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Supplementary appendix

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Supplement to: Zhou L, Xiong Y, Sera Francesco, et al. Associations of ambient exposure to benzene, toluene, ethylbenzene, and xylene with daily mortality: a multicountry time-series study in 757 global locations. *Lancet Planet Health* 2025. https://doi.org/10.1016/j.lanplh.2025.101306

Supplemental Material

Associations of ambient exposure to benzene, toluene, ethylbenzene, and xylene with daily mortality: A multi-country time-series study in 757 global locations

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Text S1. Detailed information on CESM model configuration and validation.

Daily BTEX data modelling

In this study, the CESM model uses monthly-averaged emissions from CAMS but generates daily BTEX concentrations through the following process:

First, CESM linearly interpolates emissions between the timestamps provided in the input files. Since CAMS has monthly emissions, the model just uses the date listed in the file (typically the 1st or 15th of each month) and linearly interpolates between these dates for each model timestep. If daily emissions were provided, it would interpolate between 00 UTC of each day. Next, the model's meteorology is nudged to MERRA-2 (Modern Era Retrospective-analysis for Research and Applications, Version 2), which is provided every 6 hours. Meteorological fields (e.g., temperature and wind components) are linearly interpolated between these 6-hour intervals. The model calculates meteorology at each timestep and relaxes it toward the MERRA-2 values. Additionally, chemistry is computed every 30-minute timestep, contributing to finer temporal variability in pollutant concentrations. This approach guarantees that daily BTEX variability arises from (1) interpolated emissions, (2) high-frequency meteorological nudging (MERRA-2), and (3) 30-mminute chemistry calculations.

While monthly emissions may smooth out extreme events (e.g., wildfires), the model's high-resolution meteorology and chemistry capture day-to-day concentration variations. This method is consistent with other global modeling studies, such as those using CESM with CEDS monthly emissions to simulate hourly ozone.[1-3]

BTEX model validation

To validate the model, we compared simulated daily BTEX concentrations against ground-level observations from 290 sites across the U.S. (165 sites), Canada (40 sites), and European Union (85 sites) for the year 2019 (Table S1 in the appendix pp 8–22). We acknowledge that comprehensive validation across all 757 study locations remains impractical. Compiling high-quality BTEX measurements—particularly in Asia (e.g., China, India, Japan)—pose significant challenges due to data availability and methodological heterogeneity. On one hand, there are no standardized, publicly available volatile organic compounds (VOC) monitoring networks exist for these regions. On the other hand, existing studies used diverse approaches (e.g., canister vs. sorbent tubes; passive vs. active sampling; 1-hour to 24-hour durations) and analytical techniques (GC-FID vs. GC-MS), precluding their integration into a unified validation dataset. For these reasons, our validation focuses on locations with national monitoring programs (e.g., U.S., Canada, EU countries), where standardized sampling and analytical protocols ensure data consistency. While this represents a subset of our study domain, these regions encompass wide variations in anthropogenic emissions, making them particularly valuable for identifying model biases and providing reasonable uncertainty estimates for extrapolation to other regions.

BTEX data sources included:

(1) U.S.: Ambient Monitoring Technology Information Center (AMTIC) Archive for Hazardous Air Pollutants (https://www.epa.gov/amtic/amtic-ambient-monitoring-archive-haps).

(2) Canada: National Air Pollution Surveillance Program (NAPS) data portal (https://data-donnees.ec.gc.ca/data/air/monitor/national-air-pollution-surveillance-naps-program/Data-Donnees/?lang=en).

(3) EU: European Environment Agency-Air Quality Download Service Center: (https://eeadmz1-downloads-webapp.azurewebsites.net/).

Figures S1 shows the comparison of surface BTEX concentrations between observation and model simulations over the U.S., Canada, and EU countries. We found that the root mean squared error (RMSE) between modeled and observed BTEX concentrations was 0.43–0.53 ppb. The U.S., Canada and EU countries presented slightly overestimated BTEX levels, with normalized mean bias (NMB) of 7.06%, 7.70%, and 12.64%, respectively. Similarly, these overestimations were also observed in a previous modelling study of organic aerosol by the CESM model.[4] Additionally, these validation results generally align with a previous study that incorporated the CEDS (Community Emissions Data System) emission inventory into the CESM model for VOC modeling.[1]

We acknowledge that several factors may contribute to the discrepancies between modeled and observed values. For instance, the coarse horizontal resolution (0.9° × 1.25°) could not fully capture sub-grid spatial heterogeneity in BTEX concentrations. In CESM, grid cells often encompass mixed land types (e.g., industrial, urban, and natural landscapes). When validating against ground observations, closely spaced sites with distinct local characteristics (e.g., an industrial site adjacent to a downtown site) are represented by a single grid-cell value. This introduces discrepancies, as the model cannot resolve sub-grid variability, suggesting validation errors may reflect spatial-scale mismatches rather than true model inaccuracies.

Additionally, the simplified MOZART-TS1 chemical mechanism (the model default) and uncertainties in ground-based measurements play a role. Ground-based VOC measurements typically involve canister or sorbent tube sampling over a specified period (e.g., 24 hours in the NAPS program). This process may underestimate reactive species due to oxidization by hydroxyl radicals during sampling. This could explain the model's consistent overprediction of BTEX across the U.S., Canada, and the EU—observed concentrations might have been higher initially.[2] Furthermore, the MOZART-TS1 mechanism in CESM CAM6-Chem has simplified oxidation pathways for many VOC species (e.g., terpenes), potentially biasing regional-scale predictions of VOCs, ozone, SOA, and $PM_{2.5}$ concentrations.[3]

While discrepancies exist, the model's performance falls within accepted ranges for global-scale studies. The robustness of our epidemiological findings is unlikely to be comprised, as biases are unlikely to alter exposure-response gradients.

Reference

1. Fiore AM, Milly GP, Hancock SE, et al. Characterizing Changes in Eastern U.S. Pollution Events in a Warming World. *Journal of Geophysical Research: Atmospheres*

2022; **127**(9): e2021JD035985.

2. Partha DB, Xiong Y, Prime N, Smith SJ, Huang Y. Long-term impacts of global solid biofuel emissions on ambient air quality and human health for 2000–2019. *GeoHealth* 2025; **9**(3): e2024GH001130.

3. Xiong Y, Partha D, Prime N, et al. Long-term trends of impacts of global gasoline and diesel emissions on ambient PM2.5 and O3 pollution and the related health burden for 2000–2015. *Environmental Research Letters* 2022; **17**(10): 104042

4. Liu Y, Dong X, Wang M, et al. Analysis of secondary organic aerosol simulation bias in the Community Earth System Model (CESM2.1). *Atmospheric Chemistry and Physics* 2021; **21**(10): 8003-8021

Text S2. Detailed information on data collection and evaluation of carbon dioxide emissions by sector.

We utilized sector-specific carbon dioxide (CO_2) emissions as a proxy measure for the contribution of source sectors to air pollutants.

Data collection

Data on CO_2 emissions was sourced from the Emissions Database for Global Atmospheric Research (EDGAR), which provides comprehensive datasets on greenhouse gas emissions by sector, with a spatial resolution of 0.1° latitude by 0.1° longitude (https://edgar.jrc.ec.europa.eu/dataset_ghg70). Emissions attributed to the industry sector encompass contributions from the power industry, combustion for industrial manufacturing, industrial process emissions, and fuel exploitation. Emissions from the transport sector include those generated by the road transport, non-road transport, domestic aviation and shipping.

Evaluation of CO_2 emissions

We initially extracted the CO_2 emissions data from the EDGAR database across different sectors and aggregated the emissions into two primary sectors (i.e., industry and transport). Then, we identified the relevant grid cells within the specified administrative boundaries. The location-specific CO_2 emission level was assigned as the summation of the estimates of all identified grid cells by location and sector. Finally, we calculated the annual average CO_2 emissions during the study period for each location.

Table S1. List of 290 sites for BTEX model validation.

Number	Local Site ID	Longitude	Latitude	City Name	Country
1	LACEY - COLLEGE ST	-122.821548	47.029396	Lacey	USA
2	NORTH TULSA - FIRE STATION#24	-95.976537	36.204902	Tulsa	USA
3	Evansville- U of E/University of Evansville-Carson Center	-87.532289	37.974436	Evansville	USA
4	Amanda Elem	-84.409617	39.479822	Middletown	USA
5	Near Road	-97.577981	35.50307	Oklahoma City	USA
6	SOUTH PHOENIX	-112.07526	33.40314	Phoenix	USA
7	Daniela Banu NCORE	-80.256944	26.053889	Davie	USA
8	Laredo Bridge	-99.502984	27.501826	Laredo	USA
9	Azalea Park	-82.739875	27.785866	Saint Petersburg	USA
10	Skyview	-82.714465	27.850348	Pinellas Park	USA
11	SYDNEY	-82.2304	27.96565	Valrico	USA
12	Dutchtown	-90.965628	30.229653	Not in a city	USA
13	Capitol	-91.179219	30.461981	Baton Rouge	USA
14	Italy	-96.870189	32.175417	Italy	USA
15	Donovan	-116.921374	32.578165	Otay Mesa	USA
16	Grapevine Fairway	-97.063721	32.98426	Grapevine	USA

17	Denton Airport South	-97.196284	33.219069	Denton	USA
18	JLG SUPERSITE	-112.095767	33.503833	Phoenix	USA
19	South DeKalb	-84.2905	33.6878	Not in a city	USA
20	Rubidoux	-117.41601	33.99958	Rubidoux	USA
21	Los Angeles-North Main Street	-118.22688	34.06659	Los Angeles	USA
22	Eagles Island	-77.955864	34.235536	Wilmington	USA
23	CHESTERFIELD	-80.198787	34.615367	Not in a city	USA
24	Haywood Toxics	-95.948901	34.885332	Not in a city	USA
25	Candor: EPA CASTNet Site	-79.836636	35.263165	Candor	USA
26	OKC WEST-(YUKON)	-97.751503	35.479215	Yukon	USA
27	AB Tech	-82.55889	35.57222	Asheville	USA
28	OKC NORTH	-97.475083	35.614131	Oklahoma City	USA
29	Millbrook School	-78.574167	35.856111	Raleigh	USA
30	Hattie Avenue	-80.224501	36.11094	Winston-Salem	USA
31	BLOODWORTH	-88.33389	37.07151	Smithland	USA
32	Carter G. Woodson Middle School	-77.291816	37.289616	Hopewell	USA
33	Math Science Innovation Center	-77.40027	37.55652	East Highland Park	USA
34	GRAYSON LAKE	-82.9881	38.23887	Not in a city	USA
35	Clarksville	-85.763767	38.276683	Clarksville	USA
36	Blair Street	-90.198348	38.656429	St. Louis	USA

