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1 Socioeconomic position and outdoor nitrogen dioxide (NO₂) exposure in Western Europe: a
2 multi-city analysis

3

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76

77

78 ABSTRACT

79 Background: Inconsistent associations between socioeconomic position (SEP) and outdoor air
80 pollution have been reported in Europe, but methodological differences prevent any direct
81 between-study comparison.

82 Objectives: Assess and compare the association between SEP and outdoor nitrogen dioxide
83 (NO₂) exposure as a marker of traffic exhaust, in 16 cities from eight Western European
84 countries.

85 Methods: Three SEP indicators, two defined at individual-level (education and occupation)
86 and one at neighborhood-level (unemployment rate) were assessed in three European
87 multicenter cohorts. NO₂ annual concentration exposure was estimated at participants'
88 addresses with land use regression models developed within the European Study of Cohorts
89 for Air Pollution Effects (ESCAPE; <http://www.escapeproject.eu/>). Pooled and city-specific
90 linear regressions were used to analyze associations between each SEP indicator and NO₂.
91 Heterogeneity across cities was assessed using the Higgins' I-squared test (I²).

92 Results: The study population included 5692 participants. Pooled analysis showed that
93 participants with lower individual-SEP were less exposed to NO₂. Conversely, participants
94 living in neighborhoods with higher unemployment rate were more exposed. City-specific
95 results exhibited strong heterogeneity (I²>76% for the three SEP indicators) resulting in
96 variation of the individual- and neighborhood-SEP patterns of NO₂ exposure across cities.

97 The coefficients from a model that included both individual- and neighborhood-SEP
98 indicators were similar to the unadjusted coefficients, suggesting independent associations.

99 Conclusions: Our study showed for the first time using homogenized measures of outcome
100 and exposure across 16 cities the important heterogeneity regarding the association between
101 SEP and NO₂ in Western Europe. Importantly, our results showed that individual- and
102 neighborhood-SEP indicators capture different aspects of the association between SEP and

103 exposure to air pollution, stressing the importance of considering both in air pollution health
104 effects studies.

105

106 Keywords: Europe, socioeconomic position, air pollution, environmental inequality

107

108 ABREVIATIONS

109 ECRHS: European Community Respiratory Health Survey

110 EGEA: French Epidemiological family-based study of the Genetics and Environment of
111 Asthma

112 ESCAPE: European Study of Cohorts for Air Pollution Effects

113 LUR: land use regression

114 MAUP: modifiable area unit problem

115 NO₂: Nitrogen dioxide

116 OC: occupational class

117 PM: Particulate matter

118 SAPALDIA: Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults

119 SEP: socioeconomic position

120 1. INTRODUCTION

121 Environmental inequality refers to a differential distribution of environmental hazards across
122 socioeconomic or socio-demographic groups (1). Historically, research on environmental
123 inequality has emerged in the United States (US) following the Environmental Justice
124 Movement (2–5). Repeatedly, US studies reported that lower socioeconomic or minority
125 groups were more likely to be exposed to higher traffic-related air pollution exposure such as
126 nitrogen dioxide (NO₂) or particulate matter (PM) (6). However, results from US studies
127 cannot be extended to European countries because of very different socio-spatial
128 characteristics, specifically in urban areas (7). For example, one of the main differences is that
129 in general in most US cities, lower socioeconomic groups tend to live downtown when upper
130 socioeconomic groups reside in the suburbs. In European cities, compared to US, social
131 segregation is lower and lower socioeconomic groups rather live on the outskirts of the city
132 (7).

133 In Europe, a rather limited number of studies compared to US had investigated the association
134 between socioeconomic position (SEP) and air pollution, mainly in the UK first and then in
135 other European countries (6,8). Inconsistent results have been reported in the European
136 literature (9). Some studies reported that populations with low SEP are more exposed to
137 outdoor air pollution (10–14) while other studies reported an inverse association (15–18).
138 Nonlinear association (higher exposure in middle class) (19) and no association (20) were
139 also reported. Inconsistent results were also reported within the same country, for instance in
140 France or Spain (20–23). However, these studies were difficult to compare with each other
141 because they used different methodologies to assess air pollution exposure or to define SEP
142 (6,24). Moreover, most studies relied on ecological data that can raise methodological issues
143 such as ecological fallacy, modifiable area unit problem (MAUP) or spatial autocorrelation
144 (19,25). Few studies used individual-level data (i.e. air pollution exposure at residential

145 address and individual-level SEP) or multilevel data (i.e. SEP estimated at individual- and
146 area-level) (15,17,26–30). Recent evidence showed the importance of considering SEP at both
147 individual and area levels because they are independently associated with health outcomes
148 (6,10,31–33).

149 More generally, the association between SEP and air pollution still needs to be investigated in
150 Europe (6,24) as SEP is one of the major potential determinants of variability in the
151 association between air pollution and health (2,34,35).

152 Within the framework of the multicenter European Study of Cohorts for Air Pollution Effects
153 (ESCAPE) (36), we had the opportunity to tackle this research gap using outdoor NO₂ annual
154 concentrations at participants' home addresses estimated from standardized procedures across
155 a large range of European cities (36). The main objective of the present analysis was to test
156 the environmental justice hypothesis that people with lower SEP (defined at both individual
157 and neighborhood level) were more exposed to traffic related air pollution exposure than
158 people with higher SEP in Western Europe.

159

160 2. MATERIALS AND METHODS

161 2.1. *Study population*

162 This cross-sectional study included participants of three multicenter epidemiological
163 European cohorts that had previously collaborated together (37) and were involved in the
164 ESCAPE study: the French Epidemiological family-based study of the Genetics and
165 Environment of Asthma (EGEA2) (2003–2007) (38), and two population-based studies: the
166 European Community Respiratory Health Survey (ECRHSII) (1999–2002) (39) and The
167 Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults (SAPALDIA2)
168 (2001–2003) (40). Details on each cohort are given elsewhere (38–40) and summarized in the

169 supplementary materials. For the three cohorts, information on participants were collected
170 from detailed, standardized and validated questionnaires completed by face-to-face
171 interviews.

172 Initially, the ESCAPE study included a subsample of the three cohorts (n=9556 participants,
173 Figure 1) from 20 urban areas of eight Western European countries. Of these 20 areas, we
174 were able to recover homogenized SEP data at individual and neighborhood level for 16
175 (n=5692 participants: 4002, 1078 and 612 in ECRHS, EGEA and SAPALDIA respectively;
176 Figure 1) including Norwich, Ipswich (Great Britain; GB); Antwerp (Belgium; BE); Paris,
177 Lyon, Grenoble, Marseille (France; FR); Geneva, (Switzerland; CH); Verona, Pavia, Turin
178 (Italy; IT); Oviedo, Galdakao, Barcelona, Albacete, Huelva (Spain; SP) (Figure S1). The
179 areas covered by ESCAPE were of substantially different sizes (Table S1) with a range of
180 density population from 152 to 21154 inhabitants/km² (41). Most of them could be defined as
181 metropolitan areas (large cities with surrounding smaller suburban communities) but some
182 areas were restricted to a single city (municipality). For purposes of clarity, we refer to these
183 different areas as “cities”.

184

185 *2.2. NO₂ exposure assessment*

186 We considered nitrogen dioxide (NO₂) as a marker of near-road traffic-related air pollution
187 (42). The major sources of NO₂ are motorized road traffic, industry, shipping and heating
188 (41). In the framework of ESCAPE, a single harmonized exposure assessment protocol has
189 been developed to estimate the NO₂ annual concentrations. A common protocol described in
190 detail in Beelen et al. was used to ensure high standardization of all procedures (i.e.
191 measurement and estimation model) across the study areas (36). Briefly, in each city covered,
192 two-week integrated NO₂ measurements at approximately 40 urban sites were made in three
193 different seasons over a one-year period between 2008 and 2011. City-specific land use

194 regression (LUR) models (see supplementary materials) were developed to explain the spatial
195 variation of NO₂ using a variety of geographical data including traffic, population and land
196 use variables. The model explained variances (R^2) of the LUR models ranged from 55% in
197 Huelva to 92% in Pavia, 10 out of the 16 cities have a R^2 above 75% (36). These LUR models
198 were used to assign estimates of NO₂ annual average concentrations at each participant's
199 geocoded residential address. Back-extrapolated estimates were also derived because
200 ESCAPE measurement campaigns took place after the health surveys for the three cohorts
201 (43). Correlations between back-extrapolated and non-back-extrapolated concentrations were
202 high (Pearson correlation coefficient=0.95) so we only considered the non-back-extrapolated
203 data in the present analysis.

204

205 *2.3. Markers of socioeconomic position*

206 We indexed SEP defined at two different levels:

207 *2.3.1. Individual-level SEP*

208 We characterized individual-level SEP based on educational level and occupational class. For
209 the three cohorts, educational level corresponded to the age at completion of full-time
210 education. We categorized the continuous educational variable into country-specific tertiles
211 (high, medium and low). Occupational class was based on the longest job held between
212 baseline and follow-up (in average 10–12 years), and categorized in five classes according to
213 the International Standard Classification of Occupation (ISCO-1988) (44): Manager and
214 Professional (Occupational Class-I); Technician & associate (OC-II); Other non-manual (OC-
215 III); Skilled, semi-skilled and unskilled manual (OC-IV) and “not in labor force”.

216 *2.3.2. Neighborhood-level SEP*

217 To characterize the socioeconomic residential environment of the participants, we used the
218 neighborhood unemployment rate (i.e. proportion of unemployed persons of the labor force).
219 The neighborhood level corresponded to the smallest geographical level unit (with a
220 population size ranging from 169 to 2000 inhabitants) with census-based data available in the
221 different countries (see Table S2 for neighborhood specific characteristics). We obtained the
222 unemployment rate variable from 2001 national censuses (except for France: 2008 and
223 Switzerland: 2006). As the magnitude of the unemployment rate varied across European
224 countries, we standardized it using country-specific z-scores to take this variability into
225 account.

226

227 *2.4. Strategy of analysis*

228 *2.4.1. Main analyses*

229 The strategy of analysis aimed to test the hypothesis that the NO₂ annual concentration
230 (dependent variable) differs according to the individual- and neighborhood- SEP of the
231 participants (explanatory variables).

232 We performed analyses considering first the pooled dataset and then each city separately, due
233 to the heterogeneity of the associations between SEP and air pollution among the cities
234 (assessed with the Higgins' I-squared test (I^2) (45)) We ran several multilevel linear
235 regression models (Table S3) with neighborhood random effects (plus city random effects for
236 the pooled dataset) including one individual SEP indicator (education or occupation) mutually
237 adjusted for neighborhood unemployment rate. In the supplementary materials, we present the
238 results for the single-level linear regression models that ignore the nested structure of the
239 observations.

