The Effect of Arnold's Field Fires on the Respiratory Health of the Surrounding Population

Full Technical Report

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Version Control

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0.1	01/02/2024	Descriptive Analysis	Mark Holder & Anthony Wakhisi
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0.4	03/07/2024	Revised analysis to include the LB Havering aggregate data and 14th LSOA previously missing data.	Anthony Wakhisi
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Person	Organisation	Role
Prof Klea Katsouyanni, Professor of Biostatistics and Epidemiology	Imperial College, London	Expert advisor: data analysis, interpretation and reporting
Dr Dimitris Evangelopoulos, Research Fellow, School of Public Health - Faculty of Medicine	Imperial College, London	Expert advisor: data analysis, interpretation and reporting
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Executive Summary

Background

This report details findings from an assessment of the potential impact of fire incidents at the Arnold's Field site, Launder's Lane on local residents' respiratory health. The population at risk was defined as people living in lower super output areas (LSOA) that are fully or partially within two miles radius from Arnold's Field Landfill. Fourteen Havering LSOAs were included which have an estimated resident population of **23,656 people**. In total there were **99 fire days** over the assessment period.

To assess the fire impact, time series analysis was carried out by the Havering public health team in collaboration with environmental epidemiology experts from Imperial College, London. Time series analysis is a statistical method commonly used in environmental epidemiology particularly with understanding the effect of common exposures to health outcomes across time.

In this analysis fire incidents attended by the London Fire Brigade were included as the main exposure variable whereas respiratory illness related attendances at General Practices (GP) and Accident and Emergency (A&E), GP prescriptions and hospital admissions were the health outcomes of interest. To adjust for potential confounding factors the following variables were included; the daily average levels of NO_2, wind speed, humidity, temperature, day of the week and COVID-19 lockdown dates.

Key Findings

Amongst residents of the LSOAs of interest a total of **3,537 attendances with respiratory symptoms and 1,458 attendances with major respiratory conditions** were recorded at general practices. A total of **108,182** respiratory illness related **prescriptions** were issued in general practices.

A total of **1,530 A&E attendances** and **2,482 hospital admissions** with respiratory conditions were recorded over the assessment period amongst residents in the LSOAs of interest.

As expected, residents in the LSOAs of interest **aged 65 years and over had higher primary and secondary healthcare use** for respiratory symptoms/conditions as compared to those aged below 65.

A statistically significant association was found between fire incidents and GP attendances with respiratory long term conditions (LTCs) mainly Asthma and COPD. The adjusted model results showed **a 34% increase** in risk and number of GP attendances with long term respiratory conditions **(RR 1.34, 95%CI: 1.01, 1.80)** on fire days as compared to non-fire days. This is equivalent to **approximately 2 extra GP attendances over 10 fire days as compared to non-fire days.** Overall, out of **1,231 respiratory LTC GP attendances** recorded between January 2018 and September 2023, approximately **20** could be attributed to the impact of reported fire incidents**.**

We did not find a statistically significant association between fire incidents and GP attendances with general respiratory symptoms, A&E attendances and hospital admissions with respiratory conditions. We also did not find a statistically significant association between daily average $PM_{2.5}$ levels and any of the outcome variables.

Conclusion

Our epidemiological time series analysis found a statistically significant association between fires attended by the London Fire Brigade at Arnold's Field, Launders Lane and an increase in number of GP attendances by those with long term respiratory conditions. Associations with other outcome variables were not statistically significant.

Limitations

These results should be interpreted with caution. Despite demonstrating a significant association between fire days and an increase in GP attendances by residents with long term respiratory conditions, we were unable to differentiate between arranged attendances for routine reviews and those booked by patients with acute respiratory illness. However we consider the findings from this analysis plausible as we would not expect routine reviews to significantly differ on fire days as compared to non-fire days or to be influenced by other exposure variables utilised in our models.

Dynamics of the fires occurring at the site also need to be considered. In particular, it is possible that smouldering may occur without attendance by the London Fire Brigade and that a fire reported to London Fire Brigade may have started days earlier, before it becomes big enough to be reported to London Fire Brigade.

We also acknowledge that same-day GP appointments can be difficult to access. However it is plausible that, especially amongst those with increased sensitivity, respiratory symptoms may have begun prior to the attendance by the Fire Brigade for a specific fire incident. Consultation with clinical colleagues also suggests that in some instances, those with pre-existing respiratory conditions (e.g. COPD) may be prioritised for same-day appointments if presenting with acute respiratory symptoms, although this is not universally the case.

1 Introduction

Arnold's Field is privately owned land off Launders Lane, Rainham in the South of the London Borough of Havering (Figure 1). The site was formerly a sand and gravel quarry, subsequently registered as a landfill licensed to accept inert, commercial, industrial, household and solid sludge waste. The last waste was recorded as being accepted in 1965, however significant volumes of waste were subsequently deposited there without appropriate authorisation. There are no clear records of the specific type of waste that has been deposited at the site; however, it is known to include household, commercial/industrial (including wood, paper, glass, plastic, mattresses, furniture, cables, and fabric materials) and construction waste deposits. No comprehensive information on waste depth is available, however it is known that it can be up to 5 metres deep in places.

The landfill site often catches fire, especially during hot weather. Residents complain about the nuisance caused by smoke, dust and odour from the fires and are concerned about potential health impacts. Havering Council has commissioned soil sampling and comprehensive air quality monitoring, and has undertaken an investigation of potential health risks to residents through a contract with Environmental Epidemiology experts from Imperial College London (Professor Klea Katsouyanni[1] and Dr Dimitris Evangelopoulos[2])

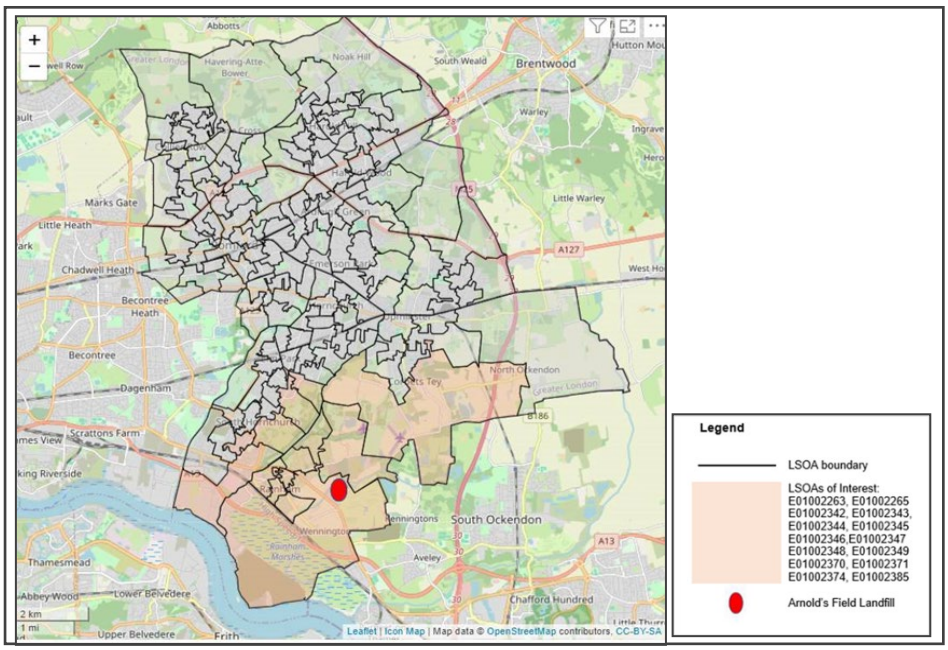
This report details the findings of the work performed with Environmental Epidemiology experts from Imperial College London; use of health care services, air quality, and meteorological data were used to inform time series models necessary to explore the relationship between days when fires occur at the site and the use of health care services by local residents as a result of respiratory symptoms.

Time series analysis is a statistical method required to explore any potential relationship between fire occurrences and use of health care services as there are a number of potential confounding factors[3] that may influence healthcare usage on any given day. These factors may be associated or not with the occurrence of a fire. For example, warmer weather may influence severity of respiratory symptoms experienced by the population, but may also be associated with the occurrence of a fire at the site.

A list of variables considered in the analysis, and the associated data sources, can be found in the methods section of this report. The aim of this analysis was to explore whether fires occurring at the Arnold's Field site are associated with an increase in use of health care services by people residing close to the site.

[1] Klea Katsouyanni Profile | Imperial College London
[2] Dimitris Evangelopoulos Publications | Imperial College London
[3] Confounding factors/variables are those that may compete with the exposure of interest (e.g. fires) in explaining the outcome (e.g. GP attendances) of a study.

Figure 1: Map of the London Borough of Havering with lower super output area (LSOA) boundaries. Arnold's Field landfill is marked by a dark red dot and the 14 LSOAs of interest nearest to the site are highlighted in light red.



2 Methods

2.1. Datasets and Sources

2.1.1 Primary & Secondary Care Data

Primary care data (GP attendances) and secondary care data (accident and emergency attendances) were obtained from NHS NEL London ICB team. Hospital admissions data was extracted from the NHS Digital Hospital Episodes Statistics (HES) database by the Havering Public Health Intelligence team. Data from NHS NEL ICB were for the period 1st January 2017 to 30th September 2023. These included all patients resident in the 14 Lower Super Output Areas (LSOAs)[4] of interest who had attended primary or secondary care services with respiratory illness within the specified period. Also included were records for all patients who were issued respiratory illness related prescriptions in primary care over the same period. Patients were excluded from the datasets if they had an 'informed dissent' code in their case-notes. Similar primary and secondary care and prescription data in aggregate format for the whole of Havering was provided for comparative / descriptive analysis.

2.1.2 Fire Days Data

Fire incidents data was sourced from the London Fire Brigade. These included fires attended to by the London Fire Brigade occurring on Arnold's field, off Launders Lane from 01 January 2018 until 30 September 2023.

[4] An LSOA is a geographical area comprised of between 400 and 1,200 households and have a usually resident population between 1,000 and 3,000 persons. Statistical geographies - Office for National Statistics (ons.gov.uk)

2.1.3 Air Pollution

Daily average air pollution data ($PM_{2.5}$ & NO_2) were obtained from the Breathe London[5] database specifically from two nodes – Rainham node (closest to landfill during the period of investigation) and Bexley Slade Green node (for comparison).

2.1.4 Meteorological Data

Temperature, Wind speed and Humidity data over the same period were sourced from the London City Airport meteorological database[6] and included in statistical modelling as potential confounding factors.

2.1.5 COVID-19 Lockdown Dates

COVID-19 lockdown dates were sourced from timeline-lockdown-social (instituteforgovernment.org.uk) and used in models to assess the impact on specified healthcare activity levels over the study period.

