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Do ultrafine particles confound studies on noise and cardiovascular disease?

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ABSTRACT

Ultrafine particles (UFP) are emitted by both jet engine aircraft and road traffic and may potentially confound associations between noise and health outcomes. However, neither UFP or noise are routinely measured resulting in a lack of understanding of their relationship. We conducted repeated short-term measurements with portable sensors to assess the correlation between noise and UFP number concentrations (PNC) for aircraft and road traffic. Noise and PNC were measured contemporaneously for 30-minutes at 160 sites (repeated three times at a range of site types) in Norwich, a medium size city in the east of England, and repeatedly up to 71 times per site at nine sites (501 in total) around Gatwick airport. In Combining all measurements at Gatwick Airport the correlation was very weak (ρ = 0.11). Strongest correlations were moderate (|>0.4-0.6|) at a residential site 1.3 km north of the runway and a site 0.6 km south of the runway. The correlation between noise and PNC in Norwich was overall moderate (ρ = 0.52) and weak (ρ <0.4) for roadside sites (n = 55) and urban background sites (n = 90) respectively. Results suggest that PNC are unlikely to be a major confounder in epidemiological studies of aircraft or road noise and cardiovascular disease.

Keywords: noise, ultra-fine particles, particle number, measurements, aircraft, road traffic.

1. INTRODUCTION

Ultrafine particles (UFP, particulate matter with one dimension less than 100 nanometres) are emitted by both road traffic and jet engines and may potentially confound associations with noise. For example, it was suggested that UFP from aircraft were a possible explanation (1) for the higher rates of cardiovascular hospital admissions and mortality found in relation to aircraft noise exposure near Heathrow airport (2). Given their small size, UFP can pass into the systemic circulation, thereby invading all organ systems (3). Previous reviews have provided suggestive evidence of adverse health effects of exposure to UFP (3, 4), affecting pulmonary/systemic inflammation and cardiovascular outcomes in 79 short term studies and 10 long term studies. However, UFPs are not routinely monitored in most areas (4). In the United Kingdom, for example, there are currently three routine UFP monitoring sites (5). We present work from measurement campaigns focusing on aircraft and road traffic with the aim of obtaining information on the level of correlations between noise and UFP.

2. METHODS

2.1 Overview

We conducted repeated short-term measurements with portable sensors to assess the correlation between noise and ultra-fine particle number concentrations (PNC) for aircraft and road traffic. For road traffic we used data collected in the EXPOsOMICS project (6). For aircraft we used data from an ongoing project looking at long-term cardiovascular impacts of aircraft noise near major airports in the UK - 'Aircraft Noise and Cardiovascular outcomes (ANCO)'.

2.2 Study areas

For aircraft noise the aim was to contemporaneously measure noise (decibels) and PNC (particles/cm^3) without confounding from other sources such as road traffic. We chose Gatwick as it is a major airport in a predominantly rural area. Gatwick lies ~40 km south of London in the county of West Sussex. Take-offs and landings are to the east or west of the airport depending on the direction of the prevailing wind. The town of Horley (population ~25,000) lies to the north and Crawley (population ~112,000), the largest town in the area, to the south. The most heavily trafficked road is the M23 motorway running north-south at ~2km east of the airport, beyond which is flat, uninterrupted countryside. The area to the west of the airport is uninterrupted, gently undulating countryside.

For road traffic, measurements were undertaken in the city of Norwich (population ~196,000) in the east of England. Norwich is the largest urban area in the county of Norfolk and lies ~160 km to the north east of London. The main local source of environmental pollution is from road traffic except in proximity to a regional airport in the north of the city.

2.3 Site selection

For aircraft noise we selected nine sites for measurements (Figure 1). Five of the sites (three to the east and two to the west of the airport) were selected both to fall on or close to the flights path and not be near to any other significant source of noise or PNC. Additionally, Site 3 (Roband) was close to the end of the runway but next to a moderately trafficked road. During a pilot of the study we measured PNC at ~10 km east and west of the airport under a range of meteorological conditions and PNC were not elevated above background due to passing of aircraft. We therefore chose to focus on the areas closer to the airport. The furthest site from the runway (Site 8, Holmlea) was 5.6 km to the east. The other three sites were co-located with air pollution monitoring stations managed by Reigate and Banstead Borough Council that are part of the London monitoring network (7), where continuous long-term measurements of noise and PNC are being made as part of this study - not presented here. Site numbers reflect the general order in which sites were visited.