37	MCMILLAN NCore-PAMS	-77.013178	38.921847	Washington	USA
38	HU-Beltsville	-76.878333	39.055277	Beltsville	USA
39	GRAND JUNCTION - PITKIN	-108.56155	39.064289	Grand Junction	USA
40	Howard County Near Road	-76.84611	39.14313	North Laurel	USA
41	Oldtown	-76.604603	39.297733	Baltimore	USA
42	Essex	-76.474444	39.310833	Essex	USA
43	Carbondale Rocky Mountain School (Boathouse)	-107.230397	39.412278	Carbondale	USA
44	PARACHUTE - HIGH SCHOOL	-108.053259	39.453654	Parachute	USA
45	Terre Haute-Fort Harrison Rd.	-87.37444	39.507688	Terre Haute	USA
46	Garfield County Library	-107.78225	39.53068	Rifle	USA
47	MLK CORNER OF MLK BLVD AND JUSTISON ST	-75.557554	39.739462	Wilmington	USA
48	Indpls.- I 70	-86.13088	39.787933	Indianapolis (Remainder)	USA
49	Indpls- Washington Park/in parking lot next to police station	-86.114444	39.810833	Indianapolis (Remainder)	USA
50	Chester	-75.3725	39.835556	Chester	USA
51	SW WASTE TREATMENT PLANT	-75.21965	39.88294	Philadelphia	USA
52	Arendtsville	-77.30968	39.92002	Not in a city	USA
53	Ritner (RIT)	-75.186921	39.922867	Philadelphia	USA
54	Barack Rec Center	-82.980105	39.928531	Columbus	USA
55	Camden Spruce Street	-75.125219	39.934559	Camden	USA

56	North East Waste (NEW)	-75.080833	39.991389	Philadelphia	USA
57	Roxborough (ROX)	-75.241209	40.049604	Philadelphia	USA
58	Marcellus	-80.243995	40.268963	Not in a city	USA
59	Hopedale	-80.933401	40.332933	Not in a city	USA
60	Steubenville	-80.6158	40.3663	Steubenville	USA
61	Flag Plaza	-79.990293	40.443367	Pittsburgh	USA
62	Rutgers University	-74.429439	40.462182	East Brunswick (Township of)	USA
63	FRESHKILLS WEST	-74.19832	40.58027	New York	USA
64	Elizabeth Lab	-74.208365	40.64144	Elizabeth	USA
65	Beaver Valley	-80.317731	40.673656	Not in a city	USA
66	PS 274	-73.92769	40.69454	New York	USA
67	QUEENS COLLEGE 2	-73.82153	40.73614	New York	USA
68	Chester2	-74.676301	40.787628	Chester	USA
69	IS 52	-73.902	40.816	New York	USA
70	PFIZER LAB SITE	-73.87809	40.8679	New York	USA
71	Bountiful Viewmont	-111.884467	40.902967	Bountiful	USA
72	Gary-IITRI/ 1219.5 meters east of Tennessee St.- old ammunition bunker	-87.304943	41.606662	Gary	USA
73	AJ	-71.72	41.615237	Not in a city	USA
74	Ogden Dunes- Water Treatment Plant	-87.199167	41.6175	Ogden Dunes (Wickliffe)	USA

75	HAMMOND CAAP- Hammond- 141st St.	-87.493609	41.639306	Hammond	USA
76	East Chicago-Marina	-87.435561	41.653501	East Chicago	USA
77	Whiting- Center St.	-87.490233	41.681393	Whiting	USA
78	CCRI Liston Campus ROOFTOP	-71.412968	41.807469	Providence	USA
79	FRANCIS SCHOOL East Providence	-71.36097	41.841039	East Providence	USA
80	Vernon St, Pawtucket	-71.379971	41.874668	Pawtucket	USA
81	IEPA TRAILER	-87.876265	41.965193	Schiller Park	USA
82	PINNACLE STATE PARK	-77.20978	42.09142	Not in a city	USA
83	NORTHBROOK WATER PLANT	-87.799227	42.139996	Northbrook	USA
84	Erie	-80.038611	42.14175	Erie	USA
85	Presque Isle	-80.11333	42.155833	Erie	USA
86	MARK TWAIN MIDDLE SCHOOL	-83.162585	42.270009	Detroit	USA
87	(Northeast corner)	-83.151415	42.281869	Detroit	USA
88	West corner	-83.161145	42.283069	Detroit	USA
89	NORTHWEST	-83.153435	42.289449	Detroit	USA
90	DUDLEY SQUARE ROXBURY	-71.0826	42.3295	Boston	USA
91	LYNN WATER TREATMENT PLANT	-70.970816	42.474642	Lynn	USA
92	S. Pearl Street	-73.756511	42.640931	Not in a city	USA
93	BUFFALO	-78.809526	42.876907	Buffalo	USA
94	GRAND ISLE BOULDVARD	-78.91859	42.98844	Tonawanda	USA

95	BROOKSIDE TERRACE	-78.89926	42.99813	Tonawanda	USA
96	MILWAUKEE - SIXTEENTH ST. HEALTH CENTER	-87.93369	43.01724	Milwaukee	USA
97	Packard Court Community Center	-79.011447	43.096373	Niagara Falls	USA
98	HORICON WILDLIFE AREA	-88.62111	43.46611	Kekoskee	USA
99	CETL - Cape Elizabeth Two Lights (State Park)	-70.207324	43.561043	Not in a city	USA
100	WOOD PLATFORM	-84.221099	43.589471	Midland	USA
101	WOOD PLATFORM2	-84.209431	43.591416	Midland	USA
102	State of Vermont District Court Parking Lot	-72.982778	43.608056	Rutland	USA
103	PDO - Portland Deering Oaks	-70.268965	43.660246	Portland	USA
104	COUNTRY KITCHEN BAKERY PARKING LOT	-70.214219	44.089406	Lewiston	USA
105	WHITEFACE BASE	-73.8589	44.39308	Not in a city	USA
106	City of Burlington Parking Lot	-73.2106	44.4762	Burlington	USA
107	PROCTOR MAPLE RESEARCH CTR	-72.86884	44.52839	Underhill (Town of)	USA
108	Rumford Avenue Parking Lot (RAP)	-70.546319	44.551419	Rumford (census name for Rumford Compact)	USA
109	KENDUSKEAG PUMP STATION (BUILDING ROOF)	-68.769675	44.79886	Bangor	USA
110	Mary Snow School	-68.772762	44.817398	Bangor	USA
111	La Grande Hall and N St. (LHN)	-118.0778	45.3235	La Grande	USA
112	Portland Cully Helensview School (PCH)	-122.575278	45.5625	Portland	USA

113	RIVERSIDE	-68.016195	46.682299	Presque Isle	USA
114	SEATTLE - BEACON HILL	-122.308628	47.568236	Seattle	USA
115	Franklin- Active Adult Center	-86.053179	39.484072	Franklin	USA
116	Azusa	-117.92391	34.1365	Azusa	USA
117	CENTER OF PARKING LOT OF PUBLIC WORKS BUILDING 1/4 MI N OF SINCLAIR	-95.998941	36.126945	Tulsa	USA
118	Calexico-Ethel Street	-115.48307	32.67618	Calexico	USA
119	El Cajon - Lexington Elementary School	-116.944308	32.789565	El Cajon	USA
120	NR-285	-84.272614	33.698643	Atlanta	USA
121	Simi Valley-Cochran Street	-118.683685	34.276316	Simi Valley	USA
122	Garinger High School	-80.785683	35.2401	Charlotte	USA
123	Bakersfield-California	-119.062613	35.356615	Bakersfield	USA
124	Fresno - Garland	-119.77321	36.78538	Fresno	USA
125	TVA SUBSTATION	-88.33087	37.0452	Calvert City (RR name Calvert)	USA
126	San Jose - Knox Avenue	-121.849783	37.338135	San Jose	USA
127	San Jose - Jackson	-121.894898	37.348497	San Jose	USA
128	Redwood City	-122.20337	37.482934	Redwood City	USA
129	Livermore	-121.784217	37.687526	Livermore	USA
130	Pleasanton - Owens Ct	-121.903019	37.701222	Pleasanton	USA
131	Oakland	-122.169935	37.743065	Oakland	USA

132	San Francisco	-122.399044	37.765946	San Francisco	USA
133	Laney College	-122.263376	37.793624	Oakland	USA
134	Oakland West	-122.282347	37.814781	Oakland	USA
135	Ft. Cronkhite	-122.527658	37.832725	Not in a city	USA
136	Berkeley- Aquatic Park	-122.302741	37.864767	Not in a city	USA
137	Concord	-122.026154	37.936013	Concord	USA
138	Richmond - 7th St.	-122.364852	37.948172	Richmond	USA
139	Stockton-Hazelton	-121.268523	37.950741	Stockton	USA
140	San Pablo	-122.356811	37.9604	San Pablo	USA
141	San Rafael	-122.520004	37.97231	San Rafael	USA
142	Bethel Island	-121.641918	38.006311	Bethel Island	USA
143	Martinez - Jones St.	-122.134467	38.012816	Martinez	USA
144	Crockett - Kendall Ave	-122.233229	38.05492	Crockett	USA
145	Vallejo	-122.237976	38.102507	Vallejo	USA
146	Napa Valley College	-122.275024	38.278849	Napa	USA
147	Dixie St.	-81.621161	38.346258	Charleston	USA
148	Sebastopol	-122.818294	38.403765	Sebastopol	USA
149	Roseville-N Sunrise Ave	-121.26498	38.74643	Roseville	USA
150	Carthage	-84.478974	39.19433	Cincinnati	USA
151	Battlement Mesa	-108.02611	39.43806	Battlement Mesa	USA