2.2. Statistical Analysis

The analysis included data for the period 1 January 2018 to 30 September 2023. Healthcare activity data was available as from 1 January 2017 but the 2017 data was excluded as no fire incident was reported in that year. The resident population of the 14 LSOAs of interest and Havering as a whole was determined using the most recent ONS population estimates (2022). [7] Most of the descriptive data analysis was carried out in MS Excel and time series regression modelling in R Studio.

2.2.1 Variables

The following variables were included in the analysis:

Exposure Variables

- Fire Incidents at the Arnold's Field site (Yes/No)
- $PM_{2.5}$ daily average ($\mu g/m^3$)

Potential Exposure Confounding Variables

- NO2 daily average (µg/m3)
- Wind speed daily average (miles per hour- mph)
- Humidity daily average (%)
- Temperature daily average (^0F)
- COVID-19 Lockdown Dates (Yes/No)

Healthcare Activity / Outcome Variables

- Daily number of attendances at general practices with respiratory symptoms[8]

[5] Breathe London

[6] London City Airport (Greater London) weather - Met Office

[7] Population estimates for England and Wales - Office for National Statistics (ons.gov.uk)

[8] Cough, sore throat, wheezing

- Daily number of attendances at general practices with a major respiratory condition[9]
- Daily number of attendances at general practices with long term respiratory conditions (LTC [10]
- Daily number of attendances at general practices with LTC and recorded respiratory symptoms.
- Daily number of respiratory prescriptions issued by primary care
- Daily number of hospital attendances at A&E with respiratory conditions (primary diagnosis)
- Daily number of hospital inpatient admissions with respiratory conditions (primary diagnosis)

2.2.2 Descriptive analysis

Population

The population at risk was defined as people living in LSOAs that are partially or fully within two miles radius from Arnold's field landfill. Numbers and percentages were calculated for persons aged under 65 and 65 years and over for each LSOA.

Fire Days & $PM_{2.5}$

Number of fire days per month and daily average $PM_{2.5}$ levels including standard deviations on fire days and non-fire days over the study period were calculated and compared. T test[11] was used to measure the statistical significance (*p* value) of the difference between the average $PM_{2.5}$ on fire days as compared to non-fire days.

Healthcare Activity

Annual counts of health activities in primary and secondary care including prescriptions were calculated for both havering as whole and the 14 LSOAs of interest. Average annual rates (2018 – 2023, rate per 1,000 population) were determined using the ONS 2022 mid-year population estimates. 95% confidence intervals were included. Average annual daily counts with standard deviations were also calculated for each variable. T test was used to measure the statistical significance (*p* value) of the difference between the average healthcare activity levels on fire days as compared to non-fire days.

Summary Statistics

Summary statistics for all numerical variables were calculated including the total daily counts, minimum, 1st Quartile, Median, Mean, 3rd Quartile, maximum values and missing data for each variable.

[9] Asthma, Chronic obstructive pulmonary disease, Bronchitis, Emphysema, Cystic fibrosis, Lung cancer, Mesothelioma, Pneumonia, Pulmonary fibrosis, Respiratory infections or any other respiratory condition.
[10] Asthma, Chronic obstructive pulmonary disease, Cystic fibrosis, Lung cancer, Mesothelioma
[11] https://www.bmj.com/about-bmj/resources-readers/publications/statistics-square-one/7-t-tests

Correlations

Trend charts for exposure and outcome variables were created to visually examine patterns over the period of study. As none of the data were normally distributed, spearman's rank-order correlation tests[12] were carried out for all numerical variables to measure the strength and direction of association. Results were presented in a matrix including correlation coefficients and *p* values.

2.3 Time Series Regression Models

To investigate whether the short-term variation in healthcare activity associated with respiratory illness among residents in the 14 LSOAs of interest could be explained by the occurrence of fire incidents at the landfill and fluctuations in $PM_{2.5}$ levels, Poisson Regression Models were utilised. Modelling included adjustment for potential confounding factors namely; temperature, relative humidity, wind speed, weekdays, holidays and COVID-19 Lockdown dates. NO_2 was also included for the purpose of sensitivity analysis.

Adjusting for seasonality and long term trends

The main assessment question was to determine whether short-term variations in the specified health outcome variables could be explained by the exposures of interest i.e. fire incidents and daily $PM_{2.5}$ Levels. However, because healthcare activity/outcome data was expected to be dominated by seasonal patterns and long term trends, it was necessary to control for these patterns in the regression models in order to effectively separate them out from the short-term associations between exposure and outcome that we were interested in. [13]

To control for seasonal patterns and long term trends we fitted a spline function of time for each outcome variable separately. A variety of splines were fitted with varied degrees of freedom i.e. 1, 4, 8 and 12 and we examined the AIC[14] values to determine which was the best fitting spline (the one with the lowest value) for each variable which was then included in all models involving the specific variable. [13]

Allowing for delayed exposure

The initial model investigated the association between various health activities /outcomes on a given day and the exposure to either fire pollutant on fire days or varied $PM_{2.5}$ levels while controlling for other potential confounders on the same day. But there was need to explore whether there was any delayed association (lag) with fire incidents in particular. To do this we created 3 and 7 day time-shifted copies of fire days and included them in the model to explore the association between healthcare activity levels and delayed fire effect over the following days respectively after the reported incident and intervention by the London Fire Brigade.[13]

To check for possible over-dispersion in the fitted Poisson models the same analyses were repeated but based on a quasi-Poisson statistical model and calculated relative

[12] Spearman's Rank Correlation: The Definitive Guide To Understand | Simplilearn

[13] Bhaskaran K, Gasparrini A, Hajat S, Smeeth L, Armstrong B (2013). Time series regression studies in environmental epidemiology, *International Journal of Epidemiology*; 42(4):1187-1195

[14] The Akaike Information Criterion (AIC) is a mathematical method for evaluating how well a model fits the data it was generated from. In statistics, AIC is used to compare different possible models and determine which one is the best fit for the data.

risks, mean and variance for the two models were compared. Partial autocorrelation function was used to check if adjustment for seasonality in various models had eliminated or reduced autocorrelation.[13]

Increase in number of GP Attendances Model

For statistically significant associations between exposure and outcome variables, based on the relative risk measures from the adjusted model, the overall extra and daily number of healthcare activities that may be attributed to the specific exposure e.g. fire days were calculated by applying the risk difference (percentage) between exposure and non-exposure days. For example the relative risk for GP attendances with respiratory long term conditions on fire days was 1.34 i.e. 34% higher as compared to non-fire days. 34% was applied to number of attendances on non-fire days to determine the extra attendances that could result from a similar number of fire days and multiplied by 10 to address the issue of resulting less than 1 value (0.2) per day (34% x 1,165 / 2,000 x10 = 2 extra GP attendances per 10 days).

2.4 Model Checking and Sensitivity Analysis

Quasi-Poisson model for over-dispersion

To check for possible over-dispersion in the fitted Poisson models the same analyses were repeated but based on a quasi-Poisson statistical model.[15] Relative risks, mean and variance for the two models were compared to identify any significant differences.[13]

Partial autocorrelation function

Partial autocorrelation function[16] was used to check if adjustment for seasonality in various models had eliminated or reduced autocorrelation.[13]

[15] Quasi Poisson Regression – Technical Documentation (zendesk.com)
[16] 10.2 - Autocorrelation and Time Series Methods | STAT 462 (psu.edu)

3 Results: Descriptive Analysis

3.1 LSOAs of interest & resident population

The estimated population of the residents in the fourteen LSOAs of interest was 23,656. 82% (19,404) were persons aged below 65 years (Table 1).

Table 1: Resident population estimates[17] by age group of the 14 LSOAs surrounding the site.

LSOA Code	LSOA Name	>65 years	65+ years	Total
E01002263	Havering 026D	1,310	341	1,651
E01002265	Havering 025A	1,095	281	1,376
E01002342	Havering 030A	1,512	235	1,747
E01002343	Havering 029A	1,276	397	1,673
E01002344	Havering 029B	1,537	330	1,867
E01002345	Havering 030B	1,763	187	1,950
E01002346	Havering 030C	1,355	189	1,544
E01002347	Havering 030D	1,370	270	1,640
E01002348	Havering 029C	1,068	397	1,465
E01002349	Havering 029D	1,147	351	1,498
E01002370	Havering 028C	1,990	276	2,266
E01002371	Havering 028D	1,359	338	1,697
E01002374	Havering 027E	1,387	253	1,640
E01002385	Havering 024A	1,235	407	1,642
Total		**19,404 (82%)**	**4,252 (18%)**	**23,656**

3.2 Fire Days

Fires attended by the London Fire Brigade occurring on Arnold's field, off Launders Lane from 01 January 2018 until 30 September 2023 were included as the independent exposure variable in our analysis. Some fires burnt for more than one day, and on some days there was more than one fire burning on the field (i.e. at a different locations on the site). As such a binary variable "fire day" was used, where a fire day was a calendar date with at least one fire occurring on the site in that 24 hour period. A monthly summary of fire days is shown in Table 2. There were a total of 99 fire days over the study period.

[17] Population estimates for England and Wales - Office for National Statistics (ons.gov.uk)

Table 2 Summary of the number of days with fires ("fire days") occurring at Arnold's Field, Launders Lane that required attendance by the London Fire Brigade (LFB) by month from 2018 - 2023.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2018	0	0	0	0	0	0	0	0	0	0	0	1	1
2019	0	0	0	1	0	1	8	1	1	1	1	0	14
2020	0	0	0	1	0	0	0	8	7	1	0	0	17
2021	0	0	0	0	3	3	0	0	0	5	5	0	16
2022	0	1	0	8	2	13	11	1	0	0	0	0	36
2023	0	0	0	0	0	0	2	12	1				15
Total	**0**	**1**	**0**	**10**	**5**	**17**	**21**	**22**	**8**	**7**	**6**	**1**	**99**

3.3 $PM_{2.5}$

The total average $PM_{2.5}$ levels on fire days attended by the London Fire Brigade was higher as compared to days without a fire. However the difference was not statistically significant (p = 0.100) (Table 3).

Table 3: Average levels of fine particulate matter ($PM_{2.5}$) on days with and without fires at Arnold's Field attended by the London Fire Brigade.

