Exploring the potential of emergency measures to reduce air pollution during air pollution episodes – Overview Report

Heather Walton, Gary Fuller, Timothy Baker and Li Yan

Environmental Research Group

King's College London

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Customer	Greater London Authority / Transport for London

Environmental Research Group
School of Public Health,
Imperial College,
Michael Uren Biomedical Engineering Hub
White City Campus
Wood Lane
London W12 0BZ

(Previously King's College London)

	Name	**Date**
Authors	Heather Walton	17th December 2019
	Timothy Baker	17th December 2019
	Gary Fuller	17th December 2019
	Li Yan	17th December 2019
Reviewed by	Gary Fuller and Heather Walton	2nd November 2020*
Approved by	Heather Walton	2nd November 2020

** Following TfL and GLA comments.*

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Summary

This series of reports examines aspects of the evidence needed to inform decisions on whether or not implementation of emergency measures[1] on air pollution episode days is likely to be effective and practical for London. This led to the following conclusions:

(i) Air pollution episode days in London do have impacts on health.

(ii) The largest impact is from moderate days rather than high or very high days because the former are more frequent.

(iii) Some studies of interventions to reduce air pollution in the short-term have shown reductions in negative health impacts but studies on this topic are few in number and difficult to do as intervention studies are in general small in size (and therefore potentially lacking statistical power), of short duration and often lack a control group in the wider region to control for unrelated time trends in health outcomes.

(iv) As the greatest overall health impact is seen from moderate days (because these are much more frequent than the high or very high days) the most effective approach to reducing the health impacts of episode days will be to reduce overall air pollution levels using long-term air pollution reduction policies.

(v) A review of the effectiveness of emergency measures to reduce pollution implemented in other places found they could reduce concentrations, if sufficiently ambitious. However, the reductions in concentrations achieved in these places were not as large as the reductions that would be required to bring concentrations down from the levels on high or very high days to the levels on low or even moderate days. Studies also raised important questions about long-term public compliance with traffic restrictions.

(vi) Forecasting of air pollution episodes in London is deliberately precautionary at present as the primary aim of the Mayor's alert system is to be able to issue protective advice to populations with specific health conditions[2]. This forecasting approach is not best suited for implementing emergency measures, which may be expensive and require actions from the whole population.

(vii) The issuing of protective health advice on episode days should, of course, be maintained and could be supplemented with advice on voluntary individual actions to reduce air pollution.

(viii) The points above relate to evidence relevant to the principle of implementing emergency measures. This research does not evaluate different scenarios for London-specific emergency measures[3]. Scenario testing was dependent on the existing evidence base discussed in this report justifying investment in a future work programme of scenario modelling, which it did not.

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[1] We regarded emergency measures as policies to reduce air pollution concentrations brought in for a short-period in response to forecasts of episodes of air pollution.

[2] More precisely, there is a preference for over predicting episode days rather than missing a prediction of episode days.

[3] To do so would require extensive developments to the current emissions and air pollution modelling approaches that are used for appraising polices such as the Ultra- Low Emission Zone. The current modelling systems focus on polices that are designed to create a permanent, instead of temporary shift in emissions.

1 Introduction

The health impacts of air pollution are well recognised and have been the motivation for air quality legislation in countries around the globe.

Emergency measures, or short-term actions are ways in which a city can respond to air pollution episodes, which are defined as periods of a few hours or a few days, when air pollution concentrations rise, or are predicted to rise, well above the normal range. Emergency measures are used by many cities across Europe and further afield. This work programme looks at the current evidence base on best practice and considers this in the London context. It considers the evidence that would be needed as part of the decision-making process if an emergency measures scheme were to be set up for London. The pathway for this decision making is shown in Figure 1.

