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Proximity of city schools in Scotland to air quality monitors: an exploratory geomapping study in five Scottish cities

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ABSTRACT

Introduction There are serious and long-term effects of air pollution on children, thus the Royal College of Physicians of Edinburgh, Air Pollution Working Group has evaluated whether air quality was being sufficiently monitored around Scottish city schools.

Methods We undertook a web-based study of school placement and air quality monitors. Data, including location, from the automatic monitors were available on the Scottish Government's air quality webpages and on the UK Government site. These data (for both nitrogen dioxide (NO_2) and particulate matter) were supplemented by the non-automatic NO_2 diffusion tube locations, the geographical locations of which were found on the relevant local council websites. 340 primary schools and 95 secondary schools were mapped between the five city council regions. Using the council maps of schools and maps of monitors, we plotted the positions of the schools and monitors on a single map, and distances between schools and monitors were calculated using Google Earth measurement tools.

Results 37% of primary schools and 36% of secondary schools are more than 1000 m away from any form of air pollution monitors and for both school types nearly two-thirds are further than 500 m away from monitors. Four out of five cities have no secondary schools within 50 m of air pollution monitors and greater than 97% of all schools are further than 50 m away from any form of air quality monitoring. The mean distance between the primary schools and air quality monitors is 1051 m and for secondary schools 997 m.

Conclusion We have shown that very few schools are near enough to an air quality monitor to provide accurate local readings. The air safety of our school children at school in five Scottish cities, many of which are on busy city streets, is unknown.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ We already know how toxic air pollution is when children are exposed in childhood, and how it can affect the health of many organs, often permanently. Recommendations have been made that every effort must be made to minimise exposure.

WHAT THIS STUDY ADDS

⇒ Although the geographical position of monitors and schools is known, combining both to determine school proximity to monitors in Scottish cities had not been evaluated. From this study we know that very few city schools, in five major Scottish cities, are close enough to air quality monitors to be certain that the school, and thus its children, are not in an area where air quality is poor.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ It is clear that monitoring around these schools is inadequate. Scottish Government statement suggests that monitors are placed where there are 'vulnerable people'. We suggest that children are vulnerable and hope this paper may elicit a policy change ensuring outdoor school air quality is monitored.

INTRODUCTION

The Royal College of Physicians of Edinburgh (RCPE), Air Pollution Working Group has expressed concern for some time about the health effects of poor air quality on our children.[1] Our children are our future, but as yet we have little information as to whether their health is harmed by transport emissions around schools.

Scotland has one of the toughest air quality regulations in the world, and the most stringent air quality objectives in Europe.[2 3] The limits of nitrogen dioxide (NO_2) to below 40 µg/m^3, particulate matter 10 (PM_{10}, having a diameter of 10 µm or less) to 18 µg/m^3, and $PM_{2.5}$ (diameter of 2.5 µm or less) to 10 µg/m^3. The World Health Organization (WHO) recommendations are 10, 10 and 5 µg/m^3 for NO_2, PM_{10} and $PM_{2.5}$ respectively, thus only the NO_2 targets are significantly higher than those proposed by WHO.[4]

However, we cannot be complacent, as even with these regulatory levels, our councils are still reporting exceedances. Areas of significant transport-derived air pollution still exist around our city streets, and our researchers are still detecting effects on health despite this legislation.[5–8] Children are among the most susceptible to air pollution,[9] and authors continue to press for addressing air pollution in critically polluted areas to reduce profound effects on children's health.[10] Gestation, infancy and early childhood are vulnerable times because the child's body is developing rapidly and has immature systems which are vulnerable to damage by toxins. Children spend a higher proportion of time outdoors and are therefore at greater risk of exposure to ambient air pollutants. There is a correlation between areas of high deprivation and poor air quality in both children[11] and adults, exacerbating pre-existing health inequalities.

More often than not, schools are sited near busy roads and traffic junctions, and air quality is worsened by the 'school run' and idling engines.[12] School-aged children spend a substantial proportion of their daytime hours in the school environment, including time spent outdoors during morning arrival, break times, lunch periods and after-school activities. These periods frequently coincide with peak traffic times, particularly during the morning and afternoon school commute. In addition, many Scottish schools encourage outdoor play throughout the year, meaning that exposure to ambient air pollution may occur during multiple periods of the school day regardless of season. It is essential our schoolchildren are protected from air pollution in playgrounds and on the roads surrounding the school, with considerable health and other benefits to be gained, including educational attainment.