240 We transformed NO₂ using a natural log transformation to obtain a normally distributed
241 variable. For ease of interpretation, we converted the regression coefficients (β s) into percent
242 change (and 95% Confidence Interval (CI)) per one unit increase in the explanatory factor
243 using the formula $[\exp(\beta)-1]*100$ (a 95% CI which does not include zero indicates the
244 presence of significant differences). The considered unit for unemployment rate was 1
245 standard deviation (SD). For the individual-level SEP variables, we considered each subgroup
246 and tested the statistical differences of the coefficients against the highest group (thus
247 reference group were high educational level and OC-I for occupational class). We deliberately
248 did not show results for participants who were not in the labor force as this class was too
249 heterogeneous to draw any kind of conclusion (i.e. housepersons, unemployed, not working
250 because of poor health, full-time student and retired). This category was excluded to assess
251 the trend across the occupational groups.

252 2.4.2. *Additional analyses*

253 We ran a sensitivity analysis using logistic regression models considering high vs. low
254 exposure (high exposure was defined as an exposure above the 75th percentile of the
255 distribution for each city). All models were adjusted for cohort, age and sex. We checked for
256 potential interactions between SEP and sex, SEP and age and between individual- and
257 neighborhood-level SEP (supplementary materials). Analyses were conducted using R
258 statistical software (Version 3.0.3) and SAS 9.3.

259 As pointed out above some “cities” included in this analysis had a wide geographic coverage.
260 For example, the city labelled “Paris” (FR) covered actually the metropolitan area of Paris-
261 Region (i.e. 12,000 km²). Therefore, we ran a sensitivity analysis by examining more in detail
262 this area: instead of considering participants of Paris in only one area, we considered three
263 distinctive areas (i.e. City of Paris, the inner-suburbs and the outer-suburbs) defined by
264 particular sociodemographic and geographic situations that could influence the association

265 between SEP and air pollution. The methods and results are presented in detail in the
266 supplementary materials and discussed in the main article.

267

268 3. RESULTS

269 *3.1. Study population characteristics*

270 The study population (Table 1a) was composed of 48% males, with a mean age (\pm standard
271 deviation; \pm SD) of 44 (\pm 11) years. Regarding the NO₂ distribution, we found substantial
272 variability between cities with a mean ranging from 21 (\pm 5) (Pavia; IT) to 57 (\pm 14) $\mu\text{g m}^{-3}$
273 (Barcelona; ES). Substantial variability was also found within cities. The average range for
274 NO₂ (difference between the highest and the lowest annual average) within each area was
275 50.3 $\mu\text{g m}^{-3}$. The largest variation for NO₂ was found in the two largest cities Paris (FR)
276 (85.0) and Barcelona (SP) (92.8).

277 Regarding the socioeconomic characteristics of the population (Table 1b), participants
278 completed their education on average at age 20 (\pm 4) years. The proportion of manual workers
279 ranged from 6% (Paris; FR) to 38% (Galdakao; SP) and was generally higher in the Spanish
280 cities. On average, participants with lower educational attainment were employed in less
281 skilled occupations (p-value for trend <0.001) (Table S4). The neighborhood unemployment
282 rate varied from 3% (Pavia; IT) to 22% (Huelva; SP). Participants with lower educational
283 attainment or less skilled occupations were more likely to live in neighborhoods with higher
284 unemployment rate. However, the associations did not reach the level of significance in 7 and
285 6 out of the 16 cities for education and occupation respectively (Tables S5a-S5b).

286

287 *3.2. Pooled results*

288 Pooled results are shown in Table 2. In the model taking into account only clustering within
289 cities, low educational level and manual occupations were associated with a lower NO₂

290 exposure (Percent difference (95% CI) Low vs. high educational level= -6.9% (-9.1; -4.7);
291 OC-IV vs. OC-I=-5.6% (-8.2; -3.0)). Conversely, higher neighborhood unemployment rate
292 was associated with higher NO₂ exposure (7.3% (6.2; 8.5) per 1 SD increase in the
293 unemployment rate). The introduction of individual- and neighborhood-SEP in the same
294 model did not substantially alter effect estimates (Low vs. High educational level= -8.7% (-
295 10.8; -6.5) and 7.8% (6.7; 8.9) per 1 SD increase in the unemployment rate). Accounting for
296 both city and neighborhood clustering decreased the effect size of both the individual- and
297 neighborhood-SEP. Associations remained significant for educational level and the
298 unemployment rate.

299

300 *3.3. City-specific results*

301 In the city-specific analyses using standard linear regression models (Table S4), associations
302 with NO₂ were highly heterogeneous for all SEP indicators ($I^2 > 76\%$, $p < 0.001$). Using
303 multilevel linear regression models, individual-SEP was weakly or not associated with NO₂
304 exposure for most cities (14 out of 16 cities). For educational level (Table 3a), significant
305 associations were only found in Lyon (FR) (Low vs. High = -3.6 (-12.3; -5.9)) and Verona
306 (IT) (-16.1 (-26.5; -4.3)). For occupational class (Table 3b), significant associations were
307 found for the middle class in Paris (FR) (OC-III vs. OC-I= -3.3 (-6.4; -0.1) and Oviedo (-8.7
308 (-15.7; -1.2)). Living in a neighborhood with higher unemployment rate was associated with
309 higher NO₂ exposure (regardless of the individual-SEP marker included in the model) in 11
310 out of 16 cities. In Oviedo (ES) and Barcelona (ES) an inverse association was observed.

311 *3.4. Additional analyses*

312 Results from the logistic regression models (high vs. low exposure) were consistent with the
313 linear regression ones for the educational level (Table S6a) as well for occupational class
314 (Table S6b).

315 In Paris-Region (FR), when considering participants in three distinctive areas (i.e. city of
316 Paris, inner suburbs and outer suburbs; supplementary materials), participants with lower
317 educational level or occupational class were less exposed to air pollution (not significant) but
318 those living in neighborhood with higher unemployment rate were more exposed. These
319 results are consistent with those observed when considering participants in one area.

320

321 4. DISCUSSION

322 We investigated, in three European cohorts, whether SEP evaluated at both individual- and
323 neighborhood-level was associated with traffic related air pollution exposure across sixteen
324 Western European cities. The pooled analyses masked important heterogeneity across the
325 cities showing that city appeared to be the major predictor of the association between SEP and
326 NO₂ exposure.

327 The associations between individual-SEP and NO₂ were generally weak and inconsistent
328 across the cities. This is in accordance with those of the three studies that used a comparable
329 approach to ours (17,20,46). Education and occupation showed the same pattern with NO₂ in
330 the pooled data and in most cities, in the city specific analyses, showing that both indicators
331 measured the same concept (47,48). The associations between neighborhood-SEP and NO₂
332 were in the opposite direction (higher exposure in lower neighborhood-SEP) compared to the
333 individual-SEP variables, both in the pooled data and in most cities in the city-specific
334 models. This has also been observed in other studies in Europe (30) and in Montreal, Canada
335 (49).

336 One possible explanation for the difference in direction is that the neighborhood-SEP is
337 capturing aspects beyond the SEP of the population living in that area, such as how
338 industrialized the neighborhood may be. Moreover, NO₂ variability was relatively small
339 across the individual-SEP groups, and after adjusting for neighborhood-SEP there was little
340 evidence of potential confounding by individual-SEP. Place of residence is strongly patterned
341 by social position and outdoor air pollution is spatially located within cities, therefore the
342 degree to which air pollution is socially patterned is likely to occur more at area-level as well
343 (33).

344 Accounting for both city and neighborhood clustering using a two level random intercept
345 model drastically decreased the size effects of the associations for both individual- and area-
346 SEP markers compared to the single level linear regression model (Table S7). This has been
347 observed in other studies (30,35,50) showing the importance to accounting for clustering in
348 analyses including spatially nested data. With the multilevel approach the effect of
349 unemployment rate remained in all cities but the effect of the individual-SEP decreased and
350 even became null for several cities showing that variability was mainly explained by the city
351 first then by the neighborhoods and for a smaller part by the individual-SEP. We looked at
352 some socioeconomic variables at city level (e.g. population density, gross domestic product,
353 etc.) to try to explain the heterogeneity of the association between SEP and NO₂ among the
354 cities using a meta-regression. However, none of the tested variables explained this
355 heterogeneity (not shown).

356 To the best of our knowledge this is the first study including a large sample of cities
357 geographically representative of Western Europe, with important within- and between-area
358 variability of air pollution exposure. We used NO₂ as a traffic-related pollutant known to have
359 a great intra-urban variability and thus was the most appropriate to study socioeconomic
360 differences at individual-level (10,41,51). The NO₂ annual concentrations have been

361 estimated at participant's residential address with a single harmonized exposure assessment
362 protocol across the cities. The measurement time of NO₂ does not overlap with the
363 questionnaire data from the cohorts. However, we assume that spatial contrasts in outdoor
364 NO₂ pollution were stable over time; an assumption supported from observations in different
365 settings in European countries (52,53). We used homogenized SEP indicators at both
366 individual- and neighborhood-level. Recent evidence showed the importance of accounting
367 SEP at both levels because they were independently associated with health outcomes (32–
368 34,46,54,55) but this had rarely been investigated with air pollution exposure (10,28,29). We
369 used an area-based indicator defined at the smallest geographical unit available in each
370 country to avoid MAUP as recommended (49,56–58).

371 Our study has some limitations. Due to data confidentiality, we did not have access to
372 participants' geographical coordinates for the present analysis and we were not able to analyze
373 their spatial distribution. We applied an aspatial multilevel model to take into account the
374 clustering of the participants within neighborhoods (46,59) but the proportion of
375 neighborhoods containing only one participant was relatively high in some cities (60). This
376 highlights a common problem in studies that were not originally designed to study area-level
377 determinants. We compared a large number of European cities, but the sample in some cities
378 was quite small and could explain the absence of associations and large confidence intervals.
379 The different areas were also of different sizes and with different population density.
380 However, the additional analysis performed for the Paris-Region suggested that the results
381 were not sensitive to this aspect.

382 We considered the unemployment rate, the sole indicator of neighborhood SEP uniformly
383 available for most of the cities with ESCAPE NO₂ estimates. This single indicator does not
384 fully describe participants' neighborhood-SEP (33) but has been used in other studies that
385 compared different countries regarding air pollution (61) and has been associated with

386 adverse health outcomes neighborhood level (61–64). We performed additional analyses with
387 country-specific deprivation indices that were available at neighborhood level only for 12 out
388 of the 16 cities (65–68) and we found consistent results compared to the ones with the
389 neighborhood unemployment rate (Table S8).

390 Finally, we did not have information on other type of exposures such as occupational and
391 indoor exposures or time-activity patterns (69) which could contribute to create or reinforce
392 environmental inequalities.

393

394 5. CONCLUSIONS

395 Unequal distribution to air pollution exposure according to SEP groups is complex in
396 European cities and no general pattern exists across cities, but rather inequalities need to be
397 specifically assessed in each city. Importantly, our results highlighted the importance of
398 taking into account both individual- and neighborhood-SEP in order to fully describe and
399 understand the complexity of current patterns of social inequalities relating to air pollution.