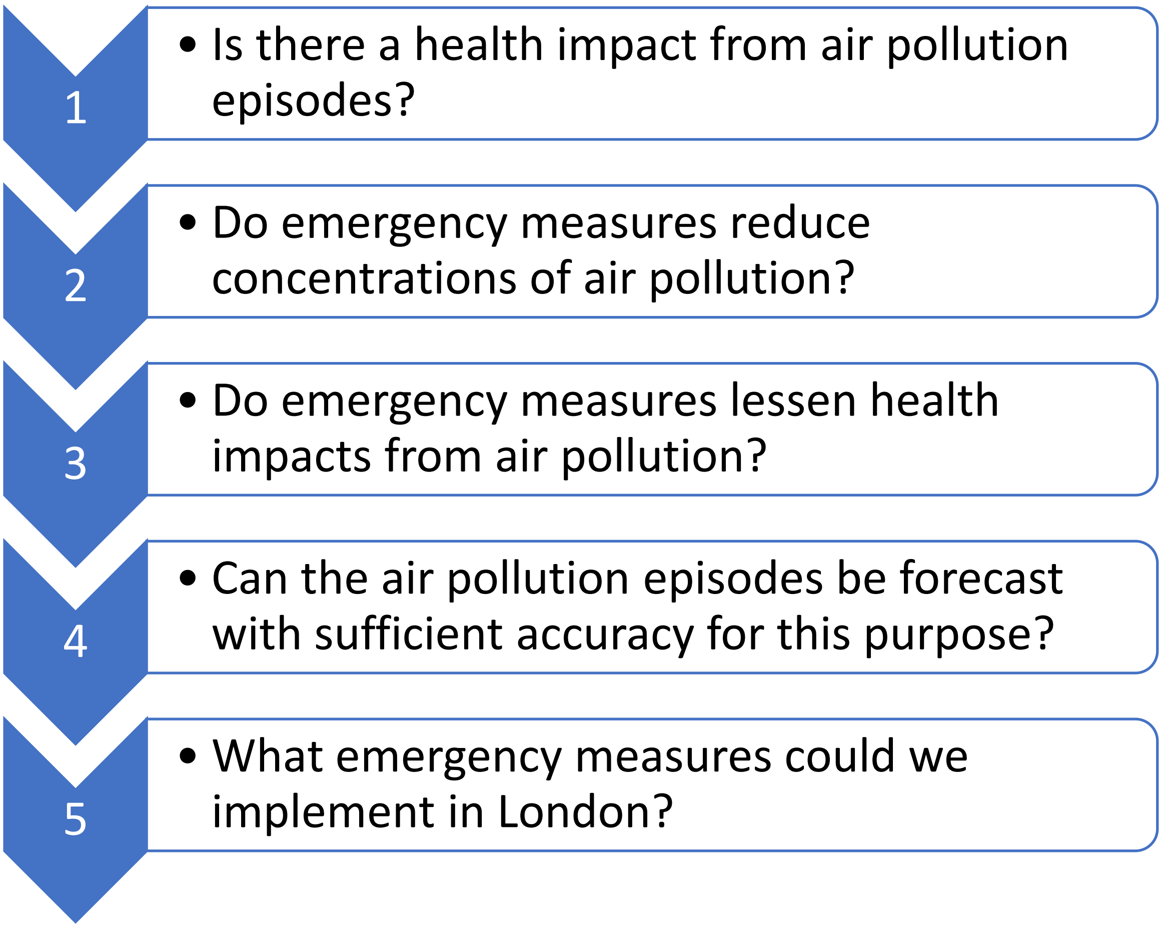

Figure 1 Pathway for decision making on emergency measures

This programme of research was not designed to include step 5 which would involve looking at different scenarios for London-specific emergency measures[4], as it is dependent on whether consideration of the earlier steps indicate that it would be an effective approach in general. Instead

[4] To do so would require extensive developments to the current emissions and air pollution modelling approaches that are used for appraising polices such as the Ultra- Low Emission Zone. The current modelling systems focus on polices that are designed to create a permanent, instead of temporary shift in emissions.

the programme sought to consider if the existing evidence base justified investment in a future work programme of scenario modelling.

Specifically, this programme of research included five work packages A to E:

- Work package A was to summarise the evidence base on health effects of short-term exposure to high levels of air pollution.
- Work package B was to estimate the magnitude of the health impact of moderate, high and very high air pollution episodes in London
- Work package C was to review evidence on the effectiveness of emergency measures in other cities including Madrid, Paris and Beijing.
- Work package D was to assess the accuracy of existing air quality forecasts in London and consider their possible use in triggering emergency air quality measures.
- Work package E was an expert workshop that considered the workpackages A to D and the conclusions that could be drawn from them[5]. Separate reports were produced for work packages A, B, C and D. This overview report draws together the most important findings from the whole programme including the workshop. It is structured as a series of questions and answers.

2 Questions and answers on key topics

2.1 What is air pollution?

Air pollutants are contaminants present in our air that impact health. They can arise from natural sources but the vast majority of the air pollution that we breathe in London is of anthropogenic (i.e human made) origin. The management of air pollution evolved and developed in the last half of the 20th century. For several decades legal limits have been set for many pollutants that harm our health or ecosystems. These include nitrogen dioxide (NO_2), particle pollution ($PM_{2.5}$ and PM_{10}) and ozone (O_3).

2.2 What are the health effects of air pollution? (Reports A and B)

Air pollution can harm our health through short-term exposures during air pollution episodes and long-term exposure to concentrations that we breathe every day. The effects of long-term exposure to air pollution are important – the effects of long-term exposure on mortality are greater than the effects of short-term exposure for example. Long-term exposure has also been linked with effects on cardiovascular[6] and respiratory disease[7]. The links between short-term exposure and long-term exposure are not fully understood e.g. the effects of long-term exposure might be the results of

[5] The workshop did not proceed to discuss evidence-based suggestions of where to set a threshold for triggering emergency measures to tackle air pollution as the findings suggested pursuing long-term measures was better.

