**CLEAN AIR ADVISORY PANEL**

# Impacts of the Covid-19 pandemic on air quality in Wales: March to October 2020

Prepared for:

Welsh Government Clean Air Programme

December 2020

**Terms of Reference**

The Clean Air Advisory Panel (CAAP) is an independent committee which provides evidence-based advice and recommendations to the Welsh Government Evidence, Innovation and Improvements Project Team on air quality matters in Wales. CAAP helps to underpin decision making of the Welsh Government Clean Air Programme Board and supports the development and improvement of Welsh Government air quality policy. Members of the Panel consist of multi-disciplinary policy makers, academia and air quality and public health practitioners.

CAAP's functions are to:

- Independently advise on and provide scientific evidence to support the development of Welsh Government clean air policy.

- Advise on current evidence in relation to air quality and its relationship with associated environmental, public health and economic factors.

- Work collaboratively across government, industry and academia, to ensure actions taken to improve airborne pollution in Wales are based on robust evidence.

- Encourage and maximise opportunities for innovative solutions which help to improve levels of airborne pollution.

- Advise the Welsh Government on future evidence needs and how they can be met.

**Membership**

| Member | Organisation |
|---|---|
| Prof. Martin Williams | Imperial College London |
| Prof. Paul Lewis | Swansea University |
| Prof. Enda Hayes | University of the West of England |
| Prof. Dudley Shallcross | University of Bristol |
| Prof. William Bloss | University of Birmingham |
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| Tom Price | Environmental Health Wales & The Wales Pollution Expert Group |
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| Alison Thomas | Transport Policy, Welsh Government |
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| Ross Hockley | Industrial Regulation Policy, Welsh Government |
| Dr Neil Paull | Economist, Welsh Government |
| Calum Shaw | Clean Air Bill Manager, Welsh Government |
| Jessica Macha | Air Quality Policy, Welsh Government |

**Tribute to Martin Williams**

Martin was a much valued and liked member of the Clean Air Advisory Panel, helping shape advice to Welsh Government on air quality policy in Wales and its underpinning evidence.

Martin brought a wealth of knowledge, experience and insight to the Panel. Most recently Martin was instrumental in the development of this advice and advice on future air quality targets for Wales. He was able to seamlessly translate complex air quality evidence into coherent policy advice having been an expert scientist with international standing and a senior civil servant during his long and distinguished career.

Working with Martin was a pleasure. Despite his clear credentials he was unassuming, supportive and always willing to listen to others. He brought a calmness and credibility to discussions, often with humour and a smile, even in complex or challenging situations.

His contribution to the Panel will help to lay the foundations of future air quality policy and legislation for the benefit of future generations in Wales. Being originally from Wales, we think this is something he is likely to have been proud.

Martin was very much liked and highly respected internationally, nationally and by all on this Panel. He will be greatly missed.

**Introduction**

The Clean Air Advisory Panel has considered key questions posed by Welsh Government regarding changes in air quality during the Covid-19 pandemic between March to October 2020 and the implementation of intervention measures. This report provides an understanding of the current evidence, an insight into the uncertainties and evidence gaps and recommendations for future policy development and evidence.

The questions considered in this review include:

Q1. What are the key benefits and dis-benefits for air quality in Wales as a result of the restriction on movement in Wales during the lockdown phase of the pandemic?

Q2. What evidence is emerging, or could be developed, around this period which could be used to support Welsh Government's decisions on air pollution mitigation measures for future policy development?

Q3. What evidence could be (or is being) developed in the longer term to understand the implications of the current situation for public health, habitats and potential mitigation measures, and how could it be done?

Q4. Does air pollution exposure (long-term, historic) increase COVID-19 health risks?

**Q1. What are the key benefits and dis-benefits for air quality in Wales as a result of the restriction on movement in Wales during the lockdown phase of the pandemic?**

***Benefits:***

- Lockdown measures taken to control the coronavirus pandemic around the world have generally had a positive impact on air pollution, and early studies showed a significant reduction in concentrations of $NO_2$ in the UK, including Wales, such as the work done by Ricardo[1]and Swansea University[2]. For the UK, the Air Quality Expert Group (AQEG[3]) report (Estimation of changes in air pollution emissions, concentrations and exposure during the COVID-19 outbreak in the UK[4]), provided evidence showing that the most pronounced changes in UK air quality during lockdown were in the urban environment and most notably for $NO_x$. Mean reductions in urban $NO_x$ averaged over the lockdown period were estimated at 30-40% with mean $NO_2$ reductions of 20-30%. In general, NOx and $NO_2$ reductions were greater at roadside than at urban background sites. The reductions in road NOx emissions were associated with increased ozone, as expected from the well-understood atmospheric chemistry. Meteorological conditions led to higher $PM_{2.5}$ during early lockdown than the average experienced in equivalent calendar periods from previous years but contributing sources and transboundary influences needed to be determined. In Scotland, $NO_2$ concentrations and mean outdoor $PM_{2.5}$ concentrations were significantly lower in the 2020 lockdown period than in the previous 3 years but despite UK motor vehicle journeys reducing by 65%, $PM_{2.5}$ concentrations in 2020 were within 1 $\mu g/m^3$ of those measured in 2017 and 2018 suggesting that traffic-related emissions may not explain variability of $PM_{2.5}$ in outdoor air in Scotland. [5]

