A preliminary analysis of changes in outdoor air quality in the City of Southampton during the 2020 COVID-19 outbreak to date

A response to DEFRA's Call for Evidence[1] on *Estimation of changes in air pollution emissions, concentrations and exposure during the COVID-19 outbreak in the UK.*

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Summary

Overall we find that:

- 2020 was already a 'cleaner air' year compared to the 2017-2019 average;
- Covid-19 lockdown appears to be amplifying this trend for NO family pollutant emissions with some days recording up to 92% lower NO2 levels than the 2017-2019 average.

However, other days show substantially higher air pollution levels compared to both pre-lockdown and previous years and this is particularly noticeable for levels of PM10 and PM2.5. These periods appear to correlate with certain wind conditions and highlight the importance of meteorological affects and/or pollution sources that are not affected by lockdown. Were it not for these conditions/sources, it seems likely that the lockdown affect in Southampton would be consistent and sustained.

More sophisticated analysis that can control for differing meteorological conditions, variable public holidays (i.e. Easter) and account for other sources of pollutants will be needed to determine the true significance of lockdown affects. We are in the process of collating data and developing statistical models that can be used to do this.

Citation:

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[1] https://uk-air.defra.gov.uk/news?view=259

Contents

Background

This call for evidence asks seven key questions:

1. What sectors or areas of socioeconomic activity do you anticipate will show a decrease in air pollution emissions, and by how much? Are there any emissions sources or sectors which might be anticipated to lead to an increase in emissions in the next three months?
2. Can you provide estimates for how emissions and ambient concentrations of NOx, NO2, PM, O3, VOC, NH3 etc may have changed since the COVID outbreak? Where possible please provide data sets to support your response.
3. What changes do you anticipate in indoor air quality as a result of the Covid-19 pandemic?
4. How might public exposure to air pollution have changed as a consequence of recent restrictions on movement?
5. How might altered emissions of air pollutants over the next three months affect UK summertime air quality?
6. Based on what is already known about air pollutants as respiratory irritants or inflammatory agents, can any insights be gained into the impact of air quality on viral infection?
7. Are there any insights that can be gained from aerosol science on possible viral transmission mechanisms?

In this brief data analysis report we address Question 2 for the City of Southampton using publicly accessible datasets.

Context

On the 16th March 2020 the UK Government invited people to voluntarily use social distancing measures to reduce the spread of COVID-19[2] before imposing a full lockdown from 00:00 on Tuesday the 23rd March 2020[3]. This resulted in unprecedented restrictions on human activities and movement across the UK. The media have reported apparent resulting reductions in air pollution levels, and linked the observed reductions directly to travel restrictions[4]. However, whilst we would assume that lockdown restrictions would reduce emissions and so increase air quality, we have yet to see substantial quantitative analysis of the extent and persistence of any resulting reductions.

This report responds by using publicly available data for the City of Southampton to compare:

- pre and during-lockdown air quality measures
- air quality measures during lockdown 2020 with average measures for the same time periods in the preceding 3 years (2017-2019)

It should be noted that air pollution levels in any given period of time are highly dependent on the prevailing meteorological conditions. As a result it can be very difficult to disentangle the affects of a reduction in source strength from the affects of local surface conditions. This is demonstrated in the following analysis where the forecast high import of pollution from Europe in the week before Easter[5] is clearly visible.

Further, air quality is not wholly driven by sources that lockdown might suppress and indeed that suppression may lead to rebound affects. For example we might expect more emissions due to increased domestic heating during cooler lockdown periods. As a result the analysis presented below must be considered a preliminary 'before meteorological adjustment' and 'before controlling for other sources' analysis of the affect of lockdown on air quality in Southampton.

Data sources

Southampton City Council collects various forms of air quality data at a number of sites across the City[6]. Two of the sites feed data to the UK Automatic Urban and Rural Network (AURN[7]) network. To avoid confusion and 'double counting' we replace the Southampton AURN site data with the data for the same site's data sourced via AURN (see Table 1) using the R openair package (Carslaw and Ropkins 2012).