[6] Cardiovascular means of the heart and blood circulation; it includes strokes and diseases of arteries and veins, as well as heart disease.

[7] There are also emerging areas of evidence on, for example, low birthweight, diabetes, dementia and possibly susceptibility to the more severe effects of the coronavirus. For the latter two in particular, the evidence is not yet fully established in general nor in terms of the balance between short- and long-term exposure contributions.

repeated exposure to peaks in air pollution or the cumulative exposure building up as a result of exposure to all levels of air pollution.

This series of reports concentrates on the effects of short-term exposure to air pollution on health, as this is most relevant to the health impacts of pollution on episode days. There are large numbers of studies showing associations between daily variations in pollution and daily variations in deaths and hospital admissions for cardiovascular and respiratory disease. We used the concentration-response relationships from these studies to calculate the health impacts of episode days (see question 2.6). Concentration-response functions were obtained from meta-analyses (combining results from previous studies) on:

- Deaths brought forward[8]
- All respiratory hospital admissions, all ages
- All cardiovascular hospital admissions, all ages
- COPD[9] admissions, all ages
- Asthma admissions in children age 0-14
- Asthma admissions in adults age 15-64
- Cardiac[10] admissions in older people (age 65+)
- Stroke admissions, all ages

There is also evidence for other effects of short-term exposure e.g. on respiratory symptoms and GP consultations. These are mentioned to provide general support for the occurrence of health effects of short-term exposure to air pollution but the calculations of the health impacts of air pollution episodes concentrated on deaths and hospital admissions as quantification of these endpoints is better established.

2.3 What are air pollution episodes? (Reports C and D)

Air pollution episodes are short periods of elevated concentrations of one or more air pollutants. In the UK, days are classified as low, moderate, high or very high air pollution (Table 1) using a method set out by the UK Government's Daily Air Quality Index. This classification method is mainly based on World Health Organization Guidelines and legal limits. The index is designed to be used as part of air pollution forecasts and real-time notification systems for the public and includes health advice for vulnerable people and for the general population. Air pollution episodes are normally defined as those times when air pollution is moderate, high or very high according to the UK index.

The Mayor's air quality forecast system issues email alerts if air pollution is forecast to be moderate, high or very high. Additional steps are taken to warn the public if high or very high air pollution is expected, including displaying information on bus stop signs and other TfL messaging services.

The UK index focuses on air pollution at individual monitoring sites. It does not consider when a warning should be issued for a whole city or a region. This research therefore required the creation of a spatial dimension to the definition of an episode.

[8] Deaths brought forward is a term used to reflect the fact that in studies of health effects of short-term variations in air pollution, it is unknown whether the deaths are brought forward by a few days, weeks or months or longer.

[9] Chronic obstructive pulmonary disease – a disease of the lungs leading to combinations of severe breathlessness, cough and phlegm. It is common in elderly smokers.

[10] Cardiac refers to the heart. It excludes strokes and diseases of the arteries and veins.

Band	Index	Ozone	Nitrogen Dioxide	Sulphur Dioxide	$PM_{2.5}$ Particles (EU Reference Equivalent)	PM_{10} Particles (EU Reference Equivalent)
		Running 8 hourly mean	hourly mean	15 minute mean	24 hour mean	24 hour mean
		μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}	μgm^{-3}
Low	1	0-33	0-67	0-88	0-11	0-16
	2	34-66	68-134	89-177	12-23	17-33
	3	67-100	135-200	178-266	24-35	34-50
Moderate	4	101-120	201-267	267-354	36-41	51-58
	5	121-140	268-334	355-443	42-47	59-66
	6	141-160	335-400	444-532	48-53	67-75
High	7	161-187	401-467	533-710	54-58	76-83
	8	188-213	468-534	711-887	59-64	84-91
	9	214-240	535-600	888-1064	65-70	92-100
Very High	10	241 or more	601 or more	1065 or more	71 or more	101 or more

Table 1 Daily Air Quality Index as defined in the update of 2013. The 24-hour mean used for PM2.5 is specified as a fixed midnight to midnight daily average.

2.4 What causes moderate, high or very high air pollution in London? (Reports C and D and Workshop E)

Day to day changes in air pollution are determined by variations in weather conditions and by changes in air pollution sources. The sources of air pollution can be local, elsewhere in a city or further afield in the UK, mainland Europe or even further afield. The combination of local geography, air pollution sources and weather patterns mean that the causes of air pollution episodes are different for each place in the world.

Causes of moderate, high and very high air pollution episodes in London include:

- Poor dispersion of air pollution emitted within or around the city. These types of air pollution episode normally happen in winter due to meteorological conditions. At these times the problem pollutants are $PM_{2.5}$, PM_{10} and also NO_2. The greatest concentrations are found close to sources, such as roads.