- A Welsh Government commissioned report ("Provisional Analysis of Welsh Air Quality Monitoring Data – Impacts of Covid-19") by Ricardo Energy and Environment provided a provisional analysis of air quality monitoring data pre- and during Covid-19 lockdown [6]. Ricardo also used statistical models to estimate the effect of Covid-19 lockdown actions on for NOx, $NO_2$, $O_3$ and $PM_{2.5}$ from January 2018 to 31st May 2020 accounting for meteorological factors. Their findings are summarised as follows:

    - From 16th March (start of social distancing) to 31st May 2020 it was estimated that $NO_2$ concentrations decreased on average by 36% at roadside sites in Wales. Furthermore,

[1] Carslaw, D. (2020). Analysis of COVID-19 lockdown on UK local air pollution. https://ee.ricardo.com/news/analysis-of-covid-19-lockdown-on-uk-local-air-pollution

[2] Lewis, P.D., Seller V.T., Price, T., Eskandari H. (2020). Estimation of ambient NO2 and PM2.5 concentration change in Wales during COVID-19 outbreak (as submitted to AQEG & Welsh Government).

[3] The AQEG provides independent scientific advice on air quality to Defra and the devolved administrations

[4] AQEG Report: Estimation of changes in air pollution emissions, concentrations and exposure during the COVID-19 outbreak in the UK (https://uk-air.defra.gov.uk/library/reports.php?report_id=1005)

[5] Dobson R., Semple S. (2020) Changes in outdoor air pollution due to COVID-19 lockdowns differ by pollutant: evidence from Scotland. Occup Environ Med.,77(11):798-800.

[6] Provisional Analysis of Welsh Air Quality Monitoring Data – Impacts of Covid-19. Ricardo Energy & Environment. https://airquality.gov.wales/reports-seminars/reports

NOx was estimated to have decreased by 49%. There were smaller estimated reductions at urban background sites.

- Ozone increased by 18% on average, with stronger increases at locations that usually experience highest $NO_x$. This is not unexpected since ozone reacts with NO to produce NO2, so less NO means less ozone is depleted. This is demonstrated by the noticeable local increases in ozone at traffic and urban sites. However, the warm sunny weather during this period will also have contributed to this increase as ozone is formed from photochemical reactions between other air pollutants and sunlight [7].
- $NO_x$ concentrations at the end of May were still considerably lower than expected and it was proposed to extend the analysis further to show how concentrations recover and the potential impact of increased congestion.
- The period after lockdown experienced much higher average concentrations of $PM_{2.5}$ (11.4 $\mu g.m^{-3}$) than the period from 1st January to lockdown (8.2 $\mu g.m^{-3}$) likely associated with the significant shift in synoptic meteorology between Jan-March and April-May [4] .
- Due to the Covid-19 restrictions it was estimated that the local contribution to $PM_{2.5}$ concentrations has decreased by less than 1.0$\mu m^{-3}$ on average across all urban monitoring sites in Wales although there is uncertainty in the estimate due to the small size of change.
- Decreases in $NO_x$ and $PM_{2.5}$ (with the exception of transboundary related increases) were estimated to be primarily during the daytime and consistent with a pattern of reduced road traffic although the small changes associated with $PM_{2.5}$ have a high degree of uncertainty.
- Reductions in the local contribution to $PM_{10}$ concentrations were estimated at around 2-3 $\mu g.m^{-3}$ although again caution was advised in interpretation due to uncertainties in factors influencing regional background levels used for comparison.
- Analysis of a limited sample of traffic data showed a significant drop in the car/light van and bus flows at the time of the lockdown and there appeared to be a clear correlation between the drop in vehicle numbers and the reduction in NOx concentrations. Analysis of black-carbon in Cardiff showed that concentrations were decreasing before lockdown and the reduction was accelerated at the time of lockdown being around 45% of model predicted levels based on data from previous years ('business as usual').

- Early data also permitted a preliminary assessment and comment by Public Health Wales on air pollution changes and provided additional data on the impacts of transport. The report also highlighted the difficulties in quantifying the impacts on health given data issues and the fact that ozone increases could offset the benefits of $NO_2$ decreases [6]. It is noted however that these issues should not provide a reason to reduce efforts to tackle road vehicle emissions.