Year	Total number of days with fire	Average $PM_{2.5}$, $\mu g/m^3$, Fire days (SD)	Average $PM_{2.5}$, $\mu g/m^3$, Non-fire days (SD)
2018	1	22	10.9 (7.4)
2019	14	11.4 (9.5)	11.0 (8.9)
2020	17	14.8 (6.9)	8.2 (6.7)
2021	16	13.5(3.9)	8.7 (6.0)
2022	36	10.1 (5.2)	10.2 (7.8)
2023	15	4.8 (2.1)	8.4 (6.4)
Total	**99**	**10.7 (6.7)**	**9.7 (7.4)**

3.4 Primary Healthcare

3.4.1 Attendance at General Practice with respiratory symptoms

A total of 3,537 attendances at general practices with respiratory symptoms were recorded among residents in the LSOAs of interest between January 2018 and September 2023. The number of attendances by age group, by year and overall rates for the entire study period are presented in Table 4. Residents aged 65 and over had a significantly higher attendance rate (33/1,000) as compared to those aged below 65 (24/1,000).

Table 4: Number and rate of attendances at general practices with respiratory symptoms among residents of the 14 LSOAs of interest, by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	501	174	675
2019	616	157	773
2020	350	111	461
2021	396	85	481
2022	504	149	653
2023	377	117	494
Total	2,744	793	3,537
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**23.5 (21.4, 25.7)**	**32.9 (27.5, 38.7)**	**25.1 (23.2, 27.2)**

Average daily GP attendances on “fire days” compared to non-fire days are shown in Table 5. On average there were less GP attendances (1.3) with respiratory symptoms on days with a fire compared to days without (1.7). However the difference was not statistically significant (p = 0.257).

Table 5: Average number of attendances at general practices with respiratory symptoms among residents of the LSOAs of interest, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of GP attendances, Fire days (SD)	Average daily number of GP attendances, Non-fire days (SD)
2018	1	3	1.8 (1.8)
2019	14	1.1 (1.2)	2.1 (2.4)
2020	17	0.6 (0.8)	1.3 (1.8)
2021	16	1.0 (1.6)	1.3 (1.8)
2022	36	1.6 (1.8)	1.8 (1.9)
2023	15	1.5 (1.4)	1.8 (1.8)
Total	**99**	**1.3 (1.5)**	**1.7 (2.0)**

3.4.2 Major respiratory conditions

A total of 1,458 attendances at general practices with major respiratory conditions were recorded among residents of the LSOAs of interest between January 2018 and September 2023. The number of attendances by age group, by year and overall rates for the entire study period are presented in Table 6. Residents aged 65 and over had a significantly higher rate (20/1,000) as compared to those aged below 65 (8.3/1,000).

Table 6: Number and rate of attendances at general practices with major respiratory conditions among residents of the 14 LSOAs of interest, by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	112	62	174
2019	116	46	162
2020	111	39	150
2021	141	61	202
2022	247	131	378
2023	238	154	392
Total	965	493	1,458
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**8.3 (7.0, 9.6)**	**20.4 (16.3, 25.2)**	**10.4 (9.1, 11.7)**

Average daily GP attendances on "fire days" compared to non-fire days are shown in Table 7. On average there were more GP attendances with major respiratory conditions on days with a fire (0.8) compared to days without (0.7) but the difference was not statistically significant (p = 0.107).

Table 7: Average number of attendances at general practices with major respiratory conditions among residents of the LSOAs of interest, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of GP attendances, Fire days (SD)	Average daily number of GP attendances, Non-fire days (SD)
2018	1	0	0.5 (0.8)
2019	14	0.2 (0.4)	0.5 (0.8)
2020	17	0.4 (0.6)	0.4 (0.7)
2021	16	0.3 (0.4)	0.6 (0.9)
2022	36	1.0 (1.3)	1.0 (1.6)
2023	15	1.6 (1.6)	1.4 (1.6)
Total	**99**	**0.8 (1.1)**	**0.7 (1.1)**

3.4.3 Respiratory Long Term Conditions

A total of 1,231 attendances at general practices with respiratory long term conditions (LTCs) were recorded among residents of the LSOAs of interest between January 2018 and September 2023. The number of attendances by age group, by year and overall rates for the entire study period are presented in Table 8. Residents aged 65 and over had a significantly higher rate (17/1,000) as compared to those aged below 65 (7.0/1,000).

Table 8: Number and rate of attendances at general practices with respiratory long term conditions among residents of the 14 LSOAs of interest, by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	108	56	164
2019	103	39	142
2020	102	31	133
2021	116	57	173
2022	199	105	304
2023	186	129	315
Total	814	417	1,231
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**7.0 (5.9, 8.2)**	**17.3 (13.5, 21.7)**	**8.7 (7.6, 10.0)**

Average daily GP attendances on “fire days” compared to non-fire days are shown in Table 9. On average there were more GP attendances with respiratory LTCs on days with a fire (0.7) compared to days without (0.6) but the difference was not statistically significant (p = 0.263).

Table 9: Average number of attendances at general practices with respiratory long term conditions among residents of the LSOAs of interest, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of GP attendances, Fire days (SD)	Average daily number of GP attendances, Non-fire days (SD)
2018	1	0	0.5 (0.8)
2019	14	0.2 (0.4)	0.4 (0.7)
2020	17	0.4 (0.6)	0.4 (0.6)
2021	16	0.3 (0.4)	0.5 (0.8)
2022	36	0.8 (1.1)	0.8 (1.4)
2023	15	1.5 (1.6)	1.1 (1.4)
Total	**99**	**0.7 (1.1)**	**0.6 (1.0)**

3.4.5 Respiratory Prescriptions

A total of 108,182 prescriptions in general practices were issued to residents of the LSOAs of interest with respiratory illness between January 2018 and September 2023. The number of prescriptions by age group, by year and overall rates for the entire study period are presented in Table 10. Residents aged 65 and over had a higher annual rate (2,041/1,000) as compared to those aged below 65 (505/1,000).

Table 10: Number and rate of prescriptions issued to residents of the 14 LSOAs of interest with respiratory illness, by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	7,941	7,278	15,219
2019	8,242	7,406	15,648
2020	9,526	7,946	17,472
2021	11,242	9,228	20,470
2022	12,158	9,745	21,903
2023	9,807	7,663	17,470
Total	58,916	49,266	108,182
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**505 (495, 515)**	**2,041 (1,998, 2085)**	**768 (757, 779)**

Average daily prescriptions on “fire days” compared to non-fire days are shown in Table 11. On average there were more prescriptions issued on days with a fire (54) as compared to days without (51). The difference was however not statistically significant (p = 0.425).

Table 11: Average number of prescriptions issued to residents of LSOAs of interest with respiratory illness, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of GP Prescriptions, Fire Days (SD)	Average daily number of GP Prescriptions, Non-fire Days (SD)
2018	1	57	41.7 (30.0)
2019	14	38.5 (32.4)	42.9 (30.5)
2020	17	53.1 (27.9)	47.5 (34.3)
2021	16	47.1 (46.8)	56.5 (37.6)
2022	36	56.3 (40.2)	60.4 (38.7)
2023	15	65.2 (37.5)	63.9 (41.9)
Total	**99**	**53.6 (37.8)**	**51.4 (36.3)**

3.5. A&E Attendances

A total of 1,530 attendances at A&E with respiratory conditions were recorded among residents of the LSOAs of interest between January 2018 and September 2023. The number of attendances by age group, by year and overall rates for the entire study period are presented in Table 12. Residents aged 65 and over had a significantly higher rate (18/1,000) as compared to those aged below 65 (9.4/1,000).

Table 12: Number and rate of A&E attendances with respiratory conditions among residents of the 14 LSOAs of interest by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	90	40	130
2019	142	67	209
2020	147	63	210
2021	237	81	318
2022	286	99	385
2023	190	88	278
Total	1,092	438	1,530
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**9.4 (8.1, 10.8)**	**18.1 (14.3, 22.7)**	**10.9 (9.6, 12.2)**

Average daily A&E attendances on “fire days” compared to non-fire days are shown in Table 13. On average there were fewer A&E attendances with respiratory conditions on days with a fire (0.7) compared to days without (0.8) but the difference was not statistically significant (p = 0.105).

Table 13: Average number of A&E attendances with respiratory conditions among residents of the LSOAs of interest, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of A&E attendances, Fire days (SD)	Average daily number of A&E attendances, Non-fire days (SD)
2018	1	0	0.5 (0.7)
2019	14	0.2 (0.4)	0.6 (0.9)
2020	17	0.6 (0.9)	0.6 (0.8)
2021	16	1.3 (0.9)	0.9 (1.1)
2022	36	0.8 (0.8)	1.1 (1.1)
2023	15	0.6 (0.6)	1.0 (1.0)
Total	99	0.7 (0.8)	0.8 (1.0)

3.6 Hospital Admissions

A total of 2,482 inpatient hospital admissions with respiratory conditions were recorded among residents of the LSOAs of interest between January 2018 and September 2023. The number of admissions by age group, by year and overall rates for the entire study period are presented in Table 14. Residents aged 65 and over had a significantly higher average annual rate (56/1,000) as compared to those aged below 65 (9.8/1,000).

Table 14: Number and rate of inpatient hospital admissions with respiratory conditions amongst residents of the 14 LSOAs of interest by age group, between January 2018 and September 2023.

Year	Age <65 years	Age 65+ years	Total
2018	243	276	519
2019	248	262	510
2020	142	202	344
2021	146	213	359
2022	192	227	419
2023	168	163	331
Total	1,139	1,343	2,482
Population	20,300	4,197	24,497
Average Annual Rate, per 1,000 population (95% CI)	**9.8 (8.4, 11.2)**	**55.7 (48.7, 63.2)**	**17.6 (16.0, 19.4)**

Average daily hospital admissions on “fire days” compared to non-fire days are shown in Table 15. On average there were similar hospital admissions with respiratory conditions on days with a fire (1.2) compared to days without (1.2) (P = 0.296).

Table 15: Average number of hospital admissions with respiratory conditions among residents of LSOAs of interest, on fire days and non-fire days, between January 2018 and September 2023.

Year	Total number of days with fire	Average daily number of hospital admissions, Fire days (SD)	Average daily number of hospital admissions, Non-fire days (SD)
2018	1	0	1.4 (1.3)
2019	14	1.3 (1.3)	1.4 (1.3)
2020	17	0.8 (1.1)	0.9 (1.1)
2021	16	1.4 (1.0)	1.0 (1.0)
2022	36	1.3 (1.2)	1.1 (1.1)
2023	15	1.3 (1.2)	1.2 (1.2)
Total	**99**	**1.2 (1.2)**	**1.2 (1.2)**

3.7 Summary Statistics

Summary statistics for all outcome and exposure numerical variables were calculated and presented in Table 16 below. These include the total counts, and daily minimum, 1st Quartile, Median, Mean, 3rd Quartile, Maximum values and Missing data.