152	Yankee	-84.394952	39.472436	Middletown	USA
153	Chico-East Avenue	-121.84047	39.76168	Chico	USA
154	Fairgrounds	-82.994424	40.002707	Columbus	USA
155	Brookpark	-81.818667	41.39629	Brook Park	USA
156	St Theodosius	-81.682383	41.477011	Cleveland	USA
157	DETROIT-SOUTHWEST (DET-SW)	-83.106667	42.302778	Detroit	USA
158	ROCHESTER 2	-77.54817	43.14618	Rochester	USA
159	Mehoopany	-76.0643	41.5658	Not in a city	USA
160	PROPERTY OWNED BY DEARBORN PUBLIC SCHOOLS	-83.148889	42.306666	Dearborn	USA
161	Chula Vista	-117.059088	32.631242	Chula Vista	USA
162	Kibby	-84.707205	39.131635	Cincinnati	USA
163	Pitt Agri. Center	-77.360126	35.641276	Not in a city	USA
164	Medford, Welch and Jackson.	-122.880266	42.33155	Medford	USA
165	San Diego - Sherman Elementary School	-117.142665	32.710177	San Diego	USA
166	S010102	-52.71147	47.56038	St_John_NL	Canada
167	S030113	-63.57366	44.64711	Halifax_NS	Canada
168	S030118	-63.573383	44.646425	Halifax_NS2	Canada
169	S040203	-66.008384	45.308762	Saint_John_NB	Canada
170	S040208	-66.00305	45.291218	Saint_John_NB2	Canada

171	S040901	-67.074036	45.086912	St_Andrews_NB	Canada
172	S050103	-73.499682	45.641026	Montreal_QC	Canada
173	S050122	-73.480819	45.448663	Brossard_QC	Canada
174	S050129	-73.573825	45.651691	Montreal_QC2	Canada
175	S050133	-73.541992	45.60176	Montreal_QC3	Canada
176	S050134	-73.57176	45.54271	Montreal_QC4	Canada
177	S050136	-73.566842	45.512189	Montreal_QC5	Canada
178	S050308	-71.220495	46.821177	Quebec_QC	Canada
179	S060104	-75.676	45.43433	Ottawa_ON	Canada
180	S060211	-83.073139	42.292889	Windsor_ON	Canada
181	S060438	-79.543425	43.71110556	Toronto_ON	Canada
182	S060440	-79.46752	43.78042	Toronto_ON2	Canada
183	S060512	-79.86167	43.25778	Hamilton_ON	Canada
184	S060904	-81.20086	42.97446	London_ON	Canada
185	S061007	-82.416816	42.912545	Sarnia_ON	Canada
186	S061009	-82.395341	42.990263	Sarnia_ON2	Canada
187	S061502	-80.50381	43.44383	Kitchener_ON	Canada
188	S062601	-80.26964	42.85685	Simcoe_ON	Canada
189	S063601	-81.48333	42.88333	Longwoods_ON	Canada
190	S065101	-79.48325	44.04431	Newmarket_ON	Canada

191	S070119	-97.14653	49.89799	Winnipeg_MB	Canada
192	S080111	-104.616	50.4527	Regina_SK	Canada
193	S090121	-113.36811	53.54823	EdmontonE_AB	Canada
194	S090130	-113.49884	53.54445	EdmontonC_AB	Canada
195	S090230	-114.0091	51.0309	Calgary_AB	Canada
196	S100111	-122.849291	49.280893	Vancouver_BC	Canada
197	S100119	-122.985666	49.21519	BurnabyS_BC	Canada
198	S100133	-122.935471	49.266702	Burnaby_BC2	Canada
199	S100134	-123.152422	49.186265	Richmond_BC	Canada
200	S100137	-123.007975	49.287483	Burnaby_BC3	Canada
201	S100141	-123.077776	49.260267	VancouverT_BC	Canada
202	S100202	-122.74194	53.91472	Prince_George_BC	Canada
203	S101005	-122.326523	49.021554	Abbotsford_Airport_BC	Canada
204	S101101	-121.940279	49.155848	Chilliwach_BC	Canada
205	S102001	-123.12821	48.77524	Saturna_BC	Canada
206	PL/SPO_PL0559A_20_001	19.0329	54.03125	Malbork, ul. Mickiewicza	Poland
207	PL/SPO_PL0560A_20_001	17.74619	54.54617	Lębork, ul. Malczewskiego	Poland
208	PL/SPO_PL0561A_20_001	18.18297	54.10411	Liniewko Kościerskie	Poland
209	ES/SP_08019042_30_M	2.1331	41.3788	BARCELONA (SANTS)	Spain
210	ES/SP_08019004_30_M	2.20452	41.40388	BARCELONA (EL POBLENOU)	Spain

211	ES/SP_08019043_30_M	2.1538	41.3853	BARCELONA (L'EIXAMPLE)	Spain
212	ES/SP_08019044_30_M	2.15239	41.39958	BARCELONA (GRÃ€CIA - SANT GERVASI)	Spain
213	ES/SP_08019054_30_M	2.14799	41.42608	BARCELONA (PARC DE LA VALL D'HEBRON)	Spain
214	ES/SP_08022006_30_M	1.84824	42.09791	BERGA (POLIESPORTIU)	Spain
215	ES/SP_08113007_30_M	1.82531	41.73028	MANRESA (PL. D'ESPANYA)	Spain
216	ES/SP_08121013_30_M	2.44325	41.54716	MATARÃ (PASSEIG DELS MOLINS)	Spain
217	ES/SP_08184006_30_M	2.0425	41.49208	RUBÃ (CA N'ORIOL)	Spain
218	ES/SP_08187012_30_M	2.10141	41.56118	SABADELL (GRAN VIA)	Spain
219	ES/SP_08202001_30_M	2.49575	41.68905	SANT CELONI (CARLES DAMM)	Spain
220	ES/SP_08283004_30_M	2.21758	41.84603	TONA (ZONA ESPORTIVA)	Spain
221	ES/SP_08305006_30_M	1.68658	41.34682	VILAFRANCA DEL PENEDÃˆS (ZONA ESPORTIVA)	Spain
222	ES/SP_08307012_30_M	1.72125	41.21904	VILANOVA I LA GELTRÃš (PL. DE LES DANSES DE VILANOVA	Spain
223	ES/SP_17013001_30_M	3.21285	41.95868	BEGUR (CENTRE D'ESTUDIS DEL MAR)	Spain
224	ES/SP_17079003_30_M	2.81655	41.97639	GIRONA (ESCOLA DE MÃšSICA)	Spain
225	ES/SP_25051001_30_M	1.7768	42.3683	BELLVER DE CERDANYA (CEIP MARE DE DÃU DE TALLÃ)	Spain
226	ES/SP_25120001_30_M	0.6157	41.6158	LLEIDA (IRURITA - PIUS XII)	Spain
227	ES/SP_25172001_30_M	1.19297	41.90665	PONTS (PONENT)	Spain

228	ES/SP_43014001_30_M	0.5817	40.7067	AMPOSTA (SANT DOMÃˆNEC - ITÃ€LIA)	Spain
229	ES/SP_43123005_30_M	1.12017	41.15078	REUS (EL TALLAPEDRA)	Spain
230	ES/SP_43148001_30_M	1.2397	41.15945	TARRAGONA (SANT SALVADOR)	Spain
231	ES/SP_43148022_30_M	1.20077	41.10368	TARRAGONA (UNIVERSITAT LABORAL)	Spain
232	ES/SP_43148028_30_M	1.24165	41.11739	TARRAGONA (PARC DE LA CIUTAT)	Spain
233	ES/SP_45153999_30_M	-4.35042	39.54633	SAN PABLO DE LOS MONTES	Spain
234	IT/SPO.IT2009A_21_GC-FID	8.57611	40.72444	RETE MONITORAGGIO ARIA REGIONE SARDEGNA CENPT	Italy
235	IT/SPO.IT2010A_21_GC-FID	8.40528	40.83139	RETE MONITORAGGIO ARIA REGIONE SARDEGNA CENPT1	Italy
236	IT/SPO.IT2040A_21_GC-FID	9.18806	39.23278	RETE MONITORAGGIO ARIA REGIONE SARDEGNA CENQU1	Italy
237	IT/SPO.IT2056A_21_GC-FID	9.115	39.23583	RETE MONITORAGGIO ARIA REGIONE SARDEGNA CENCA1	Italy
238	IT/SPO.IT2059A_21_GC-FID	8.32472	40.55333	RETE MONITORAGGIO ARIA REGIONE SARDEGNA CEALG1	Italy
239	IT/SPO.IT2072A_20_GC-FID	11.55333	45.10389	RETE MONITORAGGIO ARIA REGIONE SARDEGNA BADIA POLESINE	Italy
240	AT/SPO.05.1000.4937.20.1	13.05329	47.7974	Salzburg Rudolfsplatz	Austria
241	AT/SPO.07.2110.4897.20.1	11.39236	47.26262	Innsbruck Zentrum - Fallmerayerstraße	Austria
242	AT/SPO.08.1919.5565.20.1	9.59745	47.23915	Feldkirch Bärenkreuzung	Austria
243	AT/SPO.09.A23.65520.20.1	16.43455	48.20306	A23 Südosttangente/Wehlistraße	Austria