Hypothesis: In light of the serious and long-term effects of air pollution on children, the RCPE's Air Pollution Working Group determined to test the hypothesis whether there is adequate or inadequate air quality monitoring around Scottish schools.

METHODS

We undertook a web-based study of the proximity of school placement and air quality monitors (both PM and NO_2 monitors).

Air quality monitors: The geographical location of relevant air quality monitors in five major cities in Scotland (Glasgow, Edinburgh, Dundee, Aberdeen and Perth) were studied. They were selected because they represent the principal urban centres in Scotland with established air quality monitoring networks and a high density of schools and traffic-related pollution sources. These cities also provide geographical coverage across Scotland and include the largest population centres where concerns regarding traffic-related air pollution are greatest, and consistently have had the most Air Quality Management Areas reported to the Scottish Government. Data, including location, from the automatic monitors, both PM and NO_2 monitors, were available on the Scottish Government's air quality webpages,[13] and on the UK Government site (via Department for Environment, Food & Rural Affairs website[14]) and these data were supplemented by the non-automatic NO_2 diffusion tube locations, the geographical locations of which were found on the relevant local council websites.

Table 1 Number of primary and secondary schools within each city council area

	Primary schools (n=340)	Secondary schools (n=95)
Aberdeen (n=61)	50	11
Dundee (n=42)	34	8
Edinburgh (n=122)	92	30
Glasgow (n=184)	144	40
Perth (n=26)	20	6

Schools: In total 340 primary schools and 95 secondary schools were mapped between the five city council regions. We obtained a list of city schools from the Scottish Education Department and cross referenced this with local authority documents. This did not include private fee-paying schools. These were excluded as we hope to persuade the local councils to monitor the schools in due course, their responsibilities lie only with state schools. The relevant schools are shown in table 1 by city.

Ethical approval was not required as no personal information of any individual was accessed.

Two RCPE Scottish Clinical Leadership Fellows (AM, CM), using the council maps of schools as above, and maps of monitors from both government and local council resources, plotted the positions of the schools and monitors, respectively. Following this the distances between schools and monitors were calculated using Google Earth measurement tools.

Patient and public involvement

Our lay member (KF) was involved in the concept, the results and the discussion. She also participated as an author. One of us (JJFB) discussed this proposal with teachers and pupils at a Dundee City School (who are keen to use the data for a 'Citizen Science' study). The proposal was also discussed with members of the Scottish Government, Air Quality Section.

RESULTS

Table 2 shows the distances from air quality monitors (either PM monitored network or NO_2 diffusion tube) to the schools, both for all schools, split for primary and secondary schools, stratified by city.

The distances between air quality monitors and all primary and secondary schools in the five cities combined are also shown graphically below, for per cent under 500 m, in figure 1.

Table 2 The distances from AQMs (either PM monitored network or NO_2 diffusion tube) to the schools

Primary schools	N	%	Distance to nearest AQM	Secondary schools	N	%
All (n=340)	9	2.7	<50 m	All (n=95)	1	1.1
	17	5.0	<100 m		2	2.1
	47	13.9	<250 m		12	12.6
	125	36.9	<500 m		34	35.8
	213	62.8	<1000 m		61	64.2
Aberdeen (n=50)	3	6.0	<50 m	Aberdeen (n=11)	0	0.0
	3	6.0	<100 m		0	0.0
	8	16.0	<250 m		1	9.1
	14	28.0	<500 m		5	45.5
	26	52.0	<1000 m		7	63.6
Dundee (n=34)	0	0.0	<50 m	Dundee (n=8)	0	0.0
	0	0.0	<100 m		0	0.0
	4	11.8	<250 m		1	12.5
	10	29.4	<500 m		2	25.0
	18	52.9	<1000 m		4	50.0
Edinburgh (n=92)	3	3.3	<50 m	Edinburgh (n=30)	0	0.0
	6	6.5	<100 m		1	3.3
	13	14.1	<250 m		6	20.0
	31	33.7	<500 m		9	30.0
	58	63.0	<1000 m		18	60.0
Glasgow (n=144)	2	1.4	<50 m	Glasgow (n=40)	1	2.5
	7	4.9	<100 m		1	2.5
	19	13.2	<250 m		4	10.0
	58	40.3	<500 m		15	37.5
	96	66.7	<1000 m		27	67.5
Perth (n=20)	1	5.0	<50 m	Perth (n=6)	0	0.0
	1	5.0	<100 m		0	0.0
	3	15.0	<250 m		0	0.0
	11	55.0	<500 m		3	50.0
	14	70.0	<1000 m		5	83.3

AQM, air quality monitor; NO_2, nitrogen dioxide; PM, particulate matter.

