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RESEARCH ARTICLE

# Air pollution exposure affects circulating white blood cell counts in healthy subjects: the role of particle composition, oxidative potential and gaseous pollutants – the RAPTES project

Maaike Steenhof[1], Nicole A. H. Janssen[2], Maciej Strak[1,2]*, Gerard Hoek[1], Ilse Gosens[2], Ian S. Mudway[3], Frank J. Kelly[3], Roy M. Harrison[4,5], Raymond H. H. Pieters[1], Flemming R. Cassee[1,2], and Bert Brunekreef[1,6]

[1]*Division of Toxicology and Division of Environmental Epidemiology, Institute for Risk Assessment Sciences (IRAS), Utrecht University, Utrecht, The Netherlands,* [2]*Centre for Environmental Health, National Institute for Public Health and the Environment (RIVM), Bilthoven, The Netherlands,* [3]*MRC-PHE Centre for Environment and Health, School of Biomedical Sciences, King's College London, London, UK,* [4]*Division of Environmental Health & Risk Management, School of Geography, Earth & Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, UK,* [5]*Department of Environmental Sciences, Center of Excellence in Environmental Studies, King Abdulaziz University, Jeddah, Saudi Arabia, and* [6]*Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht, The Netherlands*

**Abstract**

Studies have linked air pollution exposure to cardiovascular health effects, but it is not clear which components drive these effects. We examined the associations between air pollution exposure and circulating white blood cell (WBC) counts in humans. To investigate independent contributions of particulate matter (PM) characteristics, we exposed 31 healthy volunteers at five locations with high contrast and reduced correlations amongst pollutant components: two traffic sites, an underground train station, a farm and an urban background site. Each volunteer visited at least three sites and was exposed for 5 h with intermittent exercise. Exposure measurements on-site included PM mass and number concentration, oxidative potential (OP), elemental- and organic carbon, metals, $O_3$ and $NO_2$. Total and differential WBC counts were performed on blood collected before and 2 and 18 h post-exposure (PE). Changes in total WBC counts (2 and 18 h PE), number of neutrophils (2 h PE) and monocytes (18 h PE) were positively associated with PM characteristics that were high at the underground site. These time-dependent changes reflect an inflammatory response, but the characteristic driving this effect could not be isolated. Negative associations were observed for $NO_2$ with lymphocytes and eosinophils. These associations were robust and did not change after adjustment for a large suite of PM characteristics, suggesting an independent effect of $NO_2$. We conclude that short-term air pollution exposure at real-world locations can induce changes in WBC counts in healthy subjects. Future studies should indicate if air pollution exposure-induced changes in blood cell counts results in adverse cardiovascular effects in susceptible individuals.

**Keywords**

Air pollution, cardiovascular effects, experimental exposure, inflammation, oxidative potential, particulate matter, volunteers, white blood cells

**History**

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## Introduction

Abundant epidemiological evidence links ambient air pollution exposure to respiratory and cardiovascular health effects (Brook et al., 2010; Brunekreef & Holgate, 2002). Currently accepted or postulated mechanisms for cardiovascular effects include initiation of systemic inflammation, changes in the autonomic nervous system and the direct action of particle and/or associated constituents on the vasculature, triggering injury and subsequent inflammation (Brook et al., 2010).

The systemic inflammatory response is characterized by the activation and mobilization of inflammatory cells into the circulation, the production of acute-phase proteins and circulating inflammatory mediators (van Eeden & Hogg, 2002). A primary component of the systemic inflammatory response is stimulation of the hematopoietic system, in particular the bone marrow, resulting in the release of white blood cells (WBC) and platelets into the circulation. In the past decades, large population-based studies have consistently shown that the circulating WBC levels to be a good predictor of cardiovascular health effects, even after adjustment for other risk factors (Bekwelem et al., 2011; Madjid et al., 2004). To date, numerous studies have investigated the association between air pollution exposure and circulating WBC with diverse outcomes (Table 1).

Current research on air pollution induced health effects has focused on identifying the critical characteristics of particulate matter (PM) that determine their biological effects

*Current address: Department of Environmental Health, Public Health Service Amsterdam, P.O. Box 2200, 1000 CE Amsterdam, The Netherlands.

Address for correspondence: Bert Brunekreef, Institute for Risk Assessment Sciences (IRAS), Utrecht University, Division of Environmental Epidemiology, P.O. Box 80178, 3508 TD, Utrecht, The Netherlands. Tel: +31-30-2539490. Fax: +31-30-2539499. E-mail: b.brunekreef@uu.nl

Table 1. Studies that investigated the association between air pollution exposure and circulating white blood cell counts in humans.

| | Study population | Exposure | Maximum dose | Duration | Blood collection (PE) | Effects on WBC |
|---|---|---|---|---|---|---|
| Observational studies | | | | | | |
| Huttunen et al., 2012 | 52 CVD patients | ambient air | | | | – |
| Pope et al., 2004 | 88 healthy elderly | ambient air | | | | – |
| Poursafa et al., 2011 | 134 healthy adults | ambient air | | | | ↑↑ total WBC |
| Rich et al., 2012 | 125 healthy adults | ambient air | | | | ↓↓ total WBC |
| Rückerl et al., 2007 | 57 CVD patients | ambient air | | | | ↓↓ total WBC |
| Schwartz, 2001 | 20 000 adults, population sample | ambient air | | | | ↑↑ total WBC |
| Seaton et al., 1999 | 112 healthy elderly | ambient air | | | | – |
| Steinvil et al., 2008 | 3659 healthy adults | ambient air | | | | – |
| Zeka et al., 2006 | 710 healthy adults | ambient air | | | | – |
| Tan et al., 2000 | healthy adults | forest fire | | | | ↑↑ % neutrohils |
| Experimental exposure studies[a] | | | | | | |
| Ghio et al., 2003 | 20 healthy adults | CAPs (C) | $PM_{10}$ 120 μg/m$^3$ | 2 h | 24 h | ↓↓ total WBC, no effect on WBC subtypes (# and %) |
| Ghio et al., 2000 | 38 healthy adults | CAPs (F) | $PM_{2.5}$ 120 μg/m$^3$ | 2 h | 18 h | – |
| Gong et al., 2003 | 12 healthy and 12 asthmatics | CAPs (F) | $PM_{2.5}$ 174 μg/m$^3$ | 2 h | 4 and 22 h | – |
| Gong et al., 2008 | 17 healthy and 14 asthmatics | CAPs (qUF) | $PM_{0.15}$ 100 μg/m$^3$ | 2 h | 4 and 22 h | – |
| Frampton et al., 2004 | 12 healthy and 16 asthmatics | CB (qUF) | $PM_{0.25}$ 25 ug/m$^3$ | 2 h | 2.5, 21 and 45 h | ↑ % neutrohils, ↓↓ % monocytes and % basophils[b] |
| Routledge et al., 2006 | 20 healthy and 20 CVD patients | CB (qUF) | $PM_{0.3}$ 50 μg/m$^3$ | 1 h | 4 and 24 h | – |
| Barath et al., 2010 | 18 healthy adults | diesel | $PM_{10}$ 250 μg/m$^3$ | 1 h | 6 h | – |
| Krishnan et al., 2013 | 15 healthy and 17 MS | diesel | $PM_{2.5}$ 200 μg/m$^3$ | 2 h | 7 and 22 h | – |
| Lucking et al., 2008 | 20 healthy adults | diesel | $PM_{10}$ 350 μg/m$^3$ | 1–2 h | 2 and 6 h | – |
| Mills et al., 2005 | 30 healthy adults | diesel | $PM_{10}$ 300 μg/m$^3$ | 1 h | 2 and 6 h | – |
| Mills et al., 2007 | 20 CVD patients | diesel | $PM_{10}$ 300 μg/m$^3$ | 1 h | 6 and 24 h | – |
| Salvi et al., 1999 | 15 healthy adults | diesel | $PM_{10}$ 300 μg/m$^3$ | 1 h | 6 h | ↑↑ # neutrophils, ↓ # lymphocytes |
| Tornqvist et al., 2007 | 15 healthy adults | diesel | $PM_{10}$ 300 μg/m$^3$ | 1 h | 24 h | – |
| Larsson et al., 2007 | 16 healthy adults | road tunnel | $PM_{10}$ 176 μg/m$^3$ | 2 h | 2 and 14 h | – |
| Klepczyńska-Nyström et al., 2012 | 20 healthy and 16 asthmatics | subway station | $PM_{10}$ 242 μg/m$^3$ | 2 h | 2 and 14 h | – |
| Barregard et al., 2006 | 13 healthy adults | wood smoke | $PM_{2.5}$ 279 μg/m$^3$ | 4 h | 3 and 22 h | – |
| Combined observational- and experimental studies | | | | | | |
| Jacobs et al., 2010 | 38 healthy cyclists | traffic | $PM_{10}$ 62.8 μg/m$^{3c}$ | 20 min | 30 min | ↑↑ % neutrophils |
| Riediker et al., 2004 | 9 healthy patrol troopers | traffic | $PM_{2.5}$ 24 μg/m$^{3c}$ | 9 h | 10–14 h | ↑↑ % neutrophils, ↓↓ % lymphocytes |
| Zuurbier et al., 2011 | 34 healthy commuters[d] | traffic | $PM_{10}$ 20.8 μg/m$^{3e}$ | 2 h | 6 h | ↓↓ total WBC and neutrophils (# and %) |

[a]Subjects performed (intermittent) exercise in all studies except for the study of Krishnan et al. (2013).
[b]Effects on monocytes and basophils were observed in females only.
[c]Average concentration.
[d]Repeated measures, $n = 352$ observations.
[e]Interquartile range.

Studies were identified through PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) using the following search terms: blood cell count AND (air pollution OR particulate matter OR diesel) AND (volunteers OR humans OR subjects). Articles retrieved were examined and studies were only included if they reported circulating white blood cell counts in humans and were published in English before May 6, 2013. Citation lists from these articles were also examined.

Two arrows indicate a significant change or association in (semi-)experimental studies or observational studies respectively, whereas one arrow represents a non-significant change in blood cell counts. Up arrows reflect an increase or positive association and down arrows a decrease or negative association. If no effect was observed this is indicated with a minus sign.

C = coarse particles; CAPs = concentrated ambient particles; CB = carbon black; CVD = cardiovascular disease; F = fine particles; h = hours; min = minutes; MS = metabolic syndrome; PE = post exposure; qUF = quasi-ultrafine particles; WBC = white blood cells; # = cell number; % = percentage of total WBC.

(Brunekreef, 2010; WHO, 2007). So far, considerable attention has been paid to particle size, number concentration, oxidative potential (OP), transition metals, organics, sulfates and nitrates and biological components such as endotoxins. Identifying the relative contribution of air pollution characteristics is particularly important in directing more informed control strategies to improve public health.

However, limitations in study design often hamper identification of the independent health effects of individual air pollution characteristics or components. Epidemiological studies typically use air pollution data obtained from central monitoring stations. This introduces pollutant specific measurement error related to the non-representativeness of central monitoring sites for personal exposure assessment. In addition, the high correlation between air pollution components in these studies makes it difficult to disentangle independent effects (Brunekreef, 2010). Controlled exposure studies on the other hand, are often limited by using individual air pollutants or sources (e.g. diesel engine exhaust) with high and constant exposures, which may not be reflective of the variable, complex mixture of particle and gas phase pollutants in ambient air.

The RAPTES project (''Risk of Airborne Particles: a Toxicological-Epidemiological Hybrid Study'') was designed to assess the independent contribution of specific air pollution characteristics to acute cardiovascular and respiratory health effects. Next to an *in vitro* study (Steenhof et al., 2011), we performed an extensive series of human exposure studies in which healthy volunteers were exposed to ambient air pollution at real-world locations with substantial differences in air pollution characteristics (Strak et al., 2011). Previously, we have investigated the effects on the respiratory system (Steenhof et al., 2013; Strak et al., 2012), as well as blood coagulation and inflammation markers (Strak et al., 2013a,b). The aim of this study was to assess the independent effect of specific air pollution characteristics on blood cell counts. We hypothesized that air pollution exposure would increase the number of WBC and that this effect would be most strongly associated with the OP of particles rather than other air pollution characteristics. This contention was based upon the view that particulate OP may be a more biologically meaningful metric for predicting human health effects than PM mass alone (Ayres et al., 2008; Borm et al., 2007).

## Methods

### *Study design*

The RAPTES study design was described previously (Strak et al., 2012). Thirty-one healthy volunteers were exposed to ambient air pollution at five different sites in the Netherlands: a continuous traffic site, a stop-and-go traffic site, an underground train station, a farm and an urban background site. The rationale for selecting different sites was to create high contrast and low correlations among different air pollutants (Strak et al., 2011). We scheduled 30 site visits on weekdays in the period from March until November 2009. Each subject participated in three to seven exposures at different sites, including at least one exposure at the underground site and for an individual subject these visits were at least 14 days apart. To minimize exposure during commuting to the sampling locations, we used a minibus equipped with a custom-made cabin air filter. The average trip time was approximately 60 min and the mean particle number concentration inside the minibus was 12 904 particles/cm$^3$ (standard deviation 3903 particles/cm$^3$), which was low compared with the exposures at the sampling sites. On-site exposures started around 09:00–09:30 a.m. and lasted for five hours. A detailed characterization of PM air pollution was performed during this five hour period. To increase the inhaled dose of air pollution, subjects cycled on a bicycle ergometer for 20 min every hour. The dose was kept similar by instructing the subjects to exercise at a heart rate corresponding to a minute ventilation rate of 20 L/min/m$^2$ as determined for each subject individually before the start of the study (Strak et al., 2012). Blood samples of each subject were collected before and at two time points after exposure (2 and 18 h) during every sampling day. A timeline of a typical sampling day is shown in Figure 1. In total, 170 observations were obtained on 30 sampling days (pre- and post-exposure).

## Study population

Volunteers were healthy, young, non-smoking subjects living at the campus of Utrecht University. We selected this population, since the student residences were less than 10 min commuting from the research center, thus to equalize and minimize the exposure outside the experiment. Details on the selection procedure as well as the in- and exclusion criteria are described previously (Strak et al., 2012). The study has been approved by the Medical Research Ethics Committee of University Medical Center Utrecht and each subject gave written informed consent.

## Exposure assessment

The methods for measuring air pollution on-site during the five hour exposure period have been described in detail elsewhere (Strak et al., 2011). Briefly, particle number concentration (PNC) was determined using a condensation particle counter measuring particles between 0.007 μm and

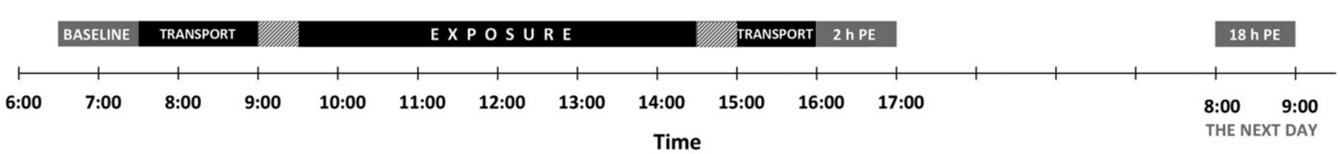


Figure 1. Timeline of a typical RAPTES sampling day (adapted from Strak et al., 2013a). Blood was drawn before exposure (baseline), 2 hours post exposure (2 h PE) and 18 hours post exposure (18 h PE) at the collection point located at the Utrecht University campus (indicated by the grey time blocks). Respiratory parameters were measured at five time points (indicated by the grey and grey-white striped time blocks) and results have been published elsewhere (Strak et al., EHP, 2012).

3 µm. $PM_{10}$ and $PM_{2.5}$ mass concentrations were collected using Harvard Impactors. The mass concentration of the coarse PM fraction ($PM_{2.5–10}$) was calculated as the difference between $PM_{10}$ and $PM_{2.5}$. After the gravimetric analysis, these PM samples were used to measure absorbance (as a measure for soot) and endotoxin concentration ($PM_{10}$ only). Additional $PM_{2.5–10}$ and $PM_{2.5}$ samples were collected using a High Volume Sampler, hereafter referred to as coarse (C) and fine (F) PM samples respectively. These samples were used for the determination of elemental carbon (EC) and organic carbon (OC), water-soluble (sol) and ''total'' (tot) acid-extracted fractions of trace metals: iron (Fe), copper (Cu), nickel (Ni) and vanadium (V), as well as inorganic components of PM (nitrate, $NO_3^-$; sulphate, $SO_4^{2-}$). Particles intrinsic oxidative potential (OP) was analyzed for the coarse, fine and quasi ultrafine (qUF) size fractions of PM sampled with an micro-orifice impactor. OP was determined *in vitro* by measuring antioxidant depletion of ascorbate ($OP^{AA}$) and reduced glutathione ($OP^{GSH}$) in synthetic human respiratory tract lining fluid and the sum of both metrics is presented as $OP^{TOTAL}$ (Godri et al., 2010). Furthermore, gaseous pollutants ozone ($O_3$) and nitrogen dioxide ($NO_2$) were measured using real-time monitors. In addition, we placed a mobile weather station next to our exposure assessment equipment to measure local meteorological conditions during the sampling days.

## Health assessment – blood cell counts

Blood was drawn by venipuncture before exposure, two hours after exposure and the next morning at the Utrecht University campus (Strak et al., 2013b). Blood was collected using 21 gauge needles into $K_2$-EDTA plasma tubes (Becton Dickinson, Plymouth, UK). Total and differential white blood cell (WBC) counts were performed by an external commercial laboratory using an automated hematology analyzer (CELL-DYN; Abbott Laboratories, Abbott Park, IL). The samples were analyzed within 24 h after collection (Strak et al., 2013b).

## Data analysis

We analyzed the associations between air pollution exposure at the sampling locations and the cell counts in blood using mixed linear regression. We used mixed models to account for correlation among measurements on the same subject across different site visits, using a random intercept model with compound symmetry as covariance structure. The dependent variables were the changes in blood cell counts between post- (2 and 18 hours) and pre-exposure measurements. Post- and pre-exposure blood cell counts were log-transformed to reduce the effect of outliers. The five-hour average concentrations of air pollutants measured at the sites were used as independent variables.

We followed the same data analysis strategy as used in our previous studies on respiratory and vascular health outcomes within the RAPTES project (Steenhof et al., 2013; Strak et al., 2012, 2013a,b). First, we specified one-pollutant models in which the association was analyzed between health endpoints and one pollutant at a time. Then, to identify the individual effects of different pollutants, we specified two-pollutant models with all possible combinations of measured pollutants. We used the following criterion to identify individual effects: an association between an air pollutant characteristic and changes in blood cell counts was considered consistent if the *p* value in the one-pollutant model was smaller than 0.1 and remained so after adjusting for all other co-pollutants in two-pollutant models. If no pollutant remained significant after adjusting for all other pollutants, our analysis was considered being unable to identify individual effects.

We included the following confounding factors in our analysis: temperature and relative humidity measured at the location during sampling, as well as the season in which the sampling day occurred (before or after the start date of the calendar summer). Baseline variability within subjects did not affect associations with the on-site exposures (data not shown) and was therefore not included as confounder. The impact of influential observations on the effect estimates (regression coefficients) was assessed using the Cook's D statistic as described in our previous publication (Steenhof et al., 2013). Since we measured a large number of air pollutants over multiple time points, we defined a large number of models, which could lead to chance findings. Therefore, we focused on consistency of significant associations and patterns observed between different cell types rather than highlighting single, isolated significant associations. Models in which two pollutants had a Spearman's rank correlation coefficient >0.7 were not interpreted, because including highly correlated variables may result in unstable effect estimates (co-linearity). Furthermore, for trace metals, data from the individual PM size fractions were aggregated ($PM_{2.5}$. + $PM_{2.5–10}$) and used as one independent variable ($PM_{10}$) to reduce the number of models. Similarly, we report absorbance, $NO_3^-$ and $SO_4^{2-}$ in the fine fraction only.

Effect estimates and their 95% confidence intervals (CI) were presented as percentage increases over our study population mean of the baseline values. We expressed these percentage increases per changes in interquartile ranges (IQR) specific to the exposure metrics. IQR is defined as the distance between the 25th and 75th percentiles and is frequently used to rescale effect estimates in (multiple) linear regression. Because the effect estimate represent the expected changes in *y* (blood cell counts) for a one unit change in *x* (air pollution exposure), the unit of the effect estimate is determined by the unit of the *x* variable (e.g. particle mass concentration [µg/m$^3$], particle number concentration [$10^3$/cm$^3$] or $NO_2$ [ppb]). Thus, by using the same standardized unit (i.e. IQR), effect estimates can be compared to each other. Additionally, it provides a meaningful unit for the observed effect (i.e. changes in blood cell counts per IQR change in exposure instead of per one unit change in exposure).

Since the underground site, compared to each outdoor site, had substantially higher concentrations of nearly all exposure parameters, we also intended to analyze the data separately for the outdoor locations and the underground location. However, in contrast to the outdoor locations, the variability in concentrations of air pollutants measured at the underground site was limited and the number of observations for this site was relatively small resulting in insufficient data for a separate analysis. Therefore, we performed the data analysis on the complete dataset (including all sites) and the outdoor dataset (excluding the underground site), but not on the underground-only dataset. All data analyses were performed using SAS 9.2 (SAS Institute, Cary, NC).

## Results

This article presents results derived from a selection of the pollutants/pollutant characteristics measured. A full overview of the analysis including all PM characteristics is shown as supplementary data for completeness. The selection is based on our previous publications showing results for $PM_{10}$ and $PM_{2.5}$ mass concentration, PNC, OC, EC and particles OP (Steenhof et al., 2013; Strak et al., 2012, 2013a,b) and also includes additional components significantly associated with changes in circulating WBC counts (i.e. metals). No associations with circulating WBC counts were observed for components such as $NO_3^-$, $SO_4^{2-}$ and endotoxin (see Appendices).

### Exposure assessment

Exposure measurements were performed during all 30 site visits. At the underground location, values of nearly all PM characteristics, especially PM mass, levels of transition metals and $OP^{TOTAL}$, were substantially higher than at the other (outdoor) sites (Table 2). At the outdoor sites, there was a large variability in concentrations of air pollutants (Appendix A). Correlations between air pollution concentrations are shown in Appendix B. $PM_{10}$ and $PM_{2.5}$ were highly correlated with each other, as well as with EC(C), OC(C), trace metals and $OP^{TOTAL}$, but not with PNC or $NO_2$. Those high correlations decreased considerably after excluding the measurements from the underground train station (outdoor dataset). However, in the outdoor dataset, we observed higher correlations for PNC with EC(C) and several other components (i.e. absorbance, Cu and Fe). Overall, the correlations between several PM characteristics were sufficiently low to investigate their independent associations with blood cell counts in two-pollutant models.

### Descriptive statistics: study population and blood cell counts

Characteristics of the 31 subjects are shown in Table 3. Blood was successfully collected pre-exposure ($n = 170$ samples), but sampling failed seven times post-exposure (three times 2 h after exposure and four times the morning after exposure), therefore 167 and 166 blood samples were analyzed at the respective time points. Between and within subject variation of the baseline blood cell counts were within normal ranges of healthy individuals (Lacher et al., 2012). Because of the low *number of basophils* at baseline (median $0.03 \times 10^9$cells/L, IQR 0.02) and little variation between post- and pre-exposure (2 h and 18 h median $0.03 \times 10^9$cells/L, IQR 0.04 and 0.03, respectively), we decided to exclude this cell type from further analysis.

Two hours post-exposure (PE), we observed a significant increase of 15% in *total number of WBC* compared to pre-exposure measurements (Table 4). Results of the differential cell counts showed that the *number of neutrophils* increased whereas the other types of WBC decreased in cell number. The increase in neutrophils was larger at the underground site than at the outdoor sites (49 and 31%, respectively). In contrast, 18 h PE, we found a significant decrease of 10% in *total number of WBC* compared to the pre-exposure measurements (Table 4). The decrease in cell numbers was smaller at the underground site than at the outdoor sites for all subtypes of WBC (Table 4; results per site are shown in Appendix C). It has to be noted that the mean differences between baseline and post-exposure cell counts as shown in Table 4 (and Appendix C) can be affected by a combination of diurnal variation (2 hours PE), exercise during the

Table 3. Study population characteristics ($n = 31$ subjects).

| Characteristic | Mean (range) or *n* (%) or median (IQR) |
|---|---|
| Age (years) | 22 (19–26) |
| BMI (kg/m$^2$) | 22 (17–32) |
| Sex (women) | 21 (68%) |
| Former smokers | 3 (10%) |
| Baseline values[a] ($\times 10^9$ cell/L blood) | |
| Total WBC | 6.4 (1.9) |
| Neutrophils | 3.2 (1.2) |
| Monocytes | 0.5 (0.2) |
| Lymphocytes | 2.4 (0.7) |
| Eosinophils | 0.2 (0.1) |
| Basophils | 0.03 (0.02) |

BMI = body mass index; IQR = interquartile range.
[a]Baseline values are median values of the pre-exposure measurements obtained prior to each individual exposure ($n = 170$).

Table 2. Interquartile range, geometric mean and minimum–maximum of 5 h average air pollution concentrations at the 30 site visits.

| | IQR | All sites ($n = 30$ visits) | Outdoor sites ($n = 21$ visits) | Underground ($n = 9$ visits) |
|---|---|---|---|---|
| $PM_{10}$ | 338 | 76 (18–450) | 37 (18–130) | 394 (354–450) |
| $PM_{2.5}$ | 107 | 39 (8–167) | 23 (8–95) | 140 (123–167) |
| PNC | 28.1 | 23.0 (7.0–74.7) | 20.7 (7.0–74.7) | 29.4 (14.6–39.8) |
| EC (C) | 6.3 | 0.3 (0.0004–10) | 0.07 (0.0004–0.5) | 8 (6–10) |
| OC (C) | 2.4 | 2 (0.5–6) | 1 (0.5–5) | 4 (3–6) |
| Cu (tot) | 5996 | 160 (4–8193) | 29 (4–97) | 7001 (5267–8193) |
| Ni (tot) | 57 | 9 (0.5–78) | 4 (0.5–31) | 68 (59–78) |
| V (tot) | 15 | 6 (0.5–49) | 3 (0.5–12) | 25 (18–49) |
| $OP^{TOTAL}$ | 2721 | 190 (16–5032) | 47 (16–142) | 3082 (2368–5032) |
| $NO_2$ | 7.6 | 20 (9–34) | 20 (9–34) | 20 (14–26) |

$PM_{10}$, $PM_{2.5}$, EC and OC are expressed in μg/m$^3$; PNC in $10^3$/cm$^3$; Cu, Ni and V in ng/m$^3$; OP in 1/m$^3$; $NO_2$ in ppb. C = coarse PM fraction; IQR = interquartile range of all sites observations; tot = total.