[2] https://www.gov.uk/government/speeches/pm-statement-on-coronavirus-16-march-2020

[3] https://www.gov.uk/government/speeches/pm-statement-on-coronavirus-22-march-2020 and also https://www.gov.uk/government/speeches/pm-address-to-the-nation-on-coronavirus-23-march-2020

[4] E.g. https://www.independent.co.uk/environment/coronavirus-air-pollution-uk-lockdown-china-italy-covid-19-a9421291.html

[5] https://airqualitynews.com/2020/04/07/people-at-risk-from-coronavirus-warned-with-very-high-air-pollution-episode-predicted-for-uk/

[6] See http://www.hantsair.org.uk/hampshire/asp/Bulletin.asp?la=Southampton

[7] https://uk-air.defra.gov.uk/networks/network-info?view=aurn

Table 1: Sites, data source, number of valid observations and latest data update

Site	Source	N Obs	Last updated
Southampton - Onslow Road (near RSH)	southampton.my-air.uk	82232	2020-04-15 07:00
Southampton - Victoria Road (Woolston)	southampton.my-air.uk	60078	2020-04-01 06:00
Southampton A33 (via AURN)	southampton.my-air.uk /AURN	214025	2020-04-26 23:00
Southampton Centre (via AURN)	southampton.my-air.uk /AURN	334734	2020-04-26 23:00

It should be noted that data sourced from the AURN network that is over 6 months old will have undergone a ratification process[8]. Data less than 6 months old (e.g. the 2020 data used here) has yet to undergo this process.

Preliminary analysis by pollutant

In this report we focus on the following key pollutants:

- NO2 – Nitrogen Dioxide
- NOx – Oxides of Nitrogen
- PM10 - PM10 particulates
- PM2.5 - PM2.5 particulates

In each case we present:

- A brief commentary on the patterns observed;
- A plot of the most recent hourly data from each site;
- A plot comparing the mean daily 2020 values with the mean daily values for 2017-2019 for each site. Note that the 2017-2019 data has been date adjusted so that weekdays and weekends align with 2020 and we use **only** the AURN data for these comparisons to avoid missing data issues with the non-AURN sites;
- A plot showing the % difference between these mean daily values. In this case a negative value indicates a lower value in 2020 relative to 2017-2019;

[8] https://uk-air.defra.gov.uk/assets/documents/Data_Validation_and_Ratification_Process_Apr_2017.pdf

NO_2

1. Large dips in NO_2 levels and reductions in their variance are visible in Figure 1 especially on the weekends of 21-22 March (pre-lockdown), 28-29 March and 18-19 April. On these days NO_2 levels are up to 92% lower than the 2017-2019 average (Figure 3).
2. The data show that 2020 was already a 'cleaner air' year before lockdown, especially in the City Centre (Figure 2, Figure 3) and the dips identified appear to be amplifying this trend, particularly at the A33 site (Figure 3, upper panel);
3. Despite the lockdown affect, it appears that meteorological affects and/or pollution from other sources may still result in poor air quality on certain days such as the week leading up to Easter (Figure 3).

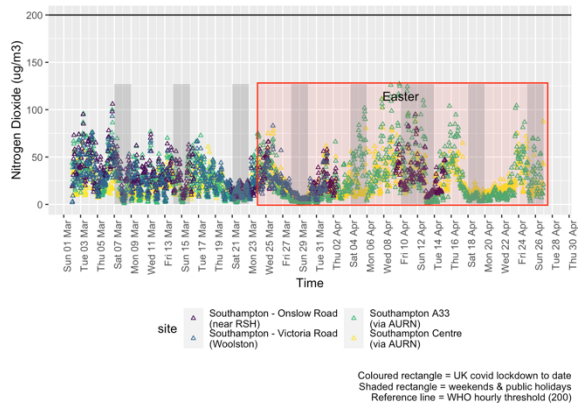

Figure 1: Nitrogen Dioxide levels, Southampton (hourly, since 1st March 2020, all sites)