[7] Air pollution impacts of Covid-19 response (Wales): A public health opinion. Public Health Wales. https://airquality.gov.wales/reports-seminars/reports

- NO and $NO_2$ concentrations have reduced as expected from a reduction in vehicle journeys, as fewer people make trips for business and private purposes. Reductions are evident across roadside and urban background monitoring stations in South and North Wales.

- $NO_2$ decreases will be especially significant at points where congestion is 'normal': busy junctions and heavily trafficked roads. Exposure is also likely to have decreased for populations living in $NO_2$ related Air Quality Management Areas. This effect is likely to be most significant at the times of day when peak traffic flow ('rush hour') is usually experienced, which may have resulted in a decrease in the number of hours when the daily mean Limit Value for $NO_2$ is breached.

- Some active travel routes would be expected to be cleaner, so people walking and cycling will do so in cleaner air. Additionally, fewer vehicles on the road may give walkers and cyclists a greater sense of safety.

- Emissions associated with aviation, and, to a lesser extent, shipping are also likely to have decreased.

- In-vehicle exposure (cars, buses and trains) is, overall, likely to decrease, as the percentage of individuals working from home, and therefore not commuting to work, increases.

- There will have been a likely decrease in industry-related emissions of $NO_2$, $PM_{2.5}$, $PM_{10}$ and $SO_2$ as heavy industries slow or halt production. This will potentially impact on both background concentrations on a regional level, and point source concentrations at discrete locations adjacent to key industries.

- The public perception of air pollution, and broader urban environmental issues (e.g. noise), may have changed during the lockdown as it is the first time that many would have experienced a positive step change in pollution levels.

***Disbenefits***:

- $PM_{10}$ and $PM_{2.5}$ concentrations across Wales significantly increased in the days immediately after lockdown and for 3 further periods in April and early May compared to levels pre-lockdown. Back trajectory modelling showed that increased $PM_{2.5}$ concentrations over this period were strongly associated with transboundary sources from continental Europe facilitated by easterly winds [5]. This pattern has been observed in previous years however and with a reduction in traffic in continental Europe, it was suggested that these increased levels in PM2.5 were due to ammonium nitrate. Therefore, it is very unlikely that the increased levels of PM2.5 in April 2020 were a consequence of lockdown.

- The increases in particulate levels may also be due to private incineration of waste as well as an increase in other domestic combustion via wood burners and open fires. The increase in private incineration might be due to public access to civic amenity sites being restricted. Depending on the type of waste that is burned, this could lead to the release of a variety of pollutants,

including PAHs, dioxins and furans alongside smoke nuisance.

- During lockdown, people are spending longer indoors with increased exposure to indoor air pollution. It is possible that an increased amount of cleaning and an increase in the use of aerosol cleaning products could be worsening indoor air pollution.

- Levels of ozone are higher than would have been expected in the absence of lockdown measures, related to the well-understood NO-O3 atmospheric chemistry (reduced occurrence of the NO+O3 titration effect). .

**Q2. What evidence is emerging, or could be developed, around this period which could be used to support Welsh Government's decisions on air pollution mitigation measures for future policy development?**

- Work by the Centre for Health and Environmental Management Research & Innovation at Swansea University[2], also published in the AQEG report, shows that in Swansea, since the UK lockdown was announced on 23rd March 2020, there had been a significant decrease in nitrogen dioxide ($NO_2$) when compared with the trend for the previous ten years and accounting for variations in weather pattern. The association between $NO_2$ concentration change and traffic count for different classes of vehicles in the city during this period showed that $NO_2$ reduction was associated with car reduction but not (or less so) with HGV and buses. Additionally, early analysis of $NO_2$ concentrations in some urban areas in Wales suggest that we are already seeing a 'bounce-back' in $NO_2$ during July, August and September 2020 due to increases in traffic volumes (this 'bounce-back' may be slowed by localised lockdowns in October 2020)[8].

- As we transition out of the lockdown period it will be critical to monitor the impact on air quality and emission levels of any return to pre-lockdown levels of motorised transport along key transport corridors. The impact of reductions in traffic flows and corresponding increases in active travel levels provides an opportunity to perform real world testing of the impact that a significant reduction in motorised vehicle journeys would have on local air quality, particularly in areas that are currently designated as Air Quality Management Areas. A similar assessment by monitoring should be made around schools and other key trip generators to assess the current levels (to act as a baseline) and then allow a full reflection of the impact of re-introducing motorised transport around the school environment.