Table 16: Summary statistics for all numerical variables in LSOAs of interest datasets

Variable	Total	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Missing Data
GP Attendances Major Respiratory Conditions: Residents Aged below 65 Years	965	0.0	0.0	0.0	0.5	1.0	7.0	0.0
GP Attendances Major Respiratory Conditions: Residents Aged 65 Years & Over	493	0.0	0.0	0.0	0.2	0.0	4.0	0.0
GP Attendances Major Respiratory Conditions: Residents of All ages	1,458	0.0	0.0	0.0	0.7	1.0	9.0	0.0
GP Attendances Respiratory LTC: Residents Aged below 65 Years	814	0.0	0.0	0.0	0.4	1.0	7.0	0.0
GP Attendances Respiratory LTC: Residents Aged 65 Years & Over	417	0.0	0.0	0.0	0.2	0.0	4.0	0.0
GP Attendances Respiratory LTC: Residents of All ages	1,231	0.0	0.0	0.0	0.6	1.0	8.0	0.0
GP Attendances Respiratory Symptoms: Residents Aged below 65 Years	2,744	0.0	0.0	1.0	1.3	2.0	11.0	0.0
GP Attendances Respiratory Symptoms: Residents Aged 65 Years & Over	793	0.0	0.0	0.0	0.4	1.0	6.0	0.0
GP Attendances Respiratory Symptoms: Residents of All ages	3,537	0.0	0.0	1.0	1.7	3.0	13.0	0.0
GP Attendances Respiratory LTC & Symptoms: Residents Aged below 65 Years	468	0.0	0.0	0.0	0.2	3.0	4.0	0.0
GP Attendances Respiratory LTC & Symptoms: Residents Aged 65 Years & Over	216	0.0	0.0	0.0	0.1	3.0	3.0	0.0
GP Attendances Respiratory LTC & Symptoms: Residents of All ages	684	0.0	0.0	0.0	0.3	1.0	5.0	0.0
Hospital A&E Attendance: Residents Aged below 65 Years	1,092	0.0	0.0	0.0	0.5	1.0	8.0	90
Hospital A&E Attendance: Residents Aged 65 Years & Over	438	0.0	0.0	0.0	0.2	0.0	3.0	90

Variable	Total	Minimum	1st Quartile	Median	Mean	3rd Quartile	Maximum	Missing Data
Hospital A&E Attendance: Residents of All ages	1,530	0.0	0.0	1.0	0.8	1.0	8.0	90
Hospital Admissions: Residents Aged below 65 Years	1,139	0.0	0.0	0.0	0.5	1.0	5.0	0.0
Hospital Admissions: Residents Aged 65 Years & Over	1,343	0.0	0.0	0.0	0.6	1.0	5.0	0.0
Hospital Admissions: Residents of All ages	2,482	0.0	0.0	1.0	1.2	2.0	6.0	0.0
GP Respiratory Prescriptions: Residents Aged below 65 Years	58,916	0.0	4.0	31.0	28.1	43.0	131.0	0.0
GP Respiratory Prescriptions: Residents Aged 65 Years & Over	49,266	0.0	3.0	27.0	23.5	36.0	84.0	0.0
GP Respiratory Prescriptions: Residents of All ages	108,182	0.0	7.0	60.0	51.5	78.0	198.0	0.0
NO_2 Daily Maximum: Rainham Node	N/A	0.2	10.9	21.8	40.6	49.0	389.1	0.0
NO_2 Daily Maximum: Bexley Node	N/A	0.0	3.7	8.2	23.3	22.9	336.1	0.0
NO_2 Daily Average: Rainham Node	N/A	0.0	3.6	8.0	12.9	14.6	192.0	8.0
NO_2 Daily Average: Bexley Node	N/A	-0.4	1.4	2.5	6.4	5.2	147.9	61.0
$PM_{2.5}$ Daily Maximum: Rainham Node	N/A	0.0	10.8	15.3	19.6	23.6	472.2	0.0
$PM_{2.5}$ Daily Maximum: Bexley Node	N/A	0.0	8.4	12.9	17.2	21.7	164.5	0.0
$PM_{2.5}$ Daily Average: Rainham Node	N/A	-0.9	5.1	7.3	9.7	11.6	57.9	176.0
$PM_{2.5}$ Daily Average: Bexley Node	N/A	1.5	5.3	7.4	10.1	11.9	62.7	129.0
Temperature (^{0}F): Daily Maximum	N/A	30.2	51.8	60.8	61.2	69.8	102.2	4.0
Temperature (^{0}F): Daily Average	N/A	26.6	47.3	54.4	55.1	63.2	86.8	3.0
Wind Speed: Daily Maximum	N/A	4.1	9.9	13.0	13.2	15.9	35.0	3.0
Wind Speed: Daily Average	N/A	1.7	5.8	7.4	7.9	9.7	21.3	3.0
Humidity: Daily Average	N/A	14.6	39.6	45.6	45.6	52.3	64.8	4.0

3.8 Spearman's Rank Correlation Matrix

Table 17 shows Spearman's rank correlation coefficients and *p* values for the association between health outcome variables and specified exposure numerical variables. Statistically significant correlations were observed between NO_2 levels and GP attendances with major respiratory conditions (0.05), long term respiratory conditions (LTC) (0.05), respiratory symptoms (0.25), LTC with recorded respiratory symptoms (0.16), hospital admissions with respiratory conditions (0.09) and GP respiratory prescriptions (0.11). A statistically significant inverse correlation was also observed between $PM_{2.5}$ levels and GP attendances with major respiratory conditions (-0.05), temperature levels and GP attendances with respiratory symptoms (-0.14), LTC with recorded symptoms (-0.09) and A&E attendance (-0.11). A statistically significant inverse correlation was also observed between humidity levels and GP attendances with respiratory symptoms (-0.10), LTC with recorded symptoms (-0.06) and A&E attendances (-0.05). It should be emphasized that these results reflect univariate correlations (not accounting for confounders).

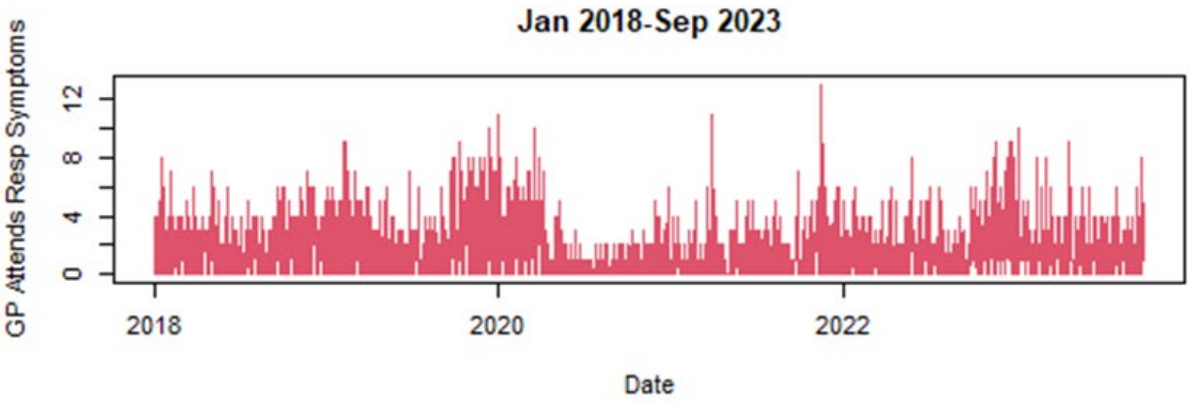
Table 17: Spearman's rank correlation matrix for all numerical exposure and outcome variables

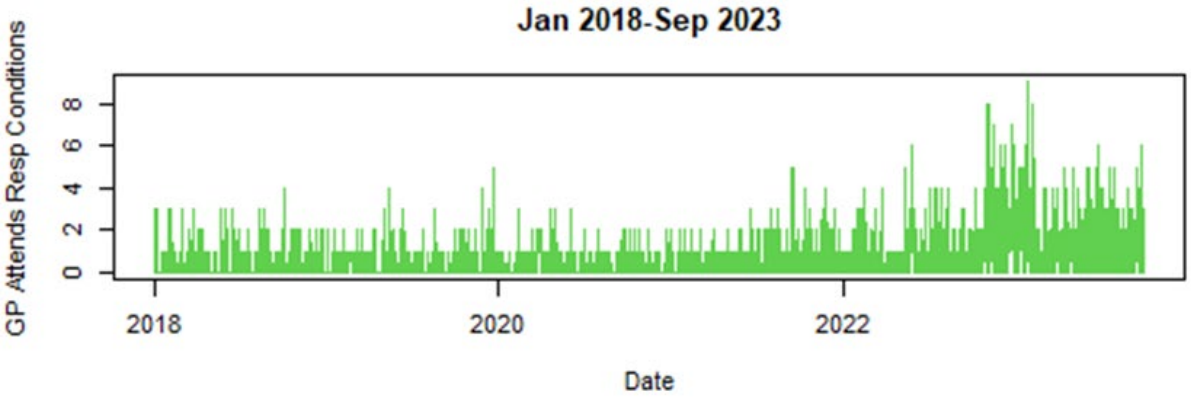
VARIABLES	GP Respiratory Conditions: All ages rho (P value)	GP Respiratory LTC: All ages rho (P value)	GP Respiratory Symptoms: All ages rho (P value)	GP Respiratory LTC & Symptoms: All ages rho (P value)	Hospital Admissions: All ages rho (P value)	A&E Attendance: All ages rho (P value)	GP Respiratory Prescriptions : All ages rho (P value)	NO2 Daily Average: Rainham rho (P value)	PM2.5 Daily Average: Rainham rho (P value)	Temperature (^{0}F): Daily Average rho (P value)	Wind Speed: Daily Average rho (P value)	Humidity: Daily Average rho (P value)
GP Respiratory Conditions: All ages	**1.000**	0.940 (<0.001)	0.360 (<0.001)	0.200 (<0.001)	0.110 (<0.001)	0.0687 (0.002)	0.490 (<0.001)	0.050 (0.024)	-0.050 (0.021)	0.000 (0.906)	0.000 (0.982)	0.020 (0.461)
GP Respiratory LTC: All ages	0.940 (<0.001)	**1.000**	0.330 (<0.001)	0.180 (<0.001)	0.110 (<0.001)	0.0516 (0.020)	0.470 (<0.001)	0.050 (0.040)	-0.020 (0.328)	0.020 (0.368)	-0.020 (0.423)	0.030 (0.165)
GP Respiratory Symptoms: All ages	0.360 (<0.001)	0.330 (<0.001)	**1.000**	0.540 (<0.001)	0.190 (<0.001)	0.0762 (0.0006)	0.560 (<0.001)	0.250 (<0.001)	0.010 (0.593)	-0.140 (<0.001)	0.000 (0.916)	-0.100 (<0.001)
GP Respiratory LTC & Symptoms: All ages	0.200 (<0.001)	0.180 (<0.001)	0.540 (<0.001)	**1.000**	0.100 (<0.001)	0.0228 (0.307)	0.240 (<0.001)	0.160 (<0.001)	-0.010 (0.759)	-0.090 (<0.001)	0.010 (0.613)	-0.060 (0.003)