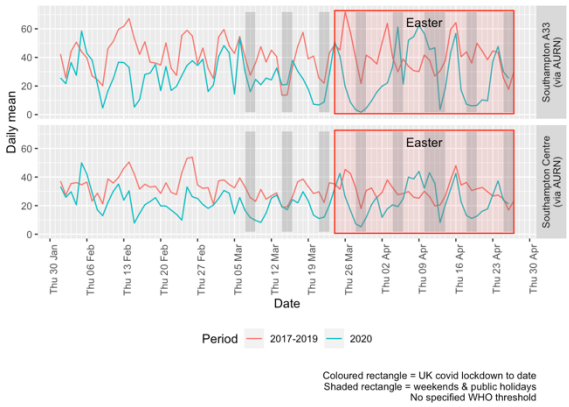

Figure 2: Nitrogen Dioxide levels, Southampton (daily mean since 1st January, 2020 compared to 2017-2019)

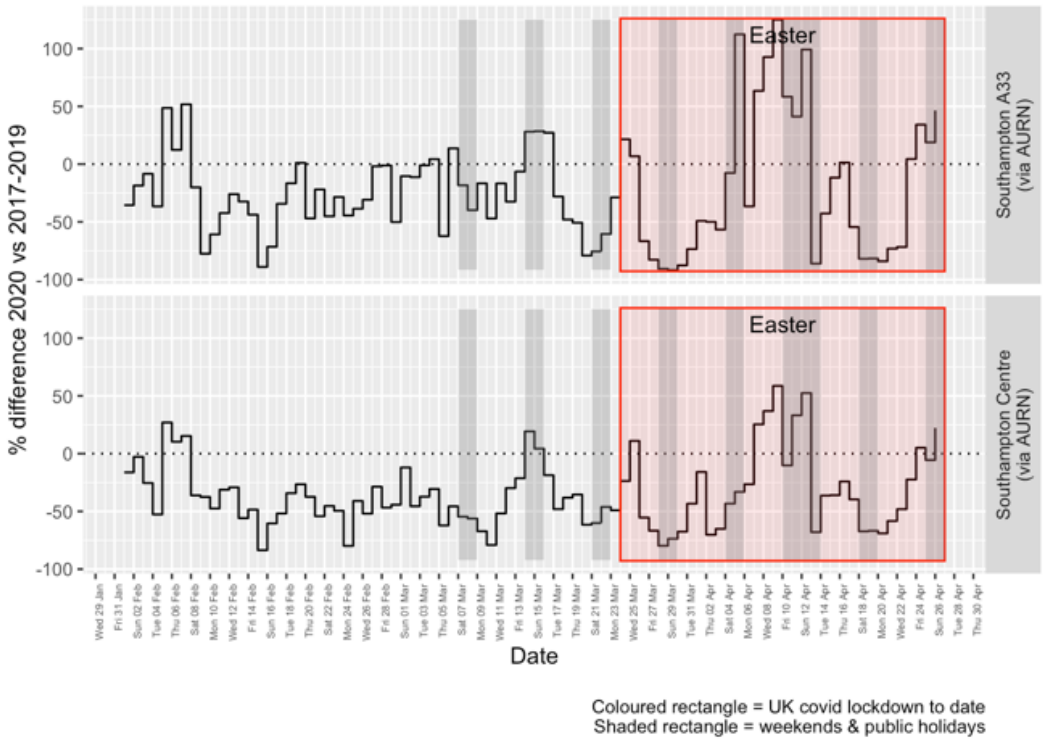

Figure 3: Nitrogen Dioxide levels, Southampton (daily mean % difference since 1st January 2020 compared to 2017-2019, negative values indicate a lower pollution level in 2020 compared to 2017-2019)

NOx

1. Oxides of nitrogen follow roughly the same patterns as NO_2;
2. To the extent that there is a lockdown affect it seems restricted to the A33 site (Figure 6, upper panel).

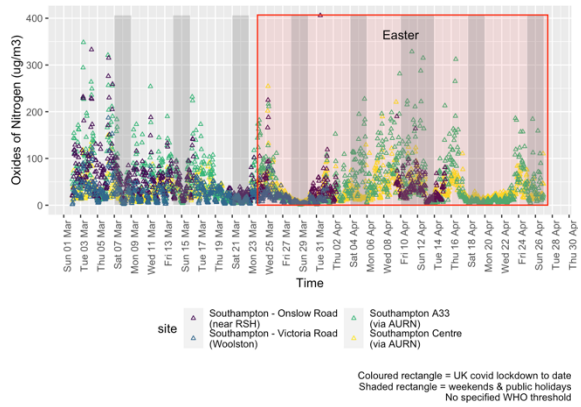

Figure 4: Oxides of Nitrogen levels, Southampton (hourly, since 1st March 2020, all sites