Table 4. Descriptive statistics: percentage change in blood cell counts over baseline.

| | Percentage change over baseline[a] (95% CI) | | |
|---|---|---|---|
| | All sites ($n = 167/166$) | Outdoor sites ($n = 124/122$) | Underground ($n = 43/44$) |
| Total WBC | | | |
| 2 h PE | 15.0 (11.8; 18.4) | 10.5 (7.1; 14.1) | 25.9 (18.6; 33.6) |
| 18 h PE | −10.4 (−12.7; −8.1) | −12.2 (−14.3; −10.0) | −4.9 (−10.6; 1.2) |
| Neutrophils | | | |
| 2 h PE | 35.0 (29.3; 41.0) | 31.0 (25.1; 37.2) | 49.2 (34.8; 65.2) |
| 18 h PE | −2.0 (−5.5; 1.7) | −3.0 (−6.8; 1.1) | 1.0 (−7.6; 10.4) |
| Monocytes | | | |
| 2 h PE | −11.3 (−19.8; −1.9) | −15.6 (−25.4; −4.6) | 4.1 (−10.4; 20.9) |
| 18 h PE | −12.2 (−14.8; −9.5) | −13.9 (−16.9; −10.8) | −6.8 (−12.0; −1.2) |
| Lymphocytes | | | |
| 2 h PE | −6.8 (−10.0; −3.4) | −6.8 (−10.2; −3.2) | −5.8 (−14.4; 3.6) |
| 18 h PE | −21.3 (−23.5; −19.1) | −22.9 (−25.2; −20.5) | −17.3 (−21.7; −12.6) |
| Eosinophils | | | |
| 2 h PE | −35.6 (−43.4; −26.8) | −36.9 (−46.1; −26.1) | −31.6 (−42.9; −18.0) |
| 18 h PE | −12.2 (−16.8; −7.3) | −13.9 (−19.5; −7.9) | −5.8 (−12.8; 1.7) |

CI = confidence interval; h = hours; $n$ = number of observations for total cell counts 2 h PE/18 h PE; PE = post exposure; WBC = white blood cells.
[a]Calculated by using log-normalized cell counts. Cell counts are expressed as $10^9$ cells/L.



experiment (both PE time points) and the air pollution exposure during exercise. The mean differences between baseline and post-exposure cell counts should therefore not be interpreted as the effect of air pollution exposure. However, as exercise was kept constant across sampling days and blood was drawn at the same time on each day, differences between sites (i.e. sampling days) could be attributed to air pollution exposure. Associations between exposure and changes in WBC (post-pre) are shown for individual air pollution characteristics in the next paragraphs.

Changes in monocytes and neutrophils were significantly correlated with each other at both time points, although the correlation coefficient was modest (Spearman's R 0.40). Correlations between the other WBC subtypes were low (Spearman's R $\leq 0.20$; Appendix D).

## Associations between exposure and blood cell counts – one pollutant models

Associations between air pollution exposure and blood cell counts are expressed as percentage change in cell counts over population-average baseline per IQR increase in air pollutant (IQRs and baseline levels are shown in Tables 2 and 3, respectively).

In one-pollutant models, the *total number of WBC* was significantly positively associated with several pollutants (Figure 2A, *p* value <0.1). These significant associations were observed at both time points (2 and 18 h PE) with the same pollutants: $PM_{10}$, $PM_{2.5}$, EC(C), $OP^{TOTAL}$ and transition metals (i.e. pollutants characterizing the underground site). Effect estimates ranged from 3.9% (total V, 2 h PE; 95% CI −0.14%–8.1%) to 8.6% ($PM_{10}$ 2 h PE; 95% CI 1.7%–16%).

Results of the differential cell count showed that the *number of neutrophils* was significantly positively associated with several pollutants 2 h PE, while there were no significant associations 18 h PE (Figure 2B). In contrast to the number of neutrophils, the *number of monocytes* was significantly positively associated with several pollutants 18 h PE, whereas there were no significant associations 2 h PE (Figure 2C). Changes in the number of neutrophils and number of monocytes were associated with the same pollutants as for the total number of WBC.

As shown in Figure 2D, the *number of lymphocytes* was significantly negatively associated with $NO_2$ at both time points (−4.6%, $p = 0.04$ 2 h PE; and −4.9%, $p = 0.005$ 18 h PE) and PNC at 18 h PE (−3.7%, $p = 0.04$). However, the latter association decreased and became non-significant after removal of two influential data points with highest Cook's distance values (PNC −2.0%, $p = 0.18$). These two data points were observations from different individuals obtained at different sampling locations and there were no reasons to assume that these values were due to sampling errors. Since the effect estimate was highly influenced by two random observations (out of 166 observations), this implicates that there was no robust association between PNC and the number of lymphocytes.

The *number of eosinophils* was also negatively associated with $NO_2$ and PNC (−19%, $p = 0.02$; and −24%, $p = 0.003$ respectively), but only observed at the 2 h PE time point (Figure 2E). As for the number of lymphocytes, the association between PNC and the number of eosinophils decreased by more than 50% after excluding two influential values (−11%, $p = 0.09$). Again, these were random observations from different individuals obtained at different sampling locations, implicating that there was no robust association between PNC and the number of eosinophils.

We also performed the same data analysis on the outdoor dataset (dataset without the underground site measurements). After excluding the underground site, associations between air pollutants and the *total number of WBC*, *number of neutrophils* and *number of monocytes* became non-significant (Appendix E). Although most effect estimates decreased and became negative, there were also effect estimates that remained relatively similar (e.g. $PM_{10}$ and $PM_{2.5}$ mass concentration with both the total number of WBC and number of neutrophils 2 h PE) or increased compared to the complete dataset (e.g. Cu(tot) with the number of monocytes 18 h PE). In the outdoor dataset, negative associations for the *number of*

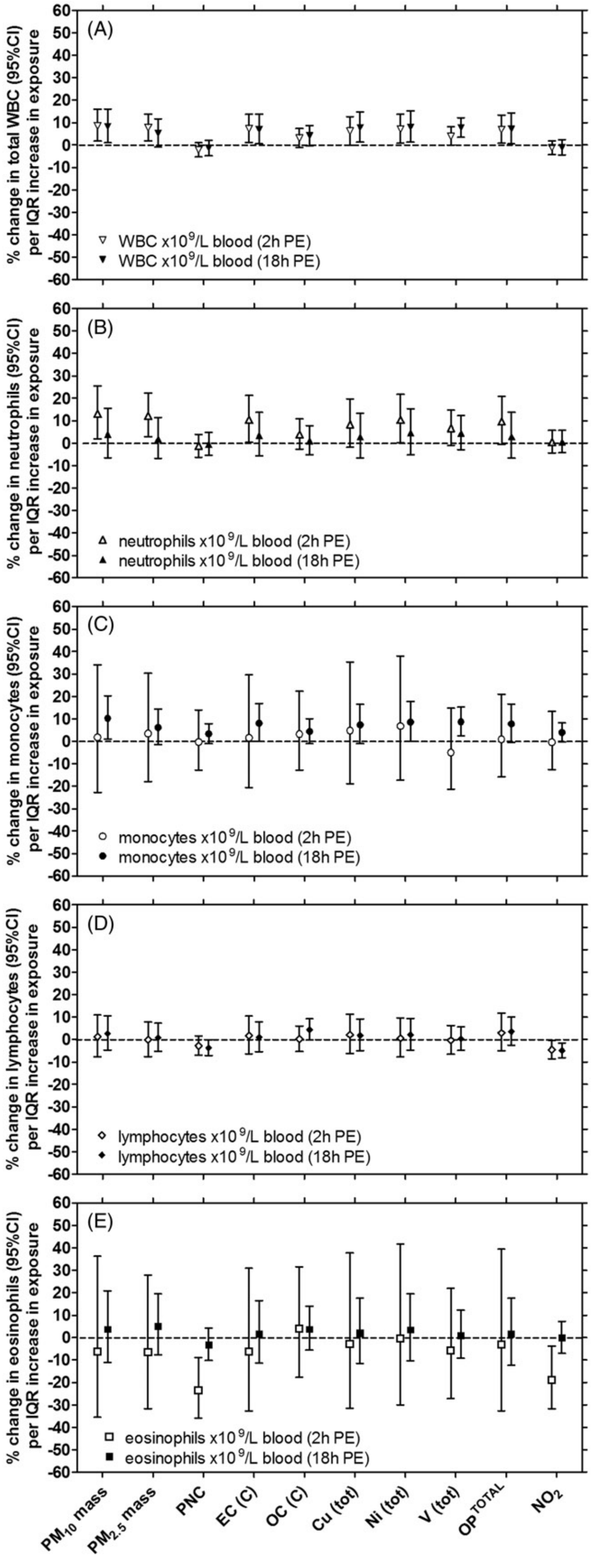


Figure 2. Associations between air pollution exposure and percentage changes (post versus pre exposure) in circulating WBC counts in *one-pollutant* models. Significant effect estimates were found for changes in total WBC counts (Figure 2A) both 2 h (open symbols) and 18 h (closed symbols) PE with multiple pollutants. Similar effects were observed for changes in the number of neutrophils (2 h PE, Figure 2B) and number of monocytes (18 h PE, Figure 2C) with the same pollutants as for the total number of WBC. Significant negative effect *continued*

*Continued*
estimates were observed for changes in lymphocytes (Figure 2D) and eosinophils (Figure 2E) with PNC and $NO_2$. Effect estimates and their 95% CI are expressed as percentage change over population-average baseline per IQR in each pollutant (IQRs and baseline levels are shown in Tables 2 and 3, respectively). All models were adjusted for temperature, relative humidity and season.

*lymphocytes* and *number of eosinophils* with $NO_2$ remained significant, although the association between the number of eosinophils and $NO_2$ was less strong than in the complete dataset (2 h PE −16%, $p = 0.11$).

A full overview of the one-pollutant model analysis on the complete and outdoor dataset, including all PM characteristics and all WBC subtypes, is available as supplementary material online at: www.informahealthcare.com/iht for completeness (RAPTES 2013 WBC).

## Associations between exposure and blood cell counts – two pollutant models

Two hours PE, none of the one-pollutant associations observed with the *total number of WBC* remained significant after controlling for any of the other pollutants (Appendix F). Eighteen hours PE, we observed consistently significant positive associations for changes in total number of WBC with water-soluble Nickel and $OP^{GSH}$(C) (Appendix G).

In two-pollutant models, none of the exposure parameters were consistently significantly positively associated with changes in the *number of neutrophils* or *number of monocytes* at any time point. All significant positive associations observed in the one-pollutant models remained significant after adding a pollutant that was not high(est) at the underground location, but became non-significant if both pollutants in the model were high at the underground site (i.e. highly correlated pollutants because of the extremely high pollutant levels at the underground site). An example is shown for $PM_{10}$, EC(C), Ni (tot) and $OP^{TOTAL}$ in Figure 3. Tables showing all pollutants analyzed can be found in Appendix H to K.

In contrast, the negative associations observed for $NO_2$ with both the *number of lymphocytes* and the *number of eosinophils* remained significant in two-pollutant models (Figure 4). The association between lymphocytes and $NO_2$ remained significant controlling for all other pollutants (Appendix L and M), whereas associations between eosinophils and $NO_2$ only lost significance after adjusting for PNC (Appendix N). We observed no other consistently significant associations for any of the other pollutants. In the outdoor dataset, associations for $NO_2$ only lost significance after controlling for $OP^{AA}$(C) and $O_3$ and thus remained a significant predictor of the number of lymphocytes after controlling for all other pollutants. As for the complete dataset, there were no other consistently significant associations with the number of lymphocytes and eosinophils in the outdoor dataset.

A full overview of the two-pollutant model analysis on the complete and outdoor dataset, including all PM characteristics and all WBC subtypes, is available as supplementary material online at: www.informahealthcare.com/iht for completeness (RAPTES 2013 WBC).

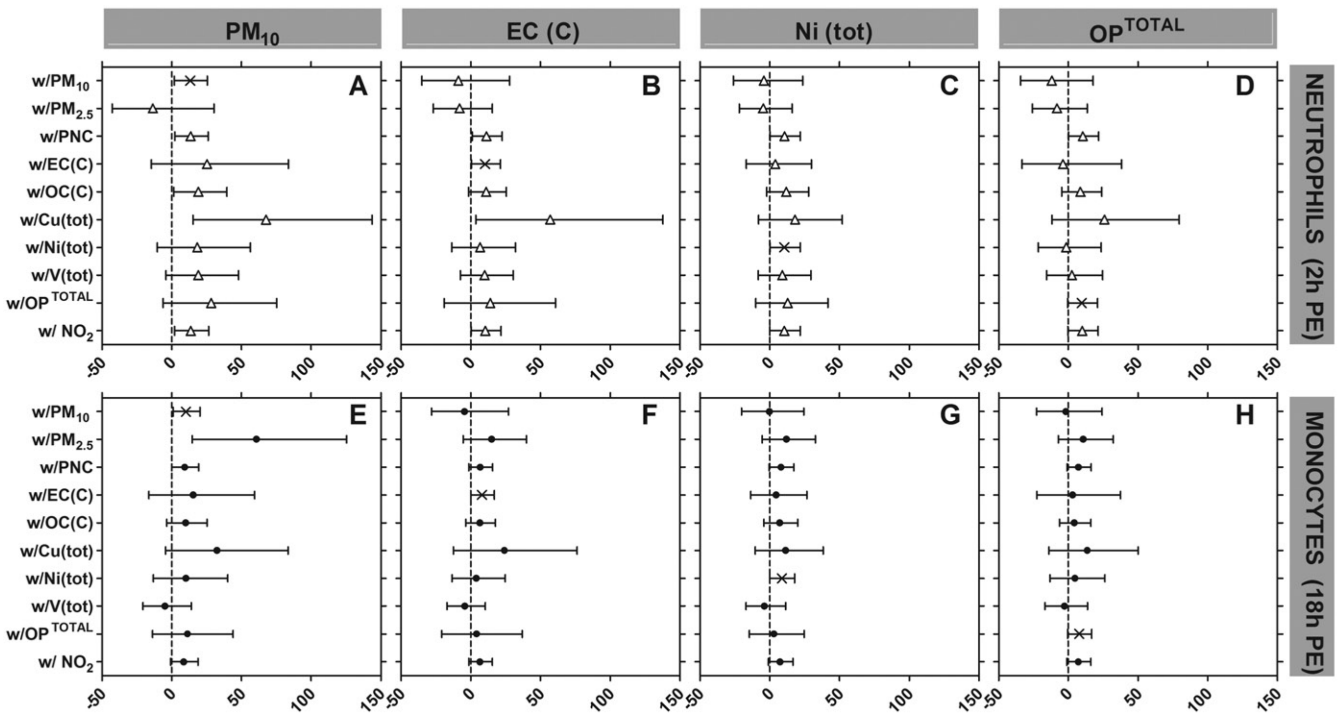


Figure 3. No consistently significant associations between air pollution exposure and percentage changes in the number of circulating *neutrophils* (2 h PE) and *monocytes* (18 h PE) in *two-pollutant* models. For both cell types, effect estimates of one-pollutant models (cross symbols) with $PM_{10}$ (Figure 3A and E), EC(C) (Figure 3B and F), total Ni (Figure 3C and G) or OP (Figure 3D and H) changed and became non-significant after adjusting for highly correlated pollutants (shown on y-axis, w = with). High correlations (Spearman's $R > 0.7$) were observed for: $PM_{10}$ with $PM_{2.5}$, OC(C), Ni(tot) and $OP^{TOTAL}$; EC(C) with Cu(tot), V(tot) and $OP^{TOTAL}$; Ni (tot) with $PM_{2.5}$, Cu (tot) and $OP^{TOTAL}$; and $OP^{TOTAL}$ with all pollutants shown except for $NO_2$ and PNC. Effect estimates and their CIs are expressed as percentage change over population-average baseline per IQR in each pollutant (IQRs and baseline levels are shown in Tables 2 and 3, respectively). All models were adjusted for temperature, relative humidity, season and adjustment pollutant.



## Discussion

We studied young, healthy volunteers at several real-world sites with contrasting PM characteristics to examine the acute effects of air pollution concentration and composition on circulating WBC differentiation. At 2 and 18 h PE, changes in the total number of WBC were significantly associated with PM characteristics that where high at the underground train station location. Two hours after exposure, a significant increase in the number of neutrophils was observed, whereas the next morning positive associations were observed with the number of monocytes. Two-pollutant models were ineffective in identifying which of the pollutants high at the underground had the strongest association. Furthermore, there were significantly *negative* associations for the number of lymphocytes and eosinophils with $NO_2$ that remained unchanged after adjustment for all other pollutants.

The time-dependent pattern of effects observed in this study indicate that air pollution exposure induces an acute inflammatory response. Two hours following the 5 h on-site exposure, the absolute number of WBC and neutrophils increased and we observed significant positive associations with the number of neutrophils for the same pollutants as for the total number of WBC. In the inflammation cascade, neutrophils are usually the first to migrate to the stressed tissue; they predominate for the first 6–24 h, peaking at 4–6 h (Kumar et al., 2009). The increase in blood neutrophils is the result of an increased efflux of neutrophils from the bone marrow storage pool and a decreased rate of loss of neutrophils from the circulation due to an increased half-life (Dale & Liles, 2003). The morning following exposure, we found positive associations with the total number of WBC and number of monocytes for the same pollutants. Monocyte recruitment into the stressed tissue usually peaks 18–24 h post challenge and they become the predominant cell type at 24–48 h (Kumar et al., 2009). Unlike neutrophils, no significant storage pool of monocytes exists in the bone marrow (Weller et al., 2003), but acute inflammation shortens the production time and induces increased production in the bone marrow (van Furth et al., 1973). This cell migration pattern corresponds to our findings, since although we observed positive associations the morning after exposure, the absolute numbers of WBC and monocytes decreased. The positive associations may thus represent an increase in monocytes that is insufficient to compensate for the migration of monocytes from the blood into the affected tissue within 18 hours after exposure.

As shown in Table 1, several studies reported no effects on circulating blood cell counts after exposure to ambient air pollution (Huttunen et al., 2012; Pope et al., 2004; Seaton et al., 1999; Steinvil et al., 2008; Zeka et al., 2006), concentrated ambient particles (Ghio et al., 2000; Gong et al., 2003), diesel exhaust (Barath et al., 2010; Krishnan et al., 2013; Lucking et al., 2008; Mills et al., 2005, 2007; Tornqvist et al., 2007), ultrafine (carbon) particles (Gong et al., 2008; Routledge et al., 2006), wood smoke (Barregard et al., 2006), road tunnel (Larsson et al., 2007) or subway air pollution (Klepczyńska-Nyström et al., 2012). However, one

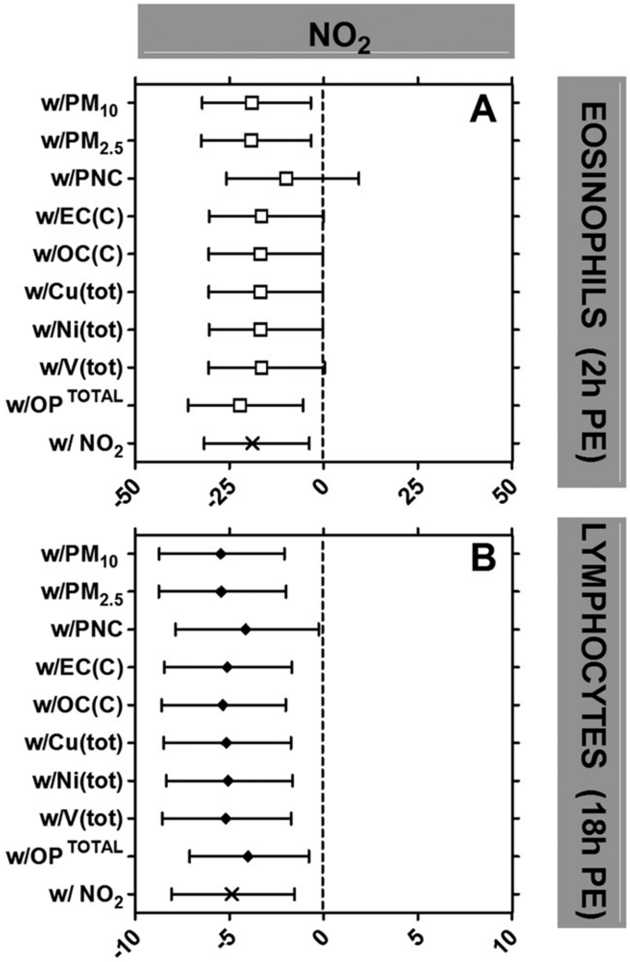


Figure 4. Consistently significant associations between $NO_2$ and percentage changes in the number of circulating *eosinophils* (2 h PE, Figure A) and *lymphocytes* (18 h PE, Figure B) in *two-pollutant* models. Effect estimates of one-pollutant models (cross symbols) remained significant after adjusting for other pollutants (shown on y-axis, w = with). Effect estimates and their 95% CI are expressed as percentage change over population-average baseline per IQR in each pollutant (IQRs and baseline levels are shown in Tables 2 and 3, respectively). All models were adjusted for temperature, relative humidity, season and adjustment pollutant.

of the differences in the study design between these studies and our work is the exposure dose and duration. In the above-mentioned studies, subjects were exposed to a maximum of 350 μg/m$^3$ $PM_{10}$ for 2 h (Lucking et al., 2008), whereas our study included one site at which subjects were exposed to an average of 394 μg/m$^3$ $PM_{10}$ for 5 h (underground train station location). After excluding measurements from this site, we no longer observed significant associations between air pollution characteristics and changes in total WBC, number of neutrophils and monocytes. A possible explanation could therefore be that there is a dose-dependent threshold for effects of air pollution on WBC.

A dose-dependent threshold is however unlikely, because, although we observed no significant effects after excluding the underground site, the effect estimates for associations between several pollutants and changes in total WBC, number of neutrophils and monocytes remained relatively similar to those observed when analyzing all sites. The absence of significant associations, may thus represent a lack of contrast in exposure rather than the absence of an effect at lower air pollution concentrations. In addition, several other studies report effects on WBC counts after exposure to lower doses of air pollution (Table 1). Some observed increases in total WBC or neutrophil counts (Frampton et al., 2004; Jacobs et al., 2010; Poursafa et al.,2011; Riediker et al., 2004; Salvi et al., 1999; Schwartz, 2001; Tan et al., 2000), whereas others found decreases in total WBC, neutrophil or monocyte counts (Ghio et al., 2003; Rich et al., 2012; Rückerl et al., 2007; Zuurbier et al., 2011). Because of major differences in study design (e.g. observational studies versus experimental studies, exposure dose, duration, study population, time of blood collection), it is difficult to compare the outcomes of these studies. For example, Jacobs et al. (2010) found an increase in percentage of neutrophils 30 minutes after 20 minutes cycling in traffic (average $PM_{10}$ concentration 62.8 μg/m$^3$), whereas Zuurbier et al. (2011) observed a decrease in number and percentage of neutrophils 6 h after 2 h in-traffic exposure (average $PM_{10}$ concentration 20.8 μg/m$^3$). Differences in study design may also be the explanation for the contrasts in the observed effects.

By using two-pollutant models we investigated the critical PM characteristics that determined the observed changes in neutrophil and monocyte counts. We found that inorganic PM components (i.e. $SO_4^{2-}$ and $NO_3^-$), gaseous pollutants ($NO_2$ and $O_3$), endotoxin and PNC did not affect the number of neutrophils and monocytes in blood, whereas we observed significant associations for PM mass concentration, absorbance, EC, OC, metals and particles OP. However, because these associations were driven by the extremely high levels of air pollution at the underground location, two-pollutant models did not distinguish which exposure metric had the strongest association. Separate analysis for the outdoor locations and the underground train station location was only possible for the outdoor locations. In the underground-only dataset, there was limited variability in concentrations of air pollutants and the number of observations for this site was relatively small, resulting in insufficient data for a separate analysis. The characteristic(s) or pollutant(s) driving the observed increases in number of neutrophils and monocytes could therefore not be isolated.

Furthermore, we observed significant decreases in the number of lymphocytes and eosinophils associated with $NO_2$ exposure. According to Rückerl et al. (2007) and Frampton et al. (2004), one explanation for the observed decreases might be that lymphocytes and eosinophils are migrating to the subendothelial space or the lung submucosa and, contrary to the number of neutrophils and monocytes, that replenishment of these WBC subtypes does not occur or will occur after more than 24 h. $NO_2$ is a free-radical promoting oxidation and the formation of nitric and nitrous acid. Thus $NO_2$ can indirectly affect cell function and viability by damaging lipids, proteins and other biomolecules (Menzel, 1976). Presumably, $NO_2$ enters the blood stream in the form of nitrite due its reaction with substrates within the respiratory tract lining fluids (Ewetz, 1993) and therefore nitrite, as well as secondary oxidation products may elicit the observed systemic effects.

Although there are numerous experimental studies that support the notion that $NO_2$ can induce airway toxicity (WHO, 2006), there are only a few human exposure studies that examined extrapulmonary effects and they show mixed results with respect to cellular changes in blood (reviewed by Hesterberg et al., 2009). For instance, Frampton et al. (2002) reported a significant decrease in blood lymphocytes with short-term exposures to 0.6 and 1.5 ppm $NO_2$ in healthy subjects, whereas Rubinstein et al. (1991) observed a non-significant increase in total WBC for 0.6 ppm $NO_2$ exposure using a similar study design. Repeated exposure to 2.0 ppm $NO_2$ did not induce cellular changes in blood (Solomon et al., 2000). $NO_2$ concentrations used in these studies were far above the levels measured in our study, yet we observed strong and consistent associations between $NO_2$ and the number of lymphocytes and eosinophils. Currently, there is still considerable debate whether the effects of $NO_2$ seen in the observational studies are due to its direct effects or rather due to PM characteristics co-varying with it (WHO, 2006). In our study however, $NO_2$ remained a significant predictor of lymphocyte and eosinophil counts controlling for a large number of PM characteristics, including PM characteristics not usually available in these types of studies. In addition, associations remained consistent when the underground measurements were removed from our analysis. This suggests that $NO_2$ may have an independent effect on lymphocyte and eosinophil cell counts.

It is uncertain whether the observed changes in blood cell counts following air pollution exposure constitute adverse health effects. It might reflect a normal response in healthy individuals rather than injury. On the other hand, our subjects were exposed for only a short period of time (5 h), it can therefore be hypothesized that continuous or repeated exposure over a long period may result in more severe effects. Furthermore, in prospective and retrospective cohort studies, as well as in case-control studies, increased levels of circulating WBC counts have been associated with adverse cardiovascular events in both healthy persons as well as those with a pre-existing cardiovascular disease (Bekwelem et al., 2011; Madjid et al., 2004). What this study thus provides is evidence that air pollution exposure can influence WBC counts in blood, which may be considered biomarkers of potential health risk in healthy as well as susceptible individuals. This provides considerable biologic plausibility for the associations between ambient air pollution exposure and cardiovascular health effects reported in previous epidemiological studies.

Details on the strengths and limitation of our study design were discussed previously (Steenhof et al., 2013; Strak et al., 2013b). In short, we used paired observations (post-, pre-exposure blood samples) and each subject was exposed at multiple sites with different air pollution sources resulting in a large number of observations with contrasting air pollution concentrations. We eliminated effects of circadian rhythm on blood cell counts by drawing the blood samples at the same time on each test day. Similarly, because exercise intensity was constant from day to day, this factor did not affect the observed associations between air pollution and our end points. In addition, as we performed our study on real-world locations, subjects were exposed to a mixture of ambient air pollutants that may be more relevant than controlled exposure studies investigating a single pollutant or source (e.g. carbon particles, diesel exhaust). Furthermore, since we measured air pollution concentrations on site during exposure of volunteers, exposure measurement error was small compared with studies relying on data from central monitoring sites. A disadvantage of studying such an extensive set of pollutants is that the multiple comparisons between the WBC subtypes and the pollutants may potentially induce chance findings. That is why in our interpretation of the results we focused on the consistency of (significant) associations across the different end points rather than individual significant associations present.