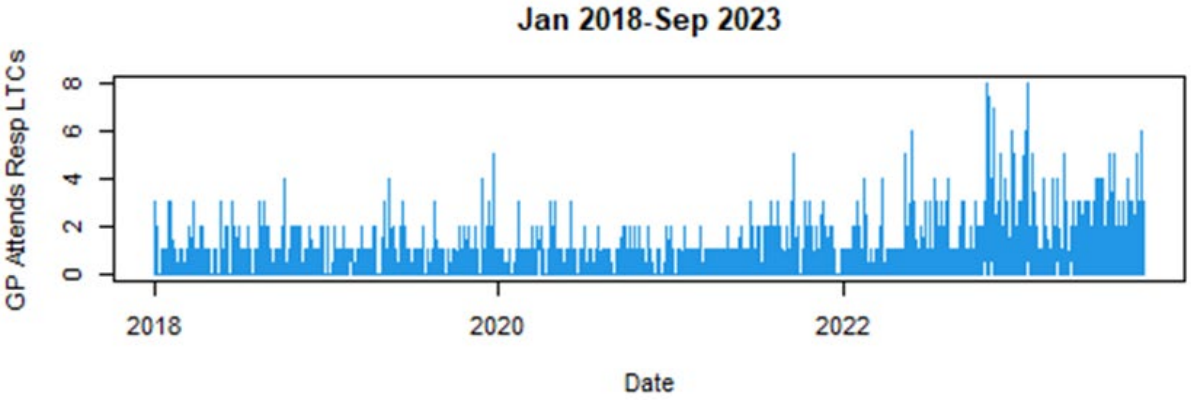
VARIABLES	GP Respiratory Conditions: All ages rho (P value)	GP Respiratory LTC: All ages rho (P value)	GP Respiratory Symptoms: All ages rho (P value)	GP Respiratory LTC & Symptoms: All ages rho (P value)	Hospital Admissions: All ages rho (P value)	A&E Attendance: All ages rho (P value)	GP Respiratory Prescriptions : All ages rho (P value)	NO2 Daily Average: Rainham rho (P value)	PM2.5 Daily Average: Rainham rho (P value)	Temperature (^{0}F): Daily Average rho (P value)	Wind Speed: Daily Average rho (P value)	Humidity: Daily Average rho (P value)
Hospital Admissions: All ages	0.110 (<0.001)	0.110 (<0.001)	0.190 (<0.001)	0.100 (<0.001)	**1.000**	0.0874 (0.000)	0.170 (<0.001)	0.090 (<0.001)	0.030 (0.146)	-0.010 (0.704)	0.010 (0.630)	0.030 (0.225)
A&E Attendance: All ages	0.069 (0.002)	0.052 (0.020)	0.076 (<0.001)	0.023 (0.307)	0.0874 (<0.001)	**1.000**	0.100 (<0.001)	-0.018 (0.413)	-0.016 (0.489)	-0.106 (<0.001)	-0.039 (0.079)	-0.053 (0.017)
GP Respiratory Prescriptions :All ages	0.490 (<0.001)	0.470 (<0.001)	0.560 (<0.001)	0.240 (<0.001)	0.170 (<0.001)	0.100 (<0.001)	**1.000**	0.110 (<0.001)	-0.030 (0.266)	0.010 (0.601)	-0.040 (0.079)	0.010 (0.586)
NO2 Daily Average: Rainham	0.050 (0.024)	0.050 (0.040)	0.250 (<0.001)	0.160 (<0.001)	0.090 (<0.001)	-0.018 (0.413)	0.110 (<0.001)	**1.000**	0.230 (<0.001)	-0.240 (<0.001)	-0.190 (<0.001)	-0.150 (<0.001)
PM2.5 Daily Average: Rainham	-0.050 (0.021)	-0.020 (0.328)	0.010 (0.593)	-0.010 (0.759)	0.030 (0.146)	-0.016 (0.489)	-0.030 (0.266)	0.230 (<0.001)	**1.000**	-0.050 (0.024)	-0.550 (<0.001)	-0.060 (0.013)
Temperature (^{0}F): Daily Average	0.000 (0.906)	0.020 (0.368)	-0.140 (<0.001)	-0.090 (<0.001)	-0.010 (0.706)	-0.106 (<0.001)	0.010 (0.601)	-0.240 (<0.001)	-0.050 (0.024)	**1.000**	0.010 (0.684)	0.900 (<0.001)
Wind Speed: Daily Average	0.000 (0.982)	-0.020 (0.423)	0.000 (0.916)	0.010 (0.613)	0.010 (0.630)	-0.039 (0.079)	-0.040 (0.079)	-0.190 (<0.001)	-0.550 (<0.001)	0.010 (0.684)	**1.000**	-0.020 (0.298)
Humidity: Daily Average	0.020 (0.461)	0.030 (0.165)	-0.100 (<0.001)	-0.060 (0.003)	0.030 (0.225)	-0.053 (0.017)	0.010 (0.586)	-0.150 (<0.001)	-0.060 (0.013)	0.90 (<0.001)	-0.020 (0.298)	**1.000**

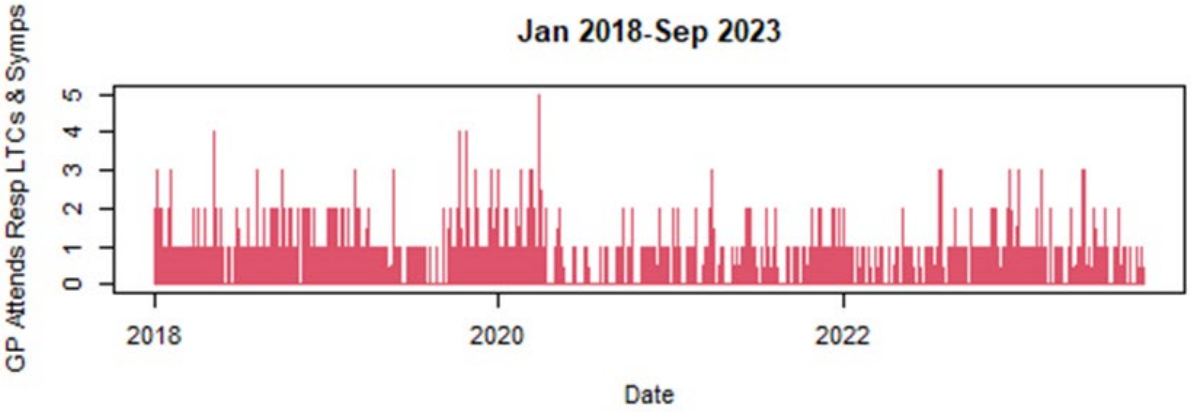
4 Results: Time Series Analysis

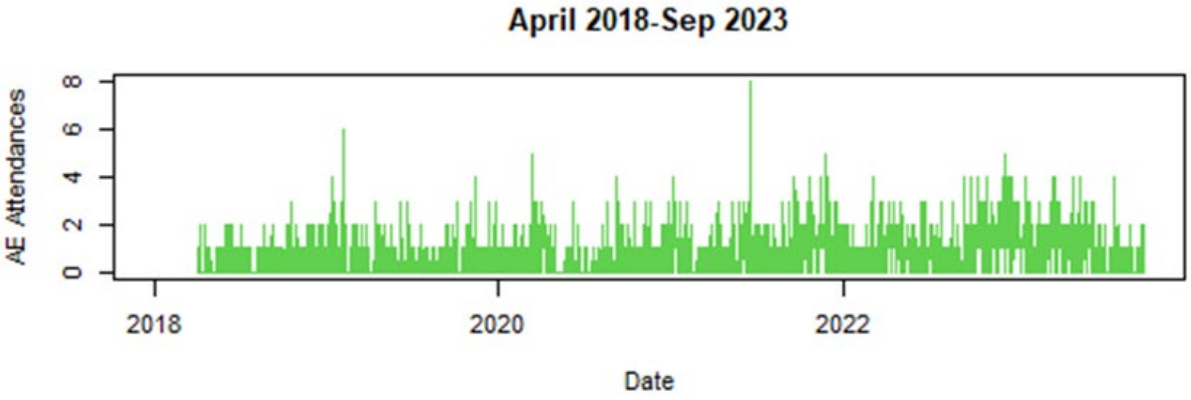
Time series charts below show individual trends for various outcome and exposure variables over the 6 year study period (January 2018 – September 2023).