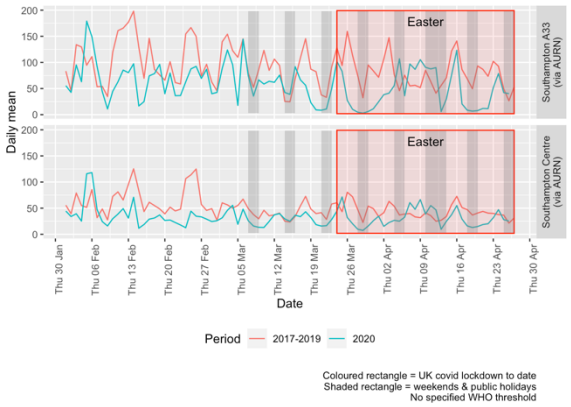

Figure 5: Oxides of Nitrogen levels, Southampton (daily mean since 1st January, 2020 compared to 2017-2019)

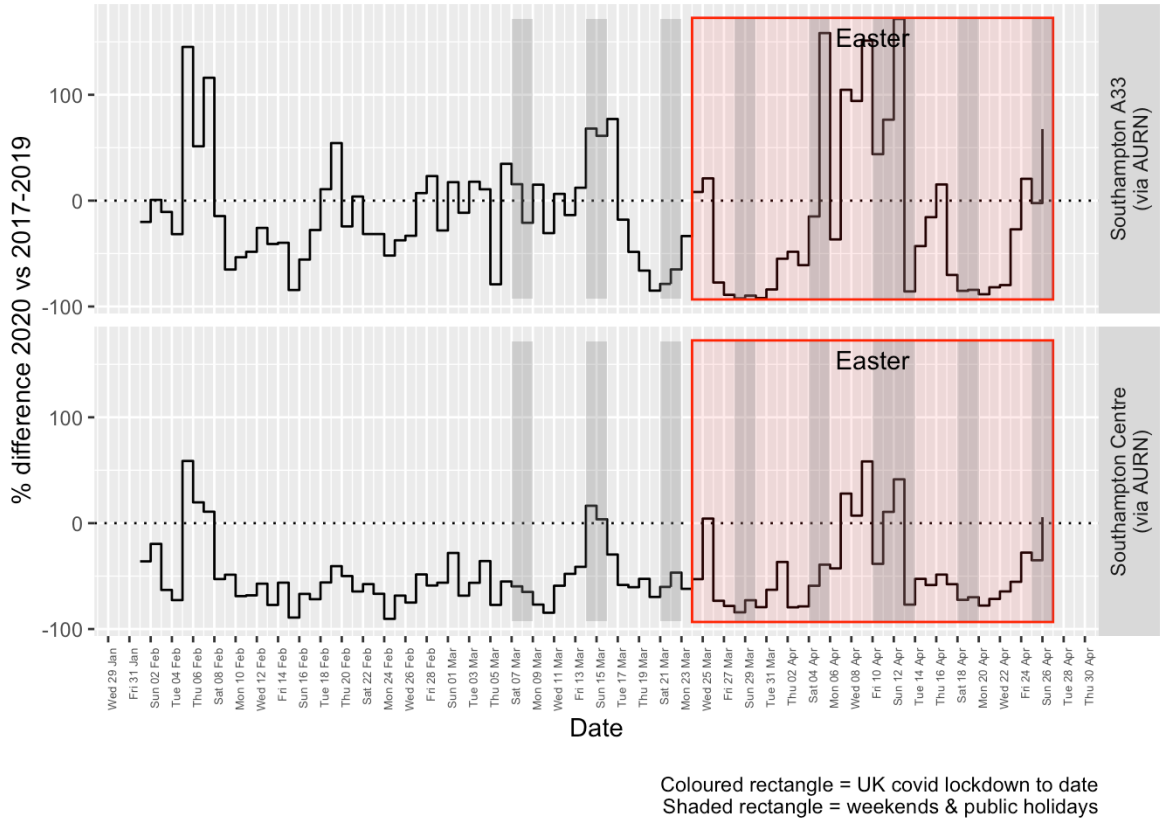

Figure 6: Oxides of Nitrogen levels, Southampton (daily mean % difference since 1st January 2020 compared to 2017-2019, negative values indicate a lower pollution level in 2020 compared to 2017-2019)