To our best knowledge, this is the first research project studying so extensively the relationship between individual components of ambient air pollution and biomarkers of effects in healthy individuals. Previously, we have shown that our approach was effective in identifying individual PM characteristics associated with effects on the airways (Steenhof et al., 2013; Strak et al., 2012) as well as blood coagulation (Strak et al., 2013a,b). In this study of circulating inflammatory cells, most associations were mainly driven by the high levels of pollutants measured at the underground train station site and therefore we could not disentangle effects of individual PM characteristics. For that reason we can neither reject nor accept our hypothesis that changes in blood cell counts are stronger and more consistently related to particles OP than with other measured air pollution characteristics. Nevertheless, we showed that several air pollution characteristics and components did not affect circulating WBC (i.e. endotoxin, PNC, $SO_4^{2-}$, $NO_3^-$ and $O_3$), thereby reducing the number of options to be investigated in future studies.

## Conclusions

In summary, this study provides evidence that short-term (5 h) air pollution exposure at real-world locations can induce changes in circulating WBC counts in young, healthy subjects. We observed acute, time-dependent increases in the total number of WBC, neutrophils and monocytes reflecting an inflammatory response. Furthermore, we found significant decreases in the number of lymphocytes and eosinophils. The observed increases in neutrophils and monocytes were driven by the high levels of air pollution at the underground train station and we were not able to isolate the PM characteristic(s) driving these effects. The observed decreases in lymphocytes and eosinophils were associated with $NO_2$ exposure. The associations we found with $NO_2$ were robust and did not change after adjustment for a wide range of other pollutants, suggesting an independent effect of $NO_2$. Future studies should indicate if air pollution exposure-induced changes in blood cell counts results in adverse cardiovascular effects in susceptible individuals.

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## Declaration of interest

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**Appendix A. Interquartile range, geometric mean and minimum-maximum of 5 h average air pollution concentrations at the 30 site visits.**

| Pollutant[a] | IQR[b] | All sites ($n=30$) | Underground ($n=9$) | Outdoor ($n=21$) | Continuous traffic ($n=5$) | Stop-and-go traffic ($n=6$) | Farm ($n=5$) | Urban background ($n=5$) |
|---|---|---|---|---|---|---|---|---|
| $PM_{10}$ | 338 | 76 (18–450) | 394 (354–450) | 37 (18–130) | 40 (36–44) | 34 (21–77) | 55 (30–130) | 26 (18–37) |
| $PM_{2.5}$ | 107 | 39 (8–167) | 140 (123–167) | 23 (8–95) | 23 (17–39) | 20 (13–63) | 36 (18–95) | 16 (8–30) |
| $PM_{2.5\text{-}10}$ | 220 | 32 (4–282) | 252 (212–282) | 13 (4–35) | 13 (4–22) | 13 (8–18) | 18 (12–35) | 9 (7–13) |
| PNC | 28.1 | 23.0 (7.0–74.7) | 29.4 (14.6–39.8) | 20.7 (7–74.7) | 66.5 (60.0–74.7) | 29.4 (12.8–42.6) | 9.6 (8.1–11.2) | 9.1 (7.0–11.8) |
| Absorbance[c] | 10 | 4.1 (0.3–16) | 13.6 (11.3–16) | 2 (0–8) | 6.1 (4.7–8) | 3.5 (1.0–6) | 1.0 (0.3–3) | 1.4 (1.2–2) |
| EC (F) | 11 | 3.8 (0.3–19) | 14.6 (12.1–19) | 2 (0–7) | 6.2 (5.6–7) | 2.8 (0.6–6) | 0.8 (0.3–2) | 1.4 (1.1–2) |
| EC (C) | 6.3 | 0.3 (0.0004–10) | 7.73 (6.4153–9.8) | 0 (0–1) | 0.45 (0.3740–0.5) | 0.30 (0.1769–0.5) | 0.02 (0.0004–0.2) | 0.0 (0.0004–0.3) |
| OC (F) | 3 | 2 (0.6–11) | 4 (2.1–11) | 1 (1–7) | 1 (0.6–4) | 1 (0.6–7) | 1 (0.6–3) | 1 (0.6–2) |
| OC (C) | 2 | 2 (0.5–6) | 4 (2.9–6) | 1 (0–5) | 1 (0.6–2) | 1 (0.9–2) | 3 (1.8–5) | 1 (0.5–1) |
| Fe (tot) | 143 067 | 3699 (132–176 699) | 154 408 (133 299–176 699) | 690 (132–2655) | 2008 (1287–2655) | 884 (698–1362) | 277 (132–513) | 365 (245–486) |
| Fe (sol) | 48 | 48 (7–431) | 114 (24–431) | 33 (7–75) | 61 (53–75) | 40 (24–71) | 15 (7–32) | 25 (16–43) |
| Cu (tot) | 5996 | 160 (4–8193) | 7001 (5267–8193) | 29 (04–97) | 90 (75–97) | 35 (23–72) | 12 (4–35) | 16 (13–22) |
| Cu (sol) | 188 | 24 (2–1637) | 517 (189–1637) | 6 (2–18) | 15 (12–18) | 6 (3–13) | 5 (3–08) | 3 (2–07) |
| Ni (tot) | 57 | 9 (0.5–78) | 68 (59.0–78) | 4 (0–31) | 3 (1.9–4) | 4 (1.6–8) | 7 (0.5–31) | 3 (2–22) |
| Ni (sol) | 2 | 2 (0.6–10) | 2 (0.9–10) | 2 (0.6–5) | 2 (0.9–5) | 2 (0.7–4) | 1 (0.6–3) | 1 (0.7–3) |
| V (tot) | 15 | 6 (0.5–49) | 25 (17.8–49) | 3 (0–12) | 3 (2.1–6) | 4 (1.3–12) | 2 (0.5–5) | 3 (1.4–6) |
| V (sol) | 2 | 2 (0.1–10) | 1 (0.1–5) | 2.2 (0.3–10) | 2 (1.2–5) | 3 (0.7–10) | 1 (0.3–4) | 2 (1.0–4) |
| Endotoxin | 0.5 | 1 (0.3–44) | 1 (1–1) | 1.1 (0.3–44) | 0 (0–1) | 0 (0–1) | 17 (11–44) | 0.5 (0.3–1) |
| $NO_3^{-}$[c] | 4 | 4 (0.6–39) | 3 (1–9) | 5 (1.2–39) | 3 (1–8) | 4 (2–19) | 7 (1–39) | 5 (3–19) |
| $SO_4^{2-}$[c] | 3 | 3 (1–21) | 2 (1–5) | 3 (1–21) | 3 (2–6) | 3 (1–5) | 4 (2–10) | 4 (2–21) |
| $OP^{AA}$ (C) | 375 | 22 (1–532) | 363 (195–532) | 5 (1–14) | 9 (6–14) | 7 (4–9) | 3 (1–9) | 4 (2–6) |
| $OP^{AA}$ (F) | 310 | 38 (3–716) | 432 (205–716) | 13 (3–70) | 16 (9–61) | 10 (3–57) | 21 (7–70) | 9 (5–29) |
| $OP^{AA}$ (qUF) | 499 | 29 (1–1678) | 644 (407–1678) | 7 (1–35) | 9 (8–13) | 11 (4–35) | 4 (1–17) | 5 (3–10) |
| $OP^{GSH}$ (C) | 341 | 27 (2–523) | 401 (276–523) | 7 (2–21) | 15 (8–21) | 9 (5–14) | 4 (2–17) | 5 (3–12) |
| $OP^{GSH}$ (F) | 323 | 24 (0.0–634) | 435 (207–634) | 6 (0–59) | 13 (4–59) | 4 (0–8) | 14 (5–40) | 2 (0.3–17) |
| $OP^{GSH}$ (qUF) | 528 | 27 (0.0–1785) | 681 (392.8–1785) | 4 (0–20) | 7 (3.0–20) | 1 (0.0–09) | 6 (0.0–12) | 6 (0.0–07) |
| $OP^{TOTAL}$ | 2721 | 190 (16–5032) | 3082 (2368–5032) | 47 (16–142) | 61 (48–76) | 50 (31–115) | 57 (21–142) | 31 (16–69) |
| $O_3$ | 22 | 7 (0.3–32) | 1 (0–6) | 18.1 (5.8–32) | 15 (6–24) | 16 (10–32) | 21 (13–26) | 22 (16–30) |
| $NO_2$ | 8 | 20 (9–34) | 20 (14–26) | 20 (9–34) | 23 (22–30) | 25 (15–34) | 17 (10–26) | 14 (9–18) |

Absorbance is expressed in $10^{-5}$/m; endotoxin is presented in EU/m$^3$; $PM_{10}$, $PM_{2.5}$, EC, OC, $NO_3^-$, $SO_4^{2-}$ are expressed in μg/m$^3$; PNC in $10^3$/cm$^3$; Fe, Cu, Ni and V in ng/m$^3$; OP in 1/m$^3$; $O^3$ and $NO_2$ in ppb. C = coarse PM fraction; F = fine PM fraction; IQR = interquartile range; $n$ = number of site visits; qUF = quasi ultrafine PM fraction; sol = water-soluble metal extraction; tot = total.

[a]Measured in $PM_{10}$ unless otherwise indicated.

[b]Interquartile ranges (IQRs) as used in this study were based on the all sites observations.

[c]Measured in $PM_{2.5}$.

## Appendix B. Spearman's correlation coefficients between PM characteristics: all sites (white) and outdoor sites only (grey).

| All sites vs outdoor | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5–10}$ | PNC | Abs. | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endo. | $NO_3^-$ | $SO_4^{2-}$ | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $PM_{10}$ | | **0.94** | **0.82** | 0.22 | **0.74** | 0.69 | 0.70 | **0.73** | **0.76** | 0.70 | 0.44 | 0.70 | **0.80** | **0.76** | 0.00 | 0.66 | −0.25 | 0.36 | 0.07 | −0.15 | **0.74** | **0.88** | **0.75** | **0.74** | **0.79** | **0.88** | **0.89** | −0.67 | 0.26 |
| $PM_{2.5}$ | **0.88** | | 0.67 | 0.15 | 0.68 | 0.64 | 0.66 | **0.79** | 0.68 | 0.62 | 0.43 | 0.65 | **0.74** | **0.71** | −0.04 | 0.67 | −0.26 | 0.34 | 0.18 | −0.04 | 0.64 | **0.94** | **0.75** | 0.68 | **0.75** | **0.86** | **0.88** | −0.65 | 0.21 |
| $PM_{2.5–10}$ | 0.55 | 0.22 | | 0.21 | **0.71** | 0.67 | 0.68 | 0.46 | **0.78** | 0.70 | 0.46 | 0.69 | **0.73** | **0.79** | 0.01 | 0.58 | −0.27 | 0.37 | −0.29 | −0.44 | **0.85** | 0.63 | 0.70 | **0.80** | 0.68 | 0.68 | **0.77** | −0.65 | 0.14 |
| PNC | 0.19 | 0.07 | 0.15 | | 0.65 | 0.67 | 0.60 | −0.04 | 0.00 | 0.62 | 0.65 | 0.60 | 0.56 | 0.07 | 0.47 | 0.25 | 0.17 | −0.32 | −0.27 | −0.16 | 0.51 | 0.12 | 0.35 | 0.53 | 0.20 | 0.23 | 0.35 | −0.37 | 0.50 |
| Abs. | 0.37 | 0.22 | 0.31 | **0.84** | | **0.98** | **0.88** | 0.49 | 0.48 | **0.92** | **0.75** | **0.89** | **0.92** | 0.64 | 0.19 | 0.66 | −0.19 | −0.01 | −0.30 | −0.36 | **0.87** | 0.69 | **0.80** | **0.84** | 0.67 | **0.72** | **0.78** | **−0.81** | 0.39 |
| EC (F) | 0.25 | 0.13 | 0.19 | **0.86** | **0.96** | | **0.89** | 0.43 | 0.42 | **0.92** | **0.74** | **0.89** | **0.90** | 0.60 | 0.24 | **0.71** | −0.15 | −0.02 | −0.35 | −0.38 | **0.87** | 0.64 | **0.78** | **0.84** | 0.69 | 0.68 | **0.76** | **−0.81** | 0.36 |
| EC (C) | 0.28 | 0.17 | 0.26 | **0.77** | **0.73** | **0.77** | | 0.36 | 0.45 | **0.88** | **0.75** | **0.92** | **0.93** | 0.54 | 0.25 | **0.77** | −0.06 | −0.07 | −0.24 | −0.41 | **0.85** | 0.65 | **0.80** | **0.89** | 0.70 | 0.69 | **0.80** | **−0.71** | 0.27 |
| OC (F) | 0.59 | **0.72** | 0.06 | −0.20 | 0.05 | −0.07 | −0.26 | | 0.46 | 0.37 | 0.20 | 0.37 | 0.53 | 0.62 | −0.18 | 0.37 | −0.35 | 0.22 | 0.36 | 0.08 | 0.41 | **0.73** | 0.55 | 0.41 | 0.43 | **0.71** | 0.60 | −0.50 | 0.19 |
| OC (C) | 0.52 | 0.39 | 0.57 | −0.06 | 0.00 | −0.13 | −0.04 | 0.08 | | 0.49 | 0.27 | 0.54 | 0.57 | 0.62 | −0.08 | 0.43 | −0.25 | 0.59 | −0.07 | −0.22 | 0.65 | 0.68 | 0.60 | 0.64 | 0.67 | **0.72** | **0.77** | −0.48 | −0.01 |
| Fe (tot) | 0.24 | 0.04 | 0.27 | **0.90** | **0.83** | **0.81** | **0.77** | −0.22 | 0.07 | | **0.78** | **0.96** | **0.88** | 0.57 | 0.15 | 0.62 | −0.26 | −0.07 | −0.31 | −0.55 | **0.82** | 0.60 | **0.75** | **0.83** | 0.68 | 0.69 | **0.72** | −0.67 | 0.27 |
| Fe (sol) | −0.05 | −0.11 | −0.01 | **0.86** | 0.65 | 0.66 | 0.59 | −0.27 | −0.23 | **0.80** | | **0.79** | **0.74** | 0.40 | 0.31 | 0.48 | −0.07 | −0.15 | −0.38 | −0.44 | 0.61 | 0.41 | 0.60 | 0.65 | 0.42 | 0.44 | 0.45 | −0.51 | 0.08 |
| Cu (tot) | 0.28 | 0.12 | 0.26 | **0.82** | **0.76** | **0.77** | **0.82** | −0.23 | 0.12 | **0.93** | 0.69 | | **0.92** | 0.53 | 0.24 | 0.67 | −0.17 | −0.05 | −0.24 | −0.46 | **0.85** | 0.64 | **0.77** | **0.88** | **0.73** | **0.73** | **0.76** | −0.70 | 0.24 |
| Cu (sol) | 0.55 | 0.41 | 0.37 | **0.71** | **0.85** | **0.80** | **0.83** | 0.09 | 0.15 | **0.78** | 0.55 | **0.82** | | 0.63 | 0.19 | 0.66 | −0.16 | 0.00 | −0.14 | −0.31 | **0.85** | **0.73** | **0.80** | **0.88** | **0.74** | **0.80** | **0.83** | **−0.73** | 0.34 |
| Ni (tot) | 0.40 | 0.27 | 0.49 | −0.09 | 0.11 | −0.01 | −0.11 | 0.37 | 0.22 | −0.10 | −0.11 | −0.16 | 0.13 | | 0.07 | 0.67 | −0.20 | 0.40 | −0.10 | −0.24 | **0.73** | 0.60 | 0.68 | **0.74** | 0.51 | 0.70 | **0.73** | −0.67 | 0.11 |
| Ni (sol) | −0.01 | −0.06 | 0.00 | 0.46 | 0.35 | 0.46 | 0.43 | −0.37 | −0.22 | 0.27 | 0.49 | 0.36 | 0.26 | 0.11 | | 0.44 | **0.74** | 0.06 | 0.03 | 0.30 | 0.26 | −0.11 | 0.24 | 0.28 | 0.04 | −0.12 | 0.04 | −0.37 | 0.26 |
| V (tot) | 0.14 | 0.19 | −0.05 | 0.20 | 0.19 | 0.29 | 0.47 | −0.18 | −0.18 | 0.04 | 0.06 | 0.21 | 0.22 | 0.16 | **0.75** | | 0.20 | 0.27 | −0.11 | −0.16 | **0.76** | 0.62 | **0.81** | **0.79** | 0.62 | 0.59 | **0.76** | **−0.80** | 0.16 |
| V (sol) | 0.04 | 0.07 | 0.00 | 0.19 | 0.14 | 0.24 | 0.42 | −0.30 | −0.17 | 0.00 | 0.11 | 0.13 | 0.13 | 0.16 | **0.81** | **0.96** | | −0.07 | 0.15 | 0.51 | −0.14 | −0.34 | −0.02 | −0.08 | −0.31 | −0.39 | −0.20 | −0.01 | 0.23 |
| Endo. | 0.22 | 0.22 | 0.22 | −0.37 | −0.30 | −0.31 | −0.49 | 0.13 | 0.40 | −0.52 | −0.45 | −0.49 | −0.42 | 0.20 | 0.08 | 0.05 | 0.14 | | −0.05 | 0.10 | 0.16 | 0.31 | 0.13 | 0.04 | 0.38 | 0.20 | 0.30 | −0.32 | −0.15 |
| $NO_3^-$ | 0.56 | **0.74** | −0.10 | −0.26 | −0.12 | −0.21 | −0.05 | 0.64 | 0.11 | −0.22 | −0.27 | −0.09 | 0.11 | 0.18 | −0.13 | 0.20 | 0.06 | 0.02 | | 0.67 | −0.31 | 0.11 | −0.08 | −0.22 | −0.17 | 0.07 | −0.05 | 0.17 | 0.27 |
| $SO_4^{2-}$ | 0.50 | **0.72** | −0.12 | −0.14 | 0.08 | 0.05 | −0.07 | 0.54 | 0.12 | −0.32 | −0.29 | −0.19 | 0.10 | 0.33 | 0.20 | 0.49 | 0.39 | 0.33 | 0.66 | | −0.42 | −0.11 | −0.22 | −0.39 | −0.30 | −0.17 | −0.16 | 0.12 | 0.29 |
| $OP^{AA}$ (C) | 0.32 | 0.04 | 0.66 | 0.53 | **0.71** | 0.67 | 0.66 | −0.15 | 0.26 | 0.55 | 0.28 | 0.64 | 0.67 | 0.28 | 0.38 | 0.37 | 0.31 | −0.25 | −0.07 | −0.03 | | 0.65 | **0.84** | **0.91** | 0.67 | **0.72** | **0.80** | **−0.84** | 0.25 |
| $OP^{AA}$ (F) | **0.74** | **0.86** | 0.10 | 0.02 | 0.21 | 0.09 | 0.10 | 0.59 | 0.34 | −0.03 | −0.15 | 0.07 | 0.34 | −0.01 | −0.22 | 0.03 | −0.07 | 0.13 | 0.66 | 0.66 | 0.05 | | **0.73** | 0.66 | **0.80** | **0.87** | **0.92** | −0.65 | 0.09 |
| $OP^{AA}$ (qUF) | 0.40 | 0.42 | 0.27 | 0.39 | 0.54 | 0.48 | 0.56 | 0.17 | 0.13 | 0.39 | 0.28 | 0.45 | 0.51 | 0.19 | 0.36 | 0.56 | 0.51 | −0.22 | 0.28 | 0.34 | 0.57 | 0.34 | | **0.82** | 0.54 | 0.66 | **0.82** | **−0.77** | 0.32 |
| $OP^{GSH}$ (C) | 0.33 | 0.19 | 0.48 | 0.53 | 0.59 | 0.59 | **0.78** | −0.14 | 0.17 | 0.56 | 0.39 | **0.75** | **0.76** | 0.30 | 0.41 | 0.46 | 0.38 | −0.50 | 0.09 | 0.06 | **0.79** | 0.13 | 0.56 | | 0.68 | **0.78** | **0.83** | **−0.72** | 0.24 |
| $OP^{GSH}$ (F) | 0.49 | 0.38 | 0.20 | 0.13 | 0.18 | 0.22 | 0.26 | 0.00 | 0.29 | 0.15 | −0.09 | 0.34 | 0.38 | −0.29 | −0.01 | 0.02 | −0.07 | 0.21 | 0.11 | 0.22 | 0.11 | 0.52 | −0.14 | 0.12 | | **0.79** | **0.81** | −0.68 | −0.02 |
| $OP_{GSH}$ (qUF) | **0.72** | 0.70 | 0.19 | 0.21 | 0.34 | 0.24 | 0.23 | 0.50 | 0.39 | 0.24 | −0.06 | 0.36 | 0.52 | 0.26 | −0.27 | −0.04 | −0.23 | −0.18 | 0.51 | 0.46 | 0.30 | **0.72** | 0.16 | 0.46 | 0.51 | | **0.91** | −0.62 | 0.12 |
| $OP^{TOTAL}$ | **0.73** | **0.73** | 0.40 | 0.22 | 0.42 | 0.35 | 0.50 | 0.24 | 0.56 | 0.23 | −0.11 | 0.38 | 0.59 | 0.28 | −0.07 | 0.37 | 0.26 | −0.02 | 0.42 | 0.54 | 0.44 | **0.82** | 0.51 | 0.56 | 0.50 | **0.82** | | **−0.72** | 0.28 |
| $O_3$ | −0.21 | −0.15 | −0.18 | −0.35 | −0.57 | −0.57 | −0.33 | −0.06 | 0.07 | −0.18 | −0.14 | −0.26 | −0.35 | −0.20 | −0.54 | −0.52 | −0.48 | −0.21 | −0.03 | −0.47 | −0.65 | −0.13 | −0.47 | −0.31 | −0.21 | −0.07 | −0.27 | | −0.36 |
| $NO_2$ | 0.49 | 0.45 | 0.28 | 0.56 | **0.74** | 0.67 | 0.60 | 0.26 | 0.06 | 0.52 | 0.34 | 0.52 | **0.71** | 0.28 | 0.28 | 0.36 | 0.27 | −0.19 | 0.26 | 0.32 | 0.55 | 0.31 | **0.74** | 0.57 | 0.08 | 0.31 | 0.58 | −0.62 | |

Shaded (grey) values are the correlations of the outdoor dataset. Spearman's R larger than 0.7 are displayed bold.

## Appendix C. Percentage change in white blood cell counts over baseline levels shown per site.

| | Baseline[a] (median, IQR) | Percentage change over baseline (95% CI)[b] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | All sites ($n$ = 167/166) | Underground ($n$ = 43/44) | Outdoor sites ($n$ = 124/122) | Urban background ($n$ = 29/28) | Farm ($n$ = 27/26) | Continuous traffic ($n$ = 31/31) | Stop-and-go traffic ($n$ = 37/37) |
| Total WBC | 6.4 (1.9) | | | | | | | |
| 2 h PE | | 15.0 (11.8; 18.4) | 25.9 (18.6; 33.6) | 10.5 (7.1; 14.1) | 17.4 (8.7; 26.7) | 11.6 (3.9; 19.9) | 9.4 (3.8; 15.4) | 7.3 (1.5; 13.3) |
| 18 h PE | | −10.4 (−12.7; −8.1) | −4.9 (−10.6; 1.2) | −12.2 (−14.3; −10.0) | −9.5 (−13.5; −5.4) | −12.2 (−17.7; −6.3) | −12.2 (−16.4; −7.8) | −13.9 (−18.0; −9.7) |
| Neutrophils | 3.2 (1.2) | | | | | | | |
| 2 h PE | | 35.0 (29.3; 41.0) | 49.2 (34.8; 65.2) | 31.0 (25.1; 37.2) | 36.3 (21.6; 52.9) | 28.4 (15.5; 42.7) | 31.0 (19.8; 43.3) | 28.4 (19.6; 37.8) |
| 18 h PE | | −2.0 (−5.5; 1.7) | 1.0 (−7.6; 10.4) | −3.0 (−6.8; 1.1) | −1.0 (−9.1; 7.8) | −3.9 (−14.1; 7.4) | −3.0 (−8.9; 3.4) | −4.9 (−11.1; 1.8) |
| Monocytes | 0.5 (0.2) | | | | | | | |
| 2 h PE | | −11.3 (−19.8; −1.9) | 4.1 (−10.4; 20.9) | −15.6 (−25.4; −4.6) | −13.1 (−27.5; 4.2) | −8.6 (−22.6; 7.9) | −15.6 (−27.1; −2.3) | −21.3 (−44.3; 11.0) |
| 18 h PE | | −12.2 (−14.8; −9.5) | −6.8 (−12.0; −1.2) | −13.9 (−16.9; −10.8) | −18.1 (−23.7; −12.2) | −14.8 (−20.5; −8.7) | −11.3 (−17.6; −4.5) | −12.2 (−18.2; −5.7) |
| Lymphocytes | 2.4 (0.7) | | | | | | | |
| 2 h PE | | −6.8 (−10.0; −3.4) | −5.8 (−14.4; 3.6) | −6.8 (−10.2; −3.2) | 1.0 (−5.9; 8.4) | −3.9 (−11.2; 4.0) | −9.5 (−14.9; −3.8) | −12.2 (−18.7; −5.1) |
| 18 h PE | | −21.3 (−23.5; −19.1) | −17.3 (−21.7; −12.6) | −22.9 (−25.2; −20.5) | −18.9 (−22.5; −15.3) | −18.9 (−24.1; −13.5) | −25.2 (−30.7; −19.1) | −25.9 (−29.0; −22.7) |
| Eosinophils | 0.2 (0.1) | | | | | | | |
| 2 h PE | | −35.6 (−43.4; −26.8) | −31.6 (−42.9; −18.0) | −36.9 (−46.1; −26.1) | −19.7 (−30.0; −8.0) | −21.3 (−31.3; −9.9) | −52.8 (−70.1; −25.3) | −44.0 (−59.4; −22.7) |
| 18 h PE | | −12.2 (−16.8; −7.3) | −5.8 (−12.8; 1.7) | −13.9 (−19.5; −7.9) | −19.7 (−33.3; −3.4) | −8.6 (−17.0; 0.6) | −19.7 (−32.0; −5.3) | −9.5 (−16.0; −2.6) |

CI = confidence interval; h = hour; IQR = interquartile range; $n$ = number of observations for total cell counts 2 h PE/18 h PE; PE = post exposure; WBC = white blood cells.
[a]Cell counts expressed as $10^9$ cells/L.
[b]Calculated by using log−normalized values.

## Appendix D. Spearman's correlation coefficients between white blood cell subtypes for percentage change in cells over baseline.

| | Neutrophils (2 h PE) | Neutrophils (18 h PE) | Monocytes (2 h PE) | Monocytes (18 h PE) | Lymphocytes (2 h PE) | Lymphocytes (18 h PE) | Eosinophils (2 h PE) | Eosinophils (18 h PE) |
|---|---|---|---|---|---|---|---|---|
| Neutrophils (2 h PE) | | **0.38** | **0.40** | 0.12 | 0.08 | 0.00 | 0.05 | 0.01 |
| Neutrophils (18 h PE) | | | **0.21** | **0.40** | **0.20** | 0.11 | 0.07 | −0.13 |
| Monocytes (2 h PE) | | | | **0.29** | **0.18** | **0.17** | 0.11 | −0.02 |
| Monocytes (18 h PE) | | | | | 0.03 | **0.18** | −0.11 | 0.00 |
| Lymphocytes (2 h PE) | | | | | | **0.42** | **0.18** | −0.08 |
| Lymphocytes (18 h PE) | | | | | | | 0.14 | 0.11 |
| Eosinophils (2 h PE) | | | | | | | | **0.24** |
| Eosinophils (18 h PE) | | | | | | | | |

Bold, underlined values indicate $p$ value <0.05.