244	AT/SPO.09.AKC.65447.20.1	16.34982	48.21911	Gemeinde Wien - MA22 Umweltschutz AKH	Austria
245	AT/SPO.09.MBA.4641.20.1	16.30002	48.18837	Hietzinger Kai	Austria
246	IE/SPO.IE.IE0028ASample1_20	-6.27806	53.35389	Dublin Rathmines Wynnefield Road	Ireland
247	IE/SPO.IE.IE0142ASample1_20	-7.79139	53.72556	Longford Town Dublin Road Railway	Ireland
248	IE/SPO.IE.IE0147ASample2_20	-7.26811	52.6388	Kilkenny Seville Lodge	Ireland
249	EE/SPO-EE0021A_00020_100	26.73472	58.37056	Tartu	Estonia
250	EE/SPO-EE0022A_00020_100	28.17917	59.37616	Narva	Estonia
251	EE/SPO-EE0018A_00020_100	24.64946	59.41417	Õismäe	Estonia
252	HU/SPO-HU0022A_00020_100	19.18418	47.43083	Budapest Gilice	Hungary
253	HU/SPO-HU0023A_00020_100	21.62444	47.51333	Debrecen Kalotaszeg	Hungary
254	HU/SPO-HU0025A_00020_100	17.64974	47.67611	Gyor Ifjusag	Hungary
255	HU/SPO-HU0027A_00020_100	20.79001	48.10694	Miskolc Buza	Hungary
256	HU/SPO-HU0030A_00020_100	18.22529	46.07111	Pecs Szabadsag	Hungary
257	HU/SPO-HU0032A_00020_100	18.92	47.30667	Szazhalombatta	Hungary
258	HU/SPO-HU0033A_00020_100	18.93611	46.97611	Dunaujvaros	Hungary
259	HU/SPO-HU0034A_00020_100	17.90112	47.09111	Veszprem	Hungary
260	HU/SPO-HU0035A_00020_100	16.57501	47.69194	Sopron	Hungary
261	HU/SPO-HU0036A_00020_100	18.96001	47.56194	Budapest Pesthidegkut	Hungary
262	HU/SPO-HU0039A_00020_100	18.74612	47.79	Esztergom	Hungary
263	HU/SPO-HU0040A_00020_100	16.83889	47.67194	Sarrod	Hungary

264	HU/SPO-HU0057A_00020_100	20.15305	46.26661	Szeged2	Hungary
265	BE/SPO-BESMA01_00020_100	5.72562	50.98158	MAASMECHELEN	Belgium
266	BE/SPO-BESN029_00020_100	2.58232	51.01628	VEURNE	Belgium
267	BE/SPO-BESN035_00020_100	4.83762	50.97754	AARSCHOT	Belgium
268	BE/SPO-BESN045_00020_100	5.36838	50.93971	HASSELT	Belgium
269	BE/SPO-BESN047_00020_100	5.35321	50.93554	HASSELT	Belgium
270	BE/SPO-BESR701_00020_100	3.7293	51.05833	GENT	Belgium
271	BE/SPO-BESR801_00020_100	4.43182	51.20966	ANTWERPEN	Belgium
272	BE/SPO-BESR893_00020_100	4.38577	51.28138	ANTWERPEN	Belgium
273	BE/SPO-BEVLU11_00020_100	4.69113	50.87966	LEUVEN	Belgium
274	BE/SPO-BEVM204_00020_100	5.61115	50.61192	ANGLEUR	Belgium
275	BE/SPO-BEVMOU1_00020_100	3.24136	50.75317	MOUSCRON	Belgium
276	BE/SPO-BEVN060_00020_100	3.45762	50.61672	HAVINNES	Belgium
277	BE/SPO-BEVN063_00020_100	4.66829	50.65544	CORROY L.G.	Belgium
278	BE/SPO-BEVN066_00020_100	6.00233	50.62886	EUPEN	Belgium
279	BE/SPO-BEVN070_00020_100	3.93971	50.46519	MONS	Belgium
280	BE/SPO-BEVN085_00020_100	6.00174	50.30321	VIELSALM	Belgium
281	BE/SPO-BEVN100_00020_100	4.59476	50.09568	DOURBES	Belgium
282	BE/SPO-BEVN113_00020_100	5.59302	50.02703	SAINT-ODE	Belgium
283	BE/SPO-BEVNM01_00020_100	4.87241	50.4632	NAMUR	Belgium

284	BE/SPO-BEVR001_00020_100	4.33382	50.84967	MOLENBEEK	Belgium
285	BE/SPO-BEVR002_00020_100	4.38472	50.82513	IXELLES	Belgium
286	BE/SPO-BEVR221_00020_100	5.62784	50.65844	LIEGE	Belgium
287	BE/SPO-BEVR240_00020_100	5.39745	50.58361	ENGIS	Belgium
288	BE/SPO-BEVR501_00020_100	4.45217	50.40931	CHARLEROI	Belgium
289	BE/SPO-BEVR502_00020_100	4.45868	50.429	LODELINSART	Belgium
290	DK/SPO-DK0045A_00020_100	12.5614	55.70028	Copenhagen	Denmark

Table S2. Summary of cause-specific deaths, GDP per capita and region classification in 46 countries or regions included in the study.

Country/Region	Locations (n)	Study periods	Cardiovascular deaths (n)	Respiratory deaths (n)	GDP per capita (US dollars)	Regions by GDP	Regions by WHO
Argentina	3	2005–2015	NA	NA	10,079	1	AMRO
Australia	3	2001–2009	NA	NA	33,244	2	WPRO
Brazil	18	2001–2018	1,002,641	386,218	8,087	1	AMRO
Canada	26	2001–2015	597,878	167,826	41,154	2	AMRO
Chile	4	2004–2014	NA	NA	13,474	2	AMRO
China	15	2001–2015	429,470	137,097	1,101	1	WPRO
Colombia	5	2001–2013	221,823	83,798	4,840	1	AMRO
Costa Rica	1	2001–2017	9,080	2,601	7,653	1	AMRO
Czech Republic	4	2001–2015	228,834	28,200	16,377	2	EURO
Ecuador	2	2014–2018	32,833	12,989	6,191	1	AMRO
Estonia	5	2001–2018	72,520	4,789	14,825	2	EURO
Finland	1	2001–2014	37,115	5,470	42,733	2	EURO
France	18	2001–2015	NA	102,584	37,195	2	EURO

France Caribbean	2	2001–2015	NA	NA	37,195	2	EURO
France Guiana	1	2001–2015	NA	NA	37,195	2	EURO
Germany	12	2001–2015	NA	NA	38,705	2	EURO
Greece	1	2001–2010	136,194	28,771	23,216	2	EURO
Guatemala	1	2009–2016	NA	NA	3,445	1	AMRO
Iran	2	2002–2015	357,680	59,394	5,505	1	EMRO
Ireland	6	2001–2007	78,424	42,367	45,229	2	EURO
Israel	1	2001–2019	NA	NA	30,727	2	EURO
Italy	16	2001–2010	156,895	81,083	37,393	2	EURO
Japan	47	2001–2015	4,935,437	2,616,276	39,259	2	WPRO
Kuwait	1	2001–2016	33,649	5,512	36,981	2	EMRO
Mexico	10	2001–2014	652,478	239,190	9,511	1	AMRO
Moldova	4	2001–2010	NA	NA	1,472	1	EURO
Netherland	5	2001–2016	NA	NA	45,835	2	EURO
Norway	1	2001–2018	21,471	6,652	77,334	2	EURO

Panama	1	2013–2016	3,862	971	13,205	2	AMRO
Paraguay	1	2004–2019	15,365	4,445	4,788	1	AMRO
Peru	18	2008–2014	NA	NA	5,573	1	AMRO
Philippines	13	2006–2019	296,938	118,536	3,069	1	WPRO
Portugal	6	2001–2018	283,491	103,066	20,134	2	EURO
Puerto Rico	1	2009–2016	NA	NA	28,164	2	AMRO
Romania	8	2001–2016	NA	NA	7,040	2	EURO
South Africa	52	2001–2013	1,039,766	898,181	6,057	1	AFRO
South Korea	36	2001–2018	578,329	194,571	23,042	2	WPRO
Spain	52	2001–2014	559,231	206,989	27,365	2	EURO
Sweden	3	2001–2016	168,968	30,440	48,778	2	EURO
Switzerland	8	2001–2013	56,994	10,174	65,556	2	EURO
Taiwan	3	2001–2014	188,155	89,328	17,743	2	WPRO
Thailand	62	2001–2008	269,502	186,057	2,933	1	WPRO
UK	67	2001–2016	1,045,534	462,564	41,061	2	EURO

Uruguay	1	2012–2016	NA	NA	17,230	2	AMRO
USA	208	2001–2006	2,274,862	727,107	41,129	2	AMRO
Vietnam	2	2009–2013	24,433	8,970	6,488	1	WPRO

Abbreviations: GDP, Gross Domestic Product; WHO, World Health Organization; AMRO, the Region of the Americas; WPRO, the Western-Pacific Region; EURO, the European Region; EMRO, the Eastern Mediterranean Region; AFRO, the African Region.

Notes: Regions by GDP were classified by GDP per capita during the study period according to World Bank, including low- and middle-income (corresponding to 1 in the table) and high-income (corresponding to 2 in the table) countries or regions.

Table S3. Descriptive statistics on daily levels (mean ± SD) of weather conditions and co-pollutants available in the analysis.

Country/Region	Temperature (°C)	Humidity (%)	PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	NO_2 (μg/m^3)	SO_2 (μg/m^3)	O_3 (μg/m^3)	CO (mg/m^3)
Total	15.20 (9.21)	70.30 (14.54)	30.93 (30.85)	14.41 (16.47)	28.06 (17.37)	8.92 (15.97)	51.46 (25.28)	0.74 (2.78)
Argentina	18.13 (6.00)	69.24 (12.99)	NA	NA	NA	NA	NA	NA
Australia	18.39 (4.69)	69.18 (11.69)	19.84 (9.15)	6.97 (4.51)	21.60 (11.05)	5.03 (7.36)	31.45 (12.49)	0.48 (0.37)
Brazil	23.47 (4.13)	73.24 (12.81)	42.40 (20.12)	NA	93.72 (43.64)	10.98 (5.80)	86.18 (39.87)	1.33 (0.77)
Canada	6.97 (10.97)	72.69 (11.56)	17.37 (12.29)	8.22 (6.53)	24.49 (13.98)	6.42 (10.69)	44.86 (20.35)	2.29 (8.69)
Chile	13.59 (4.68)	NA	56.86 (41.68)	32.08 (37.51)	25.77 (21.08)	NA	24.43 (13.72)	0.83 (0.77)
China	14.87 (10.92)	65.37 (17.68)	113.97 (75.32)	108.77 (89.83)	44.84 (22.78)	50.56 (43.88)	65.94 (50.34)	1.11 (0.72)
Colombia	23.47 (5.34)	NA	62.67 (19.25)	NA	31.48 (10.87)	17.98 (9.81)	23.92 (9.68)	NA
Costa Rica	22.70 (1.14)	NA	NA	NA	NA	NA	NA	NA
Czech Republic	9.24 (8.40)	75.73 (12.75)	31.96 (20.48)	NA	31.46 (11.93)	6.02 (4.77)	48.29 (22.45)	NA
Ecuador	21.04 (5.52)	NA	NA	16.71 (5.84)	27.56 (7.33)	16.71 (5.84)	21.70 (9.95)	0.73 (0.19)
Estonia	6.19 (9.07)	80.98 (12.52)	17.50 (13.28)	8.24 (6.57)	13.06 (10.74)	3.47 (7.80)	33.19 (12.25)	NA