For road traffic, noise and PNC were measured at 160 sites (Figure 2). The site types were selected to cover the range of geographical settings in the city representing residential locations: roadside (i.e. main roads with annual average daily traffic (AADT) > 10,000 vehicles), urban background, urban green space, industrial, and regional background (rural). We avoided sites in proximity to cafés and restaurants which can be a significant source of outdoor PNC (8).

2.4 Monitoring equipment

The same types of sensor were used to assess noise and PNC for both aircraft and road traffic. For noise we used a Cirrus Research Optimus sound level meter (CR:171B), calibrated using an acoustic calibrator at the start of each day of measurements. For PNC we used a TSI 3007 condensation particle counter (CPC) operating with a flow rate of 100 mL/min. Particles measured are in the size range 10-100 nm. Prior to each measurement the CPC was 'zero-checked'. The noise meter was mounted on a tripod and the CPC inlet elevated on a pole both at a height of about 1.5m above ground level (Figure 3). Noise (LAeq) and PNC (particles/cm^3) were continuously measured at 1 Hz resolution for each 30-minute period.

2.5 Noise and PNC measurements

Measurements around Gatwick were made between July 2019 and November 2019 during the daytime after the morning peak traffic (~0900) and before the evening peak traffic (~1600). It was not possible to visit all nine sites during the course of one day and due to inclement weather the number of sites varied between days. For road traffic, noise and PNC were also measured during the daytime off-peak hours in 2014/15. Each site (n=160) was visited three times, once in each of three seasons (summer, winter, spring/autumn).

2.6 Data analysis

With a focus on relative ranking in an epidemiological context we used Spearman's correlation (ρ) to compare measured noise and PNC. For road traffic in Norwich we used the median of the three values of PNC and noise for each site. We produced correlations for all sites and separately for sites on main roads and in background areas. For aircraft we produced correlations for each site and the overall correlation by pooling data from the nine sites. We define correlation as very weak (|0-0.2|), weak (|>0.2-0.4|), moderate (|>0.4-0.6|), strong (|>0.60-0.8|), very strong (|>0.8-1.0|).