## Appendix E. One-pollutant model associations between air pollution exposure and percentage changes (post-pre) in total white blood cell (WBC) counts, number of neutrophils and monocytes in one-pollutant models in the complete and outdoor datasets.

| | | 2 h post exposure | | 18 h post exposure | |
|---|---|---|---|---|---|
| | | WBC | Neutrophils | WBC | Monocytes |
| Pollutant | Dataset | Effect estimate (95% CI) | Effect estimate (95% CI) | Effect estimate (95% CI) | Effect estimate (95% CI) |
| $PM_{10}$ | Complete | **8.6** (1.7; 15.9) | **13.1** (1.9; 25.6) | **8.3** (1.0; 16.1) | **10.2** (1.0; 20.3) |
| | Outdoor | 18.9 (−18.6; 73.7) | 20.3 (−33.9; 118.8) | −3.2 (−34.3; 42.6) | −7.8 (−45.2; 55.0) |
| $PM_{2.5}$ | Complete | **7.7** (1.9; 13.7) | **12.1** (2.8; 22.3) | **5.2** (−0.9; 11.7) | 6.1 (−1.5; 14.3) |
| | Outdoor | 9.3 (−5.8; 26.9) | 12.6 (−10.9; 42.4) | −4.3 (−17.9; 11.6) | −4.6 (−22.3; 17.2) |
| $PM_{2.5–10}$ | Complete | **8.1** (1.2; 15.4) | **12.0** (0.7; 24.5) | **9.3** (1.9; 17.3) | **11.8** (2.4; 22.1) |
| | Outdoor | −6.3 (−60.2; 120.6) | −37.1 (−83.9; 146.5) | 50.0 (−35.9; 250.8) | 9.9 (−65.2; 247.6) |
| PNC | Complete | −2.2 (−5.3; 1.0) | −1.3 (−6.2; 3.9) | −1.4 (−4.8; 2.2) | 3.4 (−1.0; 7.9) |
| | Outdoor | −2.1 (−5.1; 1.0) | −1.2 (−6.0; 3.9) | −1.1 (−4.2; 2.2) | 2.6 (−1.6; 7.1) |
| Absorbance[a] | Complete | **5.3** (−0.3; 11.3) | **8.9** (−0.3; 18.9) | **5.3** (−0.6; 11.7) | **9.4** (1.8; 17.6) |
| | Outdoor | −4.9 (−16.3; 8.0) | −1.1 (−19.2; 21.2) | −3.6 (−15.3; 9.8) | 9.3 (−8.1; 30.0) |
| EC (F) | Complete | **4.7** (−0.7; 10.4) | **7.5** (−1.3; 17.0) | **5.0** (−0.7; 11.2) | **9.3** (1.9; 17.2) |
| | Outdoor | −6.9 (−18.4; 6.2) | −5.5 (−23.3; 16.5) | −1.5 (−13.8; 12.7) | 12.4 (−5.9; 34.4) |
| EC (C) | Complete | **7.3** (1.2; 13.7) | **10.3** (0.4; 21.2) | **6.9** (0.6; 13.7) | **8.1** (0.0; 16.8) |
| | Outdoor | −46.4 (−78.0; 30.7) | −53.1 (−88.5; 90.5) | −1.8 (−59.9; 140.4) | **197.8** (−10.1; 886.9) |
| OC (F) | Complete | 2.1 (−1.2; 5.5) | 4.0 (−1.2; 9.5) | 0.4 (−3.1; 4.0) | 0.4 (−3.9; 4.9) |
| | Outdoor | 4.2 (−0.9; 9.5) | **8.1** (0.0; 16.9) | −2.2 (−7.0; 3.0) | −3.6 (−9.9; 3.3) |
| OC (C) | Complete | 3.1 (−1.0; 7.3) | 3.9 (−2.7; 10.8) | **4.0** (−0.4; 8.7) | 4.4 (−1.1; 10.1) |
| | Outdoor | 1.1 (−4.7; 7.2) | 0.3 (−8.6; 10.2) | −1.3 (−6.9; 4.7) | −0.6 (−8.2; 7.8) |
| Fe (tot) | Complete | 7.9 (7.9; 7.9) | 11.2 (11.2; 11.2) | 8.6 (8.6; 8.6) | 10.6 (10.6; 10.6) |
| | Outdoor | −87.1 (−99.9; 1987.3) | −82.8 (−100.0; 52 926.0) | 35.8 (−99.2; 22 198.5) | 2668.3 (−97.1; 2 637 220.9) |
| Fe (sol) | Complete | 1.0 (−0.9; 3.1) | 1.5 (−1.5; 4.7) | 1.3 (−0.8; 3.5) | 0.6 (−1.9; 3.3) |
| | Outdoor | −2.5 (−9.1; 4.5) | −1.1 (−11.4; 10.6) | 2.8 (−4.1; 10.1) | 7.5 (−2.0; 18.0) |
| Cu (tot) | Complete | **6.1** (−0.1; 12.7) | 8.4 (−1.7; 19.6) | **7.7** (1.2; 14.7) | **7.4** (−1.0; 16.5) |
| | Outdoor | −84.8 (−99.9; 1938.8) | −83.6 (−100.0; 38 083.6) | 151.2 (−98.1; 33 480.7) | 12 502.8 (−82.5; 9 055 480.4) |
| Cu (sol) | Complete | 0.6 (−1.0; 2.2) | 0.8 (−1.7; 3.4) | 1.3 (−0.4; 3.0) | 0.8 (−1.3; 3.0) |
| | Outdoor | −24.1 (−70.4; 94.2) | −22.9 (−82.5; 240.2) | 31.2 (−48.3; 232.8) | 165.5 (−24.0; 827.7) |
| Ni (tot) | Complete | **7.1 (0.8; 13.8)** | **10.4** (0.1; 21.8) | **8.0** (1.2; 15.2) | **8.6** (0.0; 17.8) |
| | Outdoor | 4.3 (−12.1; 23.7) | 7.8 (−17.9; 41.4) | 7.0 (−10.5; 27.8) | 0.1 (−21.3; 27.4) |
| Ni (sol) | Complete | 0.3 (−2.1; 2.7) | −1.0 (−5.8; 4.1) | **5.9** (3.4; 8.4) | **4.4** (0.1; 8.9) |
| | Outdoor | −2.7 (−6.5; 1.3) | −4.2 (−10.1; 2.0) | 2.3 (−1.7; 6.5) | **5.8** (0.3; 11.5) |
| V (tot) | Complete | **3.9** (−0.1; 8.1) | **6.6** (−0.9; 14.7) | **7.7** (3.4; 12.2) | **8.7** (2.4; 15.4) |
| | Outdoor | **−16.1** (−29.9; 0.5) | **−22.8** (−41.9; 2.6) | −1.1 (−17.4; 18.3) | **23.4** (−3.0; 57.1) |
| V (sol) | Complete | **−2.6** (−5.2; 0.1) | **−3.9** (−8.2; 0.6) | **2.7** (−0.3; 5.8) | **3.7** (−0.2; 7.7) |
| | Outdoor | **−3.2** (−6.1; −0.2) | −5.2 (−9.6; −0.5) | 0.5 (−2.5; 3.6) | **3.9** (−0.3; 8.2) |
| Endotoxin | Complete | −0.1 (−0.3; 0.0) | −0.2 (−0.4; 0.0) | −0.1 (−0.3; 0.1) | −0.1 (−0.3; 0.1) |
| | Outdoor | −0.1 (−0.2; 0.1) | −0.1 (−0.3; 0.1) | −0.1 (−0.2; 0.1) | 0.0 (−0.2; 0.2) |
| $NO_3^-$ [a] | Complete | 0.5 (−0.8; 1.9) | 1.0 (−1.1; 3.1) | −0.5 (−1.9; 1.0) | −0.8 (−2.6; 1.0) |
| | Outdoor | 0.8 (−0.5; 2.2) | 0.8 (−1.3; 2.9) | −0.1 (−1.4; 1.3) | −0.6 (−2.3; 1.2) |
| $SO_4^{2-}$ [a] | Complete | −0.2 (−2.0; 1.6) | 0.1 (−2.8; 3.1) | −1.4 (−3.4; 0.7) | −1.2 (−3.6; 1.4) |
| | Outdoor | 0.3 (−1.5; 2.1) | 0.2 (−2.7; 3.2) | −0.7 (−2.5; 1.2) | −0.6 (−3.1; 2.0) |
| $OP^{AA}$ (C) | Complete | **10.2** (3.3; 17.5) | **14.5** (2.7; 27.6) | **9.5** (2.2; 17.4) | **9.7** (0.5; 19.7) |
| | Outdoor | −81.9 (−98.9; 199.1) | −83.2 (−99.9; 2189.4) | −43.0 (−97.2; 1049.1) | 406.2 (−93.2; 37 759.8) |
| $OP^{AA}$ (F) | Complete | **4.1** (−0.1; 8.5) | **6.0** (−0.7; 13.2) | 1.4 (−3.1; 6.1) | 4.0 (−1.6; 9.9) |
| | Outdoor | 19.1 (−28.6; 98.8) | 50.8 (−32.6; 237.3) | −33.7 (−60.6; 11.8) | −15.4 (−58.7; 73.3) |
| $OP^{AA}$ (qUF) | Complete | 3.4 (−1.3; 8.4) | 5.2 (−2.2; 13.2) | 2.8 (−2.3; 8.1) | 4.6 (−1.7; 11.2) |
| | Outdoor | 86.0 (−75.1; 1287.3) | 97.7 (−91.6; 4557.9) | −36.4 (−92.0; 403.3) | −2.8 (−94.2; 1515.3) |
| $OP^{GSH}$ (C) | Complete | **7.6** (2.1; 13.4) | **10.3** (0.7; 20.8) | **9.5** (3.5; 15.9) | **9.8** (2.1; 18.1) |
| | Outdoor | −67.0 (−92.1; 37.5) | −72.7 (−97.8; 243.5) | 18.1 (−74.8; 454.8) | **578.9** (−24.5; 6007.1) |
| $OP^{GSH}$ (F) | Complete | **5.1** (0.6; 9.8) | **6.8** (−0.6; 14.8) | **5.7** (0.9; 10.8) | **7.4** (1.2; 13.9) |
| | Outdoor | −39.3 (−72.0; 31.7) | −0.5 (−72.2; 255.5) | **−62.7** (−83.0; −18.1) | 23.1 (−58.7; 267.5) |
| $OP^{GSH}$ (qUF) | Complete | 3.3 (−1.5; 8.3) | 5.4 (−2.0; 13.5) | 3.9 (−1.2; 9.2) | 5.2 (−1.1; 12.0) |
| | Outdoor | 27.3 (−97.7; 7074.5) | 6714.9 (−88.6; 4 084 946.5) | **−98.5** (−100.0; −11.2) | 26.1 (−99.6; 35 616.9) |
| $OP^{TOTAL}$ | Complete | **6.9** (0.8; 13.3) | **9.7** (−0.5; 20.9) | **7.2** (0.5; 14.3) | **7.8** (−0.5; 16.7) |
| | Outdoor | −39.4 (−93.7; 483.0) | −40.8 (−98.9; 3016.3) | **−88.1** (−98.9; 31.0) | 39.1 (−95.8; 4516.1) |
| $O_3$ | Complete | −4.2 (−9.6; 1.5) | **−8.0** (−16.2; 0.9) | −5.0 (−10.7; 1.1) | **−10.5** (−17.0; −3.4) |
| | Outdoor | 8.3 (−4.6; 22.8) | 8.8 (−11.0; 33.0) | 2.3 (−9.8; 16.1) | −11.2 (−25.0; 5.2) |
| $NO_2$ | Complete | −1.3 (−4.4; 1.9) | 0.5 (−4.4; 5.7) | −1.1 (−4.4; 2.3) | **3.9** (−0.3; 8.3) |
| | Outdoor | −1.2 (−4.5; 2.1) | −0.9 (−6.0; 4.5) | −0.6 (−3.8; 2.8) | 3.8 (−0.7; 8.5) |

Significance levels are indicated by the use of bold ($p < 0.1$) and bold + underlined ($p < 0.05$).

Estimates are percentage increases above population-average baseline (shown in Appendix C) expressed per interquartile range in each pollutant (shown in Appendix A). All models were adjusted for temperature, relative humidity and season.

CI = confidence interval; complete data set = dataset including measurements from all sites; outdoor dataset = dataset excluding the measurements from the underground train station site; WBC = white blood cells.

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).

**Appendix F. Associations between air pollution exposure and percentage changes (post–pre) in total white blood cell (WBC) counts 2 hours after exposure in the complete dataset (including all sites).**

| Blood cell/ml - 2PE - all sites | Adjustment pollutants: $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5-10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol)[b] | Endotoxin | $NO_3^-$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $PM_{10}$ | 8.57 | −3.92 | 34.67 | 9.30 | 15.32 | 16.44 | 11.00 | 9.43 | 11.19 | 29.40 | 9.39 | 31.51 | 13.93 | 10.70 | 9.23 | 10.80 | 9.07 | 7.80 | 8.33 | 8.58 | −3.54 | 10.92 | 12.43 | −0.87 | 7.66 | 12.44 | 12.72 | 18.73 | 9.88 |
| $PM_{2.5}$ | 11.25 | 7.66 | 9.85 | 7.99 | 11.23 | 11.36 | 9.59 | 9.54 | 10.82 | 12.05 | 8.59 | 16.61 | 12.04 | 9.06 | 8.04 | 8.69 | 7.71 | 7.20 | 7.77 | 7.68 | 0.63 | 11.24 | 10.67 | 2.71 | 6.68 | 10.16 | 8.46 | 13.94 | 9.18 |
| $PM_{2.5-10}$ | −19.75 | −2.57 | 8.06 | 8.98 | 12.43 | 14.67 | 2.57 | 8.13 | 9.30 | 18.28 | 8.52 | 21.67 | 12.52 | 6.20 | 8.82 | 9.30 | 8.84 | 7.18 | 7.93 | 8.12 | −6.58 | 7.74 | 10.74 | −8.11 | 4.42 | 11.22 | 9.53 | 16.04 | 9.08 |
| PNC | −2.71 | −2.50 | −2.79 | −2.19 | −4.75 | −4.56 | −2.90 | −2.32 | −1.88 | −2.69 | −2.66 | −2.57 | −2.21 | −2.15 | −2.23 | −2.45 | −1.89 | −3.51 | −1.98 | −2.42 | −3.07 | −2.82 | −2.74 | −3.08 | −2.95 | −2.77 | −3.06 | −3.21 | −2.04 |
| Absorbance[a] | −5.42 | −3.72 | −3.55 | 9.66 | 5.32 | 22.56 | −3.16 | 4.78 | 4.72 | −1.23 | 5.65 | 3.09 | 7.03 | 1.06 | 5.97 | 3.47 | 5.57 | 4.25 | 5.39 | 5.40 | −8.09 | 1.35 | 4.53 | −7.65 | −2.61 | 4.69 | −0.77 | 7.91 | 7.91 |
| EC (F) | −6.13 | −3.82 | −5.11 | 8.68 | −13.74 | 4.73 | −4.42 | 3.98 | 3.80 | −4.43 | 4.61 | 0.47 | 5.47 | −0.50 | 5.23 | 2.01 | 5.12 | 3.65 | 4.99 | 4.84 | −9.43 | −0.42 | 3.45 | −8.92 | −4.74 | 3.62 | −1.60 | 4.99 | 6.59 |
| EC (C) | −1.80 | −1.75 | 5.03 | 8.42 | 10.67 | 12.17 | 7.27 | 7.35 | 7.32 | 10.27 | 8.89 | 29.44 | 15.51 | 5.49 | 7.76 | 7.30 | 7.48 | 5.78 | 7.14 | 7.29 | −5.39 | 8.39 | 11.32 | −3.77 | 4.11 | 11.06 | 6.67 | 11.85 | 8.06 |
| OC (F) | −0.64 | −1.51 | −0.05 | 2.23 | 0.57 | 0.96 | −0.06 | 2.09 | 1.62 | 0.42 | 2.02 | 0.64 | 2.93 | 0.38 | 2.38 | 1.31 | 1.77 | 1.70 | 1.85 | 2.18 | −0.54 | 0.33 | 0.49 | −0.23 | 0.10 | 0.64 | −0.90 | 1.14 | 3.01 |
| OC (C) | −1.73 | −2.50 | −0.78 | 2.92 | 1.16 | 1.56 | −0.04 | 2.22 | 3.05 | 0.14 | 2.65 | 0.75 | 3.18 | −0.26 | 3.05 | 1.40 | 3.01 | 3.55 | 2.79 | 3.04 | −0.94 | 1.55 | 2.21 | −1.39 | 0.39 | 2.29 | 0.06 | 1.87 | 3.31 |
| Fe (tot) | −16.46 | −4.84 | −8.61 | 8.91 | 9.40 | 13.74 | −3.22 | 7.37 | 7.72 | 7.88 | 8.12 | 36.08 | 11.35 | 3.23 | 8.54 | 8.62 | 8.48 | 6.17 | 7.84 | 7.96 | −15.56 | 7.54 | 9.17 | −18.06 | −0.01 | 8.88 | 3.37 | 12.93 | 8.73 |
| Fe (sol) | −0.31 | −0.43 | −0.14 | 1.48 | 0.00 | 0.23 | −0.78 | 0.42 | 0.65 | −0.12 | 1.03 | −0.24 | 1.22 | 0.02 | 1.04 | 0.46 | 0.95 | 0.41 | 0.99 | 1.03 | −1.12 | 0.07 | −0.67 | −0.45 | 0.18 | −0.18 | −1.17 | 0.46 | 1.14 |
| Cu (tot) | −16.35 | −8.74 | −10.31 | 6.94 | 3.03 | 5.64 | −17.97 | 5.40 | 5.37 | −18.99 | 6.63 | 6.13 | 10.39 | −2.68 | 6.70 | 3.72 | 6.57 | 4.55 | 6.01 | 6.16 | −15.64 | 2.13 | 6.44 | −15.17 | −3.42 | 6.22 | −8.35 | 6.80 | 6.77 |
| Cu (sol) | −1.54 | −1.55 | −1.29 | 0.75 | −0.59 | −0.27 | −2.45 | −0.37 | −0.09 | −1.08 | −0.18 | −1.34 | 0.60 | −0.94 | 0.60 | −0.15 | 0.61 | 0.18 | 0.48 | 0.62 | −1.25 | −0.41 | −1.36 | −1.30 | −0.65 | −1.86 | −2.16 | −0.14 | 0.70 |
| Ni (tot) | −1.66 | −1.30 | 1.87 | 7.28 | 6.13 | 7.63 | 1.94 | 6.71 | 7.43 | 4.31 | 7.11 | 9.86 | 9.67 | 7.12 | 7.46 | 6.42 | 7.34 | 5.89 | 7.17 | 7.36 | −3.01 | 7.57 | 8.53 | −1.17 | 3.87 | 8.34 | 6.63 | 8.17 | 7.61 |
| Ni (sol) | −0.54 | −0.29 | −0.62 | 0.66 | −0.45 | −0.42 | −0.62 | 0.26 | 0.03 | −0.66 | −0.04 | −0.60 | 0.06 | −0.47 | 0.26 | −1.96 | 3.26 | −0.22 | 0.55 | 0.23 | −0.50 | 0.07 | −0.07 | −0.71 | −0.57 | −0.19 | −0.28 | −0.30 | 0.35 |
| V (tot) | −1.28 | −0.67 | −0.65 | 4.31 | 1.96 | 2.71 | −0.02 | 3.27 | 3.18 | −0.45 | 3.60 | 1.81 | 4.10 | 0.54 | 6.13 | 3.91 | 6.85 | 2.90 | 4.00 | 3.92 | −1.46 | 1.86 | 3.00 | −1.35 | −0.28 | 3.12 | 2.70 | 3.91 | 4.43 |
| V (sol)[b] | −2.73 | −2.48 | −2.86 | −2.53 | −2.56 | −2.69 | −2.71 | −2.29 | −2.57 | −2.86 | −2.54 | −2.80 | −2.60 | −2.71 | −5.03 | −4.49 | −2.59 | −3.14 | −2.48 | −2.59 | −2.58 | −2.34 | −2.51 | −3.07 | −2.58 | −2.64 | −2.59 | −2.93 | −2.51 |
| Endotoxin | −0.08 | −0.09 | −0.08 | −0.17 | −0.08 | −0.08 | −0.12 | −0.10 | −0.18 | −0.12 | −0.15 | −0.13 | −0.16 | −0.13 | −0.17 | −0.13 | −0.20 | −0.12 | −0.13 | −0.12 | −0.07 | −0.08 | −0.09 | −0.08 | −0.08 | −0.09 | −0.08 | −0.09 | −0.14 |
| $NO_3^-$[a] | 0.28 | −0.06 | 0.46 | 0.30 | 0.58 | 0.66 | 0.51 | 0.24 | 0.20 | 0.58 | 0.56 | 0.54 | 0.51 | 0.62 | 0.68 | 0.66 | 0.45 | 0.71 | 0.54 | 1.03 | 0.37 | 0.42 | 0.36 | 0.39 | 0.55 | 0.35 | 0.20 | 0.40 | 0.76 |
| $SO_4^{2-}$[a] | 0.00 | −0.19 | 0.09 | −0.53 | 0.12 | 0.16 | 0.03 | −0.34 | −0.08 | 0.13 | −0.13 | 0.04 | −0.19 | 0.30 | −0.12 | 0.02 | 0.00 | −0.16 | −1.03 | −0.18 | 0.24 | −0.04 | −0.27 | 0.25 | 0.07 | −0.30 | −0.08 | −0.23 | −0.11 |
| $OP^{AA}$ (C) | 14.06 | 9.46 | 17.58 | 10.89 | 20.58 | 23.17 | 17.27 | 10.78 | 11.55 | 30.20 | 12.96 | 32.37 | 14.03 | 13.97 | 10.88 | 12.81 | 10.53 | 9.35 | 10.22 | 10.35 | 10.18 | 25.07 | 17.53 | 13.53 | 15.14 | 13.26 | 26.69 | 15.87 | 10.53 |
| $OP^{AA}$ (F) | −1.62 | −2.84 | 0.12 | 4.62 | 3.28 | 4.43 | −0.92 | 3.92 | 3.37 | 0.08 | 4.13 | 2.85 | 4.83 | −0.12 | 4.20 | 2.80 | 3.84 | 3.69 | 4.08 | 4.13 | −8.03 | 4.14 | 4.25 | −2.81 | 0.34 | 3.81 | −0.04 | 4.67 | 4.56 |
| $OP^{AA}$ (qUF) | −3.22 | −3.14 | −2.27 | 4.01 | 0.65 | 1.31 | −3.62 | 2.92 | 2.27 | −1.24 | 5.06 | −0.45 | 7.31 | −1.08 | 3.69 | 1.55 | 3.51 | 2.77 | 3.27 | 3.46 | −5.33 | −0.15 | 3.44 | −2.34 | −0.99 | 3.68 | −9.80 | 2.25 | 4.08 |
| $OP^{GSH}$ (C) | 8.37 | 5.16 | 15.21 | 8.22 | 15.50 | 17.40 | 11.52 | 7.81 | 9.19 | 26.53 | 8.40 | 24.46 | 10.87 | 8.84 | 8.34 | 9.56 | 8.21 | 6.93 | 7.67 | 7.76 | −2.51 | 11.24 | 9.87 | 7.61 | 15.27 | 9.09 | 12.36 | 11.03 | 7.82 |
| $OP^{GSH}$ (F) | 0.50 | 0.72 | 2.36 | 5.71 | 7.08 | 8.93 | 2.44 | 5.04 | 5.00 | 5.28 | 5.11 | 7.75 | 6.36 | 2.76 | 5.59 | 5.54 | 5.27 | 4.68 | 5.19 | 5.14 | −3.07 | 4.80 | 5.82 | −5.50 | 5.11 | 5.77 | 4.30 | 7.25 | 5.54 |
| $OP^{GSH}$ (qUF) | −3.28 | −2.77 | −2.66 | 3.91 | 0.48 | 1.19 | −3.48 | 2.59 | 1.98 | −1.05 | 3.85 | −0.27 | 8.81 | −0.94 | 3.61 | 1.29 | 3.66 | 2.61 | 3.09 | 3.32 | −2.63 | 0.60 | −0.23 | −1.64 | −0.95 | 3.28 | −5.18 | 1.91 | 4.07 |
| $OP^{TOTAL}$ | −3.86 | −1.43 | −1.32 | 7.63 | 7.67 | 8.60 | 0.31 | 8.06 | 7.08 | 4.08 | 9.86 | 16.78 | 14.55 | 1.03 | 7.34 | 3.70 | 7.21 | 5.99 | 6.78 | 6.85 | −12.55 | 6.93 | 21.36 | −5.07 | 1.26 | 13.72 | 6.86 | 7.61 | 7.39 |
| $O_3$ | 9.42 | 7.36 | 7.35 | −5.91 | 2.91 | 0.31 | 5.01 | −3.21 | −3.00 | 4.66 | −3.88 | 0.73 | −4.71 | 1.23 | −4.64 | −0.01 | −5.23 | −3.15 | −3.94 | −4.23 | 5.52 | 0.93 | −2.05 | 4.17 | 3.44 | −2.31 | 0.81 | −4.19 | −7.55 |
| $NO_2$ | −2.36 | −2.71 | −2.13 | −0.29 | −3.15 | −2.71 | −1.93 | −2.33 | −1.43 | −1.85 | −1.31 | −1.71 | −1.27 | −1.63 | −1.12 | −1.82 | −0.69 | −2.07 | −1.78 | −1.26 | −1.39 | −2.07 | −2.10 | −1.26 | −2.11 | −2.20 | −1.53 | −3.53 | −1.28 |

Values in each row represent effect estimates for the pollutants in two-pollutant models; values in dark grey boxes forming a diagonal are effect estimates in a one-pollutant model. Values in light grey boxes indicate Spearman's rho > 0.7. Significance levels are indicated by the use of bold ($p < 0.1$) and bold + underlined ($p < 0.05$).

For example, in the one-pollutant model, $PM_{10}$ has the effect estimate of 8.57% ($p < 0.05$). After adjusting for PNC the effect estimate is 9.30% ($p < 0.05$), whereas after adjusting for a highly correlated pollutant such as $PM_{2.5}$ the effect estimate for $PM_{10}$ decreased to −3.92% and was no longer statistically significant. Estimates are percentage increases above population-average baseline (shown in Appendix C) expressed per interquartile range in each pollutant (shown in Appendix A). All models were adjusted for temperature, relative humidity, season and adjustment pollutant. We considered an association consistent if the $p$ value in the one-pollutant model was smaller than 0.1 and remained so after adjusting for all other co-pollutants in two-pollutant models (i.e. entire row with bold values), or alternatively, if the $p$ value in the two-pollutant models remained smaller than 0.1 for hose models in which the co-pollutant was not highly correlated (Spearman's R > 0.7) with the pollutant of interest (i.e. entire row with bold values except for the grey boxes).