- The influx of air pollution from outside the London region, from air pollution sources elsewhere in the UK and Europe. This can lead to high or very high $PM_{2.5}$, PM_{10} and high O_3. At these times air pollution can be bad everywhere but is often worse where local sources add to the region-wide problem. $PM_{2.5}$ and PM_{10} episodes are worse during the springtime due to ammonia emissions from agriculture in the UK and Europe.

- Energy from strong sunlight that drives chemical reactions between air pollutants. This can lead to high or very high $PM_{2.5}$, PM_{10} and high O_3 during late spring and summer.

- Special events such as bonfire night because of emissions from bonfires and fireworks. Large fires can also cause localised problems.

- Local emissions sources including industry, waste management sites and construction.

In London, days with moderate air pollution were around 15 times more frequent than days when air pollution was high or very high.

2.5 Have the short-term health effects of pollution episodes been studied directly? (Report A)

Studies exploring the health effects of pollution episodes are reviewed in report A. The identified studies showed that, for at least some episodes, health effects are observed when pollutant concentrations are equivalent to those seen in high or very high days in the Defra Daily Air Quality Index. The studies included some data from UK episodes. Such studies are, however, challenging as each episode is typically just a few days long. This means the studies lack statistical power. For the wider number of episode studies that did not find statistically significant associations we do not know if this reflects a lack of statistical power or a lack of effect. General time-series studies have much greater statistical power as they include many episode days over a time period of several years and include concentration variations on other days as well. This is why these types of studies were used to calculate health impacts (question 2.6) rather than doing or using specific episode day studies.

2.6 What is the health impact from moderate, high and very high air pollution in London? (Report B)

Air pollution levels	Deaths brought forward	Respiratory admissions	Cardiovascular admissions
Very high	60-80 ~4%	190-220 4%	60-90 5%
High	210-310 ~15%	710-840 ~15%	240-360 ~19%
Moderate	1,200-1,600 ~81%	4,100-4,600 ~82%	990-1500 ~77%
Total	1,470 – 1,990	5,000-5,660	1,290 – 1,950

Table 2 Summary of deaths brought forward, respiratory admissions and cardiovascular in London over the period 2009-2017. Percentages shown are percentages of the total across the three types of episode days in the last row.

Our analysis estimates that high air pollution days were estimated to result in an additional **210-310 deaths brought forward, 710-840 respiratory admissions and 240-360 cardiovascular admissions in London over the period 2009-2017** compared with the number of admissions and deaths brought forward seen as a result of the average concentration of the relevant pollutant on days when all pollutants were classified as ‘low’. These numbers include health impacts for the pollutant leading to the classification of the day as a high day and also for the other pollutants on that day. The ranges in Figure 2 are for totals with and without nitrogen dioxide. The reason for this is that both particulate matter and nitrogen dioxide can increase and decrease together as weather conditions change (ozone varies differently but is often lower when the other pollutants are higher). This makes it difficult to distinguish where increased health effects on higher air pollution days are due to one or other of the pollutants or a combination of both. The mechanisms of the effects of particulate matter have been more widely studied than is the case for nitrogen dioxide. Because the relative contribution of each pollutant is not fully understood we have presented the results as a range from the totals for $PM_{2.5}$ and ozone alone to the totals for all 3 pollutants. Additional uncertainties are given in Report B.

Very high days were estimated to result in an additional **60-80 deaths brought forward, 190-220 respiratory admissions and 60-90 cardiovascular admissions over the period 2009-2017** compared with the number of admissions and deaths brought forward seen as a result of the average concentration of the relevant pollutant on low days. The relative rarity of very high days means that their total impact on health is less than the total from high days.

Moderate days were estimated to result in **1200-1600 deaths brought forward, 4100-4600 respiratory admissions and 990-1500 cardiovascular admissions over the period 2009-2017** compared with the number of admissions and deaths brought forward seen as a result of the average concentration of the relevant pollutant on low days. These totals were much greater than those on high or very high days due to the greater frequency of moderate days.

The total health impacts on very high, high and moderate days is strongly influenced by their relative frequency and does not reflect the per day impacts. For example, there were an estimated average of 23-26 respiratory hospital admissions per day on very high days compared with 18-21 and 11-13 on high and moderate days respectively.

Estimates were also made for COPD admissions, asthma admissions, cardiac admissions and stroke admissions. The results are given in report B. Report B also gives results separately by pollutant, showing $PM_{2.5}$ is usually the most important pollutant on high and very high days, although impacts from nitrogen dioxide could be similar or higher for particular health outcomes. Ozone was usually most important on moderate days.