PM10

1. PM10 spikes at much the same time as NO_2 (Figure 7) and indeed appeared to breach the WHO threshold guideline over Easter 2020 at each site (Figure 8);
2. PM10 levels were already marginally, but not consistently lower in 2020 than previous years (Figure 8, Figure 9);
3. Compared to pre-lockdown and previous years there are no clear reductions in PM10 levels that can be attributed to a lockdown affect. Indeed if anything, the opposite is the case highlighting the importance of particulate pollution sources and meteorological affects that are not constrained by lockdown (Figure 9).

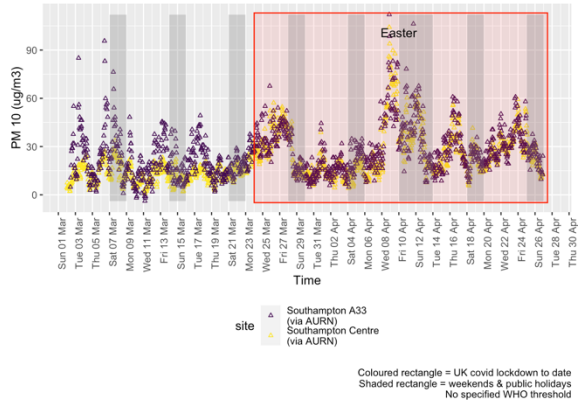

Figure 7: PM10 levels, Southampton (hourly, since 1st March 2020, all sites)

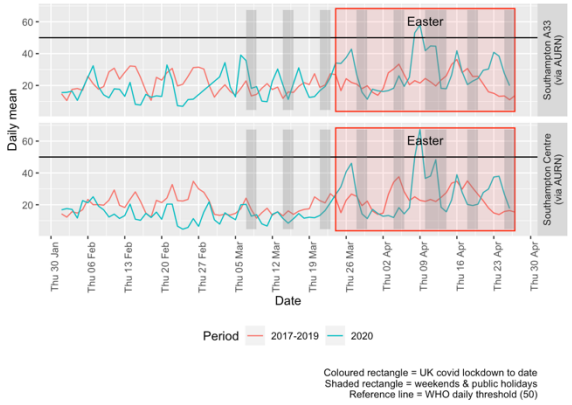

Figure 8: PM10 levels, Southampton (daily mean since 1st January, 2020 compared to 2017-2019)

