 5 10] increased risk of chronic obstructive pulmonary disease (COPD), carcinoma and cerebrovascular and cardiovascular diseases including ischaemic heart disease and strokes.[5–7]

In addition to the physical health effects, adverse outcomes have been proven on cognition, behaviour, psychomotor development and academic performance in children in relation to air pollution exposure.[11] Positive associations have been found between long-term exposure to levels of PM2.5 and declines in cognition, symptoms of depression and mental health in adolescents and adults,[12 13] with consistent patterns of white matter volume reduction demonstrated in multiple studies combining neuroimaging modalities.[11]

The WHO stated: 'air pollution is now recognised as the single biggest environmental threat to human health'.[1] This study aims to visualise newly approved or proposed school locations in England in comparison to the WHO AQG targets. We provide an overview of the current status of new school locations and the extent they attain or surpass the WHO 2021 AQG targets. Our aim is to inform public policy and increase attention on this important issue.

METHODS

Data sources

We identified 187 newly approved, and pre-approved, school proposals in England between 2017-2025.[14] Locations were acquired for 147 (79%) of these schools from their websites, proposals, consultation documents, local authority or multi-academy trust social media accounts, and contractor/architect project publications. For the seven greenfield sites that did not yet have postcodes, we identified the closest residential or business postcode using GPS coordinates, within 1–200 metres of the site. Proposals with no identifiable site at the time of our search were not included in the analysis (n=24), and an additional 16 proposals had been withdrawn.

We obtained air quality data from addresspollution.org for three WHO AQG pollutant metrics (PM2.5, PM10 and NO2). This is a free public service from the Central Office of Public Interest (COPI) that utilises air pollution data for every UK address sourced from a national 20 m/sq resolution model developed by Imperial College London's Environmental Research Group (ERG). The pollution data are annual averages from a national model based on 2019 inputs. COPI calibrated this data with real-world pollution levels recorded at over 19 500 council monitors across the UK, resulting in a more accurate national model. The website also assigns percentile rankings to addresses, assigning colour-coded rankings ranging from 'low' to 'very high', based on the address's percentile relative to nationwide pollution levels. These are determined through standardising and calculating data for each pollutant at every address.[15]

PM2.5, PM10 and NO2 levels were recorded for every school location, alongside the provided pollutant percentile. The number of WHO AQG targets breached was noted for each site (table 1, figure 1). We obtained longitude and latitude coordinates for each school location using a postcode conversion website.[16]

Statistical methods

The median (IQR) measures of PM2.5, PM10 and NO2 were presented for all schools, alongside the total number and percentage breaching each target. The pollution percentiles, were categorised into five groups, represented by a colour gradient from light yellow (least polluted) to dark red (most polluted). Longitude and latitude coordinate information was then used to depict this geographically, superimposing colours onto road maps, with marker size proportional to the school population. The analysis provided in this study was conducted without adjustment for external factors and is intended solely for descriptive purposes. All analyses were conducted on R studio version 4.2.2. Maps were built using R-package leaflet.[17]

RESULTS

The schools proposed exhibited varying sizes, with a median capacity of 420 (IQR=142 to 630). Primary Schools made up 40.8% (n=60) of the data, 29.9% (n=44) were Secondary Schools, 25.2% (n=37) were All-Through schools and 4.1% (n=6) were ages 16–19 specifically.

The median (IQR) PM2.5 reading across all school sites was 10.94 µg/m³ (9.95 to 11.53 µg/m³), more than double the WHO AQG of 5 µg/m³. PM10 showed a median (IQR) of 17.40 µg/m³ (16.18 to 18.16 µg/m³), with the lower quartile surpassing the WHO AQG of 15 µg/m³. The median (IQR) NO2 level was 17.73 µg/m³ (14.27 to 23.89 µg/m³) with the lower quartile also surpassing the WHO AQG target of 10 µg/m³. NO2 showed the most variability between locations of all three metrics. (table 1).

Every school location exceeded at least one of the WHO AQG targets, and 86% (126/147) exceeded all three (PM2.5, PM10 and NO2). Only six locations breached only one WHO target, four in the South-West and one in the South-East and one in the West Midlands, the rest breached two or more targets (table 1, figure 1).