Finland	6.43 (9.13)	74.26 (13.74)	19.99 (17.07)	16.84 (14.45)	8.55 (6.07)	8.47 (7.75)	51.38 (16.38)	0.26 (0.14)
France	12.67 (6.88)	72.38 (11.35)	20.42 (9.79)	16.32 (11.33)	26.48 (13.69)	NA	69.34 (31.02)	NA
France Caribbean	26.85 (1.38)	75.44 (5.13)	NA	NA	NA	NA	NA	NA
France Guiana	26.99 (0.79)	78.85 (4.82)	NA	NA	NA	NA	NA	NA
Germany	10.35 (7.34)	NA	23.53 (14.21)	15.37 (11.50)	28.98 (13.35)	4.63 (4.05)	40.68 (23.11)	0.36 (0.20)
Greece	18.67 (7.51)	64.76 (14.74)	43.95 (23.49)	21.92 (9.98)	51.54 (15.87)	NA	50.34 (18.89)	1.43 (0.80)
Guatemala	19.39 (1.62)	NA	NA	NA	NA	NA	NA	NA
Iran	16.86 (9.79)	49.10 (20.77)	87.54 (45.47)	39.79 (16.38)	88.46 (61.70)	98.88 (97.40)	46.51 (36.09)	3.77 (2.20)
Ireland	10.12 (4.31)	83.93 (7.20)	NA	NA	NA	NA	NA	NA
Israel	20.97 (5.56)	NA	50.80 (59.31)	22.43 (16.82)	32.96 (20.44)	NA	52.41 (20.21)	NA
Italy	15.62 (7.59)	71.25 (13.80)	NA	NA	NA	NA	NA	NA
Japan	15.56 (8.68)	68.61 (12.44)	33.21 (17.66)	20.75 (11.07)	24.00 (10.84)	4.26 (2.31)	49.38 (23.79)	0.61 (0.26)
Kuwait	27.12 (9.82)	NA	191.02 (200.65)	NA	NA	NA	90.37 (30.97)	NA
Mexico	18.64 (4.85)	57.30 (17.55)	57.64 (29.51)	27.00 (12.61)	NA	NA	71.87 (30.28)	NA

Moldova	10.70 (9.65)	NA	NA	NA	NA	NA	NA	NA
Netherland	10.73 (6.17)	81.00 (9.67)	NA	NA	NA	NA	NA	NA
Norway	5.63 (8.30)	NA	21.93 (12.28)	10.69 (5.92)	NA	NA	42.58 (16.95)	NA
Panama	28.12 (1.14)	NA	NA	NA	NA	NA	NA	NA
Paraguay	23.31 (5.34)	NA	NA	NA	NA	NA	NA	NA
Peru	17.93 (6.16)	NA	77.84 (26.01)	NA	26.75 (10.19)	12.76 (7.47)	14.40 (5.13)	NA
Philippines	28.25 (1.50)	77.29 (9.38)	NA	NA	NA	NA	NA	NA
Portugal	16.34 (5.54)	NA	23.49 (17.04)	10.60 (18.99)	16.74 (14.62)	2.96 (4.29)	54.55 (21.67)	0.34 (0.19)
Puerto Rico	26.83 (1.57)	NA	26.00 (14.59)	NA	NA	4.56 (9.24)	22.56 (11.69)	0.99 (0.43)
Romania	11.00 (9.41)	75.22 (13.47)	32.88 (20.19)	16.47 (12.19)	28.77 (18.71)	8.28 (6.73)	38.57 (22.05)	0.38 (0.57)
South Africa	18.06 (5.40)	NA	60.72 (38.10)	31.74 (19.57)	NA	NA	48.25 (20.61)	NA
South Korea	13.18 (9.69)	66.15 (16.06)	NA	NA	NA	NA	NA	NA
Spain	15.64 (7.04)	NA	28.58 (15.38)	12.99 (8.47)	28.55 (13.82)	5.64 (3.98)	50.52 (20.47)	0.41 (0.23)
Sweden	8.68 (7.49)	79.08 (12.27)	15.15 (9.30)	8.15 (5.46)	31.99 (11.16)	NA	43.45 (13.64)	1.02 (0.49)
Switzerland	10.51 (7.67)	74.23 (12.52)	23.65 (15.47)	19.26 (13.10)	32.10 (16.63)	4.43 (4.30)	49.54 (24.50)	0.53 (0.27)

Taiwan	24.02 (4.90)	74.99 (7.69)	63.49 (32.35)	37.90 (20.83)	44.06 (16.18)	14.12 (8.18)	83.95 (37.93)	0.76 (0.30)
Thailand	27.61 (2.41)	74.76 (8.90)	50.13 (30.10)	NA	25.41 (15.99)	10.52 (10.23)	35.45 (18.46)	0.70 (0.38)
UK	10.58 (5.28)	NA	20.39 (10.98)	12.32 (8.95)	26.79 (14.78)	6.24 (7.78)	43.15 (19.61)	0.32 (0.21)
Uruguay	18.63 (5.64)	NA	NA	NA	NA	NA	NA	NA
USA	14.08 (9.92)	66.77 (16.57)	24.56 (14.48)	12.54 (7.96)	27.85 (16.14)	9.90 (10.37)	56.33 (22.75)	0.65 (0.40)
Vietnam	26.91 (3.48)	78.46 (11.31)	NA	NA	NA	NA	NA	NA

Abbreviations: SD, standard deviation; PM_{10}, particulate matter with an aerodynamic diameter ≤ 10 μm; $PM_{2.5}$, particulate matter with an aerodynamic diameter ≤ 2.5 μm; NO_2, nitrogen dioxide; SO_2, sulfur dioxide; O_3, ozone; CO, carbon oxide.

Table S4. Pearson's correlation coefficients between BTEX, air pollutants, and weather conditions in the analysis.

	Benzene	Toluene	Xylenes	BTEX	PM_{10}	$PM_{2.5}$	NO_2	SO_2	O_3	CO	Temperature
Toluene	0.86										
Xylenes	0.82	0.95									
BTEX	0.92	0.97	0.96								
PM_{10}	0.27	0.31	0.28	0.30							
$PM_{2.5}$	0.44	0.47	0.43	0.46	0.73						
NO_2	0.50	0.45	0.46	0.48	0.43	0.47					
SO_2	0.31	0.27	0.28	0.29	0.30	0.32	0.40				
O_3	-0.17	-0.17	-0.22	-0.20	0.14	0.07	-0.29	-0.07			
CO	0.37	0.33	0.35	0.36	0.31	0.39	0.52	0.30	-0.22		
Temperature	-0.35	-0.13	-0.18	-0.22	0.12	0.01	-0.32	-0.17	0.36	-0.24	
Humidity	0.01	0.06	0.07	0.05	-0.21	0.08	-0.03	-0.16	-0.42	0.06	-0.07

Abbreviations as in Table S2.

Note: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene.

Table S5. Effect estimates and generalized cross-validation scores on different lag periods of BTEX in the analysis.

Lag periods	Benzene		Toluene		Xylenes		BTEX	
	Effect estimates	**GCVs**	**Effect estimates**	**GCVs**	**Effect estimates**	**GCVs**	**Effect estimates**	**GCVs**
Lag 0	0.35 (0.29, 0.40)	1.1191	0.40 (0.34, 0.46)	1.1190	0.35 (0.28, 0.41)	1.1191	0.37 (0.31, 0.43)	1.1191
Lag 1	0.36 (0.30, 0.41)	1.1191	0.43 (0.38, 0.48)	1.1190	0.43 (0.37, 0.49)	1.1191	0.42 (0.37, 0.48)	1.1190
Lag 2	0.11 (0.06, 0.16)	1.1193	0.08 (0.03, 0.13)	1.1193	0.12 (0.07, 0.18)	1.1192	0.10 (0.05, 0.15)	1.1193
Lag 3	-0.08 (-0.13, -0.04)	1.1194	-0.15 (-0.20, -0.11)	1.1194	-0.12 (-0.17, -0.07)	1.1194	-0.13 (-0.18, -0.08)	1.1194
Lag 0–1	0.49 (0.42, 0.55)	1.1191	0.58 (0.52, 0.65)	1.1189	0.56 (0.48, 0.63)	1.1190	0.55 (0.48, 0.62)	1.1190
Lag 0–2	0.50 (0.42, 0.57)	1.1191	0.58 (0.50, 0.66)	1.1190	0.59 (0.50, 0.67)	1.1190	0.57 (0.49, 0.65)	1.1190
Lag 0–3	0.42 (0.35, 0.50)	1.1192	0.47 (0.39, 0.56)	1.1192	0.49 (0.40, 0.58)	1.1192	0.47 (0.39, 0.56)	1.1192

Abbreviations: GCV, generalized cross-validation score.

Notes: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene; the effect estimates denote the percentage changes and 95% confidence intervals in daily total deaths associated with an IQR increment of BTEX concentrations.

Table S6. Percentage changes and 95% confidence intervals in daily cardiovascular deaths associated with an interquartile range increment of BTEX concentrations on lag 0–2 days by country.