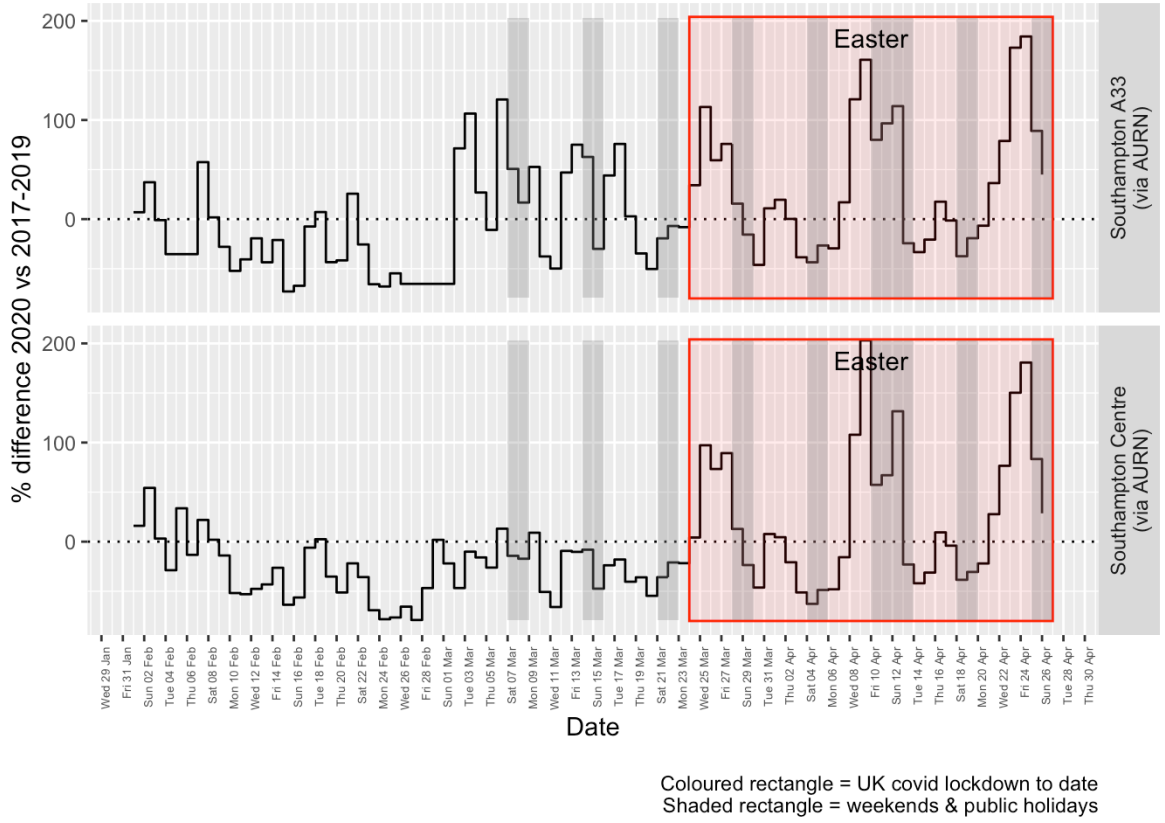

Figure 9: PM10 levels, Southampton (daily mean % difference since 1st January 2020 compared to 2017-2019, negative values indicate a lower pollution level in 2020 compared to 2017-2019)

PM2.5

1. PM2.5 spikes at much the same time as NO_2 and PM10 (compare Figure 7 and Figure 10);
2. Similarly to PM10, PM2.5 levels appeared to breach WHO guideline thresholds on several days, including over the Easter weekend 2020 (Figure 11);
3. As with other pollutants, PM2.5 levels were already marginally lower in 2020 than previous years (Figure 11, Figure 12).
4. Compared to pre-lockdown and previous years there are no clear reductions in PM2.5 levels that can be attributed to a lockdown affect and indeed there have been notable spikes (Figure 12). Again, this highlights the importance of particulate pollution sources and meteorological affects that are not constrained by lockdown.

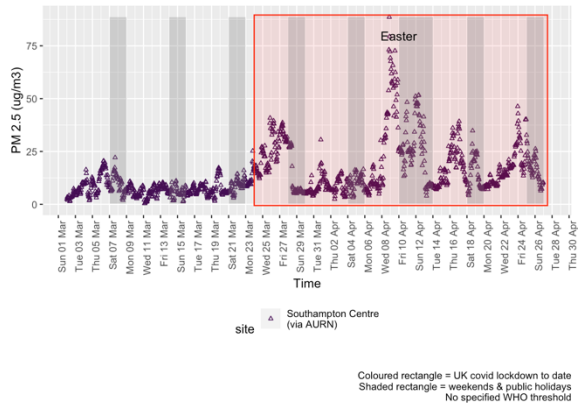

Figure 10: PM2.5 levels, Southampton (hourly, since 1st March 2020, all sites)

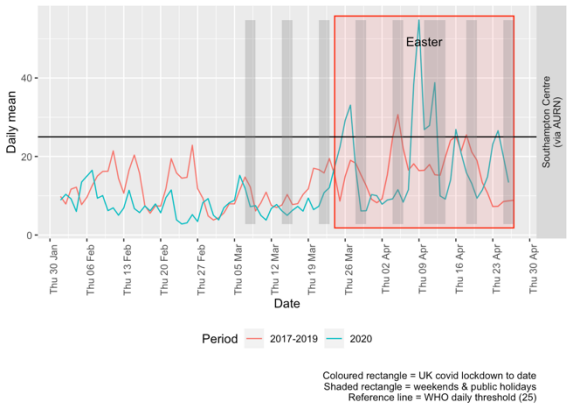

Figure 11: PM2.5 levels, Southampton (daily mean since 1st January, 2020 compared to 2017-2019)