[a]easured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).

[b]ne-pollutant estimate decreased by more than 50 % and became non-significant after excluding 1% of influential observations.

## Appendix G. Associations between air pollution exposure and percentage changes (post–pre) in total white blood cell (WBC) counts 18 hours after exposure in the complete dataset (including all sites).

| Blood cell/ml - 18PE - all sites | Adjustment pollutants: $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5-10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endotoxin | $NO_3^-$ [a] | $SO_4^{2-}$ [a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $PM_{10}$ | 8.29 | 42.28 | −33.54 | 8.92 | 13.75 | 13.36 | 4.42 | 12.01 | 6.71 | −9.54 | 7.74 | −4.36 | 8.13 | −0.65 | 3.56 | −10.12 | 7.69 | 7.59 | 8.68 | 7.87 | 3.87 | 31.95 | 14.50 | −11.87 | 1.42 | 10.08 | 16.91 | 13.19 | 9.32 |
| $PM_{2.5}$ | −21.36 | 5.22 | −12.10 | 5.53 | 1.92 | 2.42 | −7.13 | 8.31 | 2.04 | −9.74 | 4.13 | −9.73 | 3.50 | −5.67 | 2.29 | −8.43 | 5.18 | 4.70 | 6.35 | 5.15 | −4.21 | 18.32 | 6.40 | −9.07 | −3.74 | 3.69 | −0.85 | 3.17 | 6.26 |
| $PM_{2.5-10}$ | 64.19 | 25.83 | 9.34 | 10.14 | 20.12 | 20.02 | 17.15 | 12.54 | 8.57 | 18.71 | 9.06 | 7.69 | 9.98 | 6.55 | 4.03 | −8.69 | 8.47 | 8.64 | 9.36 | 8.79 | 12.23 | 30.30 | 17.32 | −7.42 | 8.46 | 13.09 | 29.52 | 17.67 | 10.18 |
| PNC | −2.00 | −1.70 | −2.17 | −1.39 | −3.90 | −3.80 | −1.90 | −1.40 | −0.84 | −1.80 | −1.74 | −1.75 | −1.36 | −1.21 | −2.99 | −1.95 | −1.09 | −2.62 | −1.88 | −1.99 | −0.81 | −1.67 | −1.79 | −1.00 | −2.19 | −1.95 | −0.79 | −2.63 | −1.08 |
| Absorbance[a] | −4.39 | 3.67 | −8.18 | 8.84 | 5.33 | 8.59 | −2.65 | 6.75 | 3.56 | −5.65 | 4.90 | −4.34 | 4.38 | −1.07 | 1.61 | −6.96 | 5.53 | 4.46 | 5.23 | 4.76 | 0.94 | 14.10 | 6.32 | −7.65 | −4.72 | 4.11 | 6.10 | 4.45 | 7.57 |
| EC (F) | −4.02 | 3.08 | −7.91 | 8.32 | −2.94 | 5.05 | −2.74 | 5.86 | 3.17 | −6.83 | 4.34 | −4.89 | 3.84 | −1.75 | 1.21 | −7.73 | 4.87 | 4.19 | 4.88 | 4.42 | −0.79 | 14.65 | 5.50 | −8.89 | −5.54 | 3.69 | 4.00 | 3.55 | 6.77 |
| EC (C) | 3.09 | 14.72 | −6.34 | 7.70 | 9.75 | 9.88 | 6.93 | 10.07 | 5.40 | −4.58 | 7.66 | −7.78 | 8.61 | 0.45 | 2.58 | −7.04 | 6.73 | 5.40 | 6.95 | 6.58 | 3.67 | 29.07 | 15.39 | −8.44 | 1.06 | 9.88 | 20.03 | 8.55 | 7.43 |
| OC (F) | −2.89 | −2.62 | −2.70 | 0.45 | −1.60 | −1.13 | −2.76 | 0.39 | −0.90 | −2.43 | −1.03 | −2.88 | −2.81 | −2.45 | 0.15 | −2.36 | 1.26 | 0.07 | 0.96 | 0.63 | −1.30 | −0.27 | −2.19 | −1.77 | −2.21 | −3.70 | −2.44 | −1.25 | 0.81 |
| OC (C) | 1.00 | 2.93 | 0.32 | 4.00 | 2.53 | 2.71 | 1.63 | 4.48 | 4.04 | 1.12 | 3.50 | 1.07 | 3.14 | 0.78 | 2.62 | −0.12 | 3.98 | 4.40 | 5.45 | 3.97 | 0.44 | 4.95 | 4.21 | −2.22 | 1.38 | 3.47 | 1.17 | 2.83 | 4.21 |
| Fe (tot) | 19.99 | 21.54 | −8.32 | 9.37 | 15.97 | 17.92 | 14.49 | 11.57 | 7.37 | 8.64 | 8.72 | 1.20 | 9.13 | 3.49 | 3.20 | −13.08 | 8.14 | 6.98 | 8.58 | 8.10 | 10.72 | 43.51 | 15.95 | −14.58 | 4.38 | 10.93 | 27.15 | 13.33 | 9.23 |
| Fe (sol) | 0.12 | 0.57 | −0.04 | 1.61 | 0.37 | 0.52 | −0.34 | 1.65 | 0.82 | −0.04 | 1.32 | −0.45 | 0.12 | 0.14 | −0.03 | −0.17 | 1.39 | 0.74 | 1.32 | 1.28 | −0.07 | 1.42 | 1.54 | −0.13 | 0.33 | 0.33 | −0.04 | 0.65 | 1.38 |
| Cu (tot) | 11.96 | 18.97 | 1.11 | 8.32 | 12.51 | 13.28 | 16.80 | 11.04 | 6.67 | 6.62 | 8.70 | 7.73 | 9.62 | 3.94 | 2.59 | −8.13 | 7.36 | 6.28 | 7.74 | 7.31 | 6.48 | 35.99 | 16.64 | −6.67 | 4.44 | 10.66 | 22.59 | 10.16 | 8.19 |
| Cu (sol) | −0.05 | 0.61 | −0.31 | 1.36 | 0.50 | 0.64 | −0.53 | 2.25 | 0.60 | −0.15 | 1.19 | −0.60 | 1.27 | −0.07 | 0.27 | −0.32 | 1.27 | 0.90 | 1.38 | 1.33 | 0.25 | 1.49 | 1.93 | −0.35 | 0.19 | 0.88 | 0.08 | 0.69 | 1.33 |
| Ni (tot) | 8.58 | 14.17 | 2.23 | 8.12 | 9.05 | 9.81 | 7.51 | 10.63 | 7.12 | 4.82 | 7.75 | 4.05 | 8.17 | 7.97 | 3.92 | −5.33 | 7.67 | 6.71 | 7.89 | 7.38 | 7.51 | 29.56 | 13.37 | −4.37 | 5.59 | 9.79 | 14.95 | 8.94 | 8.29 |
| Ni (sol) | 5.54 | 5.70 | 5.44 | 6.44 | 5.68 | 5.73 | 5.56 | 5.89 | 5.68 | 5.50 | 5.91 | 5.51 | 5.78 | 5.46 | 5.90 | 4.97 | 7.62 | 5.60 | 6.06 | 5.78 | 5.69 | 5.90 | 5.90 | 5.41 | 5.50 | 5.85 | 5.86 | 5.77 | 6.01 |
| V (tot) | 13.67 | 13.02 | 12.82 | 8.08 | 12.17 | 12.92 | 12.19 | 8.91 | 7.77 | 15.90 | 7.85 | 13.03 | 8.14 | 10.86 | 2.30 | 7.71 | 7.34 | 7.02 | 7.66 | 7.48 | 15.15 | 14.65 | 10.31 | 13.10 | 11.10 | 9.39 | 15.85 | 14.43 | 8.23 |
| V (sol) | 2.56 | 2.77 | 2.42 | 2.74 | 2.73 | 2.60 | 2.59 | 2.96 | 2.67 | 2.43 | 2.78 | 2.47 | 2.70 | 2.53 | −2.92 | 0.61 | 2.71 | 2.30 | 2.64 | 2.94 | 6.76 | 2.88 | 2.83 | 6.20 | 2.79 | 2.72 | 6.71 | 2.38 | 2.85 |
| Endotoxin | −0.07 | −0.09 | −0.06 | −0.15 | −0.06 | −0.06 | −0.12 | −0.10 | −0.18 | −0.12 | −0.15 | −0.12 | −0.15 | −0.13 | −0.10 | −0.09 | −0.15 | −0.11 | −0.10 | −0.10 | −0.08 | −0.10 | −0.09 | −0.07 | −0.07 | −0.08 | −0.09 | −0.07 | −0.13 |
| $NO_3^-$ [a] | −0.69 | −0.92 | −0.51 | −0.72 | −0.42 | −0.34 | −0.43 | −0.63 | −1.13 | −0.36 | −0.40 | −0.41 | −0.60 | −0.32 | 0.39 | −0.21 | −0.25 | −0.36 | −0.49 | 0.18 | −1.02 | −0.55 | −0.62 | −0.98 | −0.43 | −0.68 | −1.21 | −0.63 | −0.38 |
| $SO_4^{2-}$ [a] | −1.16 | −1.34 | −1.03 | −1.62 | −1.08 | −1.05 | −1.08 | −1.40 | −1.24 | −0.96 | −1.25 | −1.01 | −1.37 | −0.82 | −0.51 | −0.90 | −1.49 | −1.35 | −1.51 | −1.36 | −1.63 | −1.37 | −1.42 | −1.50 | −1.05 | −1.46 | −1.88 | −1.40 | −1.30 |
| $OP^{AA}$ (C) | 5.69 | 14.50 | −1.71 | 9.69 | 8.45 | 10.47 | 5.04 | 10.79 | 8.66 | −0.94 | 9.31 | 2.21 | 8.45 | 1.63 | 4.59 | −10.48 | 8.98 | 8.70 | 9.24 | 8.53 | 9.51 | 42.40 | 16.31 | −17.17 | 3.22 | 9.22 | 17.89 | 7.43 | 9.55 |
| $OP^{AA}$ (F) | −13.28 | −9.34 | −12.19 | 1.68 | −6.90 | −7.65 | −14.27 | 1.54 | −1.37 | −17.71 | −0.45 | −16.88 | −1.06 | −13.20 | 0.18 | −8.96 | 1.53 | 0.80 | 1.40 | 0.95 | −16.65 | 1.37 | −1.00 | −14.13 | −10.69 | −1.21 | −9.71 | −3.48 | 1.63 |
| $OP^{AA}$ (qUF) | −4.84 | −1.23 | −6.05 | 3.12 | −1.06 | −0.54 | −7.06 | 5.08 | 0.00 | −5.63 | −0.66 | −7.33 | −2.30 | −4.56 | 0.08 | −4.59 | 2.63 | 2.13 | 2.95 | 2.72 | −5.06 | 3.61 | 2.76 | −5.18 | −3.35 | −11.15 | −12.65 | −0.22 | 3.12 |
| $OP^{GSH}$ (C) | 20.92 | 18.63 | 16.45 | 9.74 | 17.44 | 19.27 | 18.14 | 10.91 | 11.62 | 23.85 | 9.49 | 16.04 | 10.14 | 13.41 | 4.94 | −5.69 | 8.49 | 8.95 | 9.29 | 8.75 | 26.92 | 29.81 | 14.70 | 9.53 | 21.00 | 10.76 | 24.12 | 11.39 | 9.56 |
| $OP^{GSH}$ (F) | 4.81 | 8.40 | 0.55 | 6.18 | 9.37 | 10.22 | 4.80 | 7.21 | 4.58 | 2.80 | 5.22 | 2.51 | 5.23 | 1.99 | 2.57 | −4.15 | 5.56 | 5.30 | 5.61 | 5.28 | 4.36 | 16.80 | 8.19 | −7.95 | 5.71 | 6.14 | 9.77 | 6.93 | 6.03 |
| $OP^{GSH}$ (qUF) | −1.49 | 1.61 | −2.97 | 4.31 | 1.43 | 1.77 | −2.65 | 8.03 | 1.46 | −1.94 | 2.98 | −2.67 | 1.27 | −1.48 | 0.39 | −2.98 | 3.48 | 3.32 | 4.12 | 3.95 | 0.26 | 4.74 | 16.31 | −1.37 | −0.62 | 3.88 | −0.46 | 1.87 | 4.39 |
| $OP^{TOTAL}$ | −6.52 | 8.11 | −14.49 | 7.38 | 1.28 | 3.16 | −11.33 | 10.33 | 5.66 | −13.38 | 6.96 | −12.64 | 6.60 | −5.77 | 2.42 | −10.95 | 6.59 | 6.40 | 7.51 | 6.79 | −6.94 | 22.19 | 26.66 | −14.15 | −4.88 | 7.78 | 7.20 | 2.53 | 7.32 |
| $O_3$ | 4.55 | −2.40 | 7.63 | −6.48 | −1.00 | −1.80 | 1.80 | −5.98 | −2.97 | 4.34 | −4.22 | 2.67 | −3.70 | 1.10 | −0.96 | 11.68 | −4.39 | −4.18 | −5.29 | −5.09 | −2.12 | −8.54 | −5.19 | 2.30 | 1.97 | −3.43 | −5.18 | −5.01 | −8.22 |
| $NO_2$ | −2.04 | −2.02 | −1.96 | −0.58 | −2.86 | −2.55 | −1.44 | −1.33 | −1.12 | −1.48 | −0.97 | −1.42 | −1.02 | −1.25 | −1.47 | −2.01 | −1.18 | −1.93 | −0.86 | −0.84 | −0.34 | −1.39 | −1.55 | −0.33 | −1.77 | −1.79 | −0.53 | −3.51 | −1.10 |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
For further explanation see Appendix F.

## Appendix H. Associations between air pollution exposure and percentage changes (post–pre) in blood neutrophils 2 h after exposure in the complete dataset (including all sites).

| | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blood perml. neutro. - 2PE - all sites | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5–10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endotoxin | $NO_3^{-}$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | 13.11 | −13.53 | 80.29 | 13.63 | 18.28 | 23.36 | 25.28 | 12.45 | 19.06 | 73.18 | 14.08 | 67.57 | 21.67 | 18.34 | 14.01 | 19.13 | 13.01 | 11.79 | 12.54 | 13.17 | 1.19 | 20.73 | 19.54 | 13.90 | 23.29 | 17.41 | 28.25 | 18.50 | 13.66 |
| $PM_{2.5}$ | 26.10 | 12.13 | 20.45 | 12.33 | 16.27 | 17.92 | 20.71 | 13.41 | 19.47 | 25.59 | 13.45 | 34.70 | 19.47 | 16.78 | 12.52 | 15.70 | 11.62 | 11.38 | 12.26 | 12.16 | 6.99 | 23.37 | 17.69 | 11.80 | 16.42 | 15.43 | 19.51 | 16.90 | 13.00 |
| $PM_{2.5–10}$ | −38.04 | −9.03 | 11.95 | 12.62 | 11.50 | 18.22 | 6.68 | 10.22 | 14.95 | 45.77 | 12.23 | 41.46 | 18.64 | 8.80 | 13.11 | 14.49 | 12.21 | 10.40 | 11.55 | 12.11 | −6.63 | 12.36 | 15.66 | 3.45 | 17.67 | 14.39 | 18.18 | 12.83 | 12.24 |
| PNC | −1.97 | −1.70 | −2.06 | −1.30 | −4.73 | −4.31 | −2.23 | −1.43 | −0.94 | −1.94 | −1.92 | −1.78 | −1.34 | −1.24 | −0.83 | −1.84 | −0.80 | −3.16 | −0.68 | −1.32 | −3.17 | −1.98 | −1.89 | −3.13 | −2.13 | −1.98 | −3.19 | −2.91 | −2.01 |
| Absorbance[a] | −4.08 | −4.22 | 0.39 | 13.45 | 8.89 | 66.55 | 1.63 | 7.10 | 8.78 | 5.43 | 9.32 | 11.70 | 12.00 | 4.22 | 10.11 | 7.05 | 8.64 | 7.07 | 8.84 | 9.13 | −7.42 | 5.76 | 8.58 | −3.22 | 5.33 | 7.84 | 2.35 | 7.01 | 10.59 |
| EC (F) | −7.60 | −5.77 | −4.71 | 11.35 | −33.91 | 7.47 | −3.42 | 5.50 | 6.61 | −1.91 | 7.11 | 5.11 | 8.74 | 0.66 | 8.64 | 3.35 | 7.55 | 5.58 | 7.77 | 7.78 | −10.47 | 1.59 | 5.82 | −6.98 | 0.36 | 5.39 | −0.56 | 2.29 | 8.39 |
| EC (C) | −8.82 | −8.03 | 4.58 | 11.23 | 8.65 | 14.17 | 10.33 | 8.64 | 11.05 | 17.02 | 12.30 | 57.02 | 23.19 | 6.71 | 11.26 | 9.97 | 10.09 | 7.95 | 9.92 | 10.41 | −5.46 | 12.64 | 16.04 | 1.99 | 11.32 | 13.42 | 13.96 | 9.23 | 10.44 |
| OC (F) | 0.49 | −0.97 | 1.40 | 4.05 | 1.85 | 2.52 | 1.42 | 4.00 | 3.57 | 2.04 | 4.00 | 2.58 | 6.22 | 1.81 | 4.22 | 2.78 | 3.28 | 3.42 | 3.62 | 4.08 | 0.13 | 2.08 | 2.88 | 0.78 | 2.11 | 2.66 | −0.12 | 2.20 | 4.36 |
| OC (C) | −3.91 | −5.72 | −2.05 | 3.81 | 0.45 | 1.32 | −0.68 | 1.98 | 3.88 | −0.37 | 3.19 | 0.69 | 3.86 | −1.15 | 3.87 | 1.27 | 3.36 | 4.67 | 2.99 | 3.89 | −0.40 | 1.20 | 2.08 | −0.20 | 0.32 | 1.86 | 1.05 | 0.82 | 3.79 |
| Fe (tot) | −36.05 | −14.05 | −23.66 | 11.97 | 4.80 | 13.78 | −6.85 | 8.61 | 11.70 | 11.22 | 11.26 | 64.23 | 16.53 | 1.60 | 12.31 | 10.63 | 11.31 | 8.43 | 10.91 | 11.43 | −20.69 | 10.39 | 12.58 | −11.30 | 9.39 | 10.66 | 6.18 | 7.84 | 11.28 |
| Fe (sol) | −0.39 | −0.69 | −0.07 | 1.87 | −0.10 | 0.34 | −0.90 | 0.29 | 1.09 | −0.01 | 1.54 | −0.08 | 2.11 | 0.12 | 1.87 | 0.65 | 1.38 | 0.62 | 1.43 | 1.55 | −1.30 | 0.11 | −1.07 | −0.28 | 0.47 | −0.60 | −1.33 | 0.39 | 1.50 |
| Cu (tot) | −31.36 | −19.82 | −19.79 | 8.99 | −2.81 | 3.05 | −31.54 | 5.31 | 7.70 | −29.90 | 8.61 | 8.41 | 14.69 | −7.18 | 9.34 | 2.41 | 8.27 | 5.83 | 8.00 | 8.53 | −21.41 | −1.56 | 7.43 | −13.81 | −1.29 | 5.95 | −13.10 | 2.09 | 8.39 |
| Cu (sol) | −2.36 | −2.54 | −1.88 | 0.92 | −1.15 | −0.55 | −3.57 | −1.25 | 0.01 | −1.53 | −0.54 | −1.83 | 0.83 | −1.39 | 0.97 | −0.34 | 0.72 | 0.20 | 0.58 | 0.82 | −1.75 | −0.80 | −2.66 | −1.61 | −0.84 | −3.77 | −3.15 | −0.69 | 0.79 |
| Ni (tot) | −4.21 | −4.79 | 2.93 | 10.47 | 6.44 | 9.75 | 3.95 | 8.33 | 11.75 | 8.98 | 10.23 | 18.18 | 14.39 | 10.40 | 10.89 | 9.01 | 10.02 | 8.47 | 10.30 | 10.90 | −0.79 | 12.17 | 12.49 | 7.13 | 11.21 | 11.00 | 12.89 | 7.58 | 10.37 |
| Ni (sol) | −1.88 | −1.41 | −2.06 | −0.67 | −2.15 | −2.16 | −2.09 | −0.76 | −0.96 | −2.04 | −1.79 | −1.92 | −1.34 | −1.64 | −0.97 | −3.68 | 3.43 | −2.21 | −0.34 | −0.93 | −1.29 | −1.20 | −1.78 | −1.26 | −1.65 | −2.06 | −1.32 | −2.15 | −1.14 |
| V (tot) | −3.85 | −3.00 | −1.59 | 7.07 | 2.01 | 4.24 | 0.32 | 4.93 | 5.88 | 0.41 | 6.08 | 5.06 | 7.17 | 1.18 | 9.38 | 6.63 | 10.17 | 4.71 | 6.61 | 6.68 | −1.98 | 3.30 | 5.35 | 2.83 | 2.73 | 5.03 | 6.28 | 2.81 | 6.76 |
| V (sol) | −3.82 | −3.46 | −4.01 | −3.89 | −3.69 | −3.94 | −3.83 | −3.26 | −3.73 | −3.98 | −3.83 | −3.90 | −3.88 | −3.76 | −5.90 | −5.88 | −3.94 | −4.80 | −3.71 | −4.02 | −4.52 | −3.55 | −3.83 | −4.92 | −3.65 | −3.96 | −4.71 | −4.36 | −4.14 |
| Endotoxin | −0.14 | −0.15 | −0.14 | −0.24 | −0.12 | −0.13 | −0.18 | −0.16 | −0.26 | −0.19 | −0.23 | −0.20 | −0.24 | −0.19 | −0.27 | −0.19 | −0.29 | −0.18 | −0.20 | −0.18 | −0.12 | −0.14 | −0.14 | −0.13 | −0.14 | −0.14 | −0.14 | −0.14 | −0.19 |
| $NO_3^{-}$[a] | 0.51 | −0.06 | 0.79 | 0.90 | 0.96 | 1.10 | 0.86 | 0.35 | 0.60 | 0.96 | 0.99 | 0.92 | 0.95 | 1.03 | 1.02 | 1.06 | 0.84 | 1.26 | 0.98 | 1.51 | 1.05 | 0.77 | 0.69 | 1.09 | 0.91 | 0.65 | 0.88 | 0.65 | 1.00 |
| $SO_4^{2-}$[a] | 0.24 | −0.07 | 0.39 | −0.08 | 0.50 | 0.55 | 0.37 | −0.26 | 0.26 | 0.51 | 0.22 | 0.40 | 0.16 | 0.78 | 0.14 | 0.35 | 0.52 | 0.15 | −1.18 | 0.11 | 0.92 | 0.22 | −0.09 | 0.92 | 0.28 | −0.16 | 0.55 | −0.10 | 0.07 |
| $OP^{AA}$ (C) | 13.21 | 6.40 | 22.27 | 15.18 | 24.26 | 29.57 | 21.83 | 14.35 | 15.14 | 43.32 | 17.77 | 47.69 | 20.07 | 15.58 | 15.19 | 17.72 | 14.29 | 12.93 | 14.30 | 14.90 | 14.49 | 36.92 | 24.86 | 31.00 | 25.13 | 17.89 | 37.82 | 18.49 | 14.70 |
| $OP^{AA}$ (F) | −4.53 | −7.79 | −0.35 | 6.33 | 2.38 | 4.93 | −1.70 | 4.57 | 5.34 | 0.34 | 5.89 | 7.07 | 7.35 | −0.87 | 6.11 | 3.57 | 5.41 | 5.25 | 5.82 | 6.08 | −10.91 | 6.02 | 5.75 | −2.43 | 2.80 | 4.90 | 0.75 | 3.82 | 6.12 |
| $OP^{AA}$ (qUF) | −4.83 | −5.30 | −2.87 | 5.56 | 0.10 | 1.71 | −4.70 | 2.15 | 4.01 | −1.21 | 7.67 | 0.62 | 12.82 | −1.42 | 5.97 | 1.69 | 5.09 | 4.10 | 4.79 | 5.23 | −6.82 | 0.41 | 5.20 | −2.13 | 0.28 | 0.06 | −12.45 | 1.29 | 5.35 |
| $OP^{GSH}$ (C) | −0.81 | −0.12 | 7.29 | 10.91 | 13.61 | 18.13 | 8.35 | 9.63 | 10.52 | 21.59 | 10.74 | 25.64 | 14.50 | 4.03 | 10.77 | 6.96 | 10.37 | 8.99 | 10.21 | 10.68 | −11.02 | 13.71 | 12.59 | 10.31 | 20.52 | 11.01 | 13.38 | 10.24 | 10.40 |
| $OP^{GSH}$ (F) | −6.35 | −3.78 | −3.61 | 7.26 | 2.92 | 6.53 | −0.87 | 5.25 | 6.57 | 1.01 | 6.35 | 7.74 | 8.34 | −0.25 | 7.19 | 4.45 | 6.31 | 6.00 | 6.77 | 6.88 | −6.28 | 4.06 | 6.59 | −7.06 | 6.80 | 6.03 | 3.10 | 4.60 | 6.91 |
| $OP^{GSH}$ (qUF) | −3.44 | −3.48 | −1.98 | 5.87 | 0.91 | 2.40 | −2.75 | 2.54 | 4.38 | 0.25 | 6.82 | 2.02 | 16.90 | −0.11 | 6.51 | 2.24 | 5.67 | 4.37 | 5.01 | 5.49 | −2.69 | 1.96 | 5.39 | −0.71 | 1.06 | 5.44 | −5.19 | 1.67 | 5.67 |
| $OP^{TOTAL}$ | −11.85 | −8.14 | −5.09 | 10.44 | 7.27 | 10.28 | −3.79 | 9.84 | 8.74 | 4.34 | 13.14 | 25.87 | 21.43 | −1.49 | 10.47 | 2.53 | 9.66 | 8.14 | 9.13 | 9.71 | −16.13 | 8.60 | 29.71 | −3.12 | 5.62 | 16.89 | 9.66 | 7.02 | 10.00 |
| $O_3$ | 4.80 | 5.44 | 0.77 | −9.50 | −2.05 | −6.07 | −1.20 | −6.23 | −7.62 | −3.02 | −7.76 | −6.74 | −9.54 | −3.26 | −9.12 | −5.42 | −8.99 | −6.52 | −7.54 | −8.06 | 3.69 | −3.81 | −6.65 | −0.10 | −3.36 | −6.33 | −2.83 | −8.03 | −10.49 |
| $NO_2$ | −0.92 | −1.48 | −0.57 | 1.48 | −1.94 | −1.27 | −0.22 | −0.93 | 0.45 | −0.09 | 0.54 | 0.11 | 0.66 | 0.14 | 1.08 | −0.29 | 1.57 | −0.58 | −0.19 | 0.50 | −0.70 | −0.44 | −0.46 | −0.44 | −0.46 | −0.63 | −0.86 | −2.65 | 0.51 |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
For further explanation see Appendix F.