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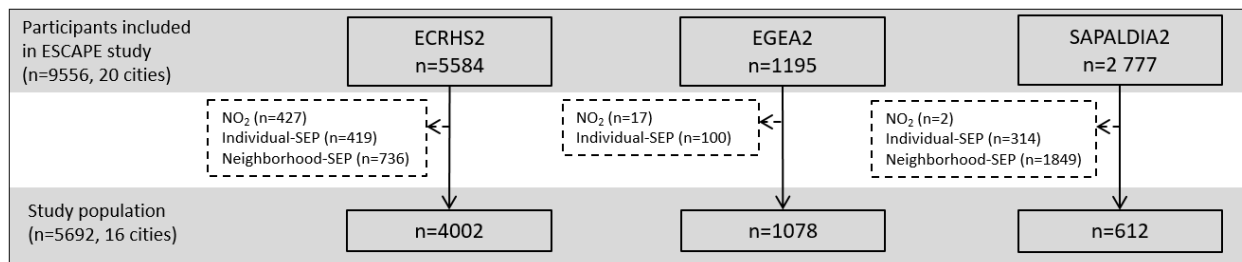
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604 Figure 1: Flow chart of the study population



605

606 Dotted frame: missing data

607 ESCAPE: European Study of Cohorts for Air Pollution Effects

608 ECRHS: European Community Respiratory Health Survey (1999-2002)

609 EGEA: Epidemiological study on Genetics and Environment of Asthma (2003-2007)

610 SAPALDIA: Swiss Cohort Study on Air Pollution and Lung and Heart Diseases in Adults (2001-2003)

611 Table 1a: Characteristics of the population (by city and data pooled)
 612

| City | Country | n | Sex | Age | NO ₂ (µg*m ⁻³) | |
|-------------------------|-------------|------|--------|------------|---------------------------------------|-------------|
| | | | Men, % | mean ±sd | mean ±sd | Q1 – Q3 |
| Norwich ^a | UK | 242 | 43.0 | 43.6 ±6.5 | 25.6 ±5.7 | 22.8 – 28.7 |
| Ipswich ^a | UK | 338 | 42.3 | 42.4 ±6.8 | 24.2 ±4.0 | 22.7 – 26.0 |
| Antwerp ^a | Belgium | 500 | 49.9 | 42.7 ±6.9 | 39.4 ±9.0 | 32.7 – 45.6 |
| Paris ^{a b} | France | 785 | 48.3 | 41.7 ±12.9 | 36.4 ±13.4 | 27.4 – 42.6 |
| Lyon ^a | France | 210 | 46.7 | 48.4 ±15.3 | 28.7 ±13.5 | 16.9 – 40.6 |
| Grenoble ^{a b} | France | 690 | 52.9 | 44.9 ±13.4 | 27.5 ±8.2 | 20.8 – 32.9 |
| Marseille ^b | France | 119 | 43.7 | 49.2 ±15.8 | 26.1 ±8.2 | 21.4 – 31.1 |
| Geneva ^c | Switzerland | 612 | 49.4 | 52.1 ±11.3 | 26.5 ±7.0 | 21.1 – 31.3 |
| Verona ^a | Italy | 179 | 44.1 | 42.6 ±7.1 | 30.7 ±13.8 | 22.6 – 40.2 |
| Pavia ^a | Italy | 188 | 53.7 | 44.2 ±6.6 | 20.5 ±4.8 | 17.6 – 21.8 |
| Turin ^a | Italy | 170 | 46.6 | 42.9 ±7.0 | 54.9 ±10.1 | 49.2 – 61.9 |
| Oviedo ^a | Spain | 315 | 49.8 | 42.9 ±7.1 | 36.6 ±12.5 | 29.3 – 43.9 |
| Galdakao ^a | Spain | 408 | 48.5 | 40.7 ±7.3 | 23.9 ±6.6 | 18.6 – 28.3 |
| Barcelona ^a | Spain | 284 | 44.4 | 41.9 ±7.1 | 57.4 ±14.1 | 49.6 – 62.4 |
| Albacete ^a | Spain | 419 | 46.8 | 40.8 ±7.3 | 28.6 ±14.8 | 19.5 – 38.1 |
| Huelva ^a | Spain | 233 | 50.2 | 41.1 ±7.2 | 25.2 ±6.4 | 20.6 – 29.8 |
| Pooled data | | 5692 | 48.2 | 43.9 ±10.6 | 31.8 ±13.6 | 22.4 – 38.6 |

613 Cities are sorted from north to south.

614 Participants were from ^aECRHS, ^bEGEA, ^cSAPALDIA; Paris: ECRHS n=386, EGEA n=399, Grenoble: ECRHS
 615 n=350, EGEA n=340.

616 Table1b: Socioeconomic characteristics of the population (by city and data pooled)

| City | n | Age at end of school mean \pm SD | Individual-level SEP | | | | Neighborhood-level SEP | |
|-------------------------|------|---------------------------------------|-----------------------------------|---|----------------------------|-----------------|---------------------------|----------------------------|
| | | | Occupational Class, % | | | | Unemployment rate* | |
| | | | Managers and Professionals (OC-I) | Technicians & Associate Professionals (OC-II) | Other non-manuals (OC-III) | Manuals (OC-IV) | <i>Not in labor force</i> | mean \pm SD (min-max) |
| Norwich ^a | 242 | 17.6 \pm 3.1 | 25.6 | 19.4 | 27.3 | 24.0 | 3.7 | 11.1 \pm 7.2 (2.1-34.1) |
| Ipswich ^a | 338 | 17.1 \pm 2.6 | 22.5 | 16.6 | 30.8 | 22.2 | 8.0 | 10.4 \pm 6.6 (2.4-32.0) |
| Antwerp ^a | 500 | 20.2 \pm 3.1 | 33.0 | 18.6 | 31.0 | 16.8 | 0.7 | 8.2 \pm 5.9 (0.8-31.2) |
| Paris ^{a,b} | 785 | 21.3 \pm 3.6 | 41.7 | 23.6 | 18.5 | 6.2 | 10.1 | 10.6 \pm 4.0 (3.0-28.0) |
| Lyon ^a | 210 | 19.5 \pm 3.7 | 20.5 | 24.8 | 26.2 | 21.0 | 7.6 | 9.1 \pm 3.8 (3.4-25.1) |
| Grenoble ^{a,b} | 690 | 20.8 \pm 3.8 | 37.5 | 20.1 | 17.4 | 13.9 | 11.0 | 9.8 \pm 4.5 (3.4-31.3) |
| Marseille ^b | 119 | 20.6 \pm 3.4 | 46.2 | 20.2 | 14.3 | 9.3 | 10.1 | 12.1 \pm 5.5 (4.9-35.0) |
| Geneva ^c | 612 | 20.5 \pm 4.3 | 32.4 | 20.4 | 24.8 | 11.4 | 11.0 | 4.3 \pm 1.4 (0.7-9.1) |
| Verona ^a | 179 | 19.0 \pm 4.7 | 25.8 | 13.7 | 29.0 | 23.7 | 7.9 | 4.5 \pm 3.0 (1.0-15.4) |
| Pavia ^a | 188 | 18.7 \pm 4.6 | 25.8 | 13.7 | 29.0 | 23.7 | 7.9 | 3.4 \pm 2.5 (0.7-14.3) |
| Turin ^a | 170 | 19.5 \pm 5.2 | 21.6 | 13.1 | 36.4 | 22.1 | 6.8 | 7.4 \pm 4.1 (1.4-21.7) |
| Oviedo ^a | 315 | 19.3 \pm 4.6 | 26.7 | 10.8 | 29.2 | 28.6 | 4.8 | 14.0 \pm 3.0 (7.5-33.3) |
| Galdakao ^a | 408 | 18.2 \pm 4.1 | 17.9 | 8.6 | 25.3 | 37.7 | 10.5 | 10.7 \pm 3.5 (3.1-21.9) |
| Barcelona ^a | 284 | 18.8 \pm 4.9 | 28.9 | 14.4 | 29.6 | 21.1 | 6.0 | 10.9 \pm 3.3 (4.1-26.4) |
| Albacete ^a | 419 | 17.7 \pm 4.9 | 17.0 | 10.0 | 29.4 | 33.2 | 10.5 | 14.6 \pm 5.3 (7.7-60.4) |
| Huelva ^a | 233 | 18.0 \pm 4.6 | 17.6 | 9.4 | 27.9 | 30.5 | 14.6 | 21.8 \pm 6.7 (10.7-41.4) |
| Pooled data | 5692 | 19.5 \pm 4.3 | 29.1 | 17.0 | 25.6 | 19.6 | 8.7 | 10.0 \pm 6.0 (0.7-60.4) |

617 Cities are sorted from north to south

618 SD=standard deviation

619 Participants were from ^a ECRHS, ^b EGEA, ^c SAPALDIA; Paris: ECRHS n=386, EGEA n=399, Grenoble: ECRHS n=350, EGEA n=340

620 OC= Occupational class. Not in labor force participants (in italics) included unemployed, retired, housepersons and students

621 * The neighborhood unemployment rate has been assigned individually to participants using their residential addresses.

622 Table 2: Pooled results for the association between NO₂ concentration (μg*m-3) and SEP markers (n=5692) in percent change (95%CI)

| | | | Multilevel model with city at level* | | | Multilevel model with neighborhood (level 2) and city (level 3)† | | |
|------------------------|--------------------|------|--------------------------------------|---|-----------------|--|---|-----------------|
| | | | Adjusted for individual factors | Mutually adjusted for individual and neighborhood SEP | | Adjusted for individual factors | Mutually adjusted for individual and neighborhood SEP | |
| Individual-level SEP | | | | | | | | |
| Educational level | High (ref) | 1917 | - | - | - | - | - | - |
| | Medium | 2001 | -4.5 (-6.6; -2.3) | -5.1 (-7.1; -3.0) | | -1.3 (-2.7; -0.2) | -1.3 (-2.7; 0.2) | |
| | Low | 1774 | -6.9 (-9.1; -4.7) | -8.7 (-10.8; -6.5) | | -1.7 (-3.2; -0.1) | -1.8 (-3.3; -0.2) | |
| | p-value for trend‡ | | <0.0001 | <0.0001 | | 0.04 | 0.03 | |
| Occupational class | | | | | | | | |
| | OC-I (ref) | 1657 | - | - | - | - | - | - |
| | OC-II | 967 | -2.6 (-5.3; 0.2) | -2.7 (-5.4; 0.01) | | 1.0 (-0.8; 2.9) | 1.0 (-0.8; 2.9) | |
| | OC-III | 1457 | -1.0 (-3.5; 1.6) | -2.0 (-4.1; 0.5) | | -0.6 (-2.3; 1.0) | -0.7 (-2.3; 1.0) | |
| | OC-IV | 1118 | -5.6 (-8.2; -3.0) | -7.9 (-10.4; -5.3) | | -0.6 (-2.5; 1.2) | -0.8 (-2.6; 1.1) | |
| | p-value for trend‡ | | 0.001 | <0.0001 | | 0.03 | 0.03 | |
| Neighborhood-level SEP | | | | | | | | |
| | Unemployment rate§ | 5692 | 7.3 (6.2; 8.5) | 7.8 (6.7; 8.9)¶ | 7.7 (6.6; 8.8)# | 3.33 (0.71; 6.01) | 3.2 (1.5; 5.0)¶ | 3.3 (1.5; 5.1)# |

623 * A multilevel model was performed with city at level-2 (random intercept for city level).