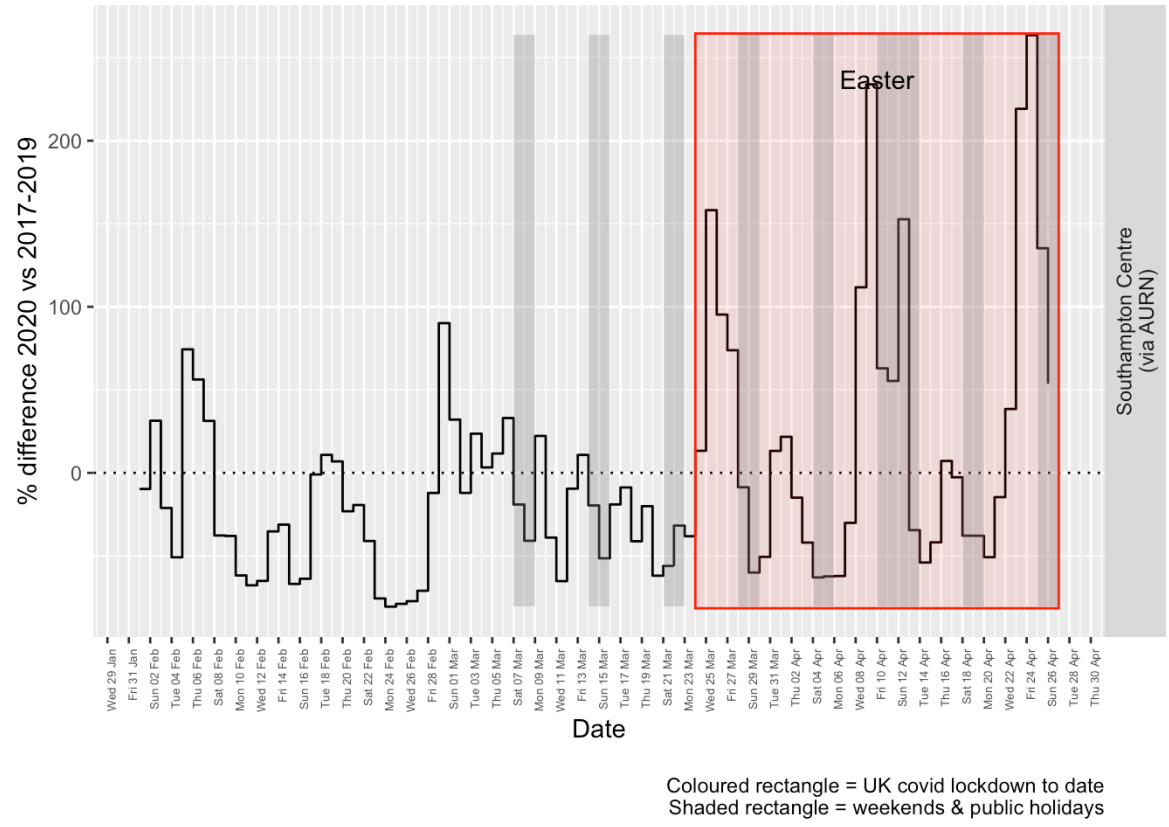

Figure 12: PM2.5 levels, Southampton (daily mean % difference since 1st January 2020 compared to 2017-2019, negative values indicate a lower pollution level in 2020 compared to 2017-2019)

Wind conditions

Figure 13 shows the wind rose for the Southampton sites for three distinct periods visible in the NO_2 data (see Figure 3):

1. 26 March - 4 April (lower NO_2)
2. 7 April - 12 April (higher NO_2)
3. 16 April - 23 April (lower NO_2)

As we can see there are clear differences in the wind conditions which align with the pollution patterns observed:

1. the first period with low NO_2 was dominated by north-north easterly winds (likely to bring reduced-traffic city and motorway air to these sites);
2. the second period when NO_2 and particulates were high was dominated by light south easterly winds (bringing continental air);
3. the third period when NO_2 was low was again dominated by north easterly winds.