Country/Region	Benzene	Toluene	Xylenes	BTEX
Total	**0.38 (0.27, 0.48)**	**0.44 (0.33, 0.56)**	**0.41 (0.29, 0.53)**	**0.42 (0.30, 0.54)**
Brazil	0.56 (0.25, 0.88)	0.75 (0.37, 1.12)	0.80 (0.40, 1.21)	0.72 (0.36, 1.08)
Canada	0.39 (0.01, 0.77)	0.48 (0.11, 0.86)	0.47 (0.08, 0.86)	0.48 (0.10, 0.86)
China	0.66 (0.27, 1.05)	0.83 (0.40, 1.26)	0.92 (0.44, 1.41)	0.81 (0.38, 1.24)
Colombia	0.30 (-0.13, 0.73)	0.34 (-0.15, 0.82)	0.32 (-0.23, 0.88)	0.34 (-0.13, 0.82)
Costa Rica	0.40 (-0.07, 0.88)	0.48 (-0.05, 1.02)	0.49 (-0.14, 1.11)	0.47 (-0.05, 0.99)
Czech Republic	0.37 (-0.06, 0.81)	0.42 (-0.03, 0.88)	0.36 (-0.10, 0.83)	0.41 (-0.04, 0.85)
Ecuador	0.43 (-0.04, 0.90)	0.53 (0.00, 1.06)	0.57 (-0.04, 1.19)	0.52 (0.00, 1.03)
Estonia	0.35 (-0.11, 0.81)	0.40 (-0.10, 0.91)	0.29 (-0.28, 0.85)	0.38 (-0.11, 0.87)
Finland	0.33 (-0.14, 0.80)	0.38 (-0.14, 0.90)	0.32 (-0.27, 0.92)	0.37 (-0.14, 0.88)
Greece	0.31 (-0.13, 0.75)	0.53 (0.05, 1.02)	0.57 (0.01, 1.13)	0.45 (-0.02, 0.94)
Iran	0.49 (0.06, 0.93)	0.62 (0.15, 1.09)	0.67 (0.13, 1.21)	0.60 (0.13, 1.06)

Ireland	0.37 (-0.07, 0.81)	0.42 (-0.05, 0.89)	0.23 (-0.22, 0.67)	0.36 (-0.08, 0.81)
Italy	0.50 (0.07, 0.94)	0.61 (0.14, 1.08)	0.61 (0.08, 1.15)	0.57 (0.11, 1.04)
Japan	0.43 (0.20, 0.67)	0.39 (0.14, 0.64)	0.27 (0.00, 0.53)	0.36 (0.11, 0.61)
Kuwait	0.41 (-0.06, 0.88)	0.51 (-0.01, 1.04)	0.54 (-0.07, 1.15)	0.49 (-0.02, 1.01)
Mexico	0.68 (0.33, 1.02)	0.88 (0.46, 1.31)	1.00 (0.52, 1.47)	0.90 (0.48, 1.32)
Norway	0.40 (-0.07, 0.87)	0.51 (-0.01, 1.04)	0.46 (-0.14, 1.07)	0.47 (-0.05, 0.98)
Panama	0.42 (-0.06, 0.90)	0.50 (-0.03, 1.04)	0.51 (-0.11, 1.14)	0.48 (-0.04, 1.01)
Paraguay	0.41 (-0.06, 0.88)	0.46 (-0.06, 0.99)	0.47 (-0.14, 1.09)	0.46 (-0.05, 0.98)
Philippines	0.71 (0.30, 1.12)	0.84 (0.39, 1.28)	0.91 (0.42, 1.41)	0.81 (0.37, 1.25)
Portugal	0.11 (-0.20, 0.41)	0.11 (-0.18, 0.40)	0.32 (-0.12, 0.77)	0.15 (-0.18, 0.47)
South Africa	0.28 (0.03, 0.54)	0.50 (0.20, 0.80)	0.70 (0.31, 1.08)	0.49 (0.18, 0.80)
South Korea	0.61 (0.23, 0.99)	0.73 (0.32, 1.14)	0.75 (0.30, 1.19)	0.71 (0.30, 1.11)
Spain	0.20 (-0.14, 0.55)	0.17 (-0.17, 0.51)	0.29 (-0.12, 0.69)	0.26 (-0.10, 0.62)
Sweden	0.17 (-0.27, 0.61)	0.21 (-0.26, 0.69)	0.12 (-0.36, 0.61)	0.20 (-0.26, 0.66)
Switzerland	0.45 (-0.01, 0.92)	0.51 (0.00, 1.02)	0.56 (-0.02, 1.14)	0.52 (0.02, 1.02)
Taiwan	0.25 (-0.19, 0.68)	0.47 (-0.02, 0.95)	0.52 (-0.03, 1.07)	0.45 (-0.02, 0.93)

Thailand	0.48 (0.07, 0.90)	0.52 (0.08, 0.96)	0.70 (0.20, 1.20)	0.55 (0.11, 0.99)
UK	0.19 (-0.10, 0.48)	0.16 (-0.14, 0.46)	-0.02 (-0.32, 0.28)	0.09 (-0.20, 0.39)
USA	0.02 (-0.16, 0.20)	0.35 (0.08, 0.62)	0.35 (0.06, 0.64)	0.34 (0.07, 0.61)
Vietnam	0.39 (-0.08, 0.86)	0.50 (-0.02, 1.03)	0.52 (-0.09, 1.14)	0.47 (-0.04, 0.99)

Note: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene.

Table S7. Percentage changes and 95% confidence intervals in daily respiratory deaths associated with an interquartile range increment of BTEX concentrations on lag 0–2 days by country.

Country/Region	Benzene	Toluene	Xylenes	BTEX
Total	**0.61 (0.45, 0.77)**	**0.70 (0.52, 0.87)**	**0.65 (0.47, 0.84)**	**0.68 (0.50, 0.86)**
Brazil	0.58 (0.02, 1.15)	0.84 (0.13, 1.55)	0.95 (0.22, 1.69)	0.84 (0.15, 1.53)
Canada	0.59 (-0.18, 1.38)	0.44 (-0.34, 1.22)	0.36 (-0.41, 1.14)	0.42 (-0.38, 1.23)
China	1.45 (0.63, 2.28)	1.83 (0.90, 2.78)	2.01 (1.03, 3.01)	1.88 (0.94, 2.83)
Colombia	0.93 (0.04, 1.83)	1.11 (0.03, 2.21)	0.97 (-0.17, 2.12)	1.08 (-0.01, 2.17)
Costa Rica	0.61 (-0.50, 1.72)	0.66 (-0.70, 2.05)	0.64 (-0.78, 2.09)	0.66 (-0.70, 2.04)
Czech Republic	0.76 (-0.27, 1.80)	0.71 (-0.46, 1.89)	0.59 (-0.54, 1.73)	0.74 (-0.44, 1.92)
Ecuador	0.65 (-0.41, 1.72)	0.48 (-0.83, 1.81)	0.42 (-0.95, 1.81)	0.51 (-0.80, 1.84)
Estonia	0.45 (-0.64, 1.55)	0.38 (-0.94, 1.73)	0.30 (-1.08, 1.69)	0.37 (-0.96, 1.71)
Finland	0.50 (-0.58, 1.60)	0.49 (-0.84, 1.83)	0.35 (-1.03, 1.75)	0.46 (-0.86, 1.80)
France	-0.02 (-0.83, 0.80)	-0.34 (-1.20, 0.53)	-0.64 (-1.47, 0.19)	-0.38 (-1.25, 0.49)
Greece	0.44 (-0.56, 1.44)	0.74 (-0.45, 1.94)	0.82 (-0.45, 2.10)	0.64 (-0.56, 1.85)

Iran	0.57 (-0.44, 1.59)	0.53 (-0.64, 1.72)	0.45 (-0.79, 1.70)	0.52 (-0.67, 1.72)
Ireland	0.56 (-0.32, 1.46)	0.50 (-0.44, 1.44)	0.41 (-0.33, 1.16)	0.50 (-0.38, 1.39)
Italy	0.24 (-0.59, 1.07)	0.34 (-0.55, 1.24)	0.40 (-0.52, 1.32)	0.30 (-0.60, 1.21)
Japan	1.24 (0.84, 1.65)	1.51 (1.06, 1.96)	1.46 (1.00, 1.93)	1.50 (1.05, 1.95)
Kuwait	0.53 (-0.56, 1.63)	0.57 (-0.77, 1.93)	0.59 (-0.82, 2.01)	0.57 (-0.77, 1.93)
Mexico	0.75 (0.06, 1.45)	1.23 (0.36, 2.12)	1.33 (0.43, 2.24)	1.23 (0.35, 2.11)
Norway	0.41 (-0.68, 1.50)	0.27 (-1.05, 1.60)	0.18 (-1.16, 1.54)	0.29 (-1.02, 1.63)
Panama	0.61 (-0.49, 1.73)	0.67 (-0.70, 2.06)	0.65 (-0.78, 2.10)	0.66 (-0.70, 2.05)
Paraguay	0.76 (-0.30, 1.83)	0.79 (-0.53, 2.12)	0.64 (-0.75, 2.05)	0.81 (-0.50, 2.13)
Philippines	1.11 (0.29, 1.94)	1.18 (0.26, 2.11)	1.14 (0.20, 2.09)	1.19 (0.27, 2.12)
Portugal	0.15 (-0.42, 0.72)	0.10 (-0.47, 0.68)	-0.04 (-0.95, 0.88)	0.11 (-0.54, 0.77)
South Africa	0.25 (-0.14, 0.65)	0.46 (0.00, 0.92)	0.69 (0.13, 1.25)	0.46 (-0.02, 0.95)
South Korea	1.01 (0.26, 1.76)	1.00 (0.17, 1.84)	0.71 (-0.14, 1.58)	0.93 (0.09, 1.78)
Spain	0.00 (-0.66, 0.66)	0.07 (-0.59, 0.74)	0.45 (-0.30, 1.20)	0.12 (-0.60, 0.85)
Sweden	0.00 (-1.02, 1.02)	-0.35 (-1.52, 0.84)	-0.35 (-1.46, 0.77)	-0.28 (-1.44, 0.89)
Switzerland	0.36 (-0.71, 1.44)	0.30 (-0.98, 1.59)	0.31 (-1.01, 1.65)	0.31 (-0.97, 1.61)

Taiwan	0.33 (-0.57, 1.25)	0.53 (-0.53, 1.59)	0.49 (-0.60, 1.60)	0.50 (-0.56, 1.57)
Thailand	0.55 (-0.18, 1.28)	0.40 (-0.35, 1.15)	0.59 (-0.22, 1.40)	0.52 (-0.26, 1.30)
UK	0.51 (0.00, 1.03)	0.35 (-0.18, 0.88)	-0.04 (-0.57, 0.49)	0.20 (-0.33, 0.74)
USA	0.03 (-0.32, 0.37)	0.22 (-0.31, 0.74)	0.26 (-0.27, 0.80)	0.24 (-0.28, 0.77)
Vietnam	0.64 (-0.45, 1.73)	0.78 (-0.54, 2.11)	0.78 (-0.60, 2.18)	0.74 (-0.58, 2.08)

Note: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene.