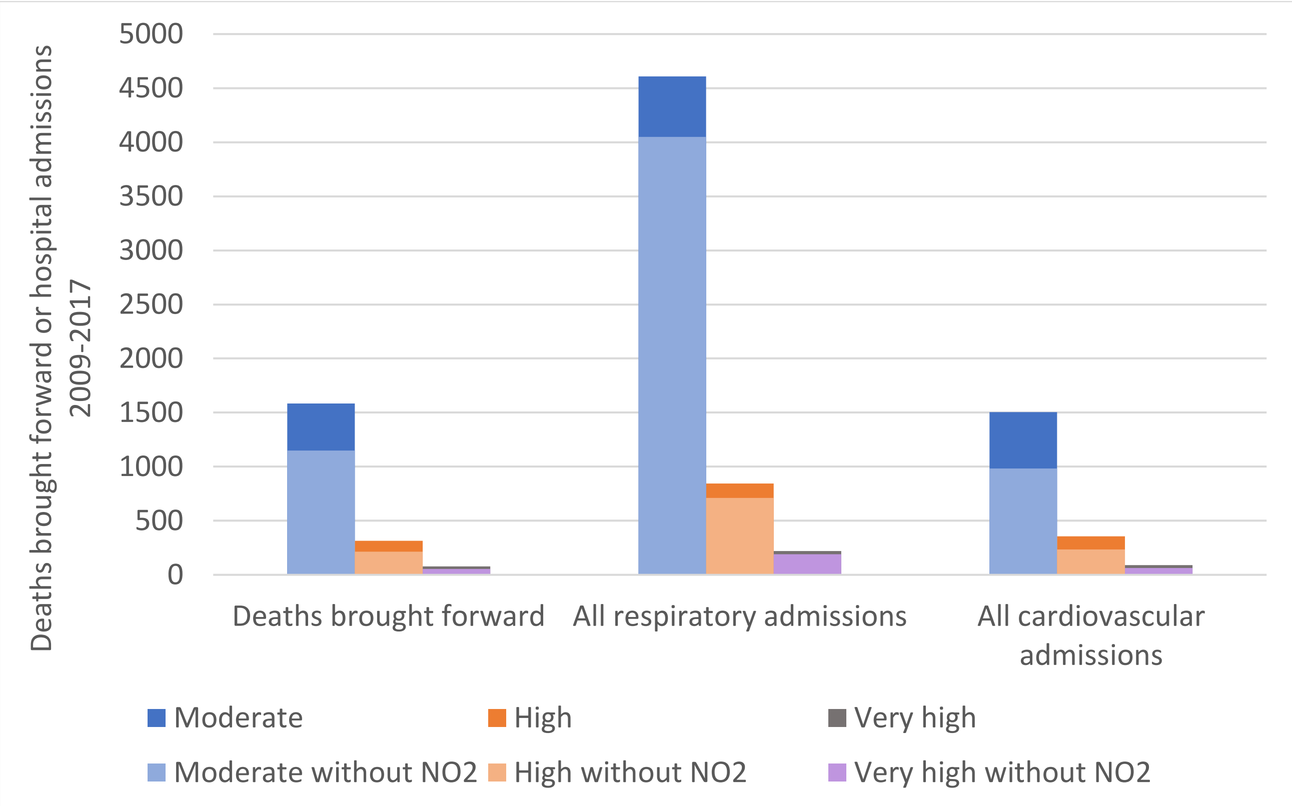

Figure 2 Total deaths brought forward, all respiratory admissions and all cardiovascular admissions, all ages, in London 2009-2017 for moderate, high and very high days compared with low days, $PM_{2.5}$ plus O_3 ***with and without NO_2.*** *This is a stacked graph i.e. the proportion of the results without NO_2 is shown as part of the higher total with NO_2.*

2.7 What are emergency measures to control air pollution? (Report C)

Emergency measures to control air pollution were first used in Los Angeles in the 1950s and are used in many European cities.

Emergency measures or short-term actions are required in EU Air Quality Directive (2008/50/EC) As a minimum these require information to be given to the public when air pollution reaches a specified concentration. This type of emergency measure is already in place in London through the DAQI alert system. Many schemes across Europe also include steps to rapidly reduce air pollution at source to try to control smog events. The majority of schemes focus on decreasing air pollution from traffic by reducing speeds, restricting certain vehicle types or reducing vehicle numbers based on their number plate. Other schemes involve free or reduced cost public transport.

Some areas of the US ban wood heating on days when air pollution is forecast to be bad.

Famously Beijing induced restrictions on industry and traffic in the run-up to the 2008 Olympics and later for an international summit and the ceremony to mark the 70^{th} anniversary of the end of World War II. These types of emergency measure are planned and do not rely on forecasts or measurements to trigger the actions.

2.8 Do emergency measures decrease air pollution concentrations? (Report A and C)

Despite their widespread adoption few emergency measures schemes have been evaluated. Instead, many short-term action plans are justified on the basis of prior knowledge of the relative contribution of pollution sources rather than evidence of the efficacy of the measures themselves. For instance, taking action to reduce traffic or wood burning is justified because these are the largest pollution sources in a particular place.