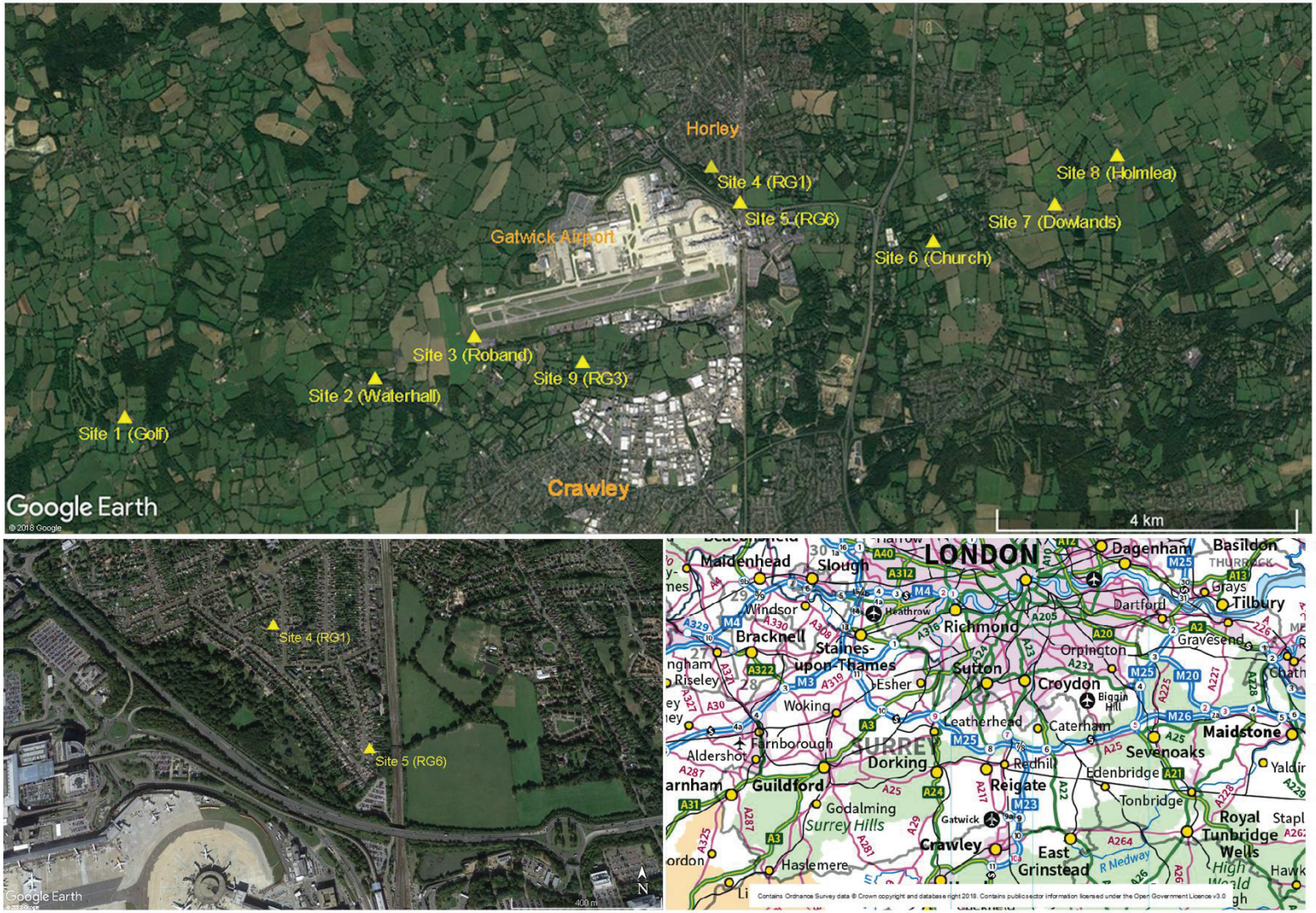


Figure 1 – study area around Gatwick airport showing the distribution of monitoring sites

For aircraft we also assessed the variability in 30-mintue median LAeq and PNC at each site. Median values were used due to the skewed distributions of both noise and PNC.