- It is important to note $NO_2$ reduction is not due to technological improvements but is a consequence of fewer journeys due to changes in behaviour patterns. This illustrates the important role that changes in social practices can have and the need for future interventions to consider how to improve local air quality via societal innovation as well as technological innovation.

[8] Hayes, E. (2020). Air Quality, Clean Air Legislation and Behaviour Changes Needed in Wales, Presentation to the Cross-Party Group Clean Air Act for Wales, 6th October 2020.

- The CAST Centre (www.case.ac.uk) undertook a UK survey to explore if Covid-19 has impacted low carbon lifestyles and attitudes towards climate action[9]. This UK wide survey, of >1,500 participants, determined that lockdown has resulted in:
    - a rise in online shopping - increased from 12% pre-lockdown to 25% now.
    - a rise in working from home – increased from 11% pre-lockdown and 36% now.
    - an appetite to continue working from home when lockdown restrictions are removed as working from home has been perceived as a positive experience.
    - less flights for holiday or leisure purposes and more online rather than face to face meetings.
    - less likely to use public transport due to health concerns.

- Children walking to school (urban located schools), particularly for primary schools would alleviate traffic and reduce pollution. Secondary school students will be more likely to walk or cycle, but parents and carers will often take their children to primary school.

- While analysis of air quality data during this period is essential to help understand the trends and impacts of the lockdown on specific pollutants, an understanding of the social implications of the restrictions is equally important especially when planning the transition out of lockdown. The current crisis has exposed the scale of radical change required to reduce roadside levels of nitrogen dioxide (and carbon emissions) and thus the inadequacy of existing incremental and often techno-centric approaches to its management.

- How Wales approaches the post-lockdown transition is critical. On the one hand, there is the strong risk that many governments may already be progressing towards a recovery based on the old Business-as-Usual model (perhaps exacerbated by citizens' reticence to use public transport because of health concerns and/or increase in economic activity ). On the other hand, cities like Milan, Paris or Brussels are working towards reimagining commuting patterns and investing in active travel to avoid returning to severe pollution levels of the pre-lockdown periods. We also see this in UK cities where pop-up cycling infrastructure has been widely welcomed and utilised.

- The public perception and awareness of air pollution has shifted during lockdown. Much like the London Smogs in the 1950 created a seismic shift in the public willingness to accept (or not accept) poor air quality, the Covid episode of 2020 has also given the public an insight into what is possible re air quality (and broader environmental improvements). Initiatives such as ClairCity (www.claircity.eu) can provide advice to shift the debate on air pollution. How can we use the evidence from the lockdown to support our public engagement and public health messages? The public have experienced notable, step change increases in air pollution in the past through air pollution episodes but this is the first time the public would have experienced notable step change air pollution reductions in their towns and cities.

[9] Whitmarsh, L. (2020). Behaviour changes for clean, green travel, Presentation for Environment Platform Wales, 7th September 2020.

- Data reflecting changes in ammonia concentrations in rural areas during lockdown may assist us in apportioning the concentration of ammonia attributable to trans-boundary impacts and that from local sources. Initial work submitted by the UK Centre for Ecology and Hydrology to AQEG [2] suggests that, for the UK, urban background[10] and urban on road and roadside emissions of ammonia are likely to have decreased by as much as 30% and 90% respectively compared with normal emissions before COVID-19. However, the total ammonia emissions are likely to have decreased by only around 2% due to the dominance of agricultural emissions.

- Bristol University are investigating whether private incineration as well as hospital and crematorium incineration of waste has contributed to a significant additional source of particles and could be explored further for Welsh hospitals.

**Q3. What evidence could be (or is being) developed in the longer term to understand the implications of the current situation for public health, habitats and potential mitigation measures, and how could it be done?**

- It should be noted that the above evidence in Q1 and Q2 is collated over a short period of time during the spring/summer months. The impact of Covid-19 and the national/local lockdowns will vary substantially across Wales. The evidence available to date indicates that air pollution emissions and concentrations have changed during different phases of lockdown (temporal variation), at different locations across Wales (spatial variation) and depending on different pollutants (e.g. $NO_2$, PM, $O_3$).

- Wales contains many areas that experience high levels of deprivation. Deprivation acts as an amplifier for the negative effects on health of air pollution[11] such that populations in deprived areas suffer proportionally higher rates of respiratory and cardiovascular ill-health. Research by the Office for National Statistics (ONS) suggests that incidence of COVID-19 cases is similarly higher in such areas when compared to the incidence in more affluent areas. It also suggests living in a deprived area also increases an individual's risk of developing severe disease[12], although causative relationships have yet to be established.