## Appendix I. Associations between air pollution exposure and percentage changes (post–pre) in blood neutrophils 18 h after exposure in the complete dataset (including all sites).

| | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blood perml. neutro. - 18PE - all sites | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5–10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol)[b] | V (tot) | V (sol) | Endotoxin | $NO_3^-$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | 3.98 | 30.53 | −30.38 | 4.23 | 3.14 | 5.49 | −4.21 | 6.17 | 4.93 | 5.75 | 1.90 | 6.98 | 2.35 | −7.10 | 1.61 | −8.52 | 3.63 | 2.34 | 4.38 | 3.65 | 0.12 | **25.95** | 7.65 | −8.73 | 10.36 | 3.66 | 12.81 | 1.57 | 3.88 |
| $PM_{2.5}$ | −18.00 | 1.91 | −10.80 | 2.02 | −2.71 | −0.99 | −8.47 | 3.42 | 1.35 | −5.69 | −0.16 | −4.63 | −0.35 | −7.67 | 0.95 | −7.19 | 1.88 | 0.92 | 2.77 | 1.94 | −5.17 | 13.68 | 1.96 | −7.58 | 0.33 | −0.24 | −1.53 | −2.92 | 1.74 |
| $PM_{2.5–10}$ | 50.59 | 18.95 | 4.91 | 5.25 | 8.11 | 10.71 | 5.96 | 6.92 | 6.39 | 44.47 | 3.05 | 17.64 | 3.91 | −2.01 | 1.87 | −6.62 | 4.39 | 3.06 | 5.00 | 4.39 | 6.99 | **24.69** | 10.30 | −3.10 | 19.83 | 6.18 | 24.17 | 5.20 | 4.83 |
| PNC | −0.76 | −0.57 | −0.88 | −0.46 | −1.87 | −1.65 | −0.26 | −0.45 | 0.24 | −0.12 | −0.40 | −0.09 | −0.03 | 0.06 | −2.32 | −0.41 | 0.16 | −2.28 | −0.82 | −1.02 | −0.09 | −0.44 | −0.62 | −0.20 | −0.72 | −0.76 | −0.03 | −1.28 | −1.03 |
| Absorbance[a] | 0.75 | 5.49 | −2.68 | 4.81 | 3.09 | 25.52 | 2.12 | 4.22 | 3.72 | 5.21 | 2.18 | 5.46 | 2.70 | 0.20 | 1.21 | −2.59 | 3.54 | 0.53 | 3.04 | 2.53 | 1.80 | 14.21 | 4.52 | −2.68 | 5.84 | 2.38 | 7.30 | 0.38 | 3.24 |
| EC (F) | −1.28 | 3.35 | −4.61 | 3.97 | −17.48 | 2.54 | −1.08 | 3.15 | 2.64 | 1.03 | 1.34 | 1.94 | 1.68 | −1.69 | 0.27 | −4.85 | 2.68 | 0.03 | 2.40 | 1.89 | −0.67 | 13.37 | 3.13 | −5.26 | 3.74 | 1.49 | 3.96 | −1.02 | 2.51 |
| EC (C) | 7.40 | 12.74 | −1.32 | 3.68 | 1.47 | 4.68 | 3.56 | 5.43 | 4.23 | 10.74 | 2.05 | 17.80 | 3.25 | −1.94 | 1.33 | −4.05 | 3.63 | 0.13 | 3.62 | 3.29 | 2.59 | **27.11** | 10.31 | −4.19 | 9.60 | 4.96 | 21.94 | 1.15 | 3.23 |
| OC (F) | −1.74 | −1.31 | −1.74 | −0.03 | −1.28 | −0.86 | −1.67 | −0.05 | −0.32 | −1.15 | −1.38 | −1.26 | −2.15 | −1.67 | 0.41 | −1.40 | 0.34 | −0.64 | 0.40 | 0.23 | −1.19 | 0.16 | −1.38 | −1.41 | −0.88 | −2.70 | −1.57 | −1.24 | −0.28 |
| OC (C) | −1.08 | 0.35 | −1.58 | 1.08 | −0.41 | 0.02 | −0.72 | 1.21 | 1.06 | −0.44 | 0.36 | −0.29 | −0.09 | −1.76 | 0.89 | −1.24 | 1.12 | 1.76 | 1.73 | 1.02 | −1.53 | 2.11 | 1.01 | −3.34 | 0.42 | 0.26 | −0.78 | −0.48 | 0.88 |
| Fe (tot) | −2.15 | 10.50 | −28.35 | 3.56 | −2.31 | 2.25 | −7.73 | 4.85 | 3.99 | 3.50 | 1.69 | 8.58 | 2.12 | −10.10 | 0.84 | −12.96 | 3.50 | −0.33 | 3.50 | 2.99 | −0.46 | 35.77 | 7.39 | −16.31 | 11.30 | 3.19 | 16.18 | −1.28 | 3.09 |
| Fe (sol) | 0.88 | 1.20 | 0.72 | 1.24 | 0.76 | 0.93 | 0.73 | 1.61 | 1.12 | 0.91 | 1.17 | 1.01 | 1.15 | 0.64 | 0.18 | 0.54 | 1.22 | 0.10 | 1.18 | 1.15 | 0.66 | 1.90 | 3.23 | 0.51 | 1.10 | 1.49 | 1.21 | 0.77 | 1.10 |
| Cu (tot) | −3.03 | 7.93 | −10.66 | 2.95 | −2.41 | 0.90 | −12.86 | 4.34 | 3.21 | −4.27 | 0.83 | 2.92 | 1.33 | −8.35 | 0.47 | −7.84 | 2.97 | −0.50 | 2.97 | 2.56 | −2.75 | **29.90** | 7.34 | −10.23 | 6.08 | 2.45 | 9.81 | −1.03 | 2.57 |
| Cu (sol) | 0.40 | 0.85 | 0.17 | 0.79 | 0.32 | 0.51 | 0.10 | 1.52 | 0.80 | 0.45 | 0.02 | 0.52 | 0.78 | 0.07 | 0.17 | 0.05 | 0.81 | 0.08 | 0.87 | 0.85 | 0.24 | 1.39 | 1.93 | −0.08 | 0.72 | 1.02 | 0.60 | 0.32 | 0.72 |
| Ni (tot) | 11.47 | 12.95 | 6.46 | 4.61 | 4.42 | 6.34 | 6.59 | 6.40 | 6.55 | 14.55 | 3.57 | 13.52 | 4.42 | 4.61 | 2.93 | −1.31 | 4.66 | 2.04 | 4.58 | 3.98 | 8.75 | **29.18** | 9.67 | 3.11 | 14.25 | 6.09 | 17.24 | 3.60 | 4.36 |
| Ni (sol)[b] | **6.15** | **6.24** | **6.10** | **7.14** | **6.12** | **6.24** | **6.13** | **6.30** | **6.26** | **6.19** | **6.19** | **6.22** | **6.20** | **6.06** | **6.28** | **6.10** | **10.11** | **5.22** | **6.54** | **6.10** | **7.18** | **6.40** | **6.54** | **7.07** | **6.34** | **6.48** | **7.37** | **6.12** | **6.23** |
| V (tot) | 10.16 | 9.66 | 8.85 | 4.56 | 6.30 | 8.20 | 7.31 | 5.26 | 5.19 | 13.60 | 3.92 | 10.05 | 4.37 | 5.29 | 0.54 | 4.44 | 4.46 | 1.94 | 4.41 | 4.26 | **15.65** | **14.56** | 7.18 | 13.24 | 10.22 | 5.59 | **18.11** | 6.95 | 4.25 |
| V (sol) | 0.89 | 0.94 | 0.83 | 0.84 | 0.98 | 0.87 | 0.92 | 0.93 | 0.89 | 0.85 | 0.99 | 0.88 | 0.92 | 0.90 | −4.75 | −0.03 | 0.85 | 0.12 | 0.80 | 1.12 | 5.39 | 0.85 | 0.94 | 5.17 | 1.00 | 0.92 | 5.22 | 0.68 | 0.70 |
| Endotoxin | −0.17 | −0.18 | −0.17 | **−0.22** | −0.18 | −0.18 | **−0.28** | −0.19 | **−0.29** | **−0.29** | **−0.28** | **−0.29** | **−0.28** | **−0.27** | **−0.23** | **−0.26** | **−0.28** | −0.18 | −0.18 | −0.18 | −0.18 | −0.20 | −0.19 | −0.18 | −0.18 | −0.18 | −0.19 | −0.17 | −0.19 |
| $NO_3^-$[a] | −0.53 | −0.62 | −0.45 | −0.51 | −0.38 | −0.35 | −0.30 | −0.47 | −0.51 | −0.27 | −0.28 | −0.29 | −0.40 | −0.24 | 0.41 | −0.22 | −0.23 | −0.18 | −0.41 | 0.24 | −0.85 | −0.46 | −0.50 | −0.85 | −0.45 | −0.56 | −0.94 | −0.53 | −0.52 |
| $SO_4^{2-}$[a] | −1.23 | −1.31 | −1.16 | −1.44 | −1.16 | −1.17 | −1.09 | −1.32 | −1.16 | −1.07 | −1.15 | −1.09 | −1.24 | −0.94 | −0.68 | −1.05 | −1.27 | −1.28 | −1.50 | −1.30 | −1.54 | −1.42 | −1.37 | −1.49 | −1.30 | −1.40 | −1.67 | −1.35 | −1.36 |
| $OP^{AA}$ (C) | 4.96 | 11.04 | −1.28 | 5.10 | 3.17 | 5.85 | 1.90 | 6.20 | 6.26 | 5.10 | 3.23 | 7.66 | 4.02 | −3.49 | 2.45 | −12.79 | 5.29 | 3.12 | 5.05 | 4.32 | 5.07 | **38.31** | 10.17 | −9.92 | 11.68 | 4.52 | 15.99 | 0.42 | 4.85 |
| $OP^{AA}$ (F) | **−12.49** | −8.61 | **−11.57** | −0.50 | −8.60 | −8.60 | **−14.86** | −0.68 | −1.93 | **−16.40** | −2.96 | **−15.76** | −2.87 | **−14.47** | −1.18 | **−10.09** | −0.72 | −1.66 | −0.53 | −0.96 | **−16.74** | −0.58 | −2.84 | **−13.61** | −6.94 | −2.77 | −9.03 | −5.78 | −0.70 |
| $OP^{AA}$ (qUF) | −3.00 | −0.16 | −4.23 | 1.20 | −1.61 | −0.78 | −5.70 | 2.51 | 0.12 | −3.11 | −5.57 | −3.74 | −3.94 | −4.31 | −1.15 | −3.90 | 0.81 | −0.23 | 1.26 | 1.08 | −3.87 | 3.52 | 1.07 | −3.83 | −0.32 | −11.46 | −6.38 | −1.57 | 0.96 |
| $OP^{GSH}$ (C) | 13.20 | 12.66 | 7.96 | 5.29 | 7.82 | 10.71 | 9.08 | 6.33 | 8.45 | 20.97 | 4.24 | 15.21 | 5.19 | 2.37 | 2.87 | −8.08 | 5.09 | 3.63 | 5.22 | 4.62 | 14.45 | **25.45** | 9.13 | 5.25 | **30.73** | 5.61 | 17.71 | 3.02 | 5.09 |
| $OP^{GSH}$ (F) | −4.36 | 1.39 | −9.14 | 1.79 | −2.42 | −1.15 | −4.77 | 2.20 | 1.11 | −5.04 | 0.34 | −2.49 | 0.24 | −6.74 | 0.25 | −6.28 | 1.55 | 0.61 | 1.56 | 1.18 | −4.42 | 8.69 | 1.85 | −16.52 | 1.61 | 0.32 | 0.08 | −1.16 | 1.53 |
| $OP^{GSH}$ (qUF) | 0.17 | 2.29 | −1.12 | 2.32 | 0.76 | 1.31 | −1.34 | 5.11 | 1.65 | 0.18 | −1.00 | 0.34 | −0.85 | −1.30 | −0.61 | −1.77 | 1.82 | 0.93 | 2.39 | 2.28 | 0.52 | 4.14 | 14.86 | −0.41 | 1.91 | 2.15 | 2.97 | 0.44 | 2.06 |
| $OP^{TOTAL}$ | −7.15 | 4.66 | −14.41 | 3.10 | −3.55 | −0.72 | −15.87 | 5.01 | 3.47 | −9.65 | −0.06 | −6.16 | 0.85 | −10.76 | −0.08 | −14.68 | 3.04 | 1.24 | 3.50 | 2.88 | −9.14 | 16.78 | 12.02 | −12.36 | 2.98 | −0.41 | 3.08 | −4.22 | 2.71 |
| $O_3$ | −2.34 | −5.93 | 0.28 | −4.26 | −3.15 | −4.43 | −2.75 | −4.48 | −4.03 | −4.58 | −2.66 | −4.45 | −3.03 | −1.21 | −1.12 | 3.64 | −3.55 | −1.38 | −3.79 | −3.66 | −5.00 | −9.50 | −4.76 | −2.83 | −4.56 | −3.03 | −8.52 | −3.49 | −4.07 |
| $NO_2$ | 0.19 | 0.34 | 0.17 | 1.12 | −0.18 | 0.05 | 0.91 | 0.70 | 1.16 | 0.97 | 1.04 | 1.01 | 1.07 | 0.95 | 0.28 | 0.51 | 1.13 | −0.59 | 0.94 | 0.88 | 1.62 | 0.65 | 0.46 | 1.61 | 0.42 | 0.28 | 1.59 | −0.59 | 0.61 |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
[b]One-pollutant estimate decreased by more than 50 % and became non-significant after excluding 1% of influential observations.
For further explanation see Appendix F.

## Appendix J. Associations between air pollution exposure and percentage changes (post–pre) in blood monocytes 2 h after exposure in the complete dataset (including all sites).

| | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blood perml. mono. - 2PE - all sites | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5-10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol)[b] | Endotoxin | $NO_3^-$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | 1.78 | −28.95 | 90.28 | 1.92 | −8.19 | −5.36 | 10.03 | −4.66 | −3.25 | −23.73 | −1.57 | −28.26 | 3.15 | −25.35 | 3.50 | 45.56 | 1.49 | 2.40 | 1.04 | 2.06 | −28.99 | −28.71 | −1.29 | −16.17 | −11.83 | 11.99 | −9.53 | 13.44 | 2.14 |
| $PM_{2.5}$ | 36.47 | 3.50 | 22.52 | 3.58 | 2.87 | 3.79 | 17.41 | −1.86 | 1.49 | 7.83 | 1.42 | 0.39 | 6.27 | −5.04 | 4.39 | 28.04 | 1.45 | 3.87 | 2.49 | 3.35 | −5.55 | −14.42 | 5.29 | 3.60 | 3.58 | 13.53 | 8.03 | 15.18 | 4.09 |
| $PM_{2.5-10}$ | −47.36 | −19.96 | 0.34 | 0.47 | −15.70 | −13.14 | −8.78 | −5.63 | −5.59 | −62.67 | −3.40 | −39.56 | 0.25 | −34.27 | 2.37 | 45.04 | 1.32 | 1.00 | 0.05 | 0.89 | **−40.20** | −28.91 | −6.02 | −41.22 | −27.01 | 7.50 | −23.91 | 6.87 | 0.56 |
| PNC | −0.44 | −0.48 | −0.35 | −0.31 | −1.63 | −1.46 | −0.77 | −0.43 | −0.42 | −0.90 | −1.62 | −1.02 | −0.64 | −0.71 | 0.79 | 0.13 | 0.67 | 0.19 | 0.34 | 0.31 | −4.36 | −0.01 | 0.43 | −4.22 | 0.29 | 0.88 | −4.18 | −0.10 | −0.13 |
| Absorbance[a] | 10.01 | 0.73 | 17.13 | 4.65 | 3.16 | 21.56 | 12.85 | −0.51 | 1.34 | 3.93 | 0.42 | −2.32 | 4.59 | −4.33 | 4.87 | 27.49 | 1.84 | 4.66 | 3.19 | 3.90 | −20.73 | −8.20 | 5.61 | −13.46 | 5.88 | 12.89 | −9.02 | 22.08 | 4.38 |
| EC (F) | 6.80 | −0.32 | 13.55 | 3.93 | −14.80 | 2.67 | 8.28 | −0.27 | 0.86 | 1.24 | 0.17 | −4.01 | 3.43 | −5.33 | 4.50 | 28.21 | 2.91 | 4.03 | 2.97 | 3.57 | −15.91 | −11.15 | 3.88 | −7.73 | 3.09 | 9.45 | −3.17 | 15.24 | 3.51 |
| EC (C) | −6.36 | −13.01 | 9.54 | 1.81 | −9.67 | −6.11 | 1.50 | −4.83 | −2.22 | −21.37 | −4.07 | −43.92 | 2.01 | −19.19 | 2.83 | 26.77 | 0.67 | 2.95 | 1.26 | 1.79 | **−31.94** | −28.76 | −4.85 | −22.77 | −10.12 | 10.47 | −34.00 | 7.80 | 1.73 |
| OC (F) | 5.50 | 4.80 | 5.62 | 4.06 | 4.21 | 4.12 | 6.09 | 4.04 | 3.94 | 4.86 | 3.60 | 4.43 | 8.15 | 3.45 | 4.17 | 7.17 | 0.13 | 4.33 | 3.80 | 3.73 | −0.32 | 3.03 | 7.98 | 0.70 | 4.81 | 13.88 | 1.20 | 5.70 | 4.69 |
| OC (C) | 4.81 | 2.43 | 5.82 | 3.23 | 2.71 | 2.91 | 4.26 | 1.22 | 3.26 | 3.13 | 2.20 | 2.10 | 4.14 | 0.47 | 3.26 | 7.69 | 1.65 | 3.02 | 2.57 | 3.31 | −3.63 | −1.79 | 0.92 | −2.00 | 0.34 | 4.02 | −1.45 | 5.14 | 3.40 |
| Fe (tot) | 36.18 | −4.72 | 177.11 | 4.08 | −0.71 | 2.22 | 36.15 | −1.85 | 0.33 | 3.71 | −0.04 | −34.77 | 5.55 | −22.57 | 5.43 | **81.34** | 3.93 | 5.53 | 3.59 | 4.39 | −32.13 | −32.63 | 1.32 | −4.53 | −5.29 | 13.65 | 1.09 | 19.09 | 4.06 |
| Fe (sol) | 2.19 | 1.69 | 2.45 | 2.22 | 1.86 | 1.91 | 2.86 | 0.81 | 1.63 | 1.95 | 1.94 | 1.70 | 5.24 | 1.24 | 2.68 | 3.22 | 1.28 | 2.56 | 1.89 | 1.94 | −0.90 | 0.86 | 4.20 | 0.14 | 1.89 | 6.90 | 0.05 | 2.55 | 2.00 |
| Cu (tot) | 40.50 | 4.36 | 62.22 | 5.12 | 7.24 | 9.26 | 89.08 | −0.23 | 2.68 | 52.57 | 1.21 | 4.75 | 9.96 | −8.73 | 6.42 | 49.77 | 4.17 | 6.54 | 4.52 | 5.22 | −17.74 | −22.91 | 6.29 | 3.06 | 5.88 | 18.61 | 8.78 | 17.86 | 5.09 |
| Cu (sol) | −0.25 | −0.89 | 0.22 | 0.31 | −0.53 | −0.29 | −0.16 | −2.39 | −0.59 | −0.58 | −3.12 | −1.59 | 0.26 | −1.41 | 0.60 | 1.53 | −0.16 | 0.53 | 0.07 | 0.17 | −3.44 | −1.65 | −1.92 | −2.87 | −0.57 | 3.36 | −4.72 | 0.56 | 0.29 |
| Ni (tot) | 37.01 | 12.23 | 52.10 | 6.85 | 11.15 | 12.41 | 30.55 | 3.06 | 6.27 | 32.39 | 4.80 | 16.19 | 10.73 | 6.78 | 7.80 | **46.42** | 5.62 | 8.10 | 6.79 | 8.05 | 1.67 | −13.00 | 5.25 | 23.16 | 5.90 | 13.93 | 20.95 | 18.39 | 7.05 |
| Ni (sol) | −3.29 | −3.20 | −3.26 | −3.32 | −3.62 | −3.67 | −3.34 | −2.82 | −3.06 | −3.53 | −4.19 | −3.70 | −3.28 | −3.54 | −3.06 | −1.88 | 12.43 | −2.79 | −2.72 | −2.71 | 0.96 | −3.67 | −3.95 | 1.22 | −3.81 | −3.37 | 1.24 | −3.13 | −3.06 |
| V (tot) | −23.98 | −19.11 | −23.88 | −5.01 | −19.12 | −20.22 | −18.56 | −8.69 | −8.86 | **−33.54** | −7.62 | −26.51 | −7.05 | **−24.64** | −3.78 | −4.99 | 2.31 | −4.63 | −4.93 | −4.81 | −7.66 | **−24.75** | −11.61 | 2.62 | −22.14 | −6.89 | 3.12 | −15.14 | −5.17 |
| V (sol)[b] | **−12.72** | **−12.67** | **−12.74** | **−12.77** | **−12.68** | **−12.73** | **−12.72** | **−12.70** | **−12.65** | **−12.74** | **−12.62** | **−12.70** | **−12.75** | **−12.65** | **−18.69** | **−13.15** | **−12.73** | **−12.80** | **−12.73** | **−13.13** | −0.85 | **−13.19** | **−13.39** | −1.09 | **−13.37** | **−13.43** | −1.03 | **−12.81** | **−12.96** |
| Endotoxin | 0.07 | 0.07 | 0.06 | 0.06 | 0.10 | 0.10 | 0.12 | 0.08 | 0.08 | 0.13 | 0.16 | 0.14 | 0.11 | 0.14 | 0.06 | 0.04 | −0.03 | 0.06 | 0.04 | 0.06 | 0.02 | 0.07 | 0.05 | 0.00 | 0.05 | 0.01 | −0.01 | 0.05 | 0.06 |
| $NO_3^-$[a] | 0.84 | 0.66 | 0.87 | 0.91 | 0.88 | 0.93 | 0.84 | 0.24 | 0.48 | 0.84 | 0.80 | 0.80 | 0.85 | 0.86 | 0.54 | 0.83 | 0.02 | 0.81 | 0.88 | 0.33 | 1.81 | 1.30 | 1.37 | 1.83 | 1.42 | 1.57 | 1.84 | 0.95 | 1.01 |
| $SO_4^{2-}$[a] | 1.59 | 1.52 | 1.58 | 1.60 | 1.74 | 1.77 | 1.63 | 1.25 | 1.62 | 1.72 | 1.60 | 1.72 | 1.58 | 2.03 | 1.33 | 1.50 | 2.69 | 1.55 | 1.27 | 1.56 | 4.29 | 2.44 | 2.14 | 4.20 | 2.32 | 2.23 | 4.07 | 1.60 | 1.62 |
| $OP^{AA}$ (C) | 46.73 | 12.29 | **72.19** | 6.50 | 35.01 | 28.06 | **61.51** | 5.89 | 10.76 | 54.69 | 8.72 | 30.97 | 16.92 | 4.92 | 6.32 | 18.29 | 6.57 | 5.75 | 5.28 | 7.22 | 5.54 | −11.46 | 15.80 | 50.91 | 24.61 | 22.75 | 45.28 | 16.35 | 5.16 |
| $OP^{AA}$ (F) | 27.62 | 17.21 | 26.78 | 5.70 | 11.55 | 14.35 | 31.64 | 3.62 | 7.06 | 32.22 | 5.01 | 24.78 | 8.80 | 14.98 | 6.30 | **30.32** | 3.77 | 6.12 | 5.42 | 6.23 | 12.01 | 5.69 | 10.35 | 16.90 | 14.44 | 12.02 | 21.22 | 15.63 | 5.71 |
| $OP^{AA}$ (qUF) | 2.48 | −1.56 | 5.25 | 1.66 | −1.58 | −0.55 | 5.96 | −6.03 | 1.92 | 1.76 | −5.72 | −1.42 | 7.62 | −0.39 | 3.76 | 11.40 | 1.30 | 2.07 | 1.07 | 1.57 | −7.26 | −6.26 | 1.72 | −1.40 | −0.50 | 73.52 | −2.11 | 3.89 | 1.63 |
| $OP^{GSH}$ (C) | 17.51 | −1.42 | 57.48 | 2.55 | 15.89 | 9.81 | 29.56 | 1.18 | 4.26 | 6.19 | 2.06 | −0.42 | 9.39 | −14.31 | 1.86 | −0.61 | 2.26 | 1.73 | 1.59 | 3.19 | −26.78 | −16.06 | 3.10 | 1.74 | 7.39 | 11.21 | 6.15 | 4.58 | 1.46 |
| $OP^{GSH}$ (F) | 11.08 | 0.17 | 25.21 | 2.56 | −1.52 | 0.29 | 10.89 | −0.68 | 2.65 | 6.45 | 1.04 | −1.00 | 3.91 | −0.83 | 3.76 | 26.86 | 1.26 | 2.90 | 2.66 | 3.27 | −11.45 | −9.69 | 3.00 | −4.38 | 2.62 | 9.18 | 1.50 | 8.07 | 2.55 |
| $OP^{GSH}$ (qUF) | −8.28 | −9.70 | −6.20 | −2.63 | −9.10 | −7.25 | −7.91 | −14.99 | −4.10 | −7.98 | −13.33 | −11.28 | −9.87 | −8.25 | −0.41 | 3.01 | −1.88 | −2.36 | −3.27 | −2.78 | −13.16 | −9.91 | −42.74 | −9.70 | −8.46 | −2.46 | −22.28 | −4.27 | −2.75 |
| $OP^{TOTAL}$ | 10.19 | −6.48 | 27.77 | 1.89 | 10.41 | 4.16 | 55.32 | −0.52 | 3.49 | 1.09 | 1.93 | −5.95 | 18.64 | −13.83 | 1.55 | −1.43 | 1.97 | 0.90 | −0.05 | 1.16 | −26.17 | −21.86 | 3.72 | −4.81 | −0.88 | 36.34 | 0.94 | 2.33 | 0.37 |
| $O_3$ | 11.51 | 14.48 | 6.45 | 1.18 | 22.05 | 15.70 | 7.37 | 6.17 | 4.84 | 14.60 | 4.26 | 14.61 | 2.00 | 13.79 | −0.59 | −15.71 | −1.90 | 0.59 | 1.95 | 1.60 | 11.02 | 17.91 | 3.91 | 3.60 | 8.75 | −3.35 | 1.61 | 1.26 | 1.15 |
| $NO_2$ | −0.67 | −1.08 | −0.48 | −0.37 | −1.49 | −1.21 | −0.60 | −1.83 | −0.78 | −0.77 | −0.80 | −0.88 | −0.48 | −0.91 | 0.07 | 0.54 | 1.94 | −0.09 | −1.11 | −0.78 | 1.76 | −0.06 | 0.39 | 1.95 | 0.32 | 1.00 | 1.98 | −0.10 | −0.43 |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
[b]One-pollutant estimate decreased by more than 50 % and became non-significant after excluding 1% of influential observations.
For further explanation see Appendix F.