624 † A multilevel model was performed with neighborhood at level-2 and city at level-3 (random intercept for city and neighborhood levels).

625 ‡ The unemployment rate has been transformed in z-score, the change in NO₂ is showed for 1 standard deviation.

626 ¶ Mutually adjusted for educational level and neighborhood unemployment rate.

627 # Mutually adjusted for occupational class and neighborhood unemployment rate.

628 All models are adjusted for cohort, age and sex.

629 Results are expressed in percent change in NO₂ (μg*m-3) concentration adjusted for cohort, age, sex. Negative value means a decrease in NO₂ (in percent) compared to the
 630 reference class for categorical variable and for 1SD increase for the continuous variable; p-value for trend were calculated by introducing the categorical variables in
 631 continuous.

632 Occupational class (OC): OC-I: Managers and Professionals, OC-II: Technician and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled and
 633 unskilled manual.

634 Table 3a: Percent change (95%CI) in NO₂ concentration (µg*m-3) in association to educational level mutually adjusted for neighborhood
 635 unemployment rate (n=5692)

| City | n | Educational level (ref=high) | | | P-value for trend | Neighborhood Unemployment rate* |
|-----------|-----|------------------------------|---------------------|------|----------------------|------------------------------------|
| | | Medium | Low | | | |
| Norwich | 242 | -0.9 (-5.7; 4.3) | -1.1 (-7.7; 6.0) | 0.71 | 9.4 (5.1; 13.8) | |
| Ipswich | 338 | 2.0 (-0.6; 4.7) | 0.5 (-2.8; 3.8) | 0.69 | 4.9 (1.0; 8.9) | |
| Antwerp | 500 | 0.6 (-2.2; 3.4) | 1.2 (-1.9; 4.3) | 0.45 | 14.9 (11.8; 18.2) | |
| Paris | 785 | 0.1 (-2.6; 2.9) | -0.3 (-3.1; 2.6) | 0.84 | 13.7 (9.7; 17.8) | |
| Lyon | 210 | -9.4 (-17.0; -0.9) | -3.6 (-12.3; -5.9) | 0.58 | 12.6 (2.2; 24.0) | |
| Grenoble | 690 | 0.5 (-2.1; 3.0) | 0.8 (-1.9; 3.7) | 0.56 | 9.3 (5.1; 13.7) | |
| Marseille | 119 | -1.9 (-10.4; 7.3) | -7.1 (-16.1; 2.9) | 0.13 | 12.1 (7.1; 17.4) | |
| Geneva | 612 | -2.0 (-4.5; 0.6) | -1.8 (-4.4; 0.9) | 0.18 | 9.5 (4.7; 14.6) | |
| Verona | 179 | -0.9 (-15.8; 16.8) | -16.1 (-26.5; -4.3) | 0.01 | 14.0 (3.6; 25.3) | |
| Pavia | 188 | 0.1 (-4.2; 4.6) | -1.4 (-5.4; 2.6) | 0.48 | 2.6 (-1.0; 6.4) | |
| Turin | 170 | 2.8 (-5.9; 12.3) | 5.9 (-3.9; 16.6) | 0.22 | 2.3 (-1.4; 6.1) | |
| Oviedo | 315 | -0.4 (-7.2; 7.0) | -5.0 (-12.3; 3.0) | 0.25 | -14.1 (-23.6; -3.3) | |
| Galdakao | 408 | -1.3 (-5.1; 2.8) | -3.3 (-7.8; 1.5) | 0.18 | 21.8 (14.1; 30.1) | |
| Barcelona | 284 | 3.3 (-2.7; 9.7) | 3.7 (-3.3; 11.2) | 0.28 | -7.7 (-12.7; -2.4) | |
| Albacete | 419 | -10.3 (-21.1; 1.9) | -8.4 (-18.4; 2.9) | 0.11 | -7.9 (-17.5; 2.9) | |
| Huelva | 233 | -1.0 (-6.1; 4.3) | -2.6 (-8.5; 3.6) | 0.39 | 1.9 (-2.3; 6.4) | |

636 Cities are sorted from north to south.

637 A multilevel linear regression model (PROC MIXED) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for cohort, age and
 638 sex.

639 Results are expressed in percent change in NO₂ (µg*m-3) concentration. Negative value means a decrease in NO₂ (in percent) compared to the reference class for the
 640 categorical variable; p-value for trend were calculated by introducing the categorical variables in continuous. The unemployment rate has been transformed in z-score, the
 641 change in NO₂ is showed for 1 standard deviation.

642 Table 3b: Percent change (95%CI) in NO₂ concentration (µg*m-3) in association to occupational class mutually adjusted for neighborhood
 643 unemployment rate (n=5692)

| City | n | Occupational class (ref=OC-I) | | | P-value for trend | Neighborhood Unemployment rate* |
|-----------|-----|-------------------------------|--------------------|--------------------|----------------------|------------------------------------|
| | | OC-II | OC-III | OC-IV | | |
| Norwich | 242 | -0.1 (-6.1; 6.2) | 0.1 (-6.1; 6.7) | 4.9 (-1.5; 11.8) | 0.45 | 9.7 (5.3; 14.3) |
| Ipswich | 338 | 2.3 (-1.2; 5.8) | 1.6 (-1.4; 4.7) | 0.6 (-2.5; 3.7) | 0.99 | 5.0 (1.2; 9.1) |
| Antwerp | 500 | 0.9 (-2.5; 4.4) | 1.6 (-1.4; 4.6) | -1.7 (-5.0; 1.7) | 0.63 | 15.1 (11.9; 8.3) |
| Paris | 785 | -2.3 (-5.0; 0.6) | -3.3 (-6.4; -0.01) | -4.8 (-9.5; 0.1) | 0.03 | 13.7 (9.7; 17.8) |
| Lyon | 210 | 3.2 (-5.7; 12.9) | -3.9 (-12.5; 5.5) | -2.1 (-11.7; 8.6) | 0.78 | 13.0 (2.5; 24.6) |
| Grenoble | 690 | 1.8 (-1.1; 4.8) | 1.1 (-2.1; 4.3) | 3.1 (-0.4; 6.7) | 0.20 | 9.1 (4.9; 13.5) |
| Marseille | 119 | -8.6 (-16.6; 0.1) | -6.9 (-15.2; 2.2) | -4.8 (-15.8; 7.7) | 0.07 | 12.1 (7.0; 17.3) |
| Geneva | 612 | 1.7 (-1.3; 4.8) | -1.0 (-3.7; 1.9) | -0.7 (-4.1; 2.8) | 0.72 | 9.3 (4.4; 14.3) |
| Verona | 179 | 1.9 (-20.8; 31.0) | -2.7 (-18.3; 15.8) | -12.9 (-28.1; 5.4) | 0.07 | 13.3 (2.9; 4.7) |
| Pavia | 188 | -2.6 (-8.2; 3.4) | -3.7 (-7.8; 0.7) | -2.5 (-7.6; 2.8) | 0.17 | 2.7 (-0.9; 6.4) |
| Turin | 170 | 9.5 (-3.6; 24.4) | 9.6 (-0.6; 20.8) | 11.7 (-0.1; 25.0) | 0.07 | 2.3 (-1.3; 6.1) |
| Oviedo | 315 | 0.8 (-9.5; 12.3) | -8.7 (-15.7; -1.2) | -5.9 (-13.2; 2.1) | 0.07 | -13.7 (-23.6; -2.8) |
| Galdakao | 408 | 3.9 (-3.1; 11.4) | 3.6 (-1.6; 9.0) | 3.3 (-1.8; 8.6) | 0.67 | 21.4 (13.6; 29.6) |
| Barcelona | 284 | 3.4 (-4.8; 12.2) | 3.4 (-2.8; 10.1) | 4.1 (-2.6; 11.2) | 0.16 | -7.7 (-12.7; -2.5) |
| Albacete | 419 | -3.7 (-18.2; 13.5) | -6.1 (-18.2; 7.8) | -4.6 (-16.5; 9.1) | 0.34 | -8.3 (-18.0; 2.6) |
| Huelva | 233 | 8.5 (-0.1; 17.9) | 4.1 (-2.1; 10.8) | 6.8 (0.1; 13.8) | 0.15 | 1.0 (-3.2; 5.3) |

644 Cities are sorted from north to south.

645 A multilevel linear regression model (PROC MIXED) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for cohort, age and
 646 sex. Results are expressed in percent change in NO₂ (µg*m-3) concentration. Negative value means a decrease in NO₂ (in percent) compared to the reference class for the
 647 categorical variable; p-value for trend were calculated by introducing the categorical variables in continuous. The unemployment rate has been transformed in z-score, the
 648 change in NO₂ is showed for 1 standard deviation.

649 Occupational class (OC): OC-I: Managers and Professionals (ref), OC-II: Technicians and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled
 650 and unskilled manual. P-value for trend were calculated by introducing the categorical variables in continuous.

651

Supplementary materials

Socioeconomic position and outdoor nitrogen dioxide (NO₂) exposure in Western Europe: a multi-city analysis

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Methods

Study population

ECRHS is a population-based cohort study. About 18,000 young adults aged 20-44 were recruited mainly across Europe in 1991 – 1993 (ECRHS I) and 10,364 participated to the first follow-up (ECRHS II) between 1999 – 2002. 4738 follow-up participants were included in the ESCAPE project from Umea (Sweden), Norwich, Ipswich (United Kingdom); Erfurt (Germany); Antwerp (Belgium); Paris-Region, Grenoble (France); Verona, Pavia, Turin (Italy); Oviedo, Galdakao, Barcelona, Albacete, Huelva (Spain) (Jarvis & ECRHS 2002).

EGEA is a French case-control and family-based study including 2047 participants aged 7-65 recruited between 1991 – 1995 (EGEA1). At the first follow-up (EGEA2), 1922 participants provided a questionnaire between 2003 – 2007. 1078 follow-up participants were included in the ESCAPE project from Paris-Region, Grenoble, Lyon and Marseille (Siroux et al. 2011).

SAPALDIA is a cohort study in Switzerland. In 1991, 9651 participants aged 20-65 were recruited for a detailed interview and health examination (SAPALDIA1). The follow-up (SAPALDIA2) was conducted in 2001-2003 at which 8047 participants provided health information. 2461 follow-up participants were included in the ESCAPE project from Basel, Geneva and Lugano (Ackermann-Lieblich et al. 2005).

NO₂ exposure assessment

Definition of the Land-use regression (LUR) methods: a LUR combines monitoring of air pollution at a small number of locations and development of stochastic models using predictor variables usually obtained through geographic information systems (GIS). The model is then applied to a large number of unsampled locations in the study area (Hoek et al. 2008). To avoid the exaggerated influence of a high NO₂ point in the models validation process, the predictor variables were truncated. All the details of the development of the models are described in a previous publication (Beelen et al. 2013) and more general information on LUR can be found in Hoek et al. 2008.