- A number of key questions and suggestions were proposed by members of the panel concerning changes in pollutant levels, health and environmental effects and societal change that could be considered for further research:

[10] 'The total concentration of a pollutant comprises those from explicit local emission sources such as roads and chimney stacks, and those that are transported into an area by the wind from further away. If all the local sources were removed, all that would remain is that which comes in from further away; it is this component that is called background'. Background Concentration Maps User Guide, May 2019. https://laqm.defra.gov.uk/documents/2017-based-background-maps-user-guide-v1.0.pdf

[11] Brunt, H., Barnes, J., Jones, S., Longhurst, J., Scally, G. and Hayes, E. T. (2017). Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. *Journal of Public Health*, 39 (3):485-497.

[12] Office for National Statistics. (2020). Deaths involving COVID-19 by local area and socioeconomic deprivation: deaths occurring between 1 March and 17 April 2020.

- Have any reductions in $NO_2$, $PM_{2.5}$, $PM_{10}$ and ozone concentrations (overall and at peak times) relative to pre-lockdown restrictions, had a significant effect on health outcomes of vulnerable people including a reduction in hospital admissions for respiratory and cardiovascular symptoms (and whether this offsets hospital admissions due to COVID-19)?

- There is a correlation between air pollution, health and socio-economic status in Wales. It is therefore pivotal that we explicitly recognise and address these inequalities as we deal with current and future health and environmental crises if we want new approaches to succeed. Enhancing local air quality management to maximise public health integration, collaboration and impact in Wales should be the first step[13].

- What impact has deprivation, and other socio-economic and/or demographic factors, had on rates of hospital admissions for respiratory and cardiovascular disease during the lockdown period?

- How do we consolidate the cultural change needed to retain and normalise the more desirable social practices driving the observed pollution reduction (e.g. homeworking) while reducing negative impacts (e.g. increased domestic energy demand including biomass burning)? Furthermore, how do we support behaviour changes associated with increased homeworking to minimise increases in exposure to indoor air pollution.

- The current crisis has illustrated the role of societal change and behaviour in reducing air pollution and emphasises the importance of social sciences (such as social practice theory) to the air quality management process. People have had to adapt to different working patterns, which emphasised online connectivity and remote working over commuting. Social practice changes should also go beyond just commuting and can also consider other daily practices such as leisure, shopping, school runs etc. A cultural shift centred on sustainability and health benefits is required to normalise this practice, which would give people more flexibility and control over their travel choices, as well as creating potential for significant efficiency savings and congestion reduction[14]. Initiatives such as ClairCity (www.claircity.eu), WeCount (www.we-count.net) and CAST (https://cast.ac.uk/) can provide the qualitative and quantitative evidence to support this.

- How can societal change be tackled in a way that is sustainable, democratic and consensual and that, crucially, does not perpetuate current patterns of inequality and social injustice in exposure to air pollution or the measures to reduce it?

[13] Brunt, H., Barnes, J., Longhurst, J., Scally, G. and Hayes, E. T. (2018). Enhancing local air quality management to maximise public health integration, collaboration and impact in Wales, UK: A Delphi study. *Environmental Science & Policy*, 80:105-116.
[14] Giovanis, E. (2018). The relationship between teleworking, traffic and air pollution. *Atmospheric Pollution Research*, *9*(1):1-14.

- How can we use the evidence from the lockdown to support our public engagement and public health messages? The public have experienced notable, step change increases in air pollution in the past through air pollution episodes but this is the first time the public would have experienced notable step change air pollution reductions in their towns and cities. The Covid episode of 2020 has given the public an insight into what is possible regarding air quality (and broader environmental improvements). This is a major public engagement opportunity and the Welsh Government's Clean Air Plan should be ambitious and utilise communication campaigns to build upon this public appetite for cleaner environments.

- Did high levels of ammonia from agricultural use in Northern Europe lead to high levels of $PM_{2.5}$ during the early stage of lockdown? Early data from back trajectory modelling suggests this to be the case [5] but the contribution of local sources should also be quantified. Evidence should be provided whether ammonia pollution was able to spread further and in higher concentrations due to lack of $NO_x$ to react with. This data could help inform longer term whether a continued decrease in traffic-emitted $NO_2$ could actually contribute to ammonia-related seasonal increases in $PM_{2.5}$ episodes. In addition, there needs to be a better understanding of the sources of rural ammonia (local and national) and how this could be monitored.

**Q4. Does air pollution exposure (long-term, historic) increase COVID-19 health risks?**

- Several points that follow summarise data from published and pre-published publicly available research examining the relationships between COVID-19 exposure and mortality (published prior to October 2020). We strongly recommend all such data and conclusions drawn should be treated with caution. Evidence for long-term exposure to air pollution and COVID-19 mortality is inconclusive and there are questions over the robustness of data, variable collinearity/confounders and analytical methods applied.