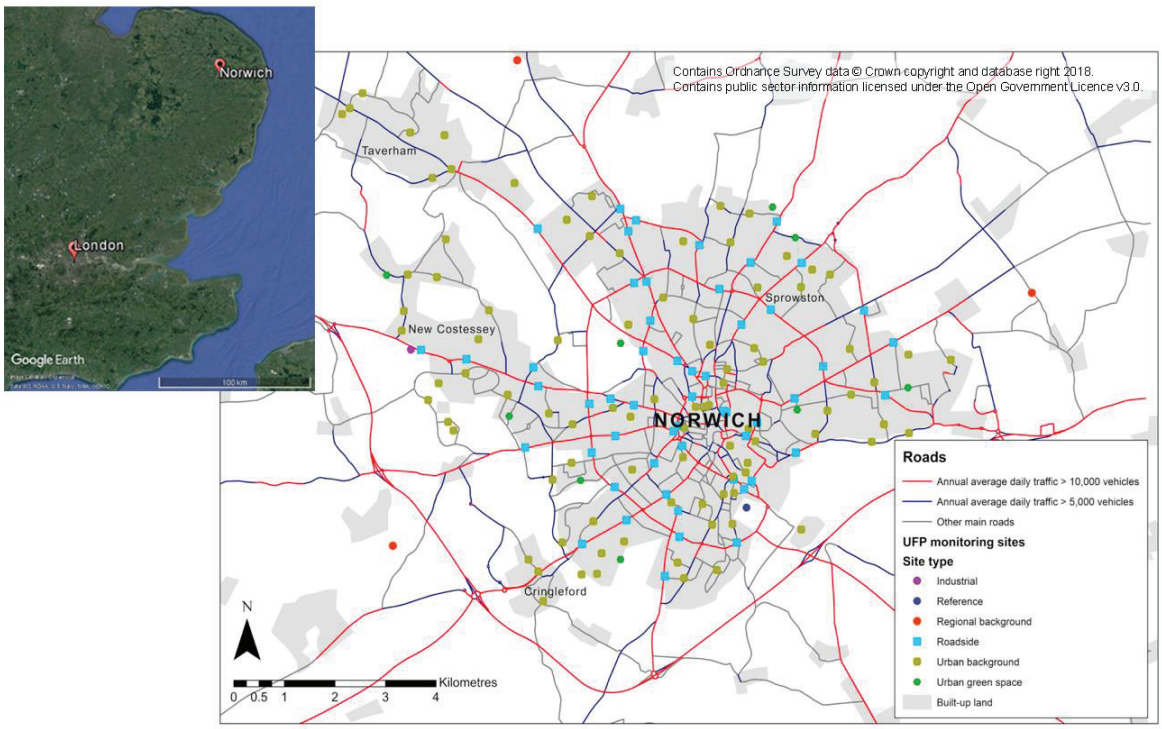


Figure 2 – study area for road traffic noise showing the distribution of monitoring sites.

Figure 3 – noise and PNC monitoring equipment

3. RESULTS

3.1 Correlations between noise and PNC

Descriptive statistics and Spearman's correlations are shown in Table 1 for sites around Gatwick Airport and in Table 2 for sites in Norwich.

Across all sites (the median values for 501 pairwise 30-minute measurements) the correlation was very weak ($\rho = 0.11$). Four of the sites (two easterly and two westerly, along flight paths) had weak or very weak negative correlation between noise and PNC. Weak positive correlations were found at Site 3 (Roband), located immediately west of the runway, and Site 4 (RG1) in a residential area of Horley. The strongest correlations were moderate (|>0.4-0.6|) at Site 5 (RG6) in a residential area in Horley and Site 9 (RG3) to the south of the runway. The overall correlation between noise and PNC in Norwich was moderate ($\rho = 0.52$). Correlations at roadside sites and urban background sites were weak. The number of sites in other categories were too small ($n < 10$) to produce correlations.

Table 1 – Summary statistics for sites around Gatwick Airport

Site type	N	Median LAeq, dB	Median PNC, particles/cm^3	Spearman's ρ (Prob. > |t|)
All	501	55.9	4928	0.11 (0.02)
Site 1 (Golf)	43	55.4	4208	-0.39 (0.01)
Site 2 (Waterhall)	52	55.7	5235	-0.23 (0.10)
Site 3 (Roband)	63	73.2	12230	0.37 (0.003)
Site 4 (RG1)	71	52.1	10658	0.39 (< 0.001)
Site 5 (RG6)	60	57.5	11845	0.52 (< 0.001)
Site 6 (Church)	68	55.0	4087	-0.12 (0.32)
Site 7 (Dowlands)	49	53.9	3657	-0.01 (0.93)
Site 8 (Holmlea)	36	55.5	4181	0.09 (0.59)
Site 9 (RG3)	59	54.1	4756	0.40 (0.002)

Table 2 – Summary statistics for site in Norwich

Site type	N	Median LAeq, dB	Median PNC, particles/cm^3	Spearman's ρ (Prob. > |t|)
All	160	65.6	7404	0.52 (< 0.001)
Roadside	55	71.5	9775	0.39 (0.002)
Urban Background	90	61.5	6450	0.31 (0.001)
Urban green space	10	57.0	5897	-
Industrial	1	62.9	5044	-
Regional background	4	58.0	3916	-

3.2 Variability in 30-minute median noise and PNC

For the nine sites around Gatwick, Figure 4 shows the variability of noise levels and Figure 5 shows the variability in PNC.

Median noise levels are similar for all sites along the flight path (~55dB) with the exception of Site 3 (Roband), close to the end of the runway, and yielded the highest median noise level (73.2 dB), and noise levels were consistently above 70 dB. The lowest variability in noise was at sites 3 (Roband) and 5 (RG6) which are the close to the runway. Site 3 (Roband) also had the highest median PNC. Site 4 (RG1) and site 5 (RG6) had relatively high median PNC but this did not correspond with elevated noise levels.