Figure S1 Study areas (in brackets: number of participants including in the present analysis)

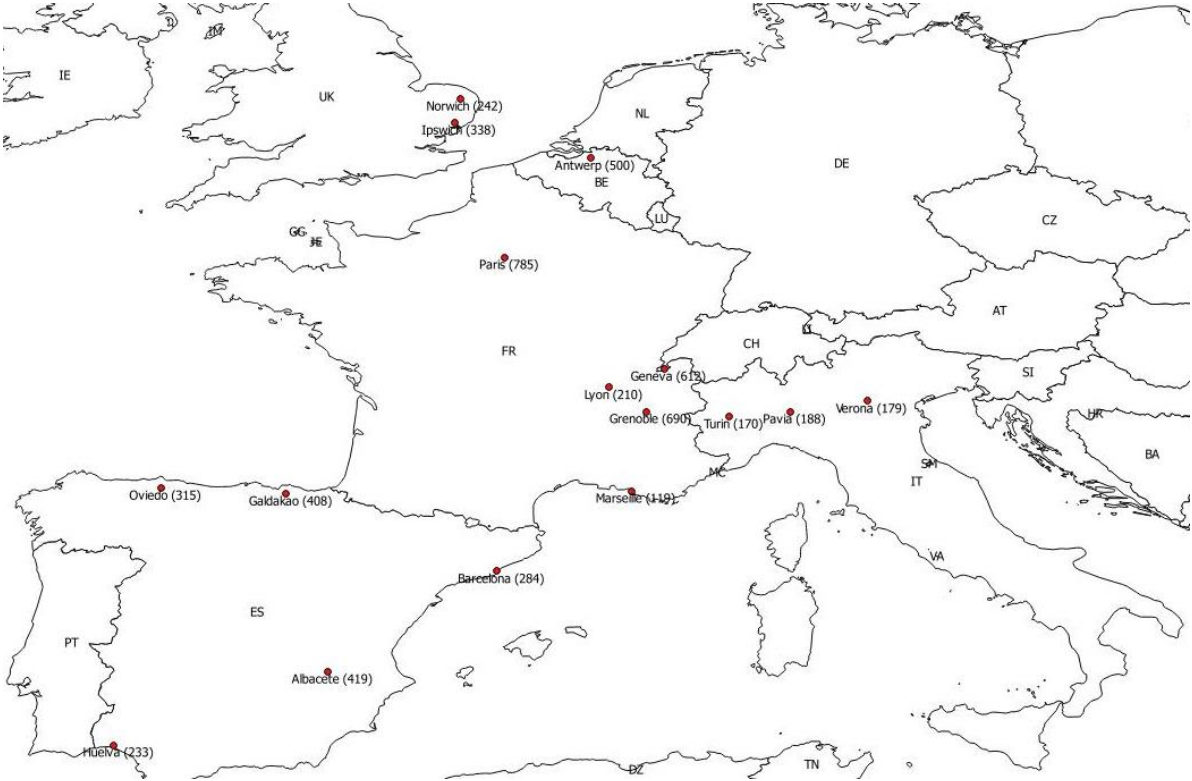


Table S1 Description of the study areas and population density

| Study area | Country | Study area description; major city | Population density of the major city (inhabitants/km ²) |
|------------|----------------|--|---|
| Norwich | United Kingdom | Norwich and surrounding areas | 4 129 |
| Ipswich | United Kingdom | Ipswich and surrounding areas | 3 247 |
| Antwerp | Belgium | Antwerp and surrounding areas | 2 479 |
| Paris | France | Paris and suburban areas | 21 154 |
| Lyon | France | Lyon and suburban areas | 10 460 |
| Grenoble | France | Grenoble and suburban areas | 8 837 |
| Marseille | France | Marseille city | 3 555 |
| Geneva | Switzerland | Geneva city and surrounding smaller towns | 12 628 |
| Verona | Italy | City of Verona and surrounding areas | 1 277 |
| Pavia | Italy | City of Pavia and surrounding areas | 1 147 |
| Turin | Italy | Turin city and five smaller municipalities | 6 902 |
| Oviedo | Spain | Oviedo city | 1 186 |
| Galdakao | Spain | Galdakao and surrounding smaller towns | 923 |
| Barcelona | Spain | Barcelona city | 15 982 |
| Albacete | Spain | Albacete city | 152 |
| Huelva | Spain | Huelva city | 987 |

Adapted from Cyrus et al., *Atmospheric Environment*, 2012 (Cyrus et al. 2012)

Table S2: Definition of neighborhood and distribution of the study population by neighborhood and city

| City | Type of neighborhood (average population size) | Study participants by neighborhood mean (min-max) | Neighborhoods with one participant (%) |
|-----------|--|---|---|
| Norwich | LSOA ^a (1200) | 2.3 (1 – 6) | 18 |
| Ipswich | | 3.0 (1 – 11) | 11 |
| Antwerp | Statistical sector (670) | 2.1 (1 – 9) | 27 |
| Paris | | 1.9 (1 – 10) | 37 |
| Lyon | IRIS ^b (2000) | 2.1 (1 – 10) | 25 |
| Grenoble | | 4.6 (1 – 16) | 4 |
| Marseille | | 1.7 (1 – 6) | 35 |
| Geneva | Sous-secteur (2000) | 4.0 (1 – 18) | 25 |
| Verona | Sezione di censimento (169) | 1.1 (1 – 3) | 80 |
| Pavia | | 1.4 (1 – 7) | 56 |
| Turin | | 1.0 (1 – 2) | 89 |
| Oviedo | Secciones censales (1000) | 2.4 (1 – 8) | 14 |
| Galdakao | | 2.6 (1 – 12) | 14 |
| Barcelona | | 1.1 (1 – 3) | 77 |
| Albacete | | 4.3 (1 – 13) | 2 |
| Huelva | | 2.7 (1 – 8) | 8 |

^a Lower layer Super Output Area

^b IRIS is a French acronym for ‘aggregated units for statistical information’.

Table S3 Description of the main analysis

| Model | Type of linear regression | Random effect | SEP | Table (column) |
|----------------------|---------------------------|---------------------|---|----------------|
| Pooled data | | | | |
| Model 1 | | | Each SEP indicator separately | 2 (1) |
| Model 2 | Multi-level | City | Education level mutually adjusted for unemployment | 2 (2) |
| Model 3 | | | Occupation class mutually adjusted for unemployment | 2 (3) |
| Model 4 | | | Each SEP indicator separately | 2 (4) |
| Model 5 | Multi-level | City + neighborhood | Education level mutually adjusted for unemployment | 2 (5) |
| Model 6 | | | Occupation class mutually adjusted for unemployment | 2 (6) |
| City-specific | | | | |
| Model 7 | Multi-level | Neighborhood | Education level mutually adjusted for unemployment | 3a |
| Model 8 | | | Occupation class mutually adjusted for unemployment | 3b |
| Model 9 | Single-level | - | Each SEP indicator separately | S6 |

Results

Supplementary analysis

We found an interaction between education and unemployment for only 4 cities (Norwich, Antwerp, Verona and Paris). We found an interaction between occupational class and sex only in Pavia (women in lower occupational class were more exposed than men). Finally, we found an interaction between unemployment and age in Grenoble (younger participants living in neighborhoods with higher unemployment rate were more exposed to NO₂) and in Huelva (only older participants living in neighborhoods with higher unemployment were exposed to NO₂).

Table S4: Mean age at completed education by occupational class (crude)

| Cities | N | Occupational class | | | | |
|---------------|------|--------------------|-------|--------|-------|---------------------|
| | | OC-I | OC-II | OC-III | OC-IV | Not in labor force* |
| Norwich | 242 | 20.0 | 18.0 | 16.6 | 16.0 | 16.0 |
| Ipswich | 338 | 18.7 | 18.6 | 16.2 | 15.9 | 16.1 |
| Antwerp | 539 | 21.8 | 20.9 | 19.6 | 17.5 | 16.5 |
| Paris | 785 | 23.0 | 20.9 | 19.1 | 18.2 | 20.8 |
| Lyon | 210 | 22.3 | 20.2 | 18.9 | 16.3 | 20.0 |
| Grenoble | 690 | 23.2 | 20.5 | 19.0 | 17.5 | 20.1 |
| Marseille | 119 | 22.5 | 19.6 | 18.8 | 16.7 | 19.7 |
| Geneva | 612 | 23.0 | 21.0 | 18.9 | 17.4 | 19.1 |
| Verona | 179 | 22.5 | 21.4 | 18.6 | 16.3 | 16.4 |
| Pavia | 190 | 21.8 | 20.6 | 18.4 | 15.2 | 17.4 |
| Turin | 176 | 23.4 | 21.9 | 18.6 | 17.1 | 14.8 |
| Oviedo | 315 | 21.5 | 21.5 | 19.8 | 16.5 | 16.2 |
| Galdakao | 408 | 22.0 | 20.0 | 18.6 | 16.6 | 15.1 |
| Barcelona | 284 | 21.8 | 19.7 | 17.9 | 16.1 | 16.2 |
| Albacete | 419 | 20.9 | 19.8 | 18.7 | 15.7 | 14.5 |
| Huelva | 233 | 22.0 | 19.0 | 18.6 | 16.1 | 15.4 |
| Pooled cities | 5692 | 22.2 | 20.4 | 18.6 | 16.5 | 17.8 |

Occupation class (OC): OC-I: Managers and Professionals, OC-II: Technicians and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled and unskilled manual.

*Category “not in the labor force” was excluded to calculate the p-value for trend.

All p-values for trend across the occupational classes were significant ($p < 0.0001$)

Table S5a: Mean unemployment rate (%) by education level (crude)

| | n | High | Medium | Low | P-value for trend |
|---------------|------|------|--------|------|-------------------|
| Norwich | 242 | 10.0 | 10.6 | 13.9 | 0.004 |
| Ipswich | 338 | 8.1 | 10.8 | 12.1 | <0.0001 |
| Antwerp | 500 | 8.4 | 7.2 | 9.0 | 0.41 |
| Paris | 785 | 10.3 | 10.3 | 11.1 | 0.05 |
| Lyon | 210 | 9.4 | 9.1 | 8.9 | 0.47 |
| Grenoble | 690 | 9.6 | 9.6 | 10.1 | 0.21 |
| Marseille | 119 | 12.8 | 11.3 | 12.3 | 0.74 |
| Geneva | 612 | 4.1 | 4.3 | 4.6 | <0.0001 |
| Verona | 179 | 4.4 | 4.9 | 4.5 | 0.89 |
| Pavia | 188 | 3.3 | 3.6 | 3.3 | 0.99 |
| Turin | 170 | 6.1 | 8.0 | 8.4 | 0.001 |
| Oviedo | 315 | 13.5 | 14.2 | 14.6 | 0.01 |
| Galdakao | 408 | 10.5 | 10.6 | 10.9 | 0.27 |
| Barcelona | 284 | 10.3 | 10.8 | 11.9 | 0.001 |
| Albacete | 419 | 13.3 | 14.5 | 15.4 | 0.001 |
| Huelva | 233 | 18.9 | 22.1 | 24.1 | <0.0001 |
| Pooled cities | 5692 | 9.4 | 10.1 | 10.7 | <0.0001 |

The neighborhood unemployment rate has been assigned individually to participants using their residential addresses.