- During the early stages of lockdown, research studies emerged suggesting long-term exposure to air pollution increases vulnerability to the most severe COVID-19 outcomes in countries including the US[15], UK[16], Italy[17] and other European countries [18]after adjusting for potential confounders. Only the US study provided an estimated risk of mortality whereby an increase of

[15] Wu, X., Nethery, R., Benjamin, M. & Braun, D., Dominici, F. (2020). Exposure to air pollution and COVID-19 mortality in the United States: A nationwide cross-sectional study. medRxiv. 10.1101/2020.04.05.20054502.
[16] Travaglio, M., Popovic, R., Yu, Y., Leal, N., Martins, L.M. (2020). Links between air pollution and COVID-19 in England. medRxiv. 10.1101/2020.04.16.20067405.
[17] Conticini, E., Frediani, B., Caro, D. (2020). Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy? Environmental Pollution. 261:114465. 10.1016/j.envpol.2020.114465.
[18] Ogen Y. (2020). Assessing nitrogen dioxide (NO2) levels as a contributing factor to coronavirus (COVID-19) fatality. Sci Total Environ., 726:138605.

1 $\mu$g/m$^3$ in $PM_{2.5}$ was predicted to be associated with an 8% increase in the COVID-19 death rate.

- Another US study found county-level average $NO_2$ concentrations were positively associated with both COVID-19 case-fatality rate and mortality rate with an increase of 7.1% and 11.2%, respectively[19]. There were no significant associations between long-term exposures to $PM_{2.5}$ or $O_3$ and COVID-19 death outcomes. However, it was estimated a 3.4 ug/m3 increase in $PM_{2.5}$ was marginally associated with 10.8% increase in COVID-19 mortality rate.

- Findings in early research outputs were criticised by experts on a number of counts including data not being at an individual level, temporal stage of epidemic curve, linkage of population size in an area to spread rate, cross-level bias in ecological studies, variance in local/regional social distancing policies, underreporting of deaths, social inequalities, lack of variance in spatial assignment of air pollution levels and lack of accounting for clustering of cases and deaths [20, 21].

- A later study by Cole et al. [22] estimated the relationship between long term air pollution exposure and Covid-19 in 355 municipalities in the Netherlands. They also found a positive relationship between $PM_{2.5}$ concentrations, COVID-19 cases, hospital admissions and deaths after controlling for a wide range of explanatory variables. They estimated a municipality with a 1 µg/m$^3$ greater $PM_{2.5}$ concentration will have 9.4 more Covid-19 cases, 3.0 more hospital admissions, and 2.3 more deaths.

- A second UK study with a preprint published online in August 2020 predicted a 0.5% and 1.4% increase in COVID-19 mortality rate for every 1 µg/m$^3$ increase in $NO_2$ and $PM_{2.5}$ respectively, after adjusting for confounding and spatial autocorrelation. The authors concluded the data provided some evidence of an effect of long-term $NO_2$ exposure on COVID-19 mortality, while the effect of $PM_{2\cdot5}$ remains more uncertain.[23]

- A third UK study published in August 2020 found ethnicity, population density and overweight/obesity were all found to have strong independent associations with COVID-19 mortality, at the local authority level although relative risk estimations were not provided.[24]

[19] Liang, D., Shi, L., Zhao, J., Liu, P., Schwartz, J., Gao, S., Sarnat, J., Liu, Y., Ebelt, S., Scovronick, N., & Chang, H. H. (2020). Urban Air Pollution May Enhance COVID-19 Case-Fatality and Mortality Rates in the United States. medRxiv. 2020.05.04.20090746. https://doi.org/10.1101/2020.05.04.20090746.

[20] https://theconversation.com/air-pollution-covid-19-and-death-the-perils-of-bypassing-peer-review-136376

[21] Villeneuve P.J. Goldberg M.S. (2020). Methodological Considerations for Epidemiological Studies of Air Pollution and the SARS and COVID-19 Coronavirus Outbreaks. Environ Health Perspect. 128(9):95001.

[22] Cole, M. A., Ozgen, C., & Strobl, E. (2020). Air Pollution Exposure and Covid-19 in Dutch Municipalities. Environmental & resource economics, 1–30. Advance online publication.

[23] Konstantinoudis, G., Padellini, T., Bennett, J.E., Davies, B., Ezzati, M., Blangiardo, M. (2020). Long-term exposure to air-pollution and COVID-19 mortality in England: a hierarchical spatial analysis. Preprint. medRxiv.2020.08.10.20171421.

[24] Bray, I., Gibson, A., White, J. (2020). Coronavirus disease 2019 mortality: a multivariate ecological analysis in relation to ethnicity, population density, obesity, deprivation and pollution. Public Health., 185:261-263.