Figure 4 – variability in noise around Gatwick Airport

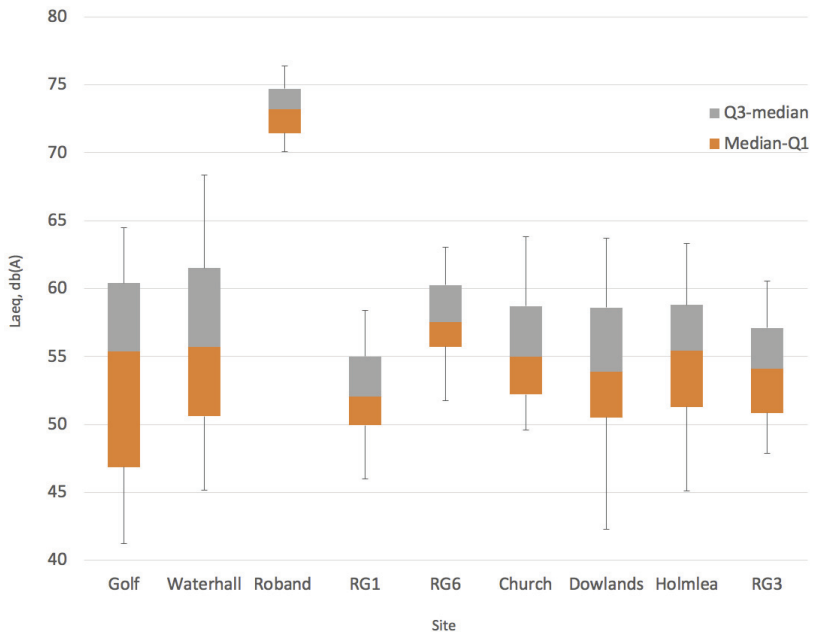
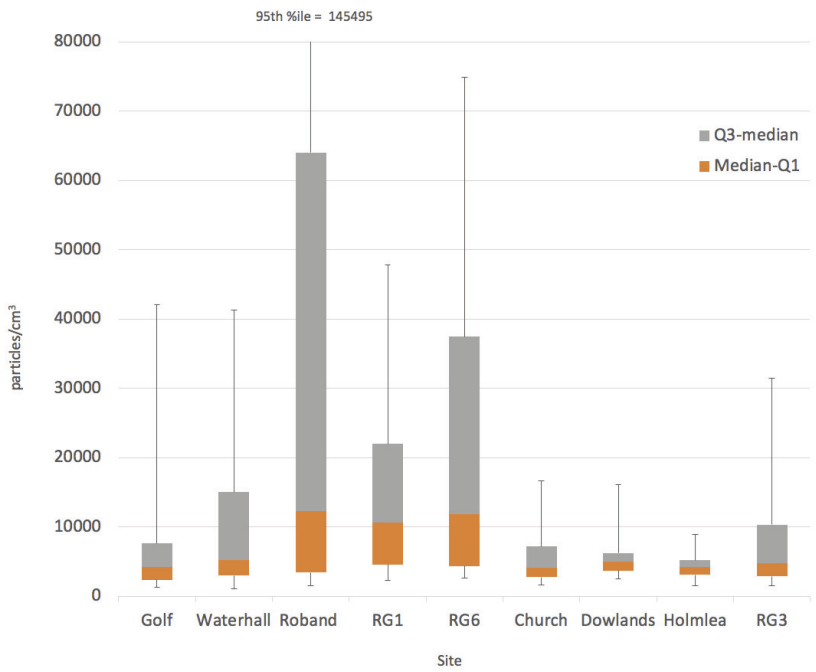


Figure 5 – variability in PNC around Gatwick Airport



4. DISCUSSION

4.1 Correlations between noise and PNC

We found overall weak correlation between noise and PNC at sites around Gatwick with moderate correlations at only two sites close to the airport. Overall correlations in Norwich were moderate where the main source of noise and PNC variability was road traffic.