The median pollution percentile was 61 (IQR = 41 to 81), whereby 76% (112/147) were in the 60th or greater percentile compared with pollution levels across the UK. Schools with elevated pollution percentiles exhibited a clustering pattern in major UK cities including London, Birmingham, Manchester,

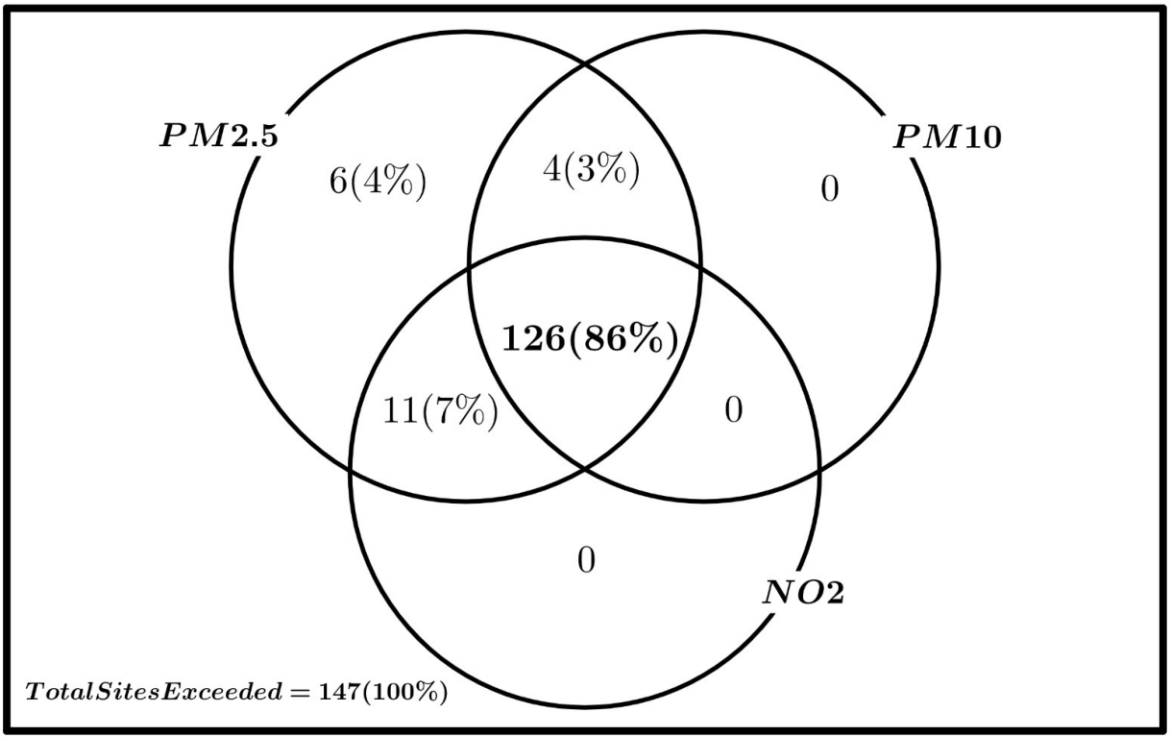

Figure 1 Venn Diagram of the number of school sites and percentage of total sites exceeding WHO AQG targets for PM2.5, PM10 and NO2.

and Leeds. Conversely, schools in other large English cities, including Liverpool, Bristol, and Newcastle, were found to have lower pollution percentiles (figure 2). Locations in Devon and Cornwall were seen to have the lowest pollution percentile.

The median pollution percentile for school locations in Central London was 90th (IQR = 83rd to 94th) with a minimum of 76th and maximum of 99th in comparison to the UK. School locations in the South-East of London appeared to have slightly lower pollution percentiles, however, this difference is minimal.

DISCUSSION

In England, children of mandatory school age spend around 7 hours a day, or 35 hours per week at school for more than half of the year. With wrap-around childcare, this can rise to as high as 55 hours a week for some children. Evidence suggests that although on average children spend around 30% of their time at school, this accounts for 44% of pollution exposure.[18]

Tackling this is complex and requires systemic national strategies to improve overall air quality as well as funding to identify high-risk schools and retrofit modern ventilation systems. Ensuring safe indoor air quality at *newly built* schools should be simpler, but only if the need for harm reduction is considered early in the process of selecting new school locations and designing sites.

In a previous publication, we showed that new school proposals do not consider air quality when assessing the suitability of a site. We obtained the proposal document for 36 (20%) of 180 of the same schools studied here (seven more proposals were approved subsequently), and searched each for the terms 'air quality' and 'pollution'. The return rate was zero.[19] This is likely due to a lack of a mandatory requirement, although even a non-mandatory prompt to consider this issue when proposing new schools could be beneficial.