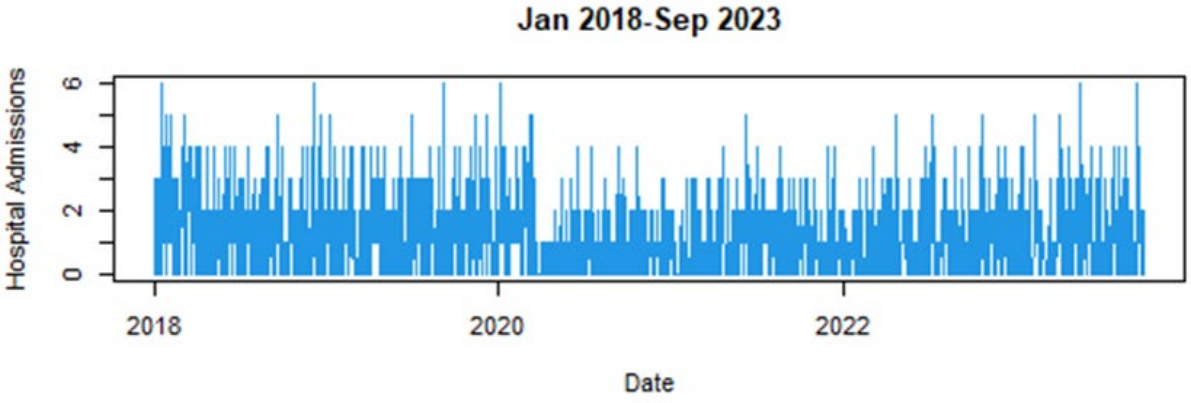


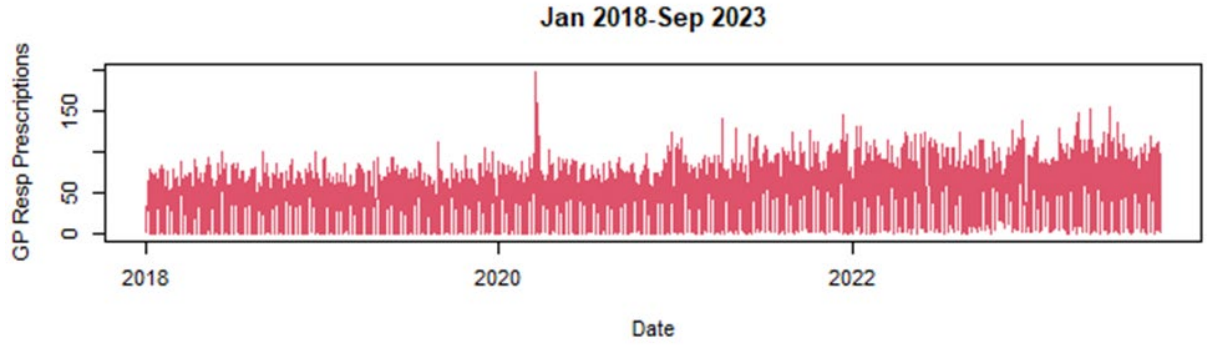


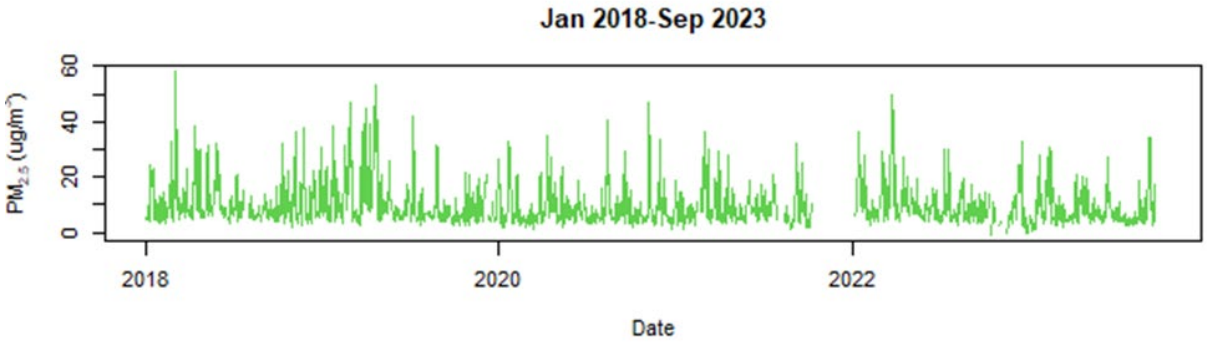


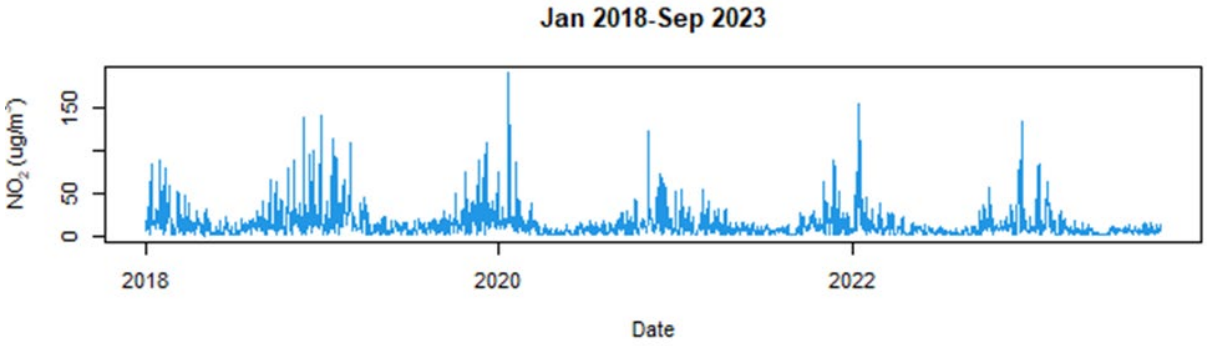

Jan 2018-Sep 2023
GP Attends Resp LTCs & Symps
0 1 2 3 4 5
2018
2020
2022
Date

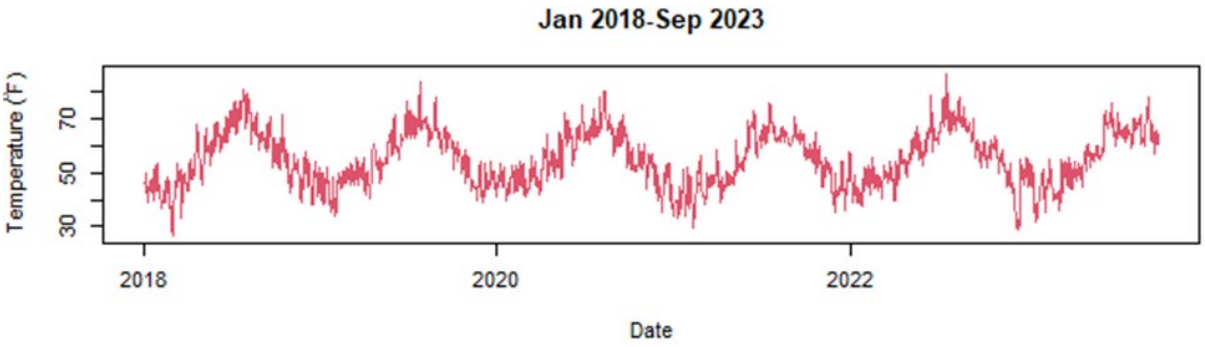

April 2018-Sep 2023
AE Attendances
0 2 4 6 8
2018
2020
2022
Date

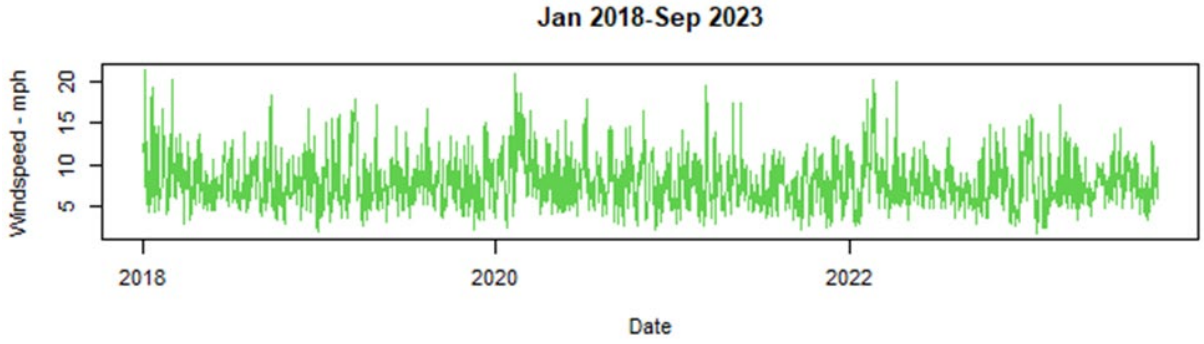

Jan 2018-Sep 2023
Hospital Admissions
0 2 4 6
2018
2020
2022
Date

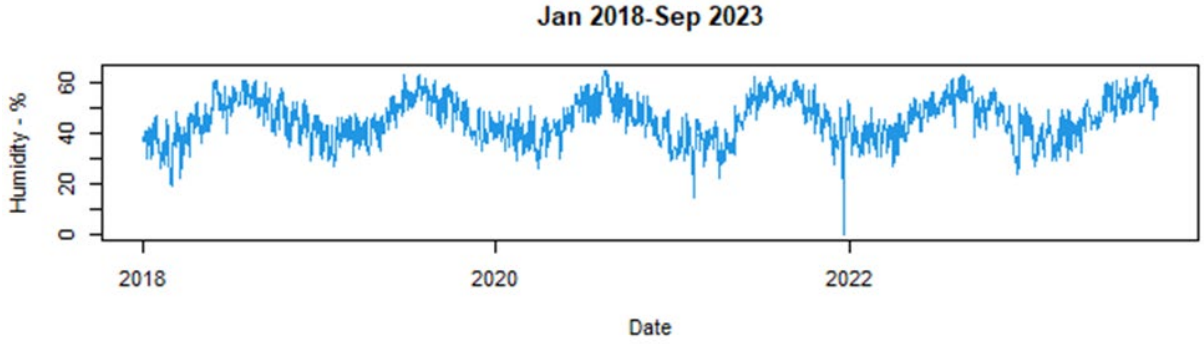

Jan 2018-Sep 2023
GP Resp Prescriptions
0
50
150
2018
2020
2022
Date


Jan 2018-Sep 2023
PM2.5 (ug/m3)
0
20
40
60
2018
2020
2022
Date


Jan 2018-Sep 2023
NO2 (ug/m3)
0
50
150
2018
2020
2022
Date


Jan 2018-Sep 2023
Temperature (F)
30
50
70
2018
2020
2022
Date


Jan 2018-Sep 2023
Windspeed - mph
5
10
15
20
2018
2020
2022
Date


Jan 2018-Sep 2023
Humidity - %
0
20
40
60
2018
2020
2022
Date

5 Results: Time Series Regression Models

The main adjusted regression model that was used to determine the significance of associations between primary exposure variables (Fire days or $PM_{2.5}$) and various outcome variables is labelled with β superscript in all tables. The model includes an adjustment for other exposure variables including; temperature, holidays, wind speed, week days and Covid19 lockdowns.

5.1 Fire days

A Statistically significant association was observed between fire incidents (fire days) and GP attendances with major respiratory conditions. The main adjusted model showed an increase of 32% (RR 1.32, 95%CI: 1.01, 1.73) in GP attendances on fire days as compared to non-fire days. Also observed was a statistically significant association between fire incidents and GP attendances with respiratory long term conditions (LTCs) (Table 18).

The adjusted model showed an increase of 34% (RR 1.34, 95%CI: 1.01, 1.80) in GP attendances on fire days as compared to non-fire days. Lagged exposure to general fire pollutants models (3 days) showed a weakened association between fire incidents and GP attendances with respiratory long term conditions (LTCs). The adjusted model showed an increase of 5.4% in GP attendances on fire days as compared to non-fire days but the difference was not statistically significant (Table 18).

A statistically significant association was observed between fire incidents and GP respiratory prescriptions in the basic model i.e. before adjustment for covariates. There was a 3.5% increase in prescriptions as compared to non-fire days but after adjustment for other exposure variables the difference was not statistically significant (Table 18).