Table S5b: Mean unemployment rate (%) by occupational class (crude)

| Cities | N | Occupational class | | | | | P-value for trend |
|---------------|------|--------------------|-------|--------|-------|---------------------|-------------------|
| | | OC-I | OC-II | OC-III | OC-IV | Not in labor force* | |
| Norwich | 242 | 8.9 | 9.2 | 13.4 | 12.6 | 10.6 | 0.0002 |
| Ipswich | 338 | 9.1 | 8.9 | 10.7 | 11.1 | 13.9 | 0.02 |
| Antwerp | 500 | 8.0 | 6.9 | 8.3 | 9.7 | 7.3 | 0.03 |
| Paris | 785 | 10.6 | 10.5 | 10.9 | 11.1 | 9.0 | 0.36 |
| Lyon | 210 | 9.5 | 9.2 | 9.5 | 7.7 | 9.8 | 0.06 |
| Grenoble | 690 | 9.4 | 9.6 | 9.8 | 11.6 | 10.0 | 0.0003 |
| Marseille | 119 | 12.2 | 10.9 | 12.8 | 13.2 | 11.6 | 0.66 |
| Geneva | 612 | 4.1 | 4.3 | 4.4 | 4.8 | 4.5 | 0.0001 |
| Verona | 179 | 4.8 | 4.8 | 4.9 | 3.5 | 4.5 | 0.15 |
| Pavia | 188 | 3.2 | 3.8 | 3.0 | 3.7 | 3.5 | 0.69 |
| Turin | 170 | 6.8 | 6.6 | 7.5 | 8.1 | 8.2 | 0.12 |
| Oviedo | 315 | 13.2 | 13.6 | 13.8 | 15.0 | 14.8 | 0.0002 |
| Galdakao | 408 | 10.1 | 10.7 | 10.6 | 11.2 | 10.0 | 0.04 |
| Barcelona | 284 | 10.2 | 10.3 | 10.4 | 11.6 | 11.3 | 0.004 |
| Albacete | 419 | 13.4 | 13.7 | 13.8 | 16.0 | 14.7 | 0.0005 |
| Huelva | 199 | 18.5 | 20.1 | 20.9 | 24.8 | 22.5 | <0.0001 |
| Pooled cities | 5692 | 9.2 | 9.1 | 10.1 | 11.8 | 10.1 | <0.0001 |

Occupation class (OC): OC-I: Managers and Professionals, OC-II: Technicians and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled and unskilled manuals.

The neighborhood unemployment rate has been assigned individually to participants using their residential addresses.

*Category “not in the labor force” was excluded to calculate the p-value for trend.

Table S6a: Odd ratios (OR) for high exposure (95% CI) in association to educational level mutually adjusted for neighborhood unemployment rate (n=5692)

| City | n | Educational level (ref=high) | | | Neighborhood Unemployment* |
|-----------|-----|------------------------------|-------------------|-------------------|----------------------------|
| | | Medium | Low | P-value for trend | |
| Norwich | 242 | 0.45 (0.21; 1.00) | 0.44 (0.17; 1.15) | 0.05 | 1.59 (1.11; 2.62) |
| Ipswich | 338 | 1.04 (0.49; 2.18) | 0.57 (0.19; 1.67) | 0.36 | 1.21 (0.78; 1.86) |
| Antwerp | 500 | 0.72 (0.40; 1.31) | 0.69 (0.36; 1.32) | 0.23 | 3.68 (2.49; 5.44) |
| Paris | 785 | 1.00 (0.64; 1.55) | 0.47 (0.29; 0.75) | 0.002 | 1.33 (1.04; 1.69) |
| Lyon | 210 | 0.49 (0.20; 1.17) | 0.37 (0.14; 0.95) | 0.04 | 1.95 (1.07; 3.56) |
| Grenoble | 690 | 0.83 (0.42; 1.63) | 0.51 (0.30; 0.89) | 0.64 | 1.63 (1.17; 2.26) |
| Marseille | 119 | 0.57 (0.15; 2.14) | 0.20 (0.04; 0.96) | 0.05 | 2.19 (1.23; 3.88) |
| Geneva | 612 | 0.80 (0.42; 1.51) | 0.87 (0.48; 1.56) | 0.62 | 1.60 (1.04; 2.45) |
| Verona | 179 | 0.60 (0.23; 1.54) | 0.23 (0.08; 0.68) | 0.009 | 1.38 (0.96; 2.00) |
| Pavia | 188 | 0.65 (0.29; 1.44) | 0.35 (0.15; 0.81) | 0.02 | 1.37 (0.89; 2.09) |
| Turin | 170 | 0.68 (0.24; 1.91) | 1.41 (0.51; 3.89) | 0.55 | 1.03 (0.68; 1.56) |
| Oviedo | 315 | 0.77 (0.45; 1.32) | 0.36 (0.16; 0.83) | 0.02 | 0.52 (0.27; 1.01) |
| Galdakao | 408 | 0.75 (0.41; 1.38) | 0.49 (0.24; 0.97) | 0.04 | 2.80 (1.53; 5.11) |
| Barcelona | 284 | 0.87 (0.45; 1.69) | 0.77 (0.35; 1.68) | 0.48 | 0.53 (0.29; 0.95) |
| Albacete | 419 | 0.74 (0.39; 1.42) | 0.63 (0.31; 1.28) | 0.21 | 0.39 (0.22; 0.72) |
| Huelva | 233 | 1.16 (0.49; 2.75) | 0.65 (0.20; 2.09) | 0.43 | 2.06 (1.16; 3.65) |

Cities are sorted from north to south.

A multilevel logistic regression model (PROC GLIMMIX) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for cohort, age, sex. High exposure (reference category) was defined as a concentration above the 75th percentile of the distribution by cities; p-value for trend were calculated by introducing the categorical variables in continuous.

Table S6b: Odd ratios (OR) for high exposure (95% CI) in association to occupational class mutually adjusted for neighborhood unemployment rate (n=5692)

| City | n | Occupational class (ref=OC-I) | | | P-value for trend | Neighborhood Unemployment t ₀₀ |
|-----------|-----|-------------------------------|-------------------|--------------------|-------------------|---|
| | | OC-II | OC-III | OC-IV | | |
| Norwich | 242 | 1.02 (0.39; 2.68) | 0.43 (0.16; 1.12) | 0.42 (0.15; 1.20) | 0.09 | 1.71 (1.17; 2.51) |
| Ipswich | 338 | 1.91 (0.79; 4.62) | 1.23 (0.54; 2.81) | 0.81 (0.17; 1.50) | 0.27 | 1.23 (0.81; 1.86) |
| Antwerp | 500 | 1.00 (0.49; 2.04) | 1.23 (0.75; 2.03) | 0.45 (0.18; 1.08) | 0.34 | 3.96 (2.65; 5.90) |
| Paris | 785 | 0.91 (0.58; 1.41) | 0.88 (0.53; 1.46) | 0.68 (0.30; 1.56) | 0.24 | 1.33 (1.04; 1.69) |
| Lyon | 210 | 0.41 (0.16; 1.08) | 0.42 (0.16; 1.11) | 0.45 (0.15; 1.36) | 0.65 | 1.94 (1.05; 3.59) |
| Grenoble | 690 | 1.19 (0.66; 2.15) | 0.89 (0.44; 1.81) | 1.07 (0.50; 2.27) | 0.75 | 1.60 (1.15; 2.23) |
| Marseille | 119 | 0.43 (0.10; 1.77) | 0.06 (0.01; 0.48) | 0.50 (0.10; 2.64) | 0.08 | 2.40 (1.34; 4.31) |
| Geneva | 612 | 0.93 (0.45; 1.92) | 0.88 (0.45; 1.73) | 0.55 (0.28; 1.12) | 0.68 | 1.62 (1.06; 2.48) |
| Verona | 179 | 1.31 (0.38; 4.49) | 1.07 (0.38; 3.03) | 0.14 (0.03; 0.83) | 0.06 | 1.28 (0.87; 1.87) |
| Pavia | 188 | 1.58 (0.59; 4.21) | 0.25 (0.10; 0.65) | 0.22 (0.07; 0.69) | 0.004 | 1.36 (0.88; 2.10) |
| Turin | 170 | 0.34 (0.06; 1.93) | 0.84 (0.29; 2.45) | 0.83 (0.24; 2.86) | 0.84 | 1.02 (0.70; 1.49) |
| Oviedo | 315 | 0.30 (0.10; 0.93) | 0.53 (0.29; 0.99) | 0.52 (0.24; 1.12) | 0.20 | 0.49 (0.25; 0.96) |
| Galdakao | 408 | 0.50 (0.20; 1.24) | 0.64 (0.31; 1.33) | 0.63 (0.31; 1.30) | 0.35 | 2.71 (1.49; 4.91) |
| Barcelona | 284 | 1.69 (0.69; 4.15) | 0.96 (0.45; 2.04) | 0.91 (0.40; 2.07) | 0.74 | 0.52 (0.29; 0.93) |
| Albacete | 419 | 0.93 (0.37; 2.36) | 0.38 (0.16; 0.90) | 0.54 (0.27; 1.09) | 0.19 | 0.38 (0.21; 0.69) |
| Huelva | 233 | 1.13 (0.33; 3.87) | 1.27 (0.47; 3.39) | 1.64 (0.57; 4.78) | 0.42 | 1.08 (1.04; 3.26) |

Cities are sorted from north to south.

A multilevel logistic regression model (PROC GLIMMIX) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for cohort, age, sex. High exposure (reference category) was defined as a concentration above the 75th percentile of the distribution by cities; p-value for trend were calculated by introducing the categorical variables in continuous.

Occupational class (OC): OC-I: Managers and Professionals (ref), OC-II: Technicians and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled and unskilled manual. P-value for trend were calculated by introducing the categorical variables in continuous.