## Appendix K. Associations between air pollution exposure and percentage changes (post–pre) in blood monocytes 18 hours after exposure in the complete dataset (including all sites).

| | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blood perml. mono. - 18PE - all sites | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5–10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endotoxin | $NO_3^-$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | 10.22 | 60.77 | −43.27 | 9.33 | −0.35 | −0.90 | 15.48 | 14.99 | 9.94 | −2.21 | 12.38 | 32.42 | 14.68 | 10.30 | 8.78 | −4.80 | 10.27 | 9.65 | 11.20 | 9.96 | 3.15 | 22.80 | 14.08 | −10.65 | 0.57 | 10.89 | 11.40 | −5.21 | 8.59 |
| $PM_{2.5}$ | −28.03 | 6.11 | −16.39 | 5.57 | −6.67 | −5.90 | −6.28 | 9.88 | 3.24 | −11.24 | 6.93 | −1.37 | 7.25 | −3.17 | 5.48 | −6.91 | 6.72 | 5.68 | 8.21 | 6.15 | −4.11 | 6.56 | 4.62 | −8.34 | −5.30 | 3.18 | −2.66 | −8.95 | 4.42 |
| $PM_{2.5–10}$ | 97.12 | 36.25 | 11.78 | 10.81 | 6.95 | 5.55 | 34.45 | 15.97 | 12.57 | 53.47 | 14.34 | 54.33 | 17.42 | 22.28 | 10.04 | −0.28 | 11.46 | 11.28 | 12.05 | 11.42 | 10.94 | 25.52 | 18.18 | −6.13 | 9.35 | 14.95 | 23.21 | 0.07 | 10.36 |
| PNC | 2.69 | 3.04 | 2.47 | 3.36 | 0.78 | 0.74 | 2.96 | 3.35 | 3.98 | 2.97 | 3.83 | 3.21 | 3.65 | 3.57 | 2.52 | 2.75 | 3.61 | 2.95 | 3.02 | 3.05 | 2.14 | 3.25 | 3.24 | 1.96 | 2.80 | 3.11 | 2.11 | 1.36 | 1.76 |
| Absorbance[a] | 9.66 | 15.88 | 4.07 | 8.64 | 9.38 | −5.86 | 15.90 | 12.23 | 8.83 | 11.14 | 12.26 | 18.96 | 12.38 | 10.01 | 8.25 | 2.80 | 10.12 | 9.26 | 9.28 | 9.03 | 6.91 | 19.24 | 12.27 | 0.11 | 7.26 | 10.25 | 10.72 | −1.43 | 7.73 |
| EC (F) | 9.99 | 14.65 | 5.16 | 8.62 | 15.78 | 9.28 | 14.10 | 11.05 | 8.56 | 11.70 | 11.32 | 18.41 | 11.12 | 10.08 | 7.98 | 2.79 | 9.43 | 9.20 | 9.03 | 8.94 | 7.59 | 21.29 | 11.33 | 1.17 | 8.08 | 9.50 | 10.11 | 0.75 | 7.76 |
| EC (C) | −4.37 | 15.01 | −15.64 | 6.78 | −6.43 | −5.18 | 8.05 | 11.78 | 6.56 | −9.48 | 12.21 | 24.15 | 15.40 | 3.95 | 6.69 | −4.33 | 8.39 | 6.88 | 8.24 | 7.82 | −0.54 | 17.02 | 12.21 | −11.26 | −2.31 | 8.42 | 4.21 | −5.66 | 6.67 |
| OC (F) | −3.52 | −3.10 | −3.33 | 0.26 | −2.99 | −2.30 | −3.14 | 0.41 | −0.98 | −2.91 | −0.14 | −2.59 | −1.46 | −2.53 | 0.75 | −2.26 | 1.75 | 0.11 | 1.42 | 0.66 | −2.72 | −1.47 | −3.72 | −3.05 | −2.59 | −4.81 | −4.64 | −3.12 | −0.92 |
| OC (C) | 0.03 | 2.60 | −0.79 | 4.55 | 0.85 | 0.98 | 1.57 | 4.85 | 4.36 | 0.74 | 4.33 | 2.11 | 4.52 | 1.15 | 4.36 | 0.67 | 4.67 | 4.76 | 6.81 | 4.34 | 2.57 | 3.17 | 3.11 | 0.59 | 0.32 | 2.64 | 3.12 | 0.13 | 3.68 |
| Fe (tot) | 13.09 | 26.39 | −27.97 | 9.28 | −1.98 | −3.00 | 23.70 | 14.29 | 9.70 | 10.57 | 13.38 | 92.35 | 15.12 | 14.32 | 8.99 | −6.86 | 10.60 | 9.33 | 10.61 | 10.19 | 3.00 | 33.81 | 15.31 | −19.80 | 1.02 | 11.33 | 13.48 | −4.51 | 8.99 |
| Fe (sol) | −1.16 | −0.57 | −1.35 | 0.01 | −1.57 | −1.31 | −1.85 | 0.68 | 0.04 | −1.28 | 0.64 | −1.37 | −0.56 | −0.78 | −0.07 | −0.86 | 0.83 | 0.08 | 0.65 | 0.62 | −1.48 | −0.36 | −3.01 | −1.25 | −0.70 | −2.51 | −2.08 | −1.25 | 0.36 |
| Cu (tot) | −16.23 | 8.90 | −26.45 | 6.24 | −9.74 | −9.80 | −13.78 | 10.51 | 5.25 | −39.62 | 10.49 | 7.40 | 11.85 | −2.66 | 5.89 | −9.08 | 7.61 | 6.12 | 7.58 | 7.10 | −6.36 | 14.28 | 8.77 | −17.53 | −8.13 | 5.44 | −5.55 | −7.20 | 6.03 |
| Cu (sol) | −1.41 | −0.49 | −1.73 | 0.58 | −1.20 | −0.89 | −2.19 | 1.34 | −0.11 | −1.36 | 1.21 | −1.36 | 0.83 | −0.88 | 0.43 | −0.78 | 0.93 | 0.49 | 1.04 | 0.90 | −0.59 | 0.02 | −1.38 | −1.16 | −0.81 | −2.93 | −1.62 | −1.21 | 0.59 |
| Ni (tot) | −0.28 | 11.99 | −8.66 | 8.12 | −0.62 | −1.01 | 4.61 | 11.40 | 7.27 | −3.16 | 9.88 | 11.33 | 11.01 | 8.55 | 7.55 | −3.87 | 8.82 | 7.50 | 8.49 | 8.10 | −1.19 | 15.33 | 9.36 | −12.29 | −1.98 | 7.22 | 3.06 | −1.89 | 7.45 |
| Ni (sol) | 3.78 | 4.17 | 3.52 | 3.47 | 3.42 | 3.30 | 3.68 | 4.42 | 4.38 | 3.58 | 4.41 | 3.75 | 4.19 | 3.89 | 4.38 | 2.16 | 2.91 | 3.87 | 4.17 | 4.18 | 3.35 | 4.24 | 3.90 | 3.13 | 3.80 | 3.69 | 3.25 | 3.09 | 3.75 |
| V (tot) | 11.97 | 13.95 | 8.88 | 7.93 | 6.70 | 6.59 | 11.89 | 10.10 | 8.28 | 13.49 | 9.57 | 15.56 | 9.94 | 11.37 | 7.26 | 8.70 | 7.51 | 8.07 | 8.62 | 8.55 | 7.33 | 14.75 | 10.51 | 1.76 | 8.09 | 9.36 | 9.35 | 3.40 | 7.53 |
| V (sol) | 3.85 | 4.03 | 3.69 | 3.54 | 4.10 | 3.81 | 3.88 | 4.14 | 3.90 | 3.73 | 3.80 | 3.80 | 3.79 | 3.84 | 1.97 | 2.22 | 3.71 | 3.37 | 3.57 | 4.02 | 5.89 | 4.09 | 3.89 | 5.49 | 4.20 | 3.73 | 5.65 | 3.22 | 3.17 |
| Endotoxin | −0.06 | −0.08 | −0.04 | −0.05 | −0.01 | −0.01 | −0.09 | −0.10 | −0.17 | −0.09 | −0.15 | −0.10 | −0.14 | −0.11 | −0.11 | −0.06 | −0.12 | −0.10 | −0.09 | −0.10 | −0.04 | −0.08 | −0.08 | −0.02 | −0.06 | −0.07 | −0.04 | −0.01 | −0.05 |
| $NO_3^-$[a] | −1.16 | −1.44 | −0.94 | −0.45 | −0.76 | −0.62 | −0.85 | −1.05 | −1.73 | −0.78 | −0.77 | −0.83 | −0.93 | −0.74 | −0.33 | −0.69 | −0.59 | −0.71 | −0.82 | −0.51 | −0.22 | −0.84 | −0.96 | −0.23 | −0.74 | −1.02 | −0.40 | −1.22 | −1.36 |
| $SO_4^{2-}$[a] | −0.97 | −1.18 | −0.82 | −0.76 | −0.70 | −0.59 | −0.93 | −1.20 | −1.09 | −0.78 | −1.10 | −0.91 | −1.19 | −0.66 | −0.77 | −0.89 | −1.45 | −1.14 | −0.73 | −1.15 | −0.38 | −0.90 | −1.12 | −0.30 | −0.71 | −1.20 | −0.64 | −1.32 | −1.45 |
| $OP^{AA}$ (C) | 6.56 | 14.63 | −0.36 | 9.28 | 2.38 | 1.30 | 9.96 | 12.42 | 6.58 | 6.38 | 12.79 | 16.92 | 10.93 | 10.62 | 8.44 | 0.13 | 10.21 | 9.27 | 9.71 | 9.52 | 9.70 | 27.19 | 14.72 | −14.89 | 2.22 | 10.20 | 13.50 | 1.64 | 9.26 |
| $OP^{AA}$ (F) | −7.24 | −0.30 | −7.90 | 3.38 | −7.03 | −8.67 | −6.04 | 4.95 | 2.14 | −11.78 | 4.26 | −4.46 | 3.80 | −4.42 | 3.63 | −5.98 | 4.55 | 3.51 | 4.07 | 3.71 | −9.35 | 3.97 | 2.10 | −9.47 | −6.79 | 1.76 | −3.98 | −5.33 | 3.22 |
| $OP^{AA}$ (qUF) | −2.91 | 1.56 | −4.66 | 3.89 | −2.59 | −2.00 | −3.42 | 8.65 | 2.47 | −3.46 | 11.06 | −1.13 | 8.02 | −0.72 | 3.29 | −2.46 | 4.79 | 3.98 | 4.96 | 4.56 | −3.68 | 2.75 | 4.55 | −4.03 | −2.00 | −5.19 | −11.75 | −3.36 | 3.57 |
| $OP^{GSH}$ (C) | 20.16 | 18.46 | 15.53 | 9.40 | 9.66 | 8.57 | 21.85 | 12.26 | 8.89 | 30.63 | 11.51 | 29.38 | 12.35 | 22.17 | 8.67 | 7.51 | 9.72 | 9.52 | 9.78 | 9.64 | 24.99 | 23.83 | 14.04 | 9.77 | 15.52 | 11.46 | 20.96 | 5.74 | 9.46 |
| $OP^{GSH}$ (F) | 6.97 | 11.38 | 1.55 | 6.67 | 2.07 | 1.26 | 8.94 | 9.22 | 6.97 | 6.54 | 7.93 | 13.43 | 8.61 | 8.56 | 6.56 | 0.66 | 7.87 | 6.97 | 7.29 | 7.10 | 5.40 | 14.70 | 8.92 | −4.18 | 7.35 | 7.32 | 9.41 | 0.78 | 6.55 |
| $OP^{GSH}$ (qUF) | −0.55 | 3.24 | −2.45 | 4.51 | −0.60 | 0.03 | −0.34 | 10.83 | 3.40 | −0.62 | 10.30 | 1.76 | 13.56 | 1.28 | 3.73 | −0.95 | 5.18 | 4.71 | 5.76 | 5.37 | −0.45 | 3.96 | 10.80 | −1.81 | 0.04 | 5.24 | −3.69 | −2.25 | 4.07 |
| $OP^{TOTAL}$ | −1.92 | 10.70 | −9.96 | 7.34 | −2.12 | −1.83 | 3.13 | 13.94 | 4.27 | −3.53 | 12.73 | 13.61 | 12.96 | 4.65 | 6.35 | −2.66 | 8.01 | 7.34 | 8.00 | 7.72 | −3.26 | 13.76 | 26.20 | −10.80 | −3.59 | 12.66 | 7.78 | −1.81 | 7.12 |
| $O_3$ | −14.08 | −17.45 | −10.44 | −9.75 | −11.69 | −9.85 | −14.78 | −12.81 | −10.44 | −13.52 | −12.04 | −15.61 | −12.75 | −11.74 | −9.37 | −7.22 | −9.99 | −10.37 | −11.16 | −10.66 | −8.23 | −15.92 | −13.39 | −4.85 | −10.01 | −12.51 | −10.61 | −10.49 | −9.73 |
| $NO_2$ | 2.94 | 3.21 | 2.92 | 3.05 | 1.98 | 2.12 | 3.61 | 4.20 | 3.93 | 3.51 | 4.26 | 3.75 | 4.18 | 3.78 | 3.70 | 2.97 | 3.76 | 3.60 | 4.81 | 4.22 | 2.62 | 3.91 | 3.84 | 2.61 | 3.55 | 3.67 | 2.44 | 0.83 | 3.92 |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
For further explanation see Appendix F.

## Appendix L. Associations between air pollution exposure and percentage changes (post–pre) in blood lymphocytes 2 h after exposure in the complete dataset (including all sites).

| | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blood perml. lymph. - 2PE - all sites | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5-10}$ | PNC | Abs.[a] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol)[b] | Endotoxin | $NO_3^-$[a] | $SO_4^{2-}$[a] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F)[c] | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | 1.21 | 23.80 | −28.71 | 1.93 | 5.86 | 3.86 | −7.64 | 0.72 | 2.21 | −25.66 | 0.94 | −12.02 | 0.62 | 4.66 | 1.76 | 7.28 | 0.94 | 1.26 | 1.77 | 0.98 | **−18.05** | −4.31 | −2.18 | **−28.32** | **−19.24** | 0.59 | −17.29 | **17.69** | 3.88 |
| $PM_{2.5}$ | −15.99 | −0.16 | −10.13 | 0.17 | −0.90 | −1.47 | −9.09 | −1.55 | −0.76 | −11.81 | −0.77 | −10.78 | −1.60 | −2.30 | 0.05 | 0.65 | −0.88 | −0.15 | 0.75 | 0.00 | **−14.33** | −9.91 | −4.70 | **−15.39** | **−12.15** | −2.42 | **−14.44** | 6.50 | 2.50 |
| $PM_{2.5-10}$ | 43.26 | 14.92 | 2.03 | 2.96 | 10.91 | 8.82 | 2.04 | 1.92 | 3.72 | −17.14 | 2.02 | −2.67 | 2.19 | 11.01 | 2.82 | 12.68 | 2.14 | 2.15 | 2.25 | 1.56 | −12.94 | 0.53 | 0.50 | **−32.50** | −19.03 | 3.20 | −9.44 | **21.77** | 4.33 |
| PNC | −2.93 | −2.83 | −3.02 | −2.82 | −3.74 | −3.81 | −3.06 | −2.85 | −2.76 | −3.04 | −3.14 | −3.01 | −2.90 | −2.77 | −2.53 | −2.79 | −2.44 | −3.23 | −3.44 | −3.55 | −3.60 | −3.44 | −3.48 | −3.67 | −3.68 | −3.44 | −3.63 | −2.62 | −0.69 |
| Absorbance[a] | −4.12 | 0.89 | −7.36 | 3.42 | 0.12 | −11.44 | −6.99 | −0.62 | 0.09 | −9.91 | −0.35 | −7.39 | −0.78 | −0.57 | 0.87 | 1.65 | −0.29 | 0.16 | 0.14 | −0.47 | **−15.49** | −6.93 | −4.04 | **−20.63** | **−16.60** | −2.20 | **−13.67** | 11.97 | 4.84 |
| EC (F) | −2.34 | 1.57 | −5.57 | 3.60 | 12.73 | 0.38 | −4.77 | −0.11 | 0.35 | −8.89 | −0.02 | −6.09 | −0.31 | −0.01 | 1.14 | 2.36 | 0.37 | 0.46 | 0.24 | −0.34 | **−13.05** | −6.19 | −2.70 | **−17.80** | **−15.70** | −1.14 | −9.25 | 10.17 | 4.22 |
| EC (C) | 8.76 | 11.49 | −0.01 | 2.85 | 9.00 | 6.64 | 1.69 | 1.26 | 2.51 | −6.97 | 1.91 | −5.72 | 2.27 | 6.44 | 2.38 | 7.10 | 1.43 | 1.70 | 1.89 | 1.46 | −11.85 | −0.81 | −1.54 | **−18.81** | −11.49 | 1.65 | −19.75 | **14.39** | 3.72 |
| OC (F) | 0.38 | 1.22 | 0.09 | 0.72 | 0.80 | 0.63 | 0.37 | 0.60 | 0.90 | 0.15 | 0.76 | 0.19 | 0.74 | 0.95 | 0.72 | 1.14 | −0.44 | 0.62 | 1.37 | 0.99 | −1.00 | −0.51 | −1.33 | −1.23 | −1.38 | −0.46 | −1.46 | 1.81 | 2.57 |
| OC (C) | −0.79 | 0.62 | −1.36 | 0.03 | 0.15 | 0.05 | −0.88 | −0.28 | 0.19 | −1.37 | 0.01 | −1.21 | −0.33 | −0.10 | 0.19 | 0.49 | −0.36 | 0.23 | 1.12 | 0.15 | −2.28 | 0.11 | −0.11 | −3.72 | −1.92 | 0.42 | −2.11 | 1.74 | 1.07 |
| Fe (tot) | 38.34 | 18.27 | 23.82 | 3.74 | 15.41 | 14.41 | 11.35 | 2.43 | 4.19 | 2.63 | 2.87 | 8.01 | 3.29 | 17.81 | 3.50 | 18.53 | 2.68 | 2.69 | 2.74 | 2.12 | −14.51 | 3.45 | 1.10 | **−29.83** | −16.91 | 3.49 | −8.33 | 22.59 | 4.94 |
| Fe (sol) | 0.15 | 0.42 | 0.00 | 0.81 | 0.35 | 0.29 | −0.11 | 0.05 | 0.29 | −0.13 | 0.29 | −0.22 | −0.03 | 0.27 | 0.59 | 0.40 | 0.11 | 0.26 | 0.33 | 0.28 | −1.13 | −0.20 | −1.56 | −0.94 | −0.45 | −0.39 | −1.40 | 0.83 | 0.69 |
| Cu (tot) | 14.35 | 14.57 | 4.55 | 3.07 | 10.16 | 8.86 | 8.43 | 1.90 | 3.34 | −4.55 | 2.58 | 2.13 | 3.08 | 11.23 | 2.92 | 10.02 | 1.96 | 2.16 | 2.32 | 1.79 | −13.10 | 1.41 | −0.05 | **−18.26** | −10.87 | 2.74 | −16.19 | **14.27** | 4.04 |
| Cu (sol) | 0.19 | 0.61 | −0.05 | 0.50 | 0.44 | 0.35 | −0.19 | 0.04 | 0.37 | −0.21 | 0.32 | −0.30 | 0.30 | 0.36 | 0.47 | 0.49 | 0.18 | 0.28 | 0.43 | 0.38 | −0.80 | −0.05 | −0.97 | −1.11 | −0.63 | −0.19 | −1.49 | 1.04 | 0.62 |
| Ni (tot) | −3.27 | 2.81 | −7.88 | 0.72 | 1.06 | 0.55 | −5.16 | −0.47 | 0.64 | −12.32 | 0.14 | −8.84 | −0.38 | 0.55 | 0.96 | 3.02 | 0.17 | 0.44 | 0.56 | −0.27 | −9.50 | −1.94 | −1.17 | −15.61 | −11.43 | 0.78 | −6.40 | 6.32 | 1.93 |
| Ni (sol) | −1.62 | −1.50 | −1.74 | −0.59 | −1.60 | −1.66 | −1.74 | −1.46 | −1.49 | −1.81 | −1.76 | −1.80 | −1.68 | −1.56 | −1.49 | −1.74 | 2.64 | −1.65 | −1.94 | −1.95 | −0.59 | −1.37 | −1.66 | −0.71 | −1.69 | −1.62 | −0.62 | −1.24 | −0.76 |
| V (tot) | −4.46 | −0.79 | −7.24 | 0.26 | −1.44 | −1.98 | −4.71 | −1.06 | −0.66 | −10.04 | −0.73 | −6.26 | −1.09 | −2.18 | 0.81 | −0.37 | 2.09 | −0.57 | −0.37 | −0.54 | −4.59 | −4.08 | −2.84 | −7.96 | **−9.60** | −1.80 | −1.85 | 4.91 | 1.51 |
| V (sol)[b] | **−4.06** | **−4.12** | **−4.08** | **−3.94** | **−4.09** | **−4.07** | **−4.05** | **−4.17** | **−4.10** | **−4.08** | **−4.07** | **−4.06** | **−4.06** | **−4.07** | **−5.58** | **−4.49** | **−4.08** | **−4.23** | **−4.27** | **−3.90** | −2.00 | **−3.81** | **−3.83** | −2.14 | **−3.73** | **−3.88** | −2.06 | **−4.00** | **−3.55** |
| Endotoxin | 0.01 | 0.00 | 0.01 | −0.05 | 0.00 | 0.01 | 0.00 | 0.01 | −0.01 | 0.01 | −0.01 | 0.00 | −0.01 | −0.01 | −0.03 | −0.02 | −0.05 | 0.00 | 0.01 | 0.00 | 0.03 | 0.02 | 0.03 | 0.03 | 0.03 | 0.02 | 0.02 | −0.02 | −0.06 |
| $NO_3^-$[a] | −0.58 | −0.58 | −0.55 | −0.93 | −0.52 | −0.51 | −0.52 | −0.75 | −0.65 | −0.51 | −0.50 | −0.53 | −0.56 | −0.49 | −0.71 | −0.49 | −0.75 | −0.53 | −0.52 | 0.14 | −1.24 | −0.82 | −0.87 | −1.24 | −0.78 | −0.84 | −1.32 | −0.42 | 0.06 |
| $SO_4^{2-}$[a] | −1.36 | −1.37 | −1.33 | −1.85 | −1.39 | −1.39 | −1.35 | −1.45 | −1.38 | −1.32 | −1.38 | −1.34 | −1.41 | −1.39 | −1.59 | −1.39 | −1.10 | −1.37 | −1.49 | −1.37 | −1.63 | −1.60 | −1.67 | −1.59 | −1.52 | −1.68 | −1.73 | −1.31 | −1.03 |
| $OP^{AA}$ (C) | **26.45** | **23.44** | 19.11 | 5.01 | **24.66** | **21.88** | 19.63 | 5.39 | 6.85 | 21.38 | 6.92 | 21.06 | 6.62 | 15.37 | 4.57 | 10.96 | 4.19 | 4.62 | 4.54 | 3.68 | 4.31 | 19.57 | 7.06 | −8.39 | −0.32 | 6.65 | 10.42 | **20.89** | 5.54 |
| $OP^{AA}$ (F) | 3.99 | 8.78 | 1.16 | 1.99 | 6.14 | 5.85 | 1.95 | 1.81 | 1.36 | −0.49 | 1.65 | 0.53 | 1.50 | 2.59 | 1.52 | 4.53 | 0.80 | 1.59 | 1.67 | 1.14 | −8.45 | 1.46 | 0.68 | −7.37 | −4.48 | 1.58 | −3.69 | **8.08** | 2.60 |
| $OP^{AA}$ (qUF) | 2.97 | 4.89 | 1.42 | 2.38 | 4.28 | 3.38 | 2.96 | 3.10 | 1.96 | 1.29 | 5.19 | 1.92 | 4.44 | 2.56 | 2.44 | 3.91 | 1.63 | 1.91 | 2.14 | 1.84 | −2.07 | 1.12 | 1.70 | −2.29 | −1.95 | 11.90 | −3.74 | 6.96 | 3.29 |
| $OP^{GSH}$ (C) | **37.29** | **21.32** | **44.52** | 5.07 | **28.58** | **25.70** | **26.43** | 5.49 | 8.27 | **39.43** | 5.82 | **24.77** | 7.15 | **20.69** | 4.63 | 14.43 | 4.40 | 4.71 | 4.56 | 3.83 | 11.99 | **14.76** | 6.76 | 4.42 | 5.83 | 7.00 | 12.91 | **19.79** | 5.21 |
| $OP^{GSH}$ (F)[c] | **18.41** | **13.16** | **18.29** | 4.27 | **17.90** | **17.64** | 12.73 | 4.51 | 4.91 | 16.20 | 3.93 | 11.86 | 4.63 | 11.92 | 3.87 | **12.55** | 3.01 | 3.66 | 3.49 | 3.07 | 3.39 | 8.05 | 4.99 | −1.11 | 3.47 | 5.93 | 7.21 | **15.18** | 4.80 |
| $OP^{GSH}$ (qUF) | 0.57 | 2.42 | −0.83 | 1.65 | 2.22 | 1.55 | 0.02 | 1.38 | 0.83 | −0.68 | 1.84 | −0.55 | 1.62 | 0.68 | 1.76 | 2.34 | 1.13 | 1.05 | 1.36 | 1.15 | −2.01 | −0.23 | −9.50 | −2.72 | −3.26 | 0.89 | −4.55 | 5.39 | 2.75 |
| $OP^{TOTAL}$ | 21.56 | **20.16** | 12.15 | 3.76 | **18.34** | 13.12 | **28.86** | 4.82 | 5.27 | 11.10 | 6.43 | 22.38 | 8.09 | 9.37 | 3.37 | 5.30 | 3.02 | 3.18 | 3.69 | 2.88 | −5.24 | 8.21 | 8.05 | −8.62 | −5.50 | 8.86 | 2.95 | **16.73** | 4.56 |
| $O_3$ | **16.46** | 8.56 | **19.28** | 1.23 | 14.14 | 12.46 | **14.92** | 4.41 | 4.09 | **19.21** | 3.81 | **13.96** | 4.97 | 7.31 | 2.08 | 8.14 | 1.85 | 2.98 | 2.39 | 2.42 | **16.96** | **12.28** | 9.58 | **19.14** | **19.03** | 8.13 | **15.94** | 2.73 | −2.85 |
| $NO_2$ | **−4.97** | **−4.94** | **−4.94** | −4.24 | **−5.66** | **−5.44** | **−4.97** | **−5.36** | **−4.70** | **−5.01** | **−4.73** | **−4.95** | **−4.75** | **−4.72** | **−4.46** | **−4.84** | −4.02 | **−4.89** | **−4.59** | **−4.34** | **−4.83** | **−5.39** | **−5.52** | **−4.80** | **−5.58** | **−5.51** | **−4.94** | **−5.35** | **−4.55** |

[a]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
[b]One-pollutant estimate decreased by more than 50 % and became non-significant after excluding 1% of influential observations.
[c]One-pollutant estimate increased by more than 50 % and became significant after excluding 1% of influential observations.
For further explanation see Appendix F.