It is difficult to assess the effectiveness of emergency measures. The major challenge is to understand what would have happened anyway, if the plan had not been enacted (because many pollution episodes would be of short duration even without measures being implemented).

The spatial-scale of interventions depends on the pollutant. Local or city-wide interventions can be effective for NO_2 but have less impact on PM and O_3 where sources can be further afield.

Evidence from traffic restrictions in Madrid and Paris based on odd or even number plates suggest that traffic reductions of between 15 to 20% can be achieved and local NO_X and NO_2 levels can be decreased by a similar amount. However, studies in Madrid, Sao Paulo and Paris raise important questions about long-term public compliance with traffic restrictions.

Modelling studies have shown that emergency actions taken simultaneously on industrial, agriculture, road transport and residential heating at a European scale could be effective and their effectiveness increases when implemented over several days. In Beijing widespread restrictions on industry and traffic (covering 500,000 km^2 and a population of nearly 300 million people) for major public events have been shown to decrease pollution concentrations by between 36 and 62%, depending on the pollutant considered. This research was undertaken before the coronavirus pandemic so does not consider the impact of lockdown measures on air quality. Similarly to Beijing during the Olympic games, cities around the world reported significant and sustained reductions in pollution due to the reduction in emissions from traffic and other sources, most notably for NO_2. In

London this led to reductions in NO_2 of between 20 – 50%[11]. However caution is needed in drawing conclusions on the efficacy of emergency measures based on these changes. Coronavirus restrictions were implemented over many months and were not in response to pollution episodes. In addition, even with lockdown restrictions in place, London still experienced pollution episodes for $PM_{2.5}$ and O_3.

There is a lack of peer-reviewed evidence on the effectiveness of wood burning bans, however there is evidence that burn bans imposed for most of a season can yield measurable health benefits.

Although there are large gaps in the evidence base for short-term actions, where evaluations have been undertaken they indicate that the actions can be effective at reducing pollution concentrations if they are sufficiently ambitious. Though as noted, some studies raise important questions about long-term public compliance with traffic restrictions.

2.9 Have emergency measures been effective for public health? (Report A)

Only two studies have looked at tailored or designed emergency measures and their associated public health benefits on the basis of forecasting air quality. One found statistically significant reductions in hospital admissions for cardiovascular and for ischaemic heart disease and the other found a non-statistically significant association between the use of the emergency measure and reductions in mortality in the elderly. Both studies shared the challenges of intervention studies in general of being small in size (and therefore potentially lacking statistical power) and lacking a control group in the wider region to control for unrelated time trends in health outcomes.

Further studies have assessed the public health benefits arising from planned short-term interventions to control air pollution for a specific high-profile event, such as the Olympic games. These have the advantage that the timing is known in advance and that emergency measures are implemented for longer periods (weeks rather than days). The studies of the Beijing Olympic Games in particular (where the emergency measures taken were particularly widespread) were consistent in showing improvements in health outcomes, including all-cause mortality, cardiovascular mortality, respiratory mortality, number of outpatient visits for asthma, birth outcomes and some cardiometabolic and respiratory biomarkers.

Studies of interventions that sought to make a permanent improvement in air pollution concentrations but where short-term (a few months) health impacts were assessed were also examined. These generally showed that the health burden from air pollution can be lessened by reducing concentrations, although the results were not always statistically significant and for some examples, more complex follow-up studies did not confirm the earlier results.

2.10 What can London learn from the emergency measures schemes in other cities? (Report C)

There is a clear need for schemes to be better designed rather than simply justified on the basis of doing something to tackle the largest pollution sources. Both modelling and monitoring have an important role to ensure that schemes are optimised and remain effective over time. In addition

[11] NO_2 concentrations, at busy roadside sites Marylebone Road and Euston Road were down 55% and 36% respectively. The mean reduction in hourly NO2 concentrations lowered by 21.5% across the capital http://www.londonair.org.uk/LondonAir/general/news.aspx?newsId=6M9TkOdzwu3JAZvaGiTcux&skip=0

many schemes focus on the steps for declaring an alert but give less attention on the steps to revoke.

Emergency measures can reduce air pollution concentrations if they are sufficiently ambitious. However, the air pollution changes achieved in Paris and Madrid would not be sufficient to bring very high or high air pollution into the low or moderate band. In order to achieve this type of change in London, emergency measures would need to achieve reductions of around 40% for NO_2, twice that achieved by the Paris and Madrid schemes. This is the same level of reduction achieved by longer-term permanent measures such as the central London Ultra Low Emission Zone (ULEZ) which contributed to a 44 per cent reduction in NO_2 at roadside sites in central London.[12] However, this is a longer term change and, due to atmospheric chemistry and time varying emissions, it does not necessarily follow that the ULEZ would be sufficient to ensure prevent all short-term occurrences of high or very high NO_2.