Our data shows that 86% of new school sites exceed three WHO AQG targets and this is not surprising given that schools are most needed in areas of higher population density, which are most likely to be affected by significant levels of pollution. Demographic changes across the UK mean the number of children enrolled in schools is projected to fall in the next 5 years[20] and beyond. This may result in a need for the closure of existing schools and building of new ones, making it even more important that new schools are designed with air pollution in mind.

Statutory and non-statutory national guidance for new school proposals[21 22] set out the standards against which each proposal is judged, including impact and equalities assessments, funding and financial viability, and public consultations. It is mandatory that each proposal includes evidence of 'suitable outdoor space in order to enable physical education … and for pupils to play outside safely'. Proposals must also specify how children will be able to 'travel sustainably, where possible, e.g. by walking, cycling or using public transport'.[21 22] Travel and outdoor play result in peaks of exposure to pollutants[18] and yet neither air quality, nor pollution is mentioned in the national guidance for new proposals.

We reviewed building regulations as we hoped once a new school was approved, poor air quality could be ameliorated by robust building design. The guidance states, 'Major UK cities now require measures to tackle the problem of exposure of staff and students to frequent high air pollution while working and studying' and 'The elevated air pollution levels close to some schools mean that designers must consider:

- … location of air intakes in unpolluted zones
- closing windows when external pollutant levels are high
- … effective air filtration in ventilation systems[23]'

Finally, a recommendation is made that 'Designers can find out about current air pollution levels in the area of a school using the 5 day air pollution forecasts provided by the Met Office'.[22] We believe this is inadequate as air quality can vary significantly according to seasonal weather and traffic.