Only a few other studies have looked at the relationship of noise and PNC from measurement data. Morelli et al. (9) found moderate correlations in the range 0.43-0.55 in the cities of Basel, Girona, and Grenoble from 20-minute measurements (N=141) where the main source of noise and PNC was road traffic. Cole-Hunter and colleagues conducted a panel study among 28 participants in Barcelona, Spain found no correlations between traffic related air pollution (TRAP) and fifteen minute mean noise exposures at either the low ($-0.079 \leq r \leq 0.0096$) or the high-traffic sites ($-0.16 \leq r \leq 0.035$) with continuous measures of noise and TRAP during four two-hour exposure periods (10). Similarly, a panel study among 42 adults (21 with and 21 without asthma) in the metropolitan Atlanta area found weak Pearson's correlation (r=0.27) between noise (N=69) and UFP (N=76) from continuous measures during two hours scripted highway commutes during morning rush hour (11).

Few studies focus on noise and UFP exposure in the working environment. Meier et al. investigated short-term health effects related to particle and noise exposure in 18 highway maintenance workers and found moderate correlation (r=0.5) between exposure to particles and noise during highway maintenance work during five 24-hr periods from a total of 50 observation days (12). One study on aircraft noise carried out in a small provincial airport in Sardinia, Italy found a weak correlation between UFP and noise (LAeq8hr: r=0.036; LC peak: r=0.097) (13)..

4.2 Variability in noise and PNC

Median 30-mintue noise levels in rural areas close or under the flight path were mostly >50dB and frequently >60dB. The higher levels of variability in noise at sites in rural areas is likely due to a combination of the variation in the types of aircraft, the frequency of aircraft movements, atmospheric conditions including wind speed and direction, and the differential effects on noise levels of take-offs and landings that are dependent on wind direction.

PNC were higher in residential locations 1.3 km to 1.7 km north of the airport than next to main roads in Norwich. We suggest that the variability in PNC is related to the direction of take-offs and meteorology. We expect the higher PNC at Sites 4 and 5 in Horley to be related to when aircraft take-off in a westerly direction (taxi and engine thrusting at the east end of the runway) and the wind direction is south or south west (see Figure 1). We also expect there to be an interaction between direction of take-off and wind direction (also possibly wind speed) that explains the high level of variability in PNC count at Site 3 (Roband).

We generally observed 'background' PNC at sites along the flight path of the same order of magnitude as the regional background (i.e. rural) sites in Norwich. There were some exceptions. At ~4.5km to the west of Gatwick Airport along the flight path 10% of 30-minute median PNC measurements were > 10,000 particles/cm3. At Site 4 (RG1) in Horley ~75% of PNC measurements were above background. Other studies have observed elevated levels of PNC at greater distances. Downwind of Los Angeles International Airport measured PNC was 4-5-fold background levels at 8-10km and 2-fold background up to 16km (14). PNC were 3-fold background levels at 7km downwind of Schiphol near Amsterdam (15). PNC at sites 4km and 7.5km from Logan International Airport (Boston, USA) were 2-fold and 1.33-fold, respectively, higher when downwind compared to all other wind directions (16).

In future work we will look at correlations between noise and PNC in relation to other metrics such as noise events (e.g. N65, N70) and look at the effects of meteorology and individual flight movements on the spatial distribution of noise and PNC.

4.3 Limitations

It was inevitable that some of the noise measurements were influenced by other sources that were out of our control, such as human voices and birdsong, and less frequently wind. Vehicles passed infrequently at sites 4 (RG1) 5 (RG6), and 9 (RG3) and regularly at site 3 (Roband). We could sometimes hear very distant traffic at other sites. The influence of human voices was more notable in the city of Norwich as would be expected within an urban area, and this was mainly in the city centre

or along main roads. Although we avoided sites close to cafés and restaurants levels of PNC may be influenced by the transfer of particles from indoor kitchens to outdoors.

5. CONCLUSIONS

We found overall weak correlations between noise levels and PNC number and moderate correlations at sites closest to Gatwick Airport. These results suggest that PNC would not be a major issue for confounding in epidemiological studies on aircraft noise and cardiovascular disease except for some areas in the near vicinity of the runway, but there is potential for some limited confounding for road traffic noise.

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