Changing high and very high particle pollution to low in London would require a 70 to 80% decrease in PM2.5 and PM10 concentrations. This is greater than that achieved in Beijing where decreases of between 36 and 62%, depending on the pollutant considered, were usually achieved when restrictions were placed on transport and industry over a very wide area, covering 500,000 km^2 and a population of nearly 300 million people.

There is some evidence that air pollution episodes can lead to long-term media interest in air pollution. Few studies have looked at whether the introduction of short-term action plans are effective as a specific tool to raise public awareness of air pollution.

2.11 Should emergency measures be aimed at high and very high days only? (Report B)

In London, days with moderate air pollution are around 15 times more frequent than days when air pollution is high or very high. The total health impact of moderate episodes was therefore much higher than that for high or very high days because of this greater frequency. From the perspective of average health events per day, high and very high days are more important,however, omitting moderate days from an emergency measures scheme would not address the main impacts from episodes. On the other hand implementing emergency measures on a more frequent basis may raise practical issues of disruption and compliance (see question 2.16).

2.12 Can air pollution be forecast? (Report D)

Air pollution can be forecast using models. It can also be forecast using measurements and knowledge of conditions and processes that have led to episodes in the past.

Air pollution forecasts can provide valuable warning of impending periods when air pollution might place an additional health burden the population. If these forecasts are sufficiently accurate and timely they can be used as the basis of short-term action plans. These plans can advise people to take extra precautions and mandate changes to decrease emissions.

[12] https://www.london.gov.uk/WHAT-WE-DO/environment/environment-publications/central-london-ulez-ten-month-report

2.13 What is the Mayor's air quality forecasting system and how is it used? (Report D)

The Mayor's air quality forecasting system is used to send out advisory messages by email to schools and other stakeholders if air pollution is forecast to be moderate, high or very high according to Defra's Daily Air Quality Index. When high or very high air pollution is forecast, information is also displayed on Transport for London infrastructure including electronic displays at bus stops, in the underground and beside trunk roads.

The London Mayor's air quality forecast service has been operating since 2017. In February 2018, operation of the system was transferred to King's College London (now Imperial College London) and its scope was extended.

The Mayor's forecast uses an ensemble approach, combining the publicly available forecasts from three providers: Defra (the Met Office), LondonAir (Imperial College London) and AirText (CERC). Each provider uses a different input data and a different forecast methodology.

2.14 How accurate are air pollution forecasts? (Report D)

The forecasts from February 2018 to the end of April 2019 from the Mayor's system were compared with measured air pollution outcomes. The main metrics for evaluating forecasts are "skill" and "accuracy". In this instance, forecasts have to be considered using skill[13] rather than accuracy metrics. A skilful forecast would correctly predict air pollution episodes but also give few false alarms. The use of skill rather than accuracy metrics are particularly important when the event being predicted is rare, such as high or very high pollution episodes.

- One of the strengths of the Mayor's forecasting service derives from being an ensemble of forecasts from three different providers who use different forecasting techniques. This decreases the chances that an air pollution episode could be missed.

- The system takes a precautionary approach by design, commensurate with its objectives to supply public information. It assumes a worst-case outcome from any single provider and therefore over-predicts but misses few episodes.

- The Mayor's forecast was more skilful when there was agreement between the different forecaster providers. Only issuing forecast alerts when there is agreement between two or more forecasters would make the service less precautionary. However, this would lead to times when a warning from a single provider was rejected and this may be hard to defend publicly, if an opportunity to provide warning advice is missed. Even if forecasting alerts were only issued when there was agreement between two or more forecasters, the system would still not be perfectly skilled, with a proportion of false alarms still being issued.

[13] Various metrics exist to determine the accuracy or skill of such forecasts. We selected the Gilbert skill score (GSS) as the most appropriate. This is the ratio of true positive predictions to the sum of true positive, false positive and false negatives. Compared with other metrics the Gilbert Skill Score has the advantage of placing less weight on the many occasions when low air pollution was correctly forecast.

2.15 Are current forecasts sufficiently accurate to trigger emergency measures? (report D and Workshop E)

Many cities trigger emergency measures based on measured concentrations of air pollution reaching a threshold and its predicted persistence for one or more days ahead. However high and very high air pollution episodes in London from February 2018 to spring 2019 have been isolated and mainly happened on a single day only. Triggering emergency measures to control these episodes would not be possible based on a scheme that was a combination of measurement and forecast of persistence. Instead emergency measures would have to be based on a forecast alone.

The current service meets a requirement to provide precautionary advice to the public. The forecasting service would need to be improved if the forecasts are to be used to enact emergency or short-term measures, such as traffic restrictions or reduced cost public transport. A clearer definition of a pollution episode would also be needed. A more skilful forecast with lower numbers of missed episodes and false alarms may also be needed given the financial cost and disruption from enacting emergency measures.