Table S7: Association between individual- and neighborhood SEP and NO₂ (µg m⁻³) using a single-level linear regression model (each SEP variable considered separately; n=5692)

| City | n | Educational level (ref=high) | | | Occupational class (ref=OC-I) | | | | Neighborhood unemployment rate |
|-----------|-----|------------------------------|----------------------|-------------------|-------------------------------|---------------------|---------------------|-------------------|--------------------------------|
| | | Medium | Low | P-value for trend | OC-II | OC-III | OC-IV | p-value for trend | |
| Norwich | 242 | -3.0 (-9.3;3.8) | 2.4 (-5.7; 11.3) | 0.77 | 0.3 (-8.1; 9.4) | -1.4 (-9.2; 7.1) | -3.9 (-12.2; 5.1) | 0.83 | 9,4 (5,1; 13,8) |
| Ipswich | 338 | 3.8 (-0.9; 8.7) | 2.7 (-3.1; 8.7) | 0.28 | 1.3 (-4.4; 7.4) | 7.2 (1.5; 13.2) | 3.6 (-2.6; 10.3) | 0.28 | 5,0 (1,1; 9,0) |
| Antwerp | 500 | -4.4 (-8.6; -0.04) | -1.5 (-6.1; 3.3) | 0.44 | -1.7 (-7.1; 4.0) | 2.1 (-2.6; 7.1) | -3.0 (-8.1; 2.4) | 0.90 | 15,0 (11,8; 18,2) |
| Paris | 785 | -7.5 (-13.0; -1.7) | -4.2 (-10.1; 2.2) | 0.12 | -3.6 (-13.7;7.7) | -1.3 (-8.2; 6.2) | -4.1 (-10.2;2.5) | 0.46 | 13,7 (9,7; 17,8) |
| Lyon | 210 | -16.5 (-29.9; -0.6) | -28.1 (-40.2; -13.4) | 0.001 | -25.5 (-39.2; -8.9) | -7.3 (-23.2; 11.8) | -12.7 (-27.7; 5.3) | 0.02 | 12,8 (2,3; 24,4) |
| Grenoble | 690 | 1.1 (-4.3; 6.8) | 1.2 (-4. 4; 7.1) | 0.68 | 2.8 (-4.3; 10.5) | 0.9 (-5.7; 8.0) | -0.6 (-6.7; 5.8) | 0.44 | 9,3 (5,1; 13,7) |
| Marseille | 119 | -14.9 (-25.4; -2.8) | -19.2 (-29.9; -6.9) | 0.004 | -2.4 (-20.2; 19.4) | -10.4 (-24.4; 6.2) | -6.1 (-19.1; 8.9) | 0.37 | 12,2 (7,1; 17,6) |
| Geneva | 612 | -0.5 (-5.8; 5.1) | -3.6 (-8.9; 2.1) | 0.22 | 2.4 (-5.1; 10.5) | -0.5 (-6.4; 5.7) | -0.5 (-6.5; 5.9) | 0.71 | 9,3 (4,5; 14,3) |
| Verona | 179 | -12.9 (-31.1; 10.1) | -25.1 (-39.8; -6.7) | 0.01 | -32.8 (-49.8; -10.0) | -6.9 (-27.7; 20.0) | 0.4 (-27.0; 37.9) | 0.008 | 14,0 (3,7; 25,5) |
| Pavia | 188 | -2.2 (-9.1; 5.3) | -6.1 (-12.4; 0.7) | 0.08 | -9.5 (-16.7; -1.6) | -9.3 (-16.0; -2.1) | 2.1 (-7.3; 12.5) | 0.003 | 2,7 (-0,9; 6,4) |
| Turin | 170 | 4.5 (-3.4; 13.0) | 8.2 (-0.6; 17.8) | 0.06 | 12.1 (1.5; 23.8) | 10.0 (0.8; 20.1) | 9.6 (-2.1; 22.7) | 0.02 | 2,8 (-0,7; 6,5) |
| Oviedo | 315 | -9.6 (-19.0; 0.9) | -22.3 (-31.1; -12.3) | <0.0001 | -27.2 (-35.7; -17.7) | -13.3 (-23.4; -1.7) | -17.1 (-29.8; -2.1) | <0.0001 | -14,4 (-24,0; -3,6) |
| Galdakao | 408 | -2.6 (-9.4; 4.8) | -1.5 (-9.4; 7.1) | 0.70 | 3.7 (-4.9; 13.1) | 8.1 (-1.6; 18.7) | 3.8 (-8.4; 17.6) | 0.39 | 21,5 (13,8; 29,7) |
| Barcelona | 284 | 0.3 (-6.7; 7.7) | -5.0 (-12.5; 3.2) | 0.25 | -2.2 (-10.2; 6.4) | 2.7 (-5.1; 11.0) | 4.4 (-5.1; 14.9) | 0.71 | -7,2 (-12,1; -2,0) |
| Albacete | 419 | -20.4 (-32.3; -6.2) | -29.6 (-40.5; -16.7) | <0.0001 | -21.0 (-34.3; -5.0) | -14.9 (-29.7; 3.2) | -11.4 (-30.7; 13.3) | 0.007 | -8,3 (-18,1; 2,6) |
| Huelva | 233 | -0.5 (-8.4; 8.29) | -1.1 (-10.0; 8.6) | 0.82 | 19.6 (8.3; 32.1) | 8.6 (-1.9; 20.2) | 10.8 (-3.0; 26.6) | 0.001 | 1,6 (-2,6; 5,9) |

Cities are sorted from north to south.

Each SEP variables were considered separately, adjusted for cohort, age and sex.

Results are expressed in percent change in NO₂ (µg*m⁻³) concentration. Negative value means a decrease in NO₂ (in percent) compared to the reference class for the categorical variable; p-value for trend were calculated by introducing the categorical variables in continuous. The unemployment rate has been transformed in z-score, the change in NO₂ is showed for 1 standard deviation.

Occupation class (OC): OC-I: Managers and Professionals, OC-II: Technicians and associate professionals, OC-III: other non-manuals, OC-IV: skilled, semi-skilled and unskilled manual.

Table S8: Percent change (95% CI) in NO₂ concentration ($\mu\text{g m}^{-3}$) in association neighborhood deprivation (alone and mutually adjusted for either educational level or occupational class)

| Cities | n | Alone | Adjusted for educational level | Adjusted for occupational class |
|-----------|-----|---------------------|--------------------------------|---------------------------------|
| Norwich | 242 | 6.8 (3.3; 10.4) | 7.2 (3.6; 10.9) | 7.1 (3.5; 10.9) |
| Ipswich | 338 | 1.2 (-0.4; 2.7) | 1.1 (-0.5; 2.6) | 1.2 (-0.4; 2.8) |
| Paris | 782 | 19.4 (15.7; 23.1) | 19.4 (15.7; 23.1) | 19.4 (15.7; 23.1) |
| Lyon | 206 | 26.4 (12.4; 42.1) | 26.1 (12.3; 41.7) | 26.9 (12.9; 42.7) |
| Grenoble | 690 | 15.0 (9.4; 20.9) | 14.9 (9.3; 20.8) | 14.8 (9.2; 20.7) |
| Marseille | 119 | 18.3 (9.7; 27.5) | 18.4 (9.9; 27.6) | 18.1 (9.7; 27.2) |
| Verona | 176 | 3.2 (-7.5; 15.1) | 3.2 (-7.5; 15.2) | 2.1 (-8.6; 14.0) |
| Pavia | 188 | -0.5 (-3.6; 2.8) | -0.5 (-3.6; 2.8) | -0.4 (-3.6; 2.8) |
| Oviedo | 315 | -12.2 (-17.8; -6.1) | -11.8 (-17.5; -5.8) | -11.9 (-17.7; -5.8) |
| Galdakao | 408 | 1.3 (-3.4; 6.2) | 2.4 (-3.7; 8.9) | 1.2 (-3.5; 6.0) |
| Barcelona | 284 | 2.7 (-0.2; 5.7) | 2.7 (-0.2; 5.8) | 2.5 (-0.4; 5.6) |
| Albacete | 419 | -13.7 (-24.7; -1.2) | -12.7 (-23.7; -0.2) | -13.4 (-24.4; -0.9) |
| Huelva | 233 | -1.1 (-6.6; 4.6) | -0.9 (-6.4; 4.8) | -1.8 (-7.1; 3.8) |

A multilevel linear regression model (PROC MIXED) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for cohort, age and sex.

Results are expressed in percent change in NO₂ ($\mu\text{g m}^{-3}$) concentration. The deprivation indices have been transformed in country-specific z-scores, the change in NO₂ is showed for 1 standard deviation. Positive value means higher exposition to NO₂. A 95% confidence interval (CI) that does not include zero indicates the presence of significant differences. Deprivation index corresponds to the Carstairs Index for GB cities (Carstairs, 1995); The French European Deprivation Index for the French cities (Pornet et al. 2012); Italian Deprivation Index for Italian cities (Caranci et al. 2010) and Index of vulnerability for the Spanish cities (Alguacil Gómez et al. 2013). Deprivation index (DI) information were not available for Antwerp, Turin and Geneva

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Annex 1: Paris-Region: a case study

Methods:

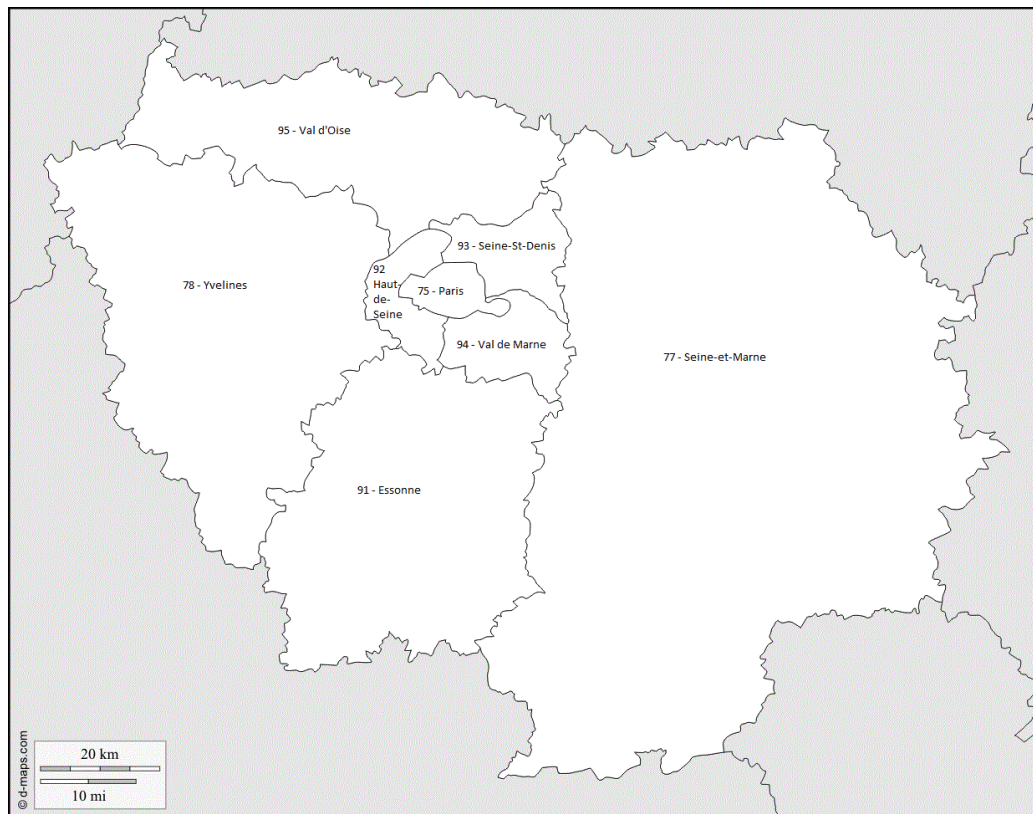
We described the departments regarding their geographical characteristics (population density, green areas) and socioeconomic indicators (unemployment, poverty, Gini index).