## Appendix M. Associations between air pollution exposure and percentage changes (post–pre) in blood lymphocytes 18 hours after exposure in the complete dataset (including all sites).

| Blood perml. lymph. - 18PE - all sites | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $PM_{10}$[a] | $PM_{2.5}$ | $PM_{2.5-10}$[a] | PNC | Abs.[b] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot)[a] | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endotoxin[c] | $NO_3^-$[b] | $SO_4^{2-}$[b] | $OP^{AA}$ (C)[a] | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$[a] | 2.69 | 30.64 | −32.75 | 3.94 | 23.72 | 17.29 | 20.75 | 7.61 | −5.86 | 12.02 | 4.29 | 8.34 | 3.28 | 3.27 | 2.41 | 9.50 | 2.50 | 4.32 | 2.70 | 2.57 | 0.50 | 18.65 | 4.76 | −12.38 | −9.66 | 3.40 | 3.85 | 27.94 | 5.67 |
| $PM_{2.5}$ | −18.91 | 0.82 | −11.77 | 1.46 | 6.89 | 4.21 | −0.87 | 5.05 | −7.80 | −5.54 | 1.62 | −5.05 | 0.09 | −3.79 | 0.67 | 1.23 | 0.68 | 1.69 | 0.80 | 0.85 | −5.59 | 8.23 | 0.03 | −9.44 | −8.10 | −0.42 | −5.88 | 11.48 | 3.77 |
| $PM_{2.5-10}$[a] | 54.12 | 19.02 | 3.66 | 5.20 | 31.07 | 25.09 | 33.32 | 8.05 | −3.50 | 64.77 | 5.52 | 20.75 | 5.04 | 10.89 | 3.37 | 15.82 | 3.46 | 5.67 | 3.65 | 3.47 | 8.36 | 18.90 | 7.41 | −7.68 | −6.33 | 5.94 | 15.53 | 32.88 | 6.22 |
| PNC | −4.01 | −3.82 | −4.15 | −3.74 | −4.57 | −4.76 | −3.95 | −3.65 | −3.53 | −3.98 | −3.82 | −3.95 | −3.81 | −3.72 | −4.39 | −3.80 | −3.63 | −2.90 | −4.03 | −4.18 | −2.86 | −3.70 | −3.87 | −3.00 | −4.21 | −3.93 | −2.89 | −3.55 | −1.61 |
| Absorbance[b] | −15.71 | −6.53 | −19.15 | 2.88 | −1.14 | −25.42 | −10.94 | 0.53 | −6.10 | −15.71 | −0.92 | −12.77 | −2.71 | −7.73 | −1.32 | −3.93 | −1.13 | 1.17 | −1.14 | −1.44 | −9.54 | −1.23 | −3.89 | −17.29 | −18.83 | −3.84 | −8.67 | 7.44 | 3.38 |
| EC (F) | −11.24 | −3.71 | −15.23 | 3.50 | 31.66 | −0.52 | −6.54 | 0.92 | −4.81 | −12.65 | −0.19 | −9.55 | −1.54 | −6.04 | −0.77 | −2.57 | −0.55 | 1.80 | −0.50 | −0.85 | −7.69 | 1.06 | −2.20 | −15.00 | −17.20 | −2.17 | −5.42 | 7.92 | 3.29 |
| EC (C) | −13.96 | 1.84 | −20.62 | 2.61 | 13.05 | 7.97 | 0.99 | 4.42 | −4.70 | −11.95 | 2.82 | −13.80 | 0.41 | −4.21 | 0.84 | 2.30 | 0.97 | 3.20 | 0.96 | 0.86 | −5.82 | 10.12 | 0.26 | −16.20 | −13.01 | −0.70 | −11.16 | 13.63 | 2.94 |
| OC (F) | −3.84 | −3.60 | −3.73 | −1.52 | −1.90 | −1.98 | −3.07 | −1.74 | −3.49 | −3.10 | −1.92 | −3.36 | −4.06 | −3.11 | −1.62 | −2.08 | −1.85 | −1.24 | −2.15 | −1.64 | −2.43 | −1.94 | −4.32 | −2.85 | −3.60 | −4.99 | −3.75 | −1.14 | −0.02 |
| OC (C) | 7.28 | 9.03 | 6.03 | 4.28 | 7.13 | 6.51 | 6.60 | 6.17 | 4.41 | 6.22 | 5.05 | 6.27 | 5.81 | 6.58 | 4.41 | 5.88 | 4.41 | 4.10 | 5.28 | 4.40 | 3.35 | 6.52 | 5.55 | 2.16 | 4.17 | 5.42 | 3.81 | 8.23 | 5.40 |
| Fe (tot) | −8.86 | 8.89 | −38.03 | 3.81 | 24.11 | 19.86 | 17.89 | 5.87 | −4.36 | 2.16 | 3.89 | 4.26 | 2.46 | 0.05 | 2.02 | 10.29 | 2.15 | 4.72 | 2.15 | 1.94 | −1.03 | 23.11 | 3.40 | −22.56 | −16.65 | 2.06 | 2.89 | 23.45 | 4.45 |
| Fe (sol) | −0.93 | −0.58 | −1.08 | 0.37 | −0.11 | −0.25 | −0.89 | 0.31 | −0.98 | −0.87 | −0.29 | −1.11 | −1.65 | −0.77 | −0.40 | −0.39 | −0.30 | 0.35 | −0.29 | −0.30 | −1.16 | −0.13 | −1.86 | −1.15 | −0.96 | −1.58 | −1.58 | 0.23 | 0.07 |
| Cu (tot)[a] | −5.14 | 7.26 | −13.61 | 3.24 | 16.75 | 12.94 | 18.39 | 5.70 | −4.04 | −1.84 | 4.18 | 1.83 | 2.39 | −0.43 | 1.71 | 5.84 | 1.82 | 4.10 | 1.81 | 1.68 | −3.41 | 19.79 | 3.34 | −13.63 | −10.47 | 1.74 | −3.67 | 15.26 | 3.76 |
| Cu (sol) | −0.25 | 0.26 | −0.51 | 0.55 | 0.76 | 0.53 | 0.19 | 1.69 | −0.93 | −0.10 | 1.39 | −0.18 | 0.28 | −0.10 | 0.24 | 0.31 | 0.27 | 0.72 | 0.26 | 0.31 | −0.22 | 0.59 | 0.12 | −0.68 | −0.51 | −0.30 | −0.67 | 1.12 | 0.60 |
| Ni (tot) | −0.73 | 5.95 | −6.59 | 2.52 | 9.95 | 8.35 | 6.34 | 5.37 | −4.50 | 2.02 | 3.30 | 2.48 | 2.32 | 2.07 | 1.97 | 5.82 | 2.05 | 3.77 | 2.08 | 1.79 | −2.12 | 12.35 | 2.12 | −12.30 | −9.17 | 1.30 | −0.43 | 11.84 | 3.52 |
| Ni (sol) | 0.33 | 0.47 | 0.20 | 2.06 | 0.64 | 0.59 | 0.40 | 0.39 | 0.47 | 0.31 | 0.67 | 0.32 | 0.39 | 0.36 | 0.49 | 0.50 | 1.17 | 1.24 | 0.61 | 0.36 | 0.90 | 0.45 | 0.35 | 0.72 | 0.18 | 0.27 | 0.84 | 0.95 | 1.29 |
| V (tot) | −5.04 | −0.51 | −8.24 | 1.28 | 3.03 | 2.17 | −1.19 | 1.50 | −2.99 | −5.50 | 0.66 | −3.31 | −0.15 | −3.15 | −0.03 | 0.29 | 0.46 | 1.93 | 0.30 | 0.20 | −0.76 | 2.35 | −0.51 | −6.52 | −7.03 | −0.79 | 0.53 | 9.15 | 2.25 |
| V (sol) | −0.21 | −0.21 | −0.25 | −0.06 | −0.28 | −0.24 | −0.22 | −0.68 | −0.08 | −0.24 | −0.27 | −0.22 | −0.22 | −0.21 | −0.93 | −0.33 | −0.24 | 0.17 | −0.21 | −0.14 | 2.27 | −0.43 | −0.33 | 2.11 | −0.18 | −0.35 | 2.17 | −0.09 | 0.44 |
| Endotoxin[c] | 0.17 | 0.16 | 0.18 | 0.11 | 0.17 | 0.17 | 0.18 | 0.15 | 0.14 | 0.19 | 0.17 | 0.19 | 0.18 | 0.18 | 0.17 | 0.18 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.16 | 0.17 | 0.17 | 0.18 | 0.17 | 0.16 | 0.14 | 0.10 |
| $NO_3^-$[b] | −0.01 | 0.01 | 0.04 | −0.42 | 0.07 | 0.07 | 0.11 | 0.43 | −0.63 | 0.11 | 0.13 | 0.10 | 0.08 | 0.13 | 0.19 | 0.12 | 0.11 | −0.12 | 0.08 | 0.51 | −0.51 | 0.19 | 0.16 | −0.51 | 0.21 | 0.14 | −0.60 | 0.19 | 0.74 |
| $SO_4^{2-}$[b] | −0.51 | −0.57 | −0.45 | −1.13 | −0.64 | −0.62 | −0.52 | −0.44 | −0.52 | −0.48 | −0.55 | −0.49 | −0.57 | −0.44 | −0.51 | −0.54 | −0.53 | −0.58 | −1.00 | −0.56 | −0.96 | −0.52 | −0.48 | −0.89 | −0.30 | −0.49 | −1.07 | −0.52 | −0.20 |
| $OP^{AA}$ (C)[a] | 3.90 | 10.86 | −3.14 | 4.94 | 15.80 | 13.92 | 10.89 | 6.69 | 0.70 | 5.14 | 6.68 | 7.88 | 4.70 | 6.33 | 3.87 | 5.14 | 4.42 | 6.19 | 4.40 | 3.93 | 4.38 | 30.04 | 7.07 | −16.65 | −5.51 | 3.82 | 6.09 | 13.89 | 5.00 |
| $OP^{AA}$ (F) | −9.61 | −5.66 | −9.36 | 0.05 | 0.17 | −1.31 | −6.61 | 0.65 | −3.98 | −11.60 | −0.58 | −11.28 | −1.58 | −7.20 | −0.74 | −2.36 | −0.80 | 0.25 | −0.63 | −0.74 | −13.61 | −0.61 | −2.62 | −12.72 | −11.27 | −1.97 | −8.99 | 2.71 | 0.34 |
| $OP^{AA}$ (qUF) | −1.78 | 0.83 | −3.11 | 1.69 | 3.35 | 2.23 | 0.57 | 5.40 | −2.51 | −1.10 | 4.67 | −1.37 | 0.46 | −0.44 | 0.65 | 1.10 | 0.71 | 2.07 | 0.79 | 0.85 | −2.11 | 3.11 | 0.85 | −3.30 | −3.28 | −2.97 | −6.72 | 5.31 | 2.19 |
| $OP^{GSH}$ (C) | 16.95 | 14.66 | 12.22 | 5.77 | 24.49 | 22.46 | 22.97 | 7.41 | 2.86 | 28.77 | 6.74 | 19.13 | 6.60 | 17.16 | 4.80 | 12.86 | 5.06 | 6.83 | 5.20 | 4.83 | 21.75 | 23.88 | 8.52 | 5.19 | 2.54 | 6.08 | 15.04 | 16.44 | 5.63 |
| $OP^{GSH}$ (F) | 9.81 | 9.18 | 7.41 | 4.18 | 19.83 | 18.87 | 13.40 | 5.61 | 0.18 | 15.27 | 3.99 | 10.90 | 3.88 | 9.50 | 3.00 | 9.33 | 3.01 | 4.15 | 3.15 | 3.03 | 7.67 | 15.36 | 5.62 | 2.15 | 3.13 | 4.61 | 10.33 | 13.89 | 4.31 |
| $OP^{GSH}$ (qUF) | −0.70 | 1.39 | −2.01 | 2.08 | 3.49 | 2.39 | 1.52 | 6.63 | −2.21 | −0.01 | 4.14 | 0.01 | 1.85 | 0.36 | 0.95 | 1.58 | 1.05 | 2.32 | 1.07 | 1.18 | 0.53 | 2.54 | 4.11 | −0.99 | −2.10 | 1.14 | 0.07 | 5.87 | 2.83 |
| $OP^{TOTAL}$ | 0.16 | 9.90 | −8.64 | 4.15 | 12.83 | 9.31 | 16.46 | 8.20 | −0.41 | 0.85 | 7.11 | 7.15 | 5.49 | 3.74 | 3.03 | 2.74 | 3.51 | 5.16 | 3.82 | 3.41 | −1.57 | 17.24 | 12.98 | −10.02 | −8.40 | 3.45 | 3.53 | 12.57 | 4.60 |
| $O_3$ | 24.82 | 13.49 | 28.17 | 1.07 | 10.49 | 10.98 | 14.95 | 2.23 | 9.92 | 20.67 | 3.59 | 15.48 | 5.71 | 11.97 | 3.68 | 13.59 | 3.24 | 1.45 | 3.39 | 3.18 | 10.25 | 6.26 | 8.10 | 14.46 | 17.97 | 8.59 | 10.53 | 3.25 | −2.60 |
| $NO_2$ | −5.45 | −5.43 | −5.41 | −4.13 | −5.64 | −5.56 | −5.11 | −4.86 | −5.35 | −5.19 | −4.84 | −5.16 | −4.97 | −5.06 | −5.01 | −5.19 | −4.89 | −4.30 | −5.32 | −4.82 | −3.85 | −4.92 | −5.13 | −3.87 | −5.31 | −5.27 | −4.00 | −5.59 | −4.86 |

[a]One-pollutant estimate increased by more than 50 % and became significant after excluding 1% of influential observations.
[b]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
[c]One-pollutant estimate decreased by more than 50 % and became non-significant after excluding 1% of influential observations.
For further explanation see Appendix F.

Appendix N. Associations between air pollution exposure and percentage changes (post–pre) in blood eosinophils 2 h after exposure in the complete dataset (including all sites).

| Blood perml. eo. - 2PE - all sites | Adjustment pollutants | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $PM_{10}$ | $PM_{2.5}$ | $PM_{2.5-10}$ | PNC[a] | Abs.[b] | EC (F) | EC (C) | OC (F) | OC (C) | Fe (tot) | Fe (sol) | Cu (tot) | Cu (sol) | Ni (tot) | Ni (sol) | V (tot) | V (sol) | Endotoxin | $NO_3^-$[b] | $SO_4^{2-}$[b] | $OP^{AA}$ (C) | $OP^{AA}$ (F) | $OP^{AA}$ (qUF) | $OP^{GSH}$ (C) | $OP^{GSH}$ (F) | $OP^{GSH}$ (qUF) | $OP^{TOTAL}$ | $O_3$ | $NO_2$ |
| $PM_{10}$ | −6.34 | 19.11 | −38.28 | 0.76 | 152.02 | 108.49 | −3.66 | 0.56 | −19.77 | −48.05 | −4.87 | −43.50 | −13.11 | −36.90 | −6.07 | −0.10 | −7.60 | −2.99 | −6.69 | −6.56 | −19.90 | −11.30 | −11.40 | −42.70 | −38.55 | −10.13 | −30.89 | 48.07 | 2.43 |
| $PM_{2.5}$ | −18.74 | −6.46 | −14.13 | −3.04 | 54.90 | 38.66 | −6.19 | −0.35 | −18.04 | −16.82 | −4.83 | −22.50 | −11.15 | −22.12 | −6.11 | −2.89 | −7.41 | −4.56 | −7.75 | −6.44 | −16.15 | −16.20 | −11.70 | −22.84 | −23.43 | −10.17 | −21.62 | 20.95 | 2.90 |
| $PM_{2.5-10}$ | 53.46 | 12.06 | −5.42 | 3.51 | 178.65 | 140.97 | 4.29 | 1.01 | −17.64 | −54.07 | −4.09 | −37.29 | −12.07 | −36.11 | −5.21 | 3.54 | −6.74 | −1.40 | −5.40 | −5.80 | −13.57 | −4.84 | −8.34 | −50.61 | −40.74 | −7.62 | −24.30 | 55.07 | 1.79 |
| PNC[a] | −23.61 | −23.46 | −23.78 | −23.57 | −23.87 | −24.32 | −22.15 | −23.50 | −21.83 | −22.17 | −22.68 | −22.22 | −22.16 | −21.88 | −23.49 | −21.89 | −21.72 | −24.05 | −25.41 | −24.93 | −28.12 | −24.81 | −24.88 | −28.35 | −25.36 | −24.94 | −28.23 | −23.50 | −19.48 |
| Absorbance[b] | −60.07 | −44.82 | −62.71 | 1.34 | −20.32 | −58.53 | −58.14 | −20.73 | −26.43 | −63.79 | −22.60 | −59.86 | −28.11 | −43.67 | −18.44 | −34.21 | −19.50 | −17.90 | −20.25 | −21.13 | −62.76 | −52.51 | −36.71 | −71.95 | −66.61 | −33.77 | −63.83 | −34.05 | −8.73 |
| EC (F) | −51.50 | −36.81 | −56.22 | 3.26 | 88.81 | −18.34 | −48.64 | −17.70 | −24.00 | −61.14 | −19.98 | −55.25 | −23.94 | −41.31 | −17.22 | −34.13 | −17.76 | −15.74 | −18.36 | −19.36 | −56.59 | −50.94 | −30.46 | −66.49 | −64.39 | −27.47 | −51.79 | −24.91 | −8.12 |
| EC (C) | −3.24 | −0.34 | −9.33 | 3.10 | 113.24 | 77.66 | −6.22 | −2.24 | −13.19 | −31.45 | −4.01 | −51.46 | −15.86 | −26.39 | −4.97 | −0.79 | −6.54 | −5.01 | −6.14 | −6.20 | −12.32 | −8.21 | −10.56 | −34.35 | −31.40 | −9.55 | −32.02 | 21.23 | −1.90 |
| OC (F) | −5.88 | −5.61 | −5.96 | −5.53 | 0.62 | −1.14 | −3.96 | −5.75 | −6.24 | −4.73 | −4.03 | −5.50 | −8.73 | −6.07 | −4.91 | −3.69 | −6.41 | −4.73 | −7.11 | −5.67 | −7.68 | −6.56 | −10.38 | −8.47 | −8.07 | −10.58 | −10.25 | −2.42 | −0.15 |
| OC (C) | 14.35 | 15.38 | 12.58 | 0.86 | 16.16 | 14.69 | 10.46 | 7.00 | 4.02 | 9.11 | 6.08 | 8.31 | 5.68 | 7.10 | 4.04 | 7.87 | 3.42 | 3.60 | 2.66 | 4.15 | 9.70 | 9.65 | 8.56 | 8.11 | 6.88 | 8.49 | 9.44 | 11.45 | 4.25 |
| Fe (tot) | 83.18 | 17.14 | 105.58 | 4.56 | 196.44 | 186.00 | 46.85 | 0.42 | −12.22 | −4.74 | −1.07 | −37.00 | −8.35 | −28.76 | −3.08 | 17.42 | −4.82 | −3.02 | −4.30 | −4.71 | 1.92 | 7.03 | −3.41 | −44.68 | −38.11 | −3.50 | −11.81 | 43.60 | 0.02 |
| Fe (sol) | −1.19 | −1.06 | −1.33 | 2.17 | 2.81 | 1.96 | −1.06 | −0.67 | −2.66 | −1.76 | −1.92 | −2.39 | −6.01 | −2.48 | −1.41 | −1.19 | −2.10 | −1.54 | −1.92 | −1.92 | −1.50 | −1.51 | −3.61 | −2.38 | −2.58 | −2.95 | −2.15 | 0.22 | −0.84 |
| Cu (tot) | 3.13 | 59.83 | 25.24 | 44.82 | 5.07 | 103.79 | 17.54 | −9.18 | 118.28 | 14.62 | 136.38 | −2.87 | 32.31 | −3.14 | −6.52 | −15.29 | −1.29 | 2.45 | −1.19 | 4.96 | −2.73 | 11.91 | 16.95 | 20.05 | −16.52 | −19.82 | −8.40 | 12.15 | −2.80 |
| Cu (sol) | 2.21 | 2.13 | 1.97 | 1.41 | 5.57 | 4.25 | 3.67 | 3.08 | −1.03 | 1.31 | 4.40 | 1.28 | −0.01 | 0.07 | 0.41 | 1.20 | −0.16 | 0.36 | −0.23 | −0.01 | 1.10 | 1.19 | 3.20 | 0.13 | −0.22 | 4.08 | 1.98 | 2.91 | 0.47 |
| Ni (tot) | 47.49 | 26.67 | 45.37 | 0.92 | 65.96 | 63.23 | 33.89 | 5.97 | −6.36 | 32.86 | 4.04 | 16.54 | −0.47 | −0.35 | 0.80 | 19.36 | −0.77 | 1.11 | 0.34 | −0.13 | 29.15 | 31.35 | 9.15 | 6.12 | −0.90 | 7.23 | 19.68 | 26.85 | 1.68 |
| Ni (sol) | −4.07 | −3.33 | −3.55 | −3.28 | 5.56 | −3.21 | −4.69 | −3.72 | −1.17 | −3.60 | −3.89 | −2.54 | −1.36 | −3.46 | −3.74 | −2.23 | −2.05 | −3.12 | −3.28 | −3.44 | −3.11 | −3.39 | −3.40 | −3.37 | −3.76 | −3.66 | −3.62 | −0.84 | −3.77 |
| V (tot) | −5.59 | −3.85 | −7.57 | 0.29 | 24.17 | 26.42 | −5.15 | −3.88 | −8.89 | −14.35 | −4.54 | −13.55 | −7.26 | −15.11 | −3.93 | −5.72 | −4.33 | −4.81 | −5.22 | −5.70 | −13.64 | −6.64 | −6.56 | −26.51 | −18.25 | −6.41 | −14.65 | 12.98 | −1.10 |
| V (sol) | −5.20 | −3.65 | −3.93 | −3.50 | −1.97 | −3.63 | −6.49 | −3.21 | −3.66 | −3.53 | −3.49 | −2.99 | −4.34 | −3.50 | −3.70 | −3.49 | −3.48 | −2.15 | −3.15 | −8.43 | −3.08 | −8.54 | −3.56 | −8.65 | −8.29 | −3.17 | −8.30 | −2.59 | −3.54 |
| Endotoxin | 0.38 | 0.38 | 0.39 | −0.07 | 0.20 | 0.22 | 0.10 | 0.37 | 0.13 | 0.12 | 0.11 | 0.14 | 0.15 | 0.15 | 0.11 | 0.09 | 0.12 | 0.39 | 0.39 | 0.39 | 0.42 | 0.42 | 0.43 | 0.44 | 0.44 | 0.43 | 0.43 | 0.30 | 0.12 |
| $NO_3^-$[b] | 0.65 | 1.08 | 0.49 | −3.30 | 0.17 | −0.15 | 1.36 | 1.61 | 1.06 | 1.33 | 1.37 | 1.37 | 1.41 | 1.39 | 0.97 | 1.19 | 1.12 | −0.05 | 0.47 | 1.14 | −0.04 | 0.22 | 0.23 | −0.03 | 0.20 | 0.24 | 0.03 | 0.88 | 2.86 |
| $SO_4^{2-}$[b] | −0.85 | −0.70 | −0.90 | −4.53 | −2.07 | −2.21 | −0.05 | −0.37 | 0.35 | −0.04 | 0.15 | 0.06 | 0.19 | 0.18 | −0.16 | −0.11 | 0.45 | −0.70 | −1.60 | −0.69 | −1.49 | −1.24 | −1.06 | −1.35 | −1.01 | −1.04 | −1.33 | −0.58 | 0.47 |
| $OP^{AA}$ (C) | 17.86 | 15.21 | 9.48 | 1.74 | 167.96 | 139.26 | 7.42 | 2.81 | −14.36 | −8.31 | −3.48 | −16.93 | −9.22 | −27.15 | −5.54 | 12.46 | −7.39 | −0.07 | −4.54 | −5.19 | −4.60 | 1.40 | −5.23 | −36.12 | −23.13 | −3.88 | −11.96 | 45.02 | −0.81 |
| $OP^{AA}$ (F) | 3.80 | 9.17 | −0.26 | 2.10 | 54.68 | 55.49 | 1.62 | 1.46 | −7.65 | −7.20 | −1.98 | −12.51 | −5.35 | −17.30 | −3.50 | 1.06 | −4.30 | −0.49 | −2.84 | −3.15 | −3.89 | −2.84 | −3.55 | −10.94 | −13.18 | −2.85 | −6.08 | 17.66 | 1.02 |
| $OP^{AA}$ (qUF) | 4.87 | 6.07 | 2.87 | 3.37 | 28.31 | 21.04 | 4.39 | 9.62 | −6.85 | −1.20 | 4.91 | −3.84 | −10.28 | −7.31 | −1.99 | 1.31 | −3.38 | 1.08 | −1.87 | −1.82 | 0.57 | 1.12 | −1.83 | −4.21 | −5.30 | 0.42 | −1.91 | 14.50 | 2.75 |
| $OP^{GSH}$ (C) | 56.06 | 24.93 | 76.75 | 5.76 | 210.22 | 179.37 | 44.80 | 6.02 | −8.21 | 58.95 | 2.08 | 15.37 | −1.90 | −6.35 | −0.29 | 37.67 | −1.57 | 3.53 | −0.65 | −1.23 | 42.47 | 14.56 | 3.43 | −0.71 | −11.59 | 2.93 | 12.79 | 48.56 | 1.40 |
| $OP^{GSH}$ (F) | 36.92 | 21.30 | 40.19 | 8.07 | 121.98 | 119.86 | 31.67 | 6.75 | −3.04 | 36.01 | 3.75 | 17.26 | 1.31 | 1.55 | 1.76 | 18.97 | 0.40 | 3.64 | 1.08 | 0.65 | 17.50 | 15.79 | 5.10 | 10.17 | 1.00 | 4.60 | 14.42 | 34.15 | 4.82 |
| $OP^{GSH}$ (qUF) | 3.76 | 4.44 | 2.24 | 3.84 | 23.39 | 16.38 | 3.47 | 10.01 | −6.86 | −1.21 | 3.12 | −3.09 | −12.53 | −6.21 | −1.67 | 1.10 | −3.12 | 0.84 | −2.00 | −1.87 | −0.68 | 0.03 | −2.32 | −4.07 | −4.96 | −1.96 | −2.67 | 14.05 | 3.49 |
| $OP^{TOTAL}$ | 33.62 | 23.18 | 23.09 | 3.60 | 150.11 | 94.75 | 40.64 | 10.21 | −12.00 | 6.02 | 0.40 | −9.08 | −10.31 | −18.48 | −3.26 | 13.61 | −5.14 | 1.16 | −2.96 | −3.14 | 8.04 | 5.41 | −0.58 | −13.75 | −17.69 | 0.19 | −3.02 | 47.19 | 2.57 |
| $O_3$ | 59.92 | 39.42 | 64.96 | 0.51 | −20.44 | −10.31 | 37.55 | 15.75 | 24.87 | 52.73 | 16.60 | 45.69 | 23.61 | 37.71 | 14.97 | 32.89 | 15.61 | 13.47 | 18.51 | 17.92 | 58.46 | 42.97 | 34.30 | 69.87 | 60.67 | 33.65 | 66.04 | 18.05 | −4.32 |
| $NO_2$ | −19.03 | −19.18 | −18.95 | −9.88 | −17.05 | −17.31 | −16.49 | −18.82 | −16.73 | −16.62 | −16.48 | −16.68 | −16.68 | −16.66 | −16.44 | −16.49 | −16.43 | −18.17 | −20.26 | −18.90 | −21.98 | −20.08 | −20.25 | −22.04 | −20.33 | −20.36 | −22.15 | −19.82 | −18.87 |

[a]One-pollutant estimate increased by more than 50 % and became significant after excluding 1% of influential observations.
[b]Measured in $PM_{2.5}$ (NB. all pollutants were measured in $PM_{10}$ unless otherwise indicated).
For further explanation see Appendix F.