5.2 $PM2_{.5}$

We did not observe any statistically significant association between daily average PM2.5 levels and any of the outcome variables in all models.

5.3 Lagged Exposure

Lagged exposure to general fire pollutants models (7 days) showed a weakened association between fire incidents and GP attendances with respiratory long term conditions (LTCs). The adjusted model showed that there was an increase of 14 % in GP attendances on fire days as compared to non-fire days but the difference was not statistically significant (Table 21)

Also observed was an association between fire incidents and A&E attendance with respiratory conditions. The adjusted model showed that there was an increase of 11% in A&E attendances on fire days as compared to non-fire days. However, the difference was not statistically significant (Table 21).

A statistically significant association was observed between fire incidents and GP respiratory prescriptions in the basic model i.e. before adjustment for covariates. There was a 2.8% increase in prescriptions as compared non-fire days but after adjustment for other exposure variables the difference was not statistically significant (Table 21).

5.4 Sensitivity Analysis for Over-dispersion

Quasi-Poisson models were employed to test for data over-dispersion. Results showed that for all indicators except GP prescriptions data were not over-dispersed. These models did not produce any statistically significant results (Table 19)

5.5 Partial autocorrelation

Partial autocorrelation function was used to check if adjustment for seasonality in various models had been eliminated or reduced. Figures 2 and 3 are examples of results from a partial autocorrelation of GP attendances with major respiratory conditions which show a significant reduction in autocorrelation.

Figure 2: Partial autocorrelation of GP attendances with major respiratory conditions

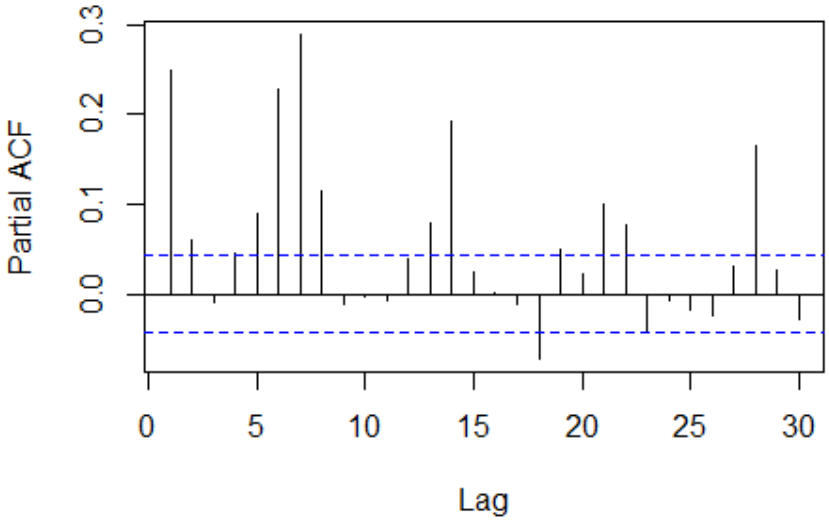
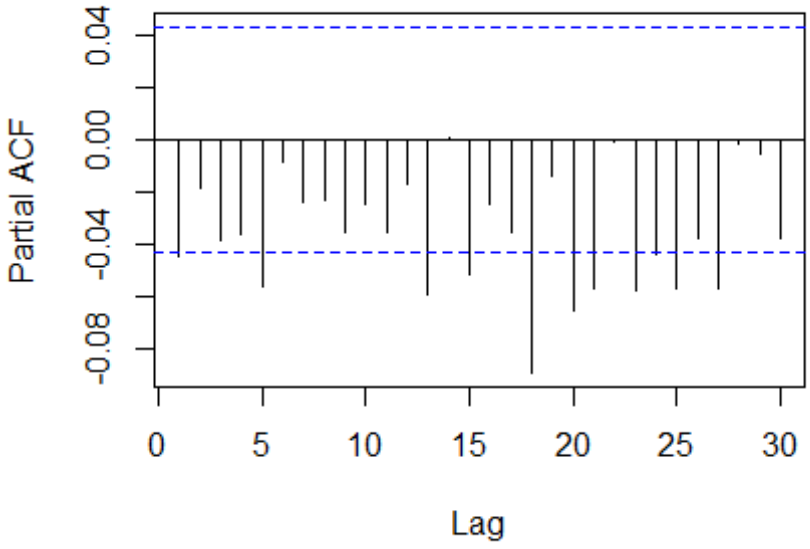


Figure 3: Partial autocorrelation of GP attendances with major respiratory conditions after adjustment for seasonality – Model 2 (Basic model + Temperature + Holidays + Wind speed + Weekdays + 12df spline)



5.6 Limitations

The accuracy of results from the modelling processes is subject to the quality of data provided to us by various sources i.e. London Fire Brigade (Fire Incidents), Breathe London (Air Quality), London City Meteorological Station (Meteorological data), NHS NEL ICB (GP Attendance, Hospital A&E Attendance) and NHS Digital (Hospital Admissions).

Fire days refer to the days when London Fire Brigade attended the site but in real terms the fire may have started days before the intervention and therefore the increased healthcare activity on fire days could have been with the cumulative impact over a number of hours / days leading to the recorded fire day. Furthermore, most recorded fire incidents occurred in clusters either on alternate days or 2 to 6 days in a row. This may have resulted in sustained and heightened exposure and harmful health impact hence contributing to the observed modest increase in health care activities over the fire days.

For outcome variables we relied entirely on the NHS data. The major respiratory conditions dataset did not include details on specific presenting symptoms apart from the main diagnosis. It was therefore not possible to differentiate between arranged attendances for routine reviews and those booked by patients with acute respiratory illness. However, we would not expect routine reviews to significantly differ on fire days as compared to non-fire days or to be influenced by other exposure variables utilised in our models.

A separate dataset for GP attendance with respiratory symptoms was available for analysis but only 55% of patients with respiratory LTCs were linked to this dataset. Also most of the dates of attendance i.e. diagnosis with major respiratory condition and recorded respiratory symptoms did not match even though the attendances in both cases were during the assessment period (2018-2023). However, we did consult with NHS colleagues and a GP representative who clarified that in most cases where reason for attendance is recorded as a specific condition e.g. COPD, it is reasonable to assume the visit was associated with the condition even where specific symptoms were not recorded.

Table 18: Poisson regression models for the impact of local population exposure to general fire pollutants (on fire days) and $PM_{2.5}$ levels on respiratory healthcare activity, adjusted for seasonality, weekdays, holidays, other meteorological factors and COVID-19 lockdown dates.

Model	Outcome 1: GP Attendances Resp Symptoms[1], Fire Incidents RR (95% CI)	Outcome 1: GP Attendances Resp Symptoms[1], $PM_{2.5}$ RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], Fire Incidents RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], $PM_{2.5}$ RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], Fire Incidents RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], $PM_{2.5}$ RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, Fire Incidents RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, $PM_{2.5}$ RR (95% CI
Basic model*	0.897 (0.734, 1.096)	0.995 (0.990, 1.000)	1.272 (0.969, 1.669)	0.996 (0.987, 1.005)	1.317 (0.984, 1.762)	1.000 (0.990, 1.010)	0.697 (0.416, 1.170)	0.993 (0.981, 1.005)
Basic model + Temperature** + Holidays*** + Wind speed + Weekdays***	1.003 (0.821, 1.226)	0.996 (0.989, 1.002)	1.323 (1.009, 1.735)	0.999 (0.989, 1.009)	1.345 (1.007, 1.798)	1.003 (0.991, 1.014)	0.786 (0.467, 1.322)	0.993 (0.979, 1.007)
β Model above + Covid19 lockdowns****	1.001 (0.819, 1.224)	0.996 (0.989, 1.002)	1.321 (1.007, 1.732)	0.999 (0.989, 1.009)	1.343 (1.005, 1.795)	1.003 (0.991, 1.014)	0.786 (0.467, 1.322)	0.993 (0.979, 1.007)
Model above + NO2	1.000 (0.818, 1.222)	0.996 (0.989, 1.002)	1.325 (1.010, 1.738)	0.999 (0.988, 1.010)	1.348 (1.009, 1.802)	1.002 (0.990, 1.014)	0.785 (0.467, 1.322)	0.991 (0.976, 1.007)

Model	Outcome 5: GP Resp Prescriptions, Fire Incidents RR (95% CI)	Outcome 5: GP Resp Prescriptions, $PM_{2.5}$ RR (95% CI)	Outcome 6: Resp Hospital Admissions, Fire Incidents RR (95% CI)	Outcome 6: Resp Hospital Admissions, $PM_{2.5}$ RR (95% CI)	Outcome 7: Resp A&E Attendance, Fire Incidents RR (95% CI)	Outcome 7: Resp A&E Attendance, $PM_{2.5}$ RR (95% CI)
Basic model*	0.951 (0.921, 0.981)	1.000 (0.999, 1.001)	1.017 (0.829, 1.247)	1.004 (0.998, 1.010)	0.947 (0.732, 1.226)	1.005 (0.997, 1.013)
Basic model + Temperature** + Holidays*** + Wind speed + Weekdays***	0.997 (0.966, 1.029)	1.000 (0.999, 1.001)	1.036 (0.845, 1.271)	1.005 (0.998, 1.012)	0.934 (0.721, 1.210)	1.003 (0.993, 1.012)
β Model above + Covid19 lockdowns****	1.000 (0.969, 1.032)	1.000 (0.999, 1.001)	1.034 (0.843, 1.268)	1.005 (0.999, 1.012)	0.935 (0.722, 1.211)	1.003 (0.993, 1.012)
Model above + NO2	1.001 (0.970, 1.033)	0.999 (0.998, 1.001)	1.031 (0.841, 1.265)	1.006 (0.999, 1.013)	0.667 (0.602, 0.739)	0.997 (0.994, 0.999)

[1]Cough, sore throat, wheezing
[2]Asthma, Chronic Obstructive Pulmonary Disease, Bronchitis, Emphysema, Cystic fibrosis, Lung cancer, Mesothelioma, Pneumonia, Pulmonary fibrosis, Respiratory infections or any other respiratory condition.
[3]Asthma, Chronic Obstructive Pulmonary Disease, Cystic fibrosis, Lung cancer, Mesothelioma
*Basic model includes the exposure of interest and a spline function of time. After comparing AIC values, 12 degrees of freedom were used for outcomes 1, 2, 3 and 5 and 8 degrees of freedom for outcomes 4, 6, and 7.
**Holidays as a binary variable
***Weekdays as a factor variable (Mon/Tue/Wed/...)
****To check the impact of lockdowns on the effect estimates. β Main Regression Model

6 Results: Sensitivity Analysis

6.1 Quasi-Poisson model for over-dispersion

Table 19: Quasi-Poisson regression models for the impact of local population exposure to general fire pollutants (on fire days) and PM2.5 levels on respiratory healthcare activity, adjusted for seasonality, weekdays, holidays, other meteorological factors and COVID-19 lockdown dates.