We ran a standard multilevel linear regression model with random effects that takes into account the hierarchical structure of the data by disentangling the residual variability at the individual, neighborhood level. We presented the results for the model including simultaneously the individual- and area-SEP markers and accounting for the neighborhood clustering. As NO₂ concentrations were positively skewed, we transformed the variables using natural log transformation. For ease of interpretation, we converted the regression coefficients (β s) into percent increase (95% CI) per unit change in the explanatory factor using the formula $[\exp(\beta)-1]*100$.

For the categorical variable, we calculated the percent increase (95% CI) for each SEP indicator's subgroup (i.e. low, medium and high for educational level) and tested the statistical differences of the coefficients against the highest SEP group (reference group). We considered three sub-regions rather than the departments as they present particular sociodemographic and geographic situations and also to have enough participants in each categories.

Results:

Figure A: Maps of Paris-Region



Paris Region is organized in three principal geographic areas: City of Paris (75), the inner suburbs (composed of three administrative “departments”: Hauts-de-Seine (92), Seine-St-Denis (93) and Val de Marne (94)) and the outer suburbs (composed of four departments: Seine-et-Marne (77), Yvelines (78), Essonne (91) and Val d’Oise (95)).

Table A. Characteristics of the departments in Paris-Region

| | Department-level | | | | Neighborhood-level | | | Individual-level data | | | |
|---------------------|------------------|-----|--------------------|------------------|--------------------|----------------|------------|---------------------------|-------------------------------|---------------------------------------|--|
| | Department | N | Population density | % of green areas | % of unemployment | % Poverty rate | Gini index | Neighborhood Unemployment | NO ₂ mean \pm sd | % of participants with high Education | % of participants with high Occupation |
| City of Paris | 75 | 389 | 21347 | 21 | 8 | 16 | 0.45 | 11.9 | 42.7 \pm 8.9 | 58.9 | 50.1 |
| Inner suburbs | 92 | 76 | 11315 | 18 | 6.2 | 12.0 | 0.40 | 9.2 | 35.9 \pm 14.2 | 47.4 | 47.4 |
| | 93 | 35 | 7892 | 12 | 10.2 | 27.0 | 0.33 | 15.4 | 41.8 \pm 20.1 | 37.1 | 37.1 |
| | 94 | 32 | 9833 | 9 | 6.7 | 15.0 | 0.35 | 9.4 | 33.7 \pm 12.0 | 46.9 | 59.4 |
| Total inner suburbs | | 143 | 10,146 \pm 1416 | 14.5 | 7.3 | 16.3 | 0.37 | 10.8 | 37.2 \pm 15.8 | 44.8 | 47.6 |
| Outer suburbs | 77 | 28 | 1761 | 59 | 5.1 | 11 | 0.32 | 9.7 | 19.8 \pm 5.6 | 14.3 | 28.6 |
| | 78 | 63 | 2400 | 54 | 4.9 | 9 | 0.36 | 7.1 | 21.7 \pm 7.4 | 39.7 | 34.9 |
| | 91 | 48 | 1856 | 48 | 4.8 | 12.0 | 0.33 | 7.5 | 24.4 \pm 7.6 | 35.4 | 43.8 |
| | 95 | 35 | 3511 | 35 | 6.7 | 16.0 | 0.32 | 9.3 | 27.5 \pm 12.1 | 34.3 | 37.1 |
| Total outer suburbs | | 174 | 2371 \pm 630 | 49.3 | 5.3 | 11.6 | 0.34 | 8.1 | 23.7 \pm 9.0 | 33.3 | 36.8 |
| Paris Region | | 706 | 14,401 \pm 8156 | 26.7 | 7.2 | 15.0 | 0.41 | 10.7 | 36.4 \pm 13.4 | 42.1 | 46.3 |

Table A: The sub-regions of Paris-Region are characterized by specific sociodemographic and socioeconomic situations. The outer suburbs are characterized globally by a low population density and high superficies of green areas. The unemployment (at department level and neighborhood level) and poverty rate are also less marked in this area compared to Paris or the inner suburbs. Regarding the participants, those living in the outer suburbs have lower education level and held less skilled occupations compared to Paris or the inner suburbs.

As expected, the more the participants lived far from Paris, the less they were exposed to NO₂. They were twice less exposed than those residing within Paris city (23.7 vs. 42.7). That is to say, even if Paris and its inner suburbs are more polluted areas they concentrate the most educated participants with the higher skills. This could explain the reverse association between education/occupation and NO₂ exposure.

Neighborhood unemployment is higher than unemployment measured at department level, however its distribution is the same (higher in Paris and inner suburbs than in the outer suburbs). At department level, NO₂ mean increases as expected with higher density and decreases with higher green areas.

Regarding, the socioeconomics characteristics, the NO₂ increases with higher unemployment and higher poverty rate.

Table B: Pearson correlation between individual, neighborhood and “department” characteristics

| | | Individual-level | | | Neighborhood-level | Department-level | | | | |
|--------------------|--------------------|-------------------|----------------------------|-----------------------------|--------------------|--------------------|-------------|-------------------|--------------|------------|
| | | NO ₂ | Individual Education level | Individual Occupation class | Unemployment rate | Population density | Green areas | Unemployment rate | Poverty rate | Gini index |
| Individual-level | NO ₂ | 0 | | | | | | | | |
| | Education level | 0.03 <i>ns</i> | 0 | | | | | | | |
| | Occupation class | 0.05 <i>ns</i> | 0.46* | 0 | | | | | | |
| Neighborhood-level | Unemployment | 0.39* | -0.08° | -0.03 <i>ns</i> | 0 | | | | | |
| | Population density | 0.66* | 0.08° | 0.12” | 0.35* | 0 | | | | |
| | Green areas | -0.62* | -0.11” | -0.12” | -0.35* | -0.69* | 0 | | | |
| Department-level | Unemployment rate | 0.62* | 0.07 <i>ns</i> | 0.06 <i>ns</i> | 0.49* | 0.73* | 0.79* | 0 | | |
| | Poverty rate | 0.45* | 0.04 <i>ns</i> | 0.02 <i>ns</i> | 0.45* | 0.39* | - | 0.90* | 0 | |
| | | | | | | | 0.65* | | | |

*P-value: NS non-significant, ° [0.05-0.01]; ” [0.01-0.001]; **p*<10-5*

Table B: As expected, mean NO₂ concentrations exposure estimated at residential address increased with higher population density and less greens areas at department level in the Paris-Region. At department level, participants with higher education level or higher occupation class appeared to live in higher density areas with less green spaces. At this level, there was no correlation between NO₂ and education level or occupation class. Unemployment rate at neighborhood level was positively correlated with unemployment (<0.0001) and poverty rate (<0.0001) at department level. Green areas was positively associated to unemployment at department (not at neighborhood level). Unlike in the US, wealthier people generally live in more urban areas. Individual-SEP markers were relatively well correlated to each other (*r*=0.46, *p*<0.0001), but they were weakly or not correlated to area-SEP (i.e. unemployment (both at neighborhood and department level) and poverty rate. This discrepancy could suggest a selection bias where only the high-SEP person living in disadvantaged neighborhood participated to the study. However, low correlation between individual- and area-SEP has been also found in other European studies, suggesting that, unlike in the US, the urban segregation that could explain environmental health inequalities at individual-level was not verified in Europe.

Table C: Percent increase in NO₂ (µg m⁻³) concentration (95%CI) in relation to educational level with adjustment for neighborhood unemployment rate in Paris-Region (n=706)

| | n | Educational level (ref=high) | | | Neighborhood Unemployment t _∞ |
|---------------|-----|------------------------------|------------------|-------------------|--|
| | | Medium | Low | P-value for trend | |
| Paris-Region | 785 | 0.1 (-2.6; 2.9) | -0.3 (-3.1; 2.6) | 0.84 | 13.7 (9.7; 17.8) |
| City of Paris | 420 | 1.5 (-2.0; 5.2) | 1.0 (-2.5; 4.6) | 0.53 | 4.8 (1.5; 8.2) |
| Inner Suburbs | 156 | 0.3 (-1.7; 2.4) | 0.3 (-1.7; 2.4) | 0.67 | 7.3 (1.1; 13.9) |
| Outer suburbs | 209 | -1.2 (-5.9; 3.8) | -2.0 (-7.5; 3.8) | 0.48 | 5.4 (-1.7; 13.0) |

A multilevel linear regression model (PROC MIXED) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for study, age, sex
Reference= High education level, *p*-value for trend were calculated by introducing the categorical variables in continuous.
∞ Unemployment has been transformed in z-score, the increase/decrease in NO₂ is showed for 1 standard deviation in the unemployment rate

We found the similar results by pooling participants in Paris-Region compared to pooling them by sub-regions that were not artefacts and with characteristics that could influence the association. The unemployment rate however became no longer significant in the outer suburbs.

Table D: Percent increase in NO₂ (µg m⁻³) concentration (95%CI) in relation to occupational class with adjustment for neighborhood unemployment rate in Paris-Region (n=706)

| City | n | Occupational class (ref=OC-I) | | | | P-value for trend | Neighborhood Unemployment [∞] |
|---------------|-----|-------------------------------|--------------------|-------------------|------|-------------------|--|
| | | OC-II | OC-III | OC-IV | | | |
| Paris-Region | 785 | -2.3 (-5.0; 0.6) | -3.3 (-6.4; -0.01) | -4.8 (-9.5; 0.1) | 0.03 | 13.7 (9.7; 17.8) | |
| City of Paris | 420 | -1.5 (-5.0; 2.1) | -3.4 (-7.3; 0.7) | -3.1 (-9.2; 3.5) | 0.16 | 5.0 (1.7; 8.4) | |
| Inner Suburbs | 156 | -0.3 (-1.8; 1.3) | 1.5 (-0.4; 3.5) | -0.9 (-3.5; 1.8) | 0.35 | 7.2 (1.0; 13.8) | |
| Outer suburbs | 209 | -3.2 (-8.4; 2.3) | -4.4 (-10.6; 2.2) | -2.8 (-11.4; 6.6) | 0.34 | 5.4 (-1.7; 13.0) | |

A multilevel linear regression model (PROC MIXED) was performed with neighborhood at level-2 (random intercept for neighborhood level); adjusted for study, age, sex

Occupation class (OC): OC-I: Manager and Professional, OC-II: Technician and associate professional, OC-III: other non-manual, OC-IV: skilled manual, semi-skilled or unskilled manual

[∞] Unemployment has been transformed in z-score, the increase/decrease in NO₂ is showed for 1 standard deviation in the unemployment rate

We found the similar results by pooling participants in Paris-Region compared to pooling them by sub-regions that were not artefacts and with characteristics that could influence the association. However, the associations were no longer significant.