Table S8. Multicollinearity diagnostics through variance inflation factors (VIF) across the two-pollutant models.

Pollutant	Locations (n)	Benzene	Toluene	Xylenes	BTEX
BTEX chemicals	368	1.84 (0.50)	1.45 (0.29)	1.51 (0.31)	1.58 (0.36)
PM_{10}	368	1.34 (0.24)	1.33 (0.25)	1.31 (0.25)	1.33 (0.26)
BTEX chemicals	358	1.73 (0.46)	1.39 (0.29)	1.48 (0.31)	1.52 (0.35)
$PM_{2.5}$	358	1.31 (0.19)	1.30 (0.18)	1.28 (0.19)	1.30 (0.19)
BTEX chemicals	345	1.69 (0.44)	1.39 (0.29)	1.50 (0.30)	1.53 (0.34)
NO_2	345	1.55 (0.31)	1.58 (0.35)	1.58 (0.35)	1.58 (0.35)
BTEX chemicals	316	1.58 (0.40)	1.26 (0.25)	1.38 (0.28)	1.40 (0.32)
SO_2	316	1.32 (0.37)	1.32 (0.38)	1.33 (0.39)	1.33 (0.38)
BTEX chemicals	405	1.51 (0.44)	1.28 (0.24)	1.37 (0.29)	1.38 (0.33)
O_3	405	1.41 (0.40)	1.43 (0.42)	1.45 (0.43)	1.44 (0.42)
BTEX chemicals	297	1.61 (0.43)	1.30 (0.22)	1.43 (0.28)	1.44 (0.30)
CO	297	1.47 (0.38)	1.48 (0.38)	1.49 (0.40)	1.49 (0.39)

Abbreviations: PM_{10}, particulate matter with an aerodynamic diameter ≤ 10 µm; $PM_{2.5}$, particulate matter with an aerodynamic diameter ≤ 2.5 µm; NO_2, nitrogen dioxide; SO_2, sulfur dioxide; O_3, ozone; CO, carbon oxide.

Note: xylenes exposure is a summation of ethylbenzene, m/p-xylene, and o-xylene. Results were presented as the mean and standard deviation across the locations.

Table S9. Percentage change in association between BTEX and total mortality per interquartile range increment in location characteristics.

Variable	IQR	Percentage change	P-value
Annual mean temperature (°C)	8.17	0.18 (0.07, 0.30)	0.002
Gross domestic product (US $)	33,041	-0.36 (-0.52, -0.20)	<0.001
Latitude (°)	24.31	-0.15 (-0.22, -0.08)	<0.001
Fossil CO_2 emission by transport ($kg/m^2/s$)	3.60E-07	0.01 (-0.05, 0.06)	0.762
Fossil CO_2 emission by industry ($kg/m^2/s$)	7.53E-07	0.02 (0.01, 0.03)	0.002

Abbreviations: IQR, interquartile range; CO_2, carbon dioxide.

Notes: the effects of location characteristics were assessed by including each variable in the meta-regression model separately. P-value denotes the statistical significance for the variable.

Table S10. Stratified results of percentage changes and 95% confidence intervals in daily total deaths associated with an interquartile range increment of BTEX concentrations on lag 0–2 days.

Classification	Group	Benzene		Toluene		Xylenes		BTEX	
		Estimates	p-value	Estimates	p-value	Estimates	p-value	Estimates	p-value
WHO region	AMRO	0.15 (-0.17, 0.48)	Ref	0.64 (0.23, 1.06)	Ref	0.66 (0.17, 1.15)	Ref	0.64 (0.21, 1.07)	Ref
	WPRO	0.70 (0.37, 1.04)	0.021	0.88 (0.47, 1.30)	0.42	0.90 (0.41, 1.39)	0.51	0.88 (0.45, 1.32)	0.44
	EURO	0.18 (-0.16, 0.51)	0.10	0.15 (-0.26, 0.57)	0.10	0.11 (-0.37, 0.60)	0.12	0.15 (-0.28, 0.58)	0.11
GDP	Low- and middle-income	0.46 (0.19, 0.74)	0.20	0.75 (0.32, 1.18)	0.32	1.04 (0.41, 1.69)	0.18	0.78 (0.34, 1.24)	0.30
	High-income	0.21 (-0.06, 0.48)		0.44 (0.01, 0.86)		0.43 (-0.20, 1.06)		0.45 (0.01, 0.89)	
Gini index	>0.5	0.21 (0.00, 0.42)	0.20	0.67 (0.37, 0.97)	0.25	0.83 (0.40, 1.27)	0.17	0.68 (0.36, 1.01)	0.29
	≤0.5	0.41 (0.19, 0.63)		0.42 (0.13, 0.72)		0.40 (-0.02, 0.83)		0.44 (0.12, 0.76)	
Educational attainment (% Total)	≤75	0.48 (0.40, 0.56)	0.26	0.52 (0.26, 0.79)	0.99	0.90 (0.38, 1.42)	0.20	0.60 (0.30, 0.91)	0.62
	>75	0.41 (0.34, 0.49)		0.53 (0.26, 0.79)		0.42 (-0.09, 0.93)		0.50 (0.19, 0.80)	
Health expenditure (% GDP)	≤9	0.49 (0.24, 0.74)	0.041	0.70 (0.29, 1.10)	0.16	0.79 (0.27, 1.32)	0.16	0.72 (0.31, 1.13)	0.15
	>9	0.12 (-0.13, 0.37)		0.29 (-0.12, 0.69)		0.26 (-0.27, 0.78)		0.29 (-0.12, 0.70)	

Abbreviations as in Table S1.

Notes: The African Region and the Eastern Mediterranean Region were excluded from regional analysis classified by WHO because they only included one or two countries. Educational attainment refers to the percentage of population ages 25 and over that attained or completed lower secondary education. Health expenditure refers to the level of current health expenditure expressed as a percentage of GDP. Z tests were applied to assess statistical significance for differences among groups.

Table S11. Index weights for weighted quantile sum analysis.

Country/Region	Locations (n)	Benzene	Toluene	Xylenes
Total	757	0.36	0.31	0.34
Argentina	3	0.62	0.14	0.24
Australia	3	0.08	0.45	0.46
Brazil	18	0.44	0.23	0.33
Canada	26	0.37	0.31	0.32
Chile	4	0.29	0.32	0.39
China	15	0.23	0.33	0.44
Colombia	5	0.42	0.25	0.33
Costa Rica	1	0.08	0.00	0.92
Czech Republic	4	0.60	0.10	0.30
Ecuador	2	0.68	0.08	0.24
Estonia	5	0.48	0.27	0.24

Finland	1	0.01	0.07	0.92
France	18	0.45	0.30	0.25
France Caribbean	2	0.35	0.23	0.42
France Guiana	1	0.05	0.72	0.23
Germany	12	0.55	0.19	0.26
Greece	1	0.11	0.71	0.19
Guatemala	1	0.45	0.13	0.42
Iran	2	0.35	0.24	0.42
Ireland	6	0.19	0.51	0.30
Israel	1	0.23	0.20	0.57
Italy	16	0.47	0.28	0.26
Japan	47	0.31	0.39	0.30
Kuwait	1	0.74	0.05	0.21
Mexico	10	0.28	0.36	0.36
Moldova	4	0.27	0.29	0.44

Netherland	5	0.40	0.24	0.36
Norway	1	0.04	0.26	0.71
Panama	1	0.27	0.37	0.36
Paraguay	1	0.94	0.02	0.04
Peru	18	0.36	0.27	0.37
Philippines	13	0.37	0.28	0.35
Portugal	6	0.18	0.30	0.53
Puerto Rico	1	0.97	0.02	0.01
Romania	8	0.29	0.44	0.27
South Africa	52	0.28	0.33	0.40
South Korea	36	0.33	0.27	0.40
Spain	52	0.26	0.36	0.38
Sweden	3	0.12	0.26	0.62
Switzerland	8	0.35	0.35	0.29
Taiwan	3	0.09	0.32	0.58

Thailand	62	0.31	0.25	0.44
UK	67	0.38	0.34	0.28
Uruguay	1	0.86	0.10	0.04
USA	208	0.40	0.30	0.30
Vietnam	2	0.30	0.22	0.48

Note: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene.

Table S12. Effect estimates of BTEX exposure in the sensitivity analyses.

Model	Locations (n)	Benzene	Toluene	Xylenes	BTEX
S1					
df = 6/year	757	0.49 (0.42, 0.56)	0.57 (0.50, 0.65)	0.58 (0.50, 0.67)	0.56 (0.48, 0.64)
df = 7/year	757	0.50 (0.42, 0.57)	0.58 (0.50, 0.66)	0.59 (0.50, 0.67)	0.57 (0.49, 0.65)
df = 8/year	757	0.50 (0.43, 0.57)	0.59 (0.51, 0.67)	0.60 (0.52, 0.69)	0.58 (0.50, 0.66)
df = 9/year	757	0.51 (0.44, 0.58)	0.61 (0.53, 0.69)	0.62 (0.53, 0.70)	0.60 (0.52, 0.67)
df = 10/year	757	0.52 (0.45, 0.59)	0.62 (0.55, 0.70)	0.64 (0.55, 0.72)	0.61 (0.53, 0.69)
S2					
Lag 0–7	757	0.52 (0.45, 0.59)	0.66 (0.59, 0.74)	0.62 (0.54, 0.71)	0.61 (0.54, 0.69)
Lag 0–10	757	0.52 (0.45, 0.59)	0.68 (0.60, 0.75)	0.62 (0.54, 0.70)	0.61 (0.54, 0.69)
Lag 0–14	757	0.52 (0.45, 0.59)	0.68 (0.60, 0.75)	0.61 (0.53, 0.69)	0.61 (0.53, 0.68)
Lag 0–21	757	0.52 (0.45, 0.59)	0.69 (0.61, 0.76)	0.62 (0.53, 0.70)	0.61 (0.54, 0.69)
S3					
with RH	552	0.56 (0.47, 0.66)	0.66 (0.56, 0.76)	0.65 (0.55, 0.75)	0.64 (0.54, 0.74)

without RH	552	0.58 (0.48, 0.67)	0.64 (0.54, 0.74)	0.63 (0.53, 0.73)	0.63 (0.53, 0.73)
S4					
exclude locations without 5-year data	739	0.48 (0.41, 0.56)	0.57 (0.49, 0.65)	0.58 (0.49, 0.66)	0.55 (0.48, 0.63)
S5					
exclude locations with >10% missing data	702	0.48 (0.41, 0.56)	0.56 (0.48, 0.64)	0.56 (0.47, 0.64)	0.54 (0.46, 0.62)

Abbreviations: *df*, degrees of freedom; RH, relative humidity.