In terms of school proximity to air quality monitors, 37% of primary schools and 36% of secondary schools are more than 1000 m away from any form of air pollution monitors, and for both school types nearly two thirds are further than 500 m away from monitors. Four out of five cities had no secondary schools within 50 m of air pollution monitors, and greater than 97% of all schools are further than 50 m away from any form of air pollution monitoring. The mean distance between the primary schools and air quality monitors is 1051 m, and for secondary schools, 997 m.

DISCUSSION

We obtained publicly available, published data on air quality monitor placement from the Scottish and UK governments, and local councils in Edinburgh, Glasgow, Aberdeen, Dundee and Perth. By analysing these data, we have shown that very few schools are near enough to a networked or non-automatic air quality monitor to provide accurate local readings. It is of concern that the air safety of our school children at school in these five Scottish cities, many of which are on busy city streets, is unknown. Without monitoring close to schools, policymakers and local authorities cannot determine whether children are being exposed to pollutant concentrations that exceed recommended guideline levels. To our knowledge, this is the first study to examine the proximity of schools to air quality monitoring infrastructure across multiple Scottish cities. These findings highlight a gap between the current air quality monitoring infrastructure

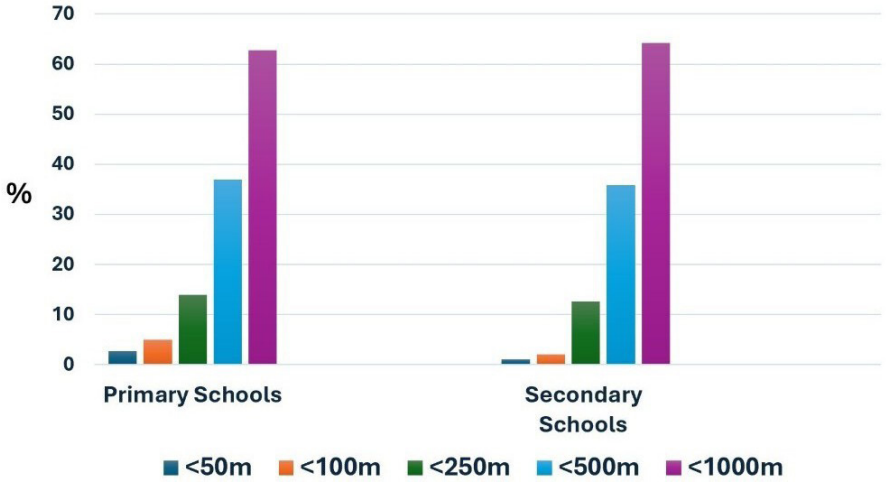

Figure 1 Percentage of primary and secondary schools within 50 m, 100 m, 250 m and 1000 m of the nearest air quality monitor.

and locations where children spend substantial portions of their day. Schools represent critical environments for exposure assessment, yet our results indicate that monitoring networks are not designed with these locations in mind. As a result, current monitoring systems may not adequately capture pollutant levels experienced by children during the school day.

The RCPE emphasised the need to protect children from air pollution by writing to the Net Zero Committee of the Scottish Government in 2023[15] asking for closer monitoring of school air quality. The Net Zero report indicates that 'The Royal College of Physicians of Edinburgh recommended placing air quality monitors at all Scottish city primary schools for at least one year and, once completed, for the same monitoring at secondary schools'. However, local authority representatives responded that 'they already tended to prioritise sensitive locations when siting monitoring stations'. This work has shown that, while55 monitors are often placed near traffic hot spots, school proximity is not taken into account. Indeed, the majority of both primary and secondary schools are not close enough to monitors to provide any meaningful readings. We know from published work that substantial variations can be detected in air quality measurements, such that pollution levels can be two to three times higher within 0.5 km of a monitor than at a distance of 1000 and 2000 m, respectively.[16 17] Further, pollution is highly localised. Traffic emissions ($PM_{2.5}$, NO_2, ultrafine particles) can change dramatically over tens of metres, especially near busy roads, junctions or industrial sources. For example, NO_2 levels on a main road may be 30–50% higher than a quiet street only 50–100 m away.[18] Second, school environments are unique. Schools often sit beside busy drop-off/pick-up roads, bus stops or playgrounds with poor dispersion. These microenvironments can produce spikes in exposure that a background monitor 1–2 km away will miss.[19] Further, meteorology and street design matter. Wind direction, street canyons, vegetation and nearby buildings create local variation. A monitor downwind versus upwind of a road will record very different values, even if only 500 m apart.[20]