- Due to the findings of some of the early studies in the US and Italy, the Scientific Advisory Group for Emergencies (SAGE) asked the Office for National Statistics (ONS) to take the lead in investigating UK data for any correlations between common air pollutants that are known to impact respiratory and cardiovascular health and rates of COVID-19 related mortality. In August 2020, the ONS subsequently published a report 'Coronavirus (COVID-19) related mortality rates and the effects of air pollution in England'. [25] Given criticisms of previous studies that failed to account properly for collinearity of confounding factors and varying rates of infection across geographical areas, the ONS study grouped geographic areas according to Indices of Multiple Deprivation (IMDs), population density and average $PM_{2.5}$ exposure over five years. This also meant regional variations in infections would, to some degree, be also smoothed out. Key findings are summarised as follows:

    - Their modelling showed that $NO_x$, $NO_2$ and $PM_{2.5}$ all had a strongest association between mortality and 10-year exposures but correlation was reported as weak.

    - The estimated correlation between air pollution and age-adjusted COVID-19 mortality rates was higher earlier in the pandemic compared to later on as the disease spread more widely.

    - As lockdown progressed week by week, the correlation between $PM_{2.5}$ and mortality fell rapidly but then stabilised mirroring the slowing death rate change. It was not clear whether the remaining air pollution effect showed an independent causal association or reflected other factors.

    - Further modelling was carried controlling for sex, ethnicity, Indices of Multiple Deprivation (IMDs), smoking rates, cardiovascular co-morbidities for COVID-19, "other" co-morbidities for COVID-19, and population density.

    - When controlling for ethnicity, air pollution exposure had no statistically significant impact on COVID-19 deaths. Furthermore, there was significant collinearity between ethnicity and air pollution. It was suggested that if there was a causal link between air pollution and COVID-19-related mortality, it would partially explain the disparities in COVID-19 outcomes for minority ethnic groups. However, ethnic minorities were more likely to live in polluted areas.

    - Estimated odds ratios for a 1 $\mu g\ m^{-3}$ change in long-term average exposure to $PM_{2.5}$ were between 1.01 (statistically insignificant) and 1.07 (when ethnicity is removed from the model entirely).

    - Estimated odds ratios for a 1 $\mu g\ m^{-3}$ change in long-term average exposure to $NO_2$ were between 1.006 (statistically insignificant) and 1.02 (when ethnicity is removed from the

[25] Office for National Statistics: Coronavirus (COVID-19) related mortality rates and the effects of air pollution in England, 13th August 2020.

model entirely).

  - The report concludes $PM_{2.5}$ and $NO_2$ may correlate with increased mortality rates from COVID-19 infection but the scale of impact may be smaller than reported in earlier papers. It was suggested air pollution was unlikely to be the sole driver of differing mortality statistics for minority ethnic groups. Furthermore, the degree of correlation found when ethnicity was not controlled for was likely to be an overestimate of the air pollution effect.

  - A negative correlation with COVID-19 mortality was found for ozone exposure. An explanation suggested exposure to higher ozone might act as proxy for living in the rural environment.

- Further published estimated associations between air pollutants and COVID-19 in other countries have been systematically reviewed in Copat et al [26].

- No reports have currently been published estimating the impacts of indoor air pollution on COVID-19 mortality.

- A number of studies have emerged showing evidence of 'air pollution-to-human transmission' (airborne viral infectivity) of COVID-19. An example of a literature review of some early worldwide data is provided by Domingo *et al*. [27]. Early studies have generally focused on statistical analyses of associations between pollutants, environmental factors such as temperature and humidity, infection rate in people and demographic and geographical factors that can explain the transmission dynamics of COVID-19 over time. [28] Generally, studies conclude urban air pollution, weather and specific climate conditions can have a significant impact on the increased rates of confirmed COVID-19 cases. There is, however, conflicting evidence suggesting $PM_{10}$ does not act as a mechanism for COVID-19 diffusion through the air and that the pandemic's diffusion patterns are caused by a multiplicity of environmental, economic and social factors.[29]

- It is likely that increased data availability over time will increase confidence in quantifying possible COVID-19 susceptibility and air pollution linkage.

[26] Copat, C., Cristaldi, A., Fiore, M., Grasso, A., Zuccarello, P., Signorelli, S. S., Conti, G. O., & Ferrante, M. (2020). The role of air pollution (PM and NO2) in COVID-19 spread and lethality: A systematic review. Environ. Res, 191, 110129.
[27] Domingo, J.L., Marquès, M., Rovira, J. (2020). Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic. A review. Environ Res., 188:109861.
[28] Zoran, M.A., Savastru, R.S., Savastru, D.M., Tautan, M.N. (2020). Assessing the relationship between surface levels of PM2.5 and PM10 particulate matter impact on COVID-19 in Milan, Italy. Sci Total Environ. 10:738-139825.
[29] Bontempi E. (2020). First data analysis about possible COVID-19 virus airborne diffusion due to air particulate matter (PM): The case of Lombardy (Italy). Environ Res., 186:109639.