Notes: xylenes exposure is a summation of ethylbenzene, m-xylene, p-xylene, and o-xylene; the effect estimates denote the percentage changes and 95% confidence intervals in daily total deaths associated with an IQR increment in BTEX concentrations; S1–change the *df* in the smoothness of calendar day (6–10/year); S2–change lag time for temperature; S3–further adjust for RH; S4–exclude locations without data of at least 5 years; S5–exclude locations with a missing data rate of more than 10%.

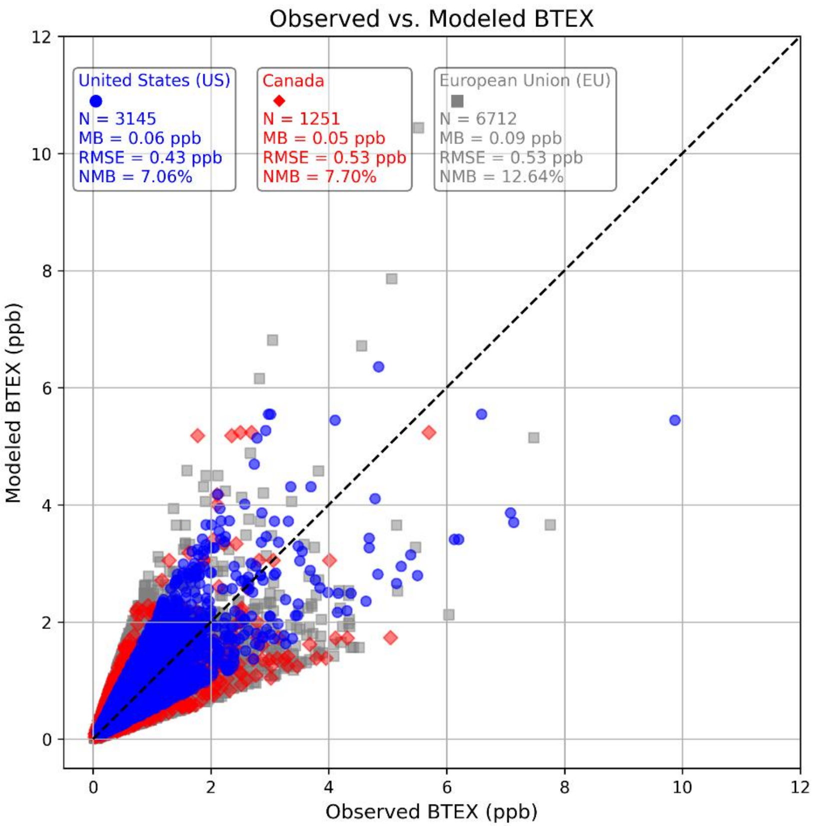
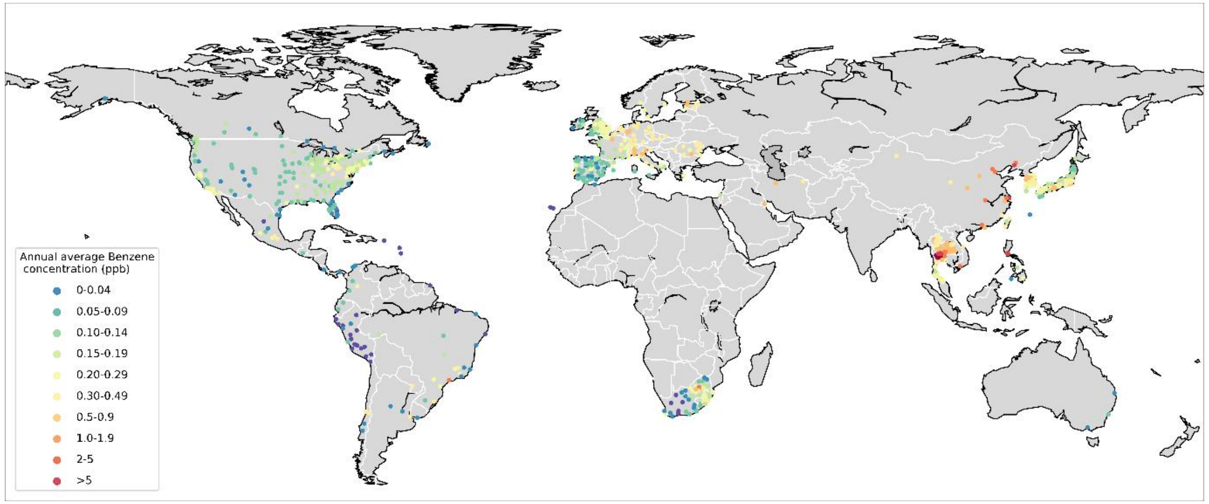
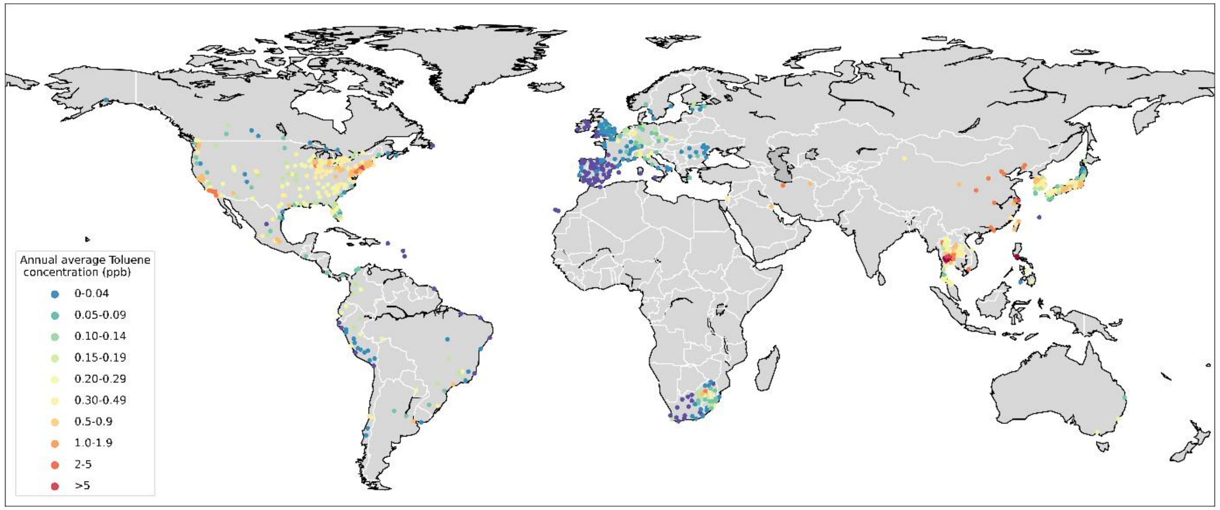


Figure S1. Comparison of surface BTEX concentrations between modeled and observed values over the U.S., Canada, and European Union for 2019. The black dashed line represents 1:1 reference line. Statistical metrics, including sample size (N), mean bias (MB), root mean square error (RMSE), and normalized mean bias (NMB), are provided.


Annual average Benzene concentration (ppb)
0-0.04
0.05-0.09
0.10-0.14
0.15-0.19
0.20-0.29
0.30-0.49
0.5-0.9
1.0-1.9
2-5
>5


Annual average Toluene concentration (ppb)
0-0.04
0.05-0.09
0.10-0.14
0.15-0.19
0.20-0.29
0.30-0.49
0.5-0.9
1.0-1.9
2-5
>5

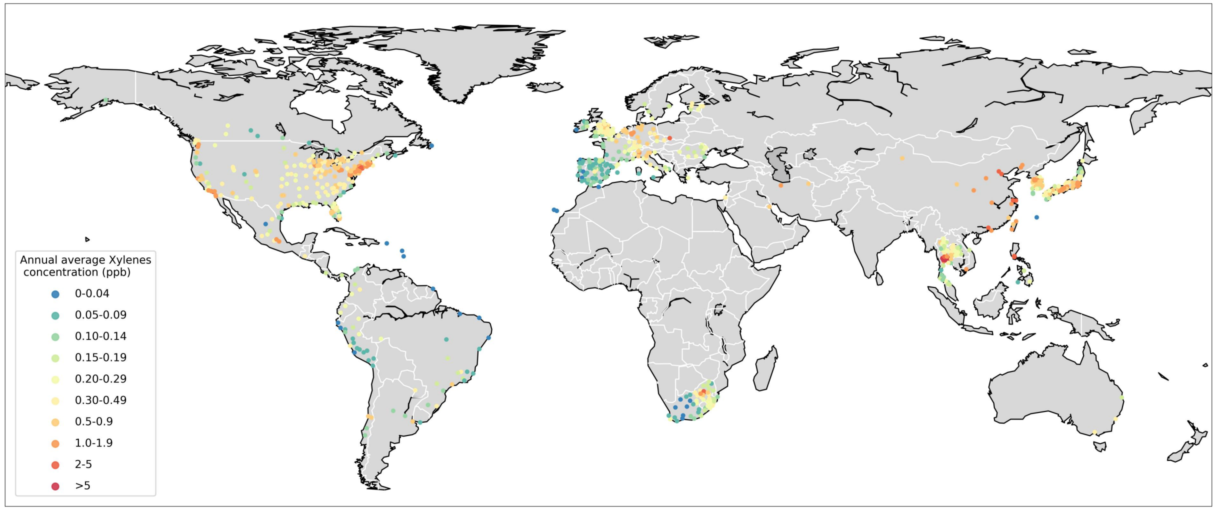


Figure S2. Annual average concentrations of benzene, toluene, and xylenes of 757 locations included in the analyses.