Model	Outcome 1: GP Attendances Resp Symptoms[1], Fire Incidents RR (95% CI)	Outcome 1: GP Attendances Resp Symptoms[1], $PM_{2.5}$ RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], Fire Incidents RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], $PM_{2.5}$ RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], Fire Incidents RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], $PM_{2.5}$ RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, Fire Incidents RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, $PM_{2.5}$ RR (95% CI
Basic model*	0.897 (0.683, 1.178)	0.995 (0.988, 1.002)	1.272 (0.926, 1.747)	0.996 (0.985, 1.007)	1.317 (0.941, 1.843)	1.000 (0.989, 1.011)	0.697 (0.402, 1.210)	0.993 (0.980, 1.006)
Basic model + Temperature** + Holidays*** + Wind speed + Weekdays***	1.003 (0.810, 1.243)	0.996 (0.989, 1.002)	1.323 (0.987, 1.775)	0.999 (0.988, 1.010)	1.345 (0.976, 1.855)	1.003 (0.990, 1.015)	0.769 (0.444, 1.333)	0.993 (0.979, 1.007)
βModel above + Covid19 lockdowns****	1.000 (0.807, 1.239)	0.996 (0.989, 1.002)	1.343 (0.975, 1.852)	0.999 (0.988, 1.010)	1.343 (0.975, 1.852)	1.003 (0.990, 1.015)	0.786 (0.460, 1.341)	0.993 (0.979, 1.006)
Model above + NO2	1.000 (0.807, 1.239)	0.996 (0.989, 1.003)	1.326 (0.988, 1.777)	0.999 (0.987, 1.011)	1.348 (0.978, 1.859)	1.002 (0.989, 1.016)	0.786 (0.460, 1.342)	0.991 (0.977, 1.006)

Model	Outcome 5: GP Resp Prescriptions, Fire Incidents RR (95% CI)	Outcome 5: GP Resp Prescriptions, $PM_{2.5}$ RR (95% CI)	Outcome 6: Resp Hospital Admissions, Fire Incidents RR (95% CI)	Outcome 6: Resp Hospital Admissions, $PM_{2.5}$ RR (95% CI)	Outcome 7: Resp A&E Attendance, Fire Incidents RR (95% CI)	Outcome 7: Resp A&E Attendance, $PM_{2.5}$ RR (95% CI)
Basic model*	0.951 (0.814, 1.111)	1.000 (0.995, 1.005)	1.017 (0.820, 1.261)	1.004 (0.998, 1.010)	0.947 (0.728, 1.232)	1.005 (0.997, 1.013)
Basic model + Temperature** + Holidays*** + Wind speed + Weekdays***	0.997 (0.937, 1.062)	1.000 (0.998, 1.002)	1.036 (0.840, 1.277)	1.005 (0.998, 1.012)	0.934 (0.717, 1.216)	1.003 (0.993, 1.012)
β Model above + Covid19 lockdowns****	1.000 (0.939, 1.064)	1.000 (0.998, 1.003)	1.034 (0.839, 1.275)	1.005 (0.998, 1.012)	0.935 (0.718, 1.217)	1.003 (0.993, 1.012)
Model above + NO2	1.001 (0.941, 1.066)	0.999 (0.997, 1.002)	1.031 (0.836, 1.271)	1.006 (0.997, 1.013)	0.667 (0.462, 0.963)	0.997 (0.988, 1.005)

[1]Cough, sore throat, wheezing
[2]Asthma, Chronic Obstructive Pulmonary Disease, Bronchitis, Emphysema, Cystic fibrosis, Lung cancer, Mesothelioma, Pneumonia, Pulmonary fibrosis, Respiratory infections or any other respiratory condition.
[3]Asthma, Chronic Obstructive Pulmonary Disease, Cystic fibrosis, Lung cancer, Mesothelioma
*Basic model includes the exposure of interest and a spline function of time. After comparing AIC values, 12 degrees of freedom were used for outcomes 1, 2, 3 and 5 and 8 degrees of freedom for outcomes 4, 6, and 7.
**Holidays as a binary variable
***Weekdays as a factor variable (Mon/Tue/Wed/...)
****To check the impact of lockdowns on the effect estimates. β Main Regression Model

6.2 Poisson regression models for lagged impact

6.2.1 Three days Lag

Table 20: Poisson regression models for delayed impact on local population with exposure to general fire pollutants (3 days following London Fire Brigade intervention) on respiratory healthcare activity, adjusted for seasonality, weekdays, holidays, other meteorological factors and COVID-19 lockdown dates.

Model	Outcome 1: GP Attendances Resp Symptoms[1], Fire Days Lag3 RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], Fire Days Lag3 RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], Fire Days Lag3 RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, Fire Days Lag3 RR (95% CI)
Basic model*	0.982 (0.832, 1.159)	0.884 (0.690, 1.132)	1.020 (0.786, 1.325)	0.970 (0.674, 1.396)
Basic model + Temperature + Holidays** + Wind speed + Weekdays***	0.938 (0.794, 1.108)	0.920 (0.714, 1.184)	1.056 (0.809, 1.379)	0.940 (0.654, 1.353)
βModel above + Covid19 lockdowns****	0.935 (0.792, 1.105)	0.935 (0.792, 1.105)	1.054 (0.807, 1.376)	0.940 (0.654, 1.352)
Model above + NO2	0.931 (0.788, 1.000)	0.921 (0.715, 1.186)	1.059 (0.811, 1.384)	0.939 (0.652, 1.351)

Model	Outcome 5: GP Resp Prescriptions, Fire Days Lag3 RR (95% CI)	Outcome 6: Resp Hospital Admissions, Fire Days Lag3 RR (95% CI)	Outcome 7: Resp A&E Attendance, Fire Days Lag3 RR (95% CI)
Basic model*	1.035 (1.008, 1.063)	1.059 (0.896, 1.250)	0.992 (0.803, 1.224)
Basic model + Temperature + Holidays** + Wind speed + Weekdays***	1.018 (0.991, 1.045)	1.040 (0.881, 1.228)	0.987 (0.799, 1.218)
βModel above + Covid19 lockdowns****	1.021 (0.993, 1.048)	1.038 (0.879, 1.226)	0.988 (0.800, 1.220)
Model above + NO2	1.024 (0.996, 1.052)	1.032 (0.874, 1.219)	0.979 (0.793, 1.209)

[1]Cough, sore throat, wheezing
[2]Asthma, Chronic Obstructive Pulmonary Disease, Bronchitis, Emphysema, Cystic fibrosis, Lung cancer, Mesothelioma, Pneumonia, Pulmonary fibrosis, Respiratory infections or any other respiratory condition.
[3]Asthma, Chronic Obstructive Pulmonary Disease, Cystic fibrosis, Lung cancer, Mesothelioma
*Basic model includes the exposure of interest and a spline function of time. After comparing AIC values, 12 degrees of freedom were used for outcomes 1, 2, 3 and 5 and 8 degrees of freedom for outcomes 4, 6, and 7.
**Holidays as a binary variable
***Weekdays as a factor variable (Mon/Tue/Wed/...)
****To check the impact of lockdowns on the effect estimates. β Main Regression Model

6.2.2 Seven days Lag

Table 21: Poisson regression models for delayed impact on local population due exposure to general fire pollutants (7 days following London Fire Brigade intervention) on respiratory healthcare activity, adjusted for seasonality, weekdays, holidays, other meteorological factors and COVID-19 lockdown dates.

Model	Outcome 1: GP Attendances Resp Symptoms[1], Fire Days Lag7 RR (95% CI)	Outcome 2: GP Attendances Major Resp Conditions[2], Fire Days Lag7 RR (95% CI)	Outcome 3: GP Attendances Resp LTC[3], Fire Days Lag7 RR (95% CI)	Outcome 4: GP Attendances Resp LTC & Symptoms, Fire Days Lag7 RR (95% CI)
Basic model*	1.040 (0.894, 1.210)	1.064 (0.844, 1.341)	1.191 (0.928, 1.528)	0.964 (0.701, 1.326)
Basic model + Temperature + Holidays** + Wind speed + Weekdays***	0.993 (0.852, 1.156)	1.023 (0.809, 1.293)	1.143 (0.888, 1.470)	0.952 (0.690, 1.313)
βModel above + Covid19 lockdowns****	0.990 (0.851, 1.153)	1.020 (0.807, 1.289)	1.140 (0.886, 1.467)	0.952 (0.691, 1.313)
Model above + NO2	0.988 (0.848, 1.151)	1.026 (0.811, 1.296)	1.147 (0.892, 1.476)	0.953 (0.691, 1.314)

Model	Outcome 5: GP Resp Prescriptions, Fire Days Lag7 RR (95% CI)	Outcome 6: Resp Hospital Admissions, Fire Days Lag7 RR (95% CI)	Outcome 7: Resp A&E Attendance, Fire Days Lag7 RR (95% CI)
Basic model*	1.028 (1.002, 1.055)	1.075 (0.923, 1.252)	1.113 (0.919, 1.349)
Basic model + Temperature + Holidays** + Wind speed + Weekdays***	0.980 (0.955, 1.005)	1.064 (0.913, 1.240)	1.105 (0.912, 1.340)
βModel above + Covid19 lockdowns****	0.983 (0.958, 1.008)	1.063 (0.912, 1.238)	1.107 (0.913, 1.342)
Model above + NO2	0.985 (0.960, 1.011)	1.058 (0.908, 1.233)	1.102 (0.908, 1.336)

[1]Cough, sore throat, wheezing
[2]Asthma, Chronic Obstructive Pulmonary Disease, Bronchitis, Emphysema, Cystic fibrosis, Lung cancer, Mesothelioma, Pneumonia, Pulmonary fibrosis, Respiratory infections or any other respiratory condition.
[3]Asthma, Chronic Obstructive Pulmonary Disease, Cystic fibrosis, Lung cancer, Mesothelioma
*Basic model includes the exposure of interest and a spline function of time. After comparing AIC values, 12 degrees of freedom were used for outcomes 1, 2, 3 and 5 and 8 degrees of freedom for outcomes 4, 6, and 7.
**Holidays as a binary variable
***Weekdays as a factor variable (Mon/Tue/Wed/...)
****To check the impact of lockdowns on the effect estimates. β Main Regression Model