There is evidence from validation studies, for example, validation work consistently shows that the correlation between central-site monitors and local exposure weakens with distance, especially beyond a few hundred metres. For traffic-related pollutants (NO_2, black carbon, ultrafine particles), the decay in concentration is steep within the first 100–300 m from the road.[20].

Thus, in over 60% of schools, child exposure to air pollution is unknown, which this group believes is unacceptable. This is important as, in schoolchildren, we know that the brain,[21] lung, heart[22] hormone systems and immunity can all be harmed by air pollution. On days where air pollution was above guideline levels, hospital admissions for children rose significantly in Tayside, Scotland, and it was estimated that admissions could be reduced by 40% if levels were to be kept within legal limits.[6]

We are not the only group to have investigated the proximity of schools to polluted air. An investigation by the Guardian newspaper with Greenpeace in 2017 showed that more than 2000 schools and nurseries in the UK were close to roads with harmful levels of diesel fumes.[23] The clean air and climate charity, Global Action Plan, undertook an analysis in 2021 that found more than a quarter of UK schools, from nurseries to sixth-form colleges, were in locations with high levels of particle pollution.[24] This means an estimated 3.4 million children are learning in an unhealthy environment in the UK. We are aware that there are various algorithms which can sometimes appear to be able to estimate pollution levels from data at a distance. However, we do not believe these are sensitive enough for our purpose. Pollutant levels vary greatly over short distances (eg, near roads,

buildings, local sources). A monitor tens or hundreds of metres away may not reflect local peaks or troughs. Algorithm estimates may smooth over local extremes or miss hot-spots.[25] If the available monitors are few and far apart, as in our case, interpolation or modelling must extrapolate, and predictions become more speculative, with lower confidence. Further, pollutants fluctuate with weather, traffic, diurnal cycles and meteorology. Static models may not capture short-term peaks or lulls, causing temporal errors and smoothing of spikes.[26] We have already shown that short-term bursts of air pollution promote hospital admissions in children.[6] Algorithms depend on covariates (land use, traffic, elevation, meteorology). If those inputs are incomplete, inaccurate or missing, the estimate is biased leading to under/overestimation.

It is imperative to establish accurate air pollution levels in Scotland, as often the introduction of small changes in traffic movement around schools can effect improvement in air pollution and thus health.[27] Targeted 'greening' can reduce playground pollution levels[28 29] and within classrooms, air purifiers could be used to reduce particles where levels are persistently high.[30 31] We also recognise the importance of indoor air pollution in our schools, but this paper on outdoor air quality remains important while the majority of our traffic is powered by internal combustion engines, and most city schools are situated on, or close by, main roads. Knowing localised air quality outside our schools will drive policy such as low traffic neighbourhoods, if required, driven by focused monitoring.

The strengths of this study include its novelty—a robust assessment of Scottish schools in relation to air quality monitoring has not previously been studied—and it provides evidence to the Scottish Government for the need for a planned programme of school monitoring to ensure our schools are safe. This study has, however, some limitations. First, only five Scottish cities were included in the analysis. These were chosen as major urban centres with established air quality problems hosting most of Scotland's Air Quality Management Areas; however, the findings may not necessarily generalise to smaller towns or rural areas. Also, we evaluated the proximity of schools to monitors rather than directly measuring pollutant concentrations at school sites. However, the purpose of this exploratory study was to assess whether monitoring infrastructure exists close enough to schools to provide meaningful estimates of local air quality. Future work could include direct monitoring of pollutant levels at school sites to validate the extent to which existing monitoring networks accurately reflect local exposure conditions.

In conclusion, there is overwhelming evidence that air pollution harms the health of school children. What is missing in Scotland is data on air pollutant levels in near-school areas, and whether pollutants are presently at levels above recommended guidelines. As mitigation can produce significant health benefits, we recommend and are campaigning for the introduction of air quality monitors by local councils at appropriate proximity to city schools as a matter of priority.

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