**Panel recommendations**

1. *Evidence to support Welsh Government's decisions on air pollution mitigation measures for future policy development*

    - Evidence developed by the Centre for Health and Environmental Management Research & Innovation at Swansea University showed NO2 reduction in Swansea during the first UK-wide lockdown period (beginning 23 March 2020) was associated with car reduction but not (or less so) with HGV and buses. It would be useful if further research using traffic count data to correlate against NO2 concentration change could be carried out in other geographical areas in Wales. Further modelling is being carried out to study the longitudinal patterns for PM2.5, ozone and ammonia in Wales during lockdown.

    - Walking buses, clean route maps could all help parents to choose to walk rather than drive their children.

    - Consideration should be given to how public transport use is unlikely to return to pre-lockdown levels in the short term (in China 92% of car use has returned to normal but public transport use is 50% of normal use) whether through user choice or social distancing restrictions.

    - Evidence should be collected to determine how working from home and car sharing will reduce primary pollution dramatically and speed up public transport. People should be encouraged to take public transport although the drop-off in use is far higher than for private vehicles. Unless managed carefully, we could see more cars on the road in some areas rather than less after this pandemic.

    - People who have taken up cycling or walking for exercise or to get to work in the reduced traffic should be encouraged to continue to do so. It would also be perfectly reasonable for the Clean Air Plan to advocate more people work from home on a permanent basis or semi-permanent basis supporting the Welsh Government announcement of 30% of workforce to be working from home.

    - The public perception and awareness of air pollution has shifted during lockdown. The Clean Air Plan for Wales should be ambitious and utilise communication campaigns to build upon this public appetite for cleaner environments. Initiatives such as ClairCity (www.claircity.eu) can provide advice to shift the debate on air pollution.

    - Satellite and ground level modelled data for pollutants including $PM_{2.5}$, Ozone and Ammonia could supplement measured data to help determine the contribution of transboundary effects to concentrations observed during lockdown.

2. *Development of longer-term evidence to understand the implications of the current situation for public health, habitats and potential mitigation measures*

- The evidence available to date indicates that air pollution emissions and concentrations have changed during different phases of lockdown (temporal variation), at different locations across Wales (spatial variation) and depending on different pollutants (e.g. NO2, PM, O3 and NH3). A bespoke, Wales-specific, study is recommended to be undertaken to understand these variations when the longer-term data becomes available.

- Data and understanding of quantified reduced traffic-related pollutant concentrations could provide evidence to support future business cases that seek to deliver longer-term interventions which remove, reduce or restrict traffic movements. There is a consensus that more real-time monitoring is required in urban as well as rural areas

- Source apportioned traffic-related air pollution emissions by motive, demographics and income in Wales using pre- and post-lockdown data would allow a new perspective to be developed on air pollution. It would enable the determination of the influence of the 'where' and the 'what' and the 'who' and 'why' on local air pollution. The ClairCity project methodology could support policy development and communication strategies in Wales as it allows the public to connect their lived experiences and daily activities with the generation of pollution.

- Deprivation acts as an amplifier for the negative effects on health of air pollution[30] such that populations in deprived areas suffer proportionally higher rates of respiratory and cardiovascular ill-health. Further research is needed to understand the causes.

- Research should aim to quantify the effects that changes in NO2, PM2.5, PM10 and ozone have had on health accounting for the impacts of COVID-19 morbidity and mortality. Research should also use the evidence created during lockdown to inform strategies to help behavioural, social and cultural changes needed to tackle air pollution and to address inequalities and inform approaches to possible future pandemics.

- The panel recommend there should be consultation with the Committee on the Medical Effects of Air Pollutants (COMEAP) for guidance prior to planning further studies on the impacts of COVID-19 and lockdown on health in Wales.

3. *Long term exposure to air pollution and COVID-19 health risks*
   - Evidence for long-term exposure to air pollution and COVID-19 mortality is inconclusive and there are questions over the robustness of data, variable collinearity/confounders and analytical methods applied. We recommend that evidence should be reviewed and updated every six months.

[30] Brunt, H., Barnes, J., Jones, S., Longhurst, J., Scally, G., Hayes, E. T. (2017). Air pollution, deprivation and health: Understanding relationships to add value to local air quality management policy and practice in Wales, UK. *Journal of Public Health*, 39 (3):485-497.

- Data on links between COVID-19 transmission by air pollutants is premature. We recommend evidence in the emerging literature should also be reviewed and updated every six months.