2.16 Is it better to tackle short-term air pollution episodes or the everyday air pollution that determines longer term exposure? (Workshop E)

The cost and disruption to the running of the city to control around five high or very high air pollution episodes in a year, is likely to be less than for emergency measures for moderate days, which may require actions on more than 30 days per year. It would therefore be better to make these measures part of the everyday running of the city. This would lead to wider benefits from controlling long term exposure as well.

The most effective approach to reducing the health impacts of air pollution will be to reduce overall air pollution levels using long-term air pollution reduction policies. These could be used in conjunction with short term emergency measures during high and very high days but emergency measures on their own would not be sufficient.

2.17 Can the current alerting system be improved? (Workshop E)

Given the health impact of air pollution episodes it would be imprudent and irresponsible to do nothing to address them. Providing information to the public via the Mayor’s forecasting service is one response to this challenge and falls within the scope of short-term action plans envisaged in the air quality Directive.

However the Directive and the UK daily air quality index were conceived around a decade ago. This was before the widespread adoption of smart phones, with the first ones being marketed in 2008 and the roll out of 4G following its technical definition in 2010. Developments in behavioural economics and behaviour change have also been rapid over the last decade. A recent study on the air quality alerts with the CityAir app[14] highlights the potential for messaging to be redesigned to address barriers changing behaviour rather than just advising people of moderate, high or very high air pollution. Currently direct messaging targets vulnerable people and asks them to take protective actions but this could be extended to encourage pollution reduction by the wider society.

[14] D’Antoni et al (2019) Environment International 124:216-235

There is more work still to be done to make sure alerts messaging meets vulnerable groups. The GLA has stated that it is currently undertaking a review evaluating how to further improve London's air quality alerts system, including by adopting the same approach as used by the NHS for COVID-19 messaging, ensuring vital information reaches the most vulnerable and at-risk Londoners.

3 Conclusions

This report adds to previous work, particularly in drawing together all the relevant material in one place. While health impacts of episode days have previously been analysed[15], this work applied analysis to London for the first time and included a wider range of health outcomes. Intervention studies have been reviewed previously but not with a particular focus on emergency measures in particular. The work also involved speaking to contacts in other cities to obtain, for example, Government reports that are not easily available from searches of journal articles. While forecasting accuracy has been discussed previously, this was not for this particular dataset or with the perspective of forecasting specifically for consideration of emergency measures.

Summary

We came to the following conclusions:

- (i) Air pollution episode days in London do have impacts on health.
- (ii) The largest impact is from moderate days rather than high or very high days because the former are more frequent.
- (iii) Some direct studies of interventions to reduce air pollution in the short-term have shown reductions in negative health impacts but these studies are few in number and difficult to do, as intervention studies are, in general, small in size (and therefore potentially lacking in statistical power), short in duration and often lack a control group in the wider region to control for unrelated time trends in health outcomes.
- (iv) As the greatest health impact is seen from moderate days (because these are much more frequent than the high or very high days), the most effective approach to reducing the health impacts of episode days will be to reduce overall air pollution levels with long-term air pollution reduction policies.
- (v) A review of the effectiveness of emergency measures to reduce pollution implemented in other places found they reduce pollutant concentrations, if sufficiently ambitious. However, the reductions in concentrations achieved in these places were not as large as required to bring concentrations down from the levels on high or very high days to the levels on low or even moderate days. Studies also raised important questions about long-term public compliance with traffic restrictions.
- (vi) Forecasting of air pollution episodes in London is deliberately precautionary at present as the primary aim of the Mayor's alert system is to be able to issue protective health advice to populations with specific health conditions[16]. This approach is not best suited to forecasting for the purpose of implementing emergency measures, which may be expensive and require actions from the whole population.
- (vii) The issuing of protective health advice on episode days should, of course, be maintained and could be supplemented with advice on voluntary individual actions to reduce air pollution.

[15] E.g. http://erg.ic.ac.uk/research/home/aspire-project.html
[16] See footnote 2.

(viii) The points above relate to evidence relevant to the principle of implementing emergency measures. This research does not evaluate different scenarios for London-specific emergency measures[17]. Scenario testing was dependent on the existing evidence base discussed in this report justifying investment in a future work programme of scenario modelling, which it did not.

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5 References

The reports below can be found on the project page at the following link http://erg.ic.ac.uk/research/home/emergency-measures-project.html

Report A

Walton H and Yan L (2020) Health Effects of Short-Term Exposures to Air Pollution With Particular Reference to the Concentration Range on High and Very High Days

Report B

Walton H, Baker T, Evangelopoulos D and Fuller G (2020) Health Impacts of Air Pollution Episodes in London 2009-2017

Report C

Fuller G, Baker T and Walton H (2020) Effectiveness of short-term (emergency) actions to control urban air pollution – review of schemes

Report D

Fuller G, Baker T and Walton H (2020) Forecasting Accuracy for Emergency Measures

[17] See footnote 3.