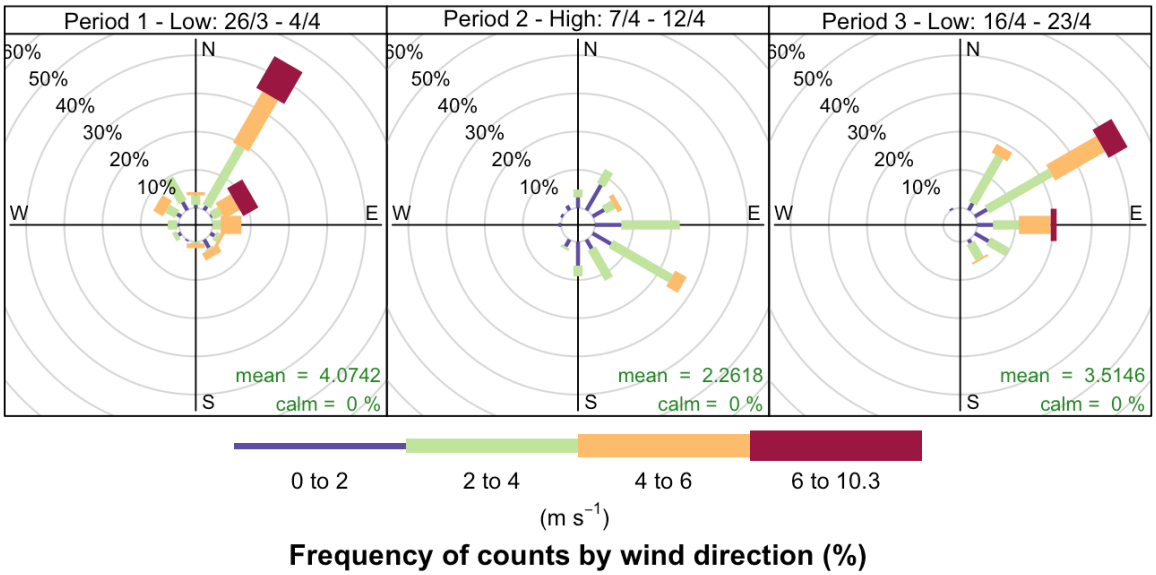

Figure 13: Windrose for Southampton sites by period.

Summary and next steps

Overall we find that 2020 was already a 'cleaner air' year compared to the 2017-2019 average. Lockdown appears to be amplifying this trend for NO family pollutant emissions with some days recording up to 92% lower NO_2 levels than the 2017-2019 average.

However, other days show substantially higher air pollution levels compared to both pre-lockdown and previous years and this is particularly noticeable for levels of PM10 and PM2.5. These periods appear to correlate with certain wind conditions and highlight the importance of meteorological affects and/or pollution sources that are not constrained by lockdown. Were it not for these conditions/sources, it seems likely that the lockdown affect in Southampton would be consistent and sustained.

More sophisticated analysis that can control for differing meteorological conditions, variable public holidays (i.e. Easter) and account for other sources of pollutants will be needed to determine the true significance of lockdown affects. We are in the process of collating data and developing statistical models that can be used to do this.

Updates

We regularly re-run the analysis on which this paper is based with updated data. The latest version is always available at:

- https://cfsotago.github.io/airQual/sccAirQualExplore_lockdown2020.html

This includes updated and more detailed analysis as well as exploration of missing data.

Data and code availability

The data can be downloaded from:

- https://uk-air.defra.gov.uk/networks/network-info?view=aurn and
- http://www.hantsair.org.uk/hampshire/asp/home.asp?la=Southampton

An extract as used for this analysis can be downloaded from:

- https://github.com/CfSOtago/airQual/tree/master/data

The code is available for re-use under the Apache License Version 2.0, January 2004 from:

- https://github.com/CfSOtago/airQual.

Acknowledgements

AURN data is (c) Crown 2020 copyright Defra and available for re-use via https://uk-air.defra.gov.uk, licenced under the Open Government Licence (OGL).

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References

Carslaw, David C., and Karl Ropkins. 2012. 'Openair — An R Package for Air Quality Data Analysis'. *Environmental Modelling & Software* 27–28 (0): 52–61. https://doi.org/10.1016/j.envsoft.2011.09.008.