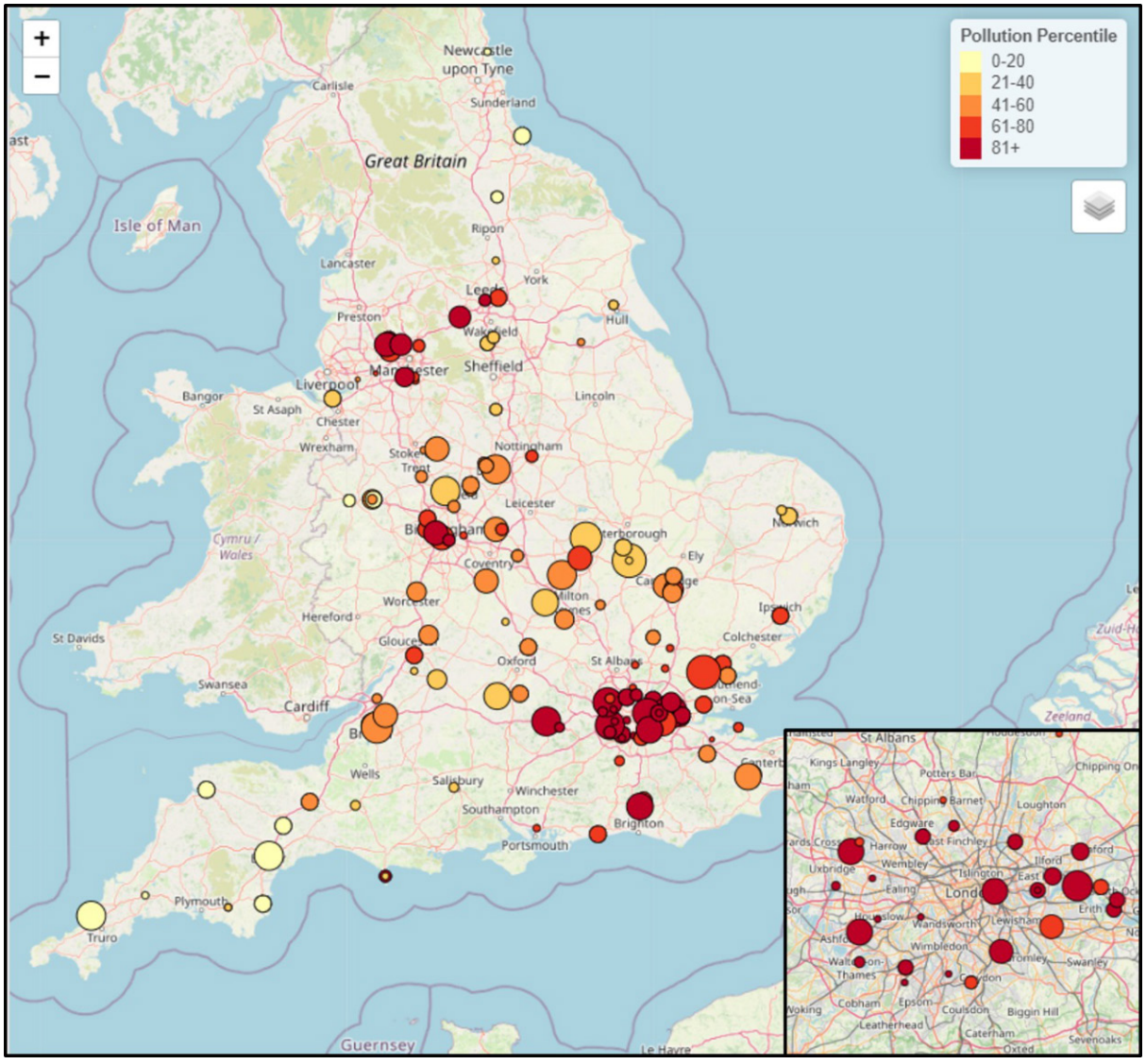

Figure 2 Pollution percentile mapped onto school sites in England, with inset of the City of London.

The regulations fail to take into account how widespread poor air quality is, and place greater emphasis on ventilation and fresh air than filtration systems. However, unfiltered natural ventilation (windows and passive vents) brings polluted outdoor air inside and assumes that major pollutants are absent, which we have demonstrated is not the case.

The 2022 Department for Education Sustainability and Climate Change Strategy[24] sets out how schools can contribute to improving air quality by working towards carbon neutrality, but does not mention protecting children from the impact of the poor air quality that currently exists.

Comprehensive recommendations have already been made by the Royal College of Paediatrics and Child Health (RCPCH) regarding protection from poor air quality at home and school, with regards to construction and maintenance of buildings, and enforcement measures. These include:

- 'Legally enforceable standards for indoor and outdoor air quality
- Increased Local Authority powers and funding to enforce adherence to minimum safe standards
- Access to site-specific air quality monitoring
- Revision of Buildings Regulations to ensure air quality checks are done at completion of construction and meeting standards is required for building sign-off and continues to be monitored once buildings are in use.'[25]

However, performing air quality monitoring only once construction is complete risks missing the opportunity to reduce exposure to pollution by better building design and other interventions.

Limitations

This study provides descriptive analysis using annual average air quality data derived from postcodes at new school locations, with figures serving as estimates of population exposure, thus limiting the depth of the analysis. Pollution levels are sensitive to factors such as time of day and seasonality, suggesting that a more detailed analysis could benefit from more granular pollution data. Furthermore, the data used in this analysis comes from a 2019 national model developed by Imperial College London. This data represents a snapshot from 5 years ago and current pollution levels will vary. However, given the disruptions caused by the COVID-19 pandemic, using 2019 as a reference may be reasonable to assess 'normal' pre-pandemic pollution levels.

We did not analyse the reasons for identified poor air quality at individual sites, which may include proximity to roads and other transport routes, manufacturing sites etc. Dependent on the main cause different local interventions, such as traffic reduction strategies (congestion zones, low traffic neighbourhoods, 'School Streets' which involve temporary road closures at peak times of school drop-off and pick-up) may be fast and effective ways to improve air quality locally. We have therefore limited our recommendations to ways that indoor air quality can be improved, even if outdoor pollutants remain high, as we believe this could have significant health benefits and this aspect is not well considered in any existing literature or guidance.

RECOMMENDATIONS AND CONCLUSION

We believe that the Department for Education should update the guidance on new school proposals so that an air quality assessment is mandatory at the proposal stage. New buildings or campuses of existing schools should be given the same consideration and therefore planning regulations also need to be updated. These actions would ensure that:

1. Air quality dialogue is included in the public consultation stage.
2. Sites and buildings can be designed that minimise the impact of air pollution on children.

Building Regulations must also be updated to emphasise that poor air quality is widespread and significantly detrimental to health. The suggested voluntary use of 5 day Met Office air pollution forecasts should be replaced. Both here and in the school proposal guidance, long-term exposure needs to be assessed according to the most up-to-date monitoring and modelled data. If two or more WHO AQG targets are breached we believe that on-site monitoring should be undertaken and expert advice should be sought.

Unless current recommendations are replaced with mandatory standards, it is unlikely that those proposing or designing new schools will make these assessments unless there is an individual already involved in the process who is both well-informed and passionate about reducing the impact of pollution.

We hope this study can influence school proposers, designers and national policy. The public health implications of avoidable childhood exposure to poor air quality could have significant effects on both the quality adjusted life years of the population and financial health expenditure in the United Kingdom. Children deserve protection from avoidable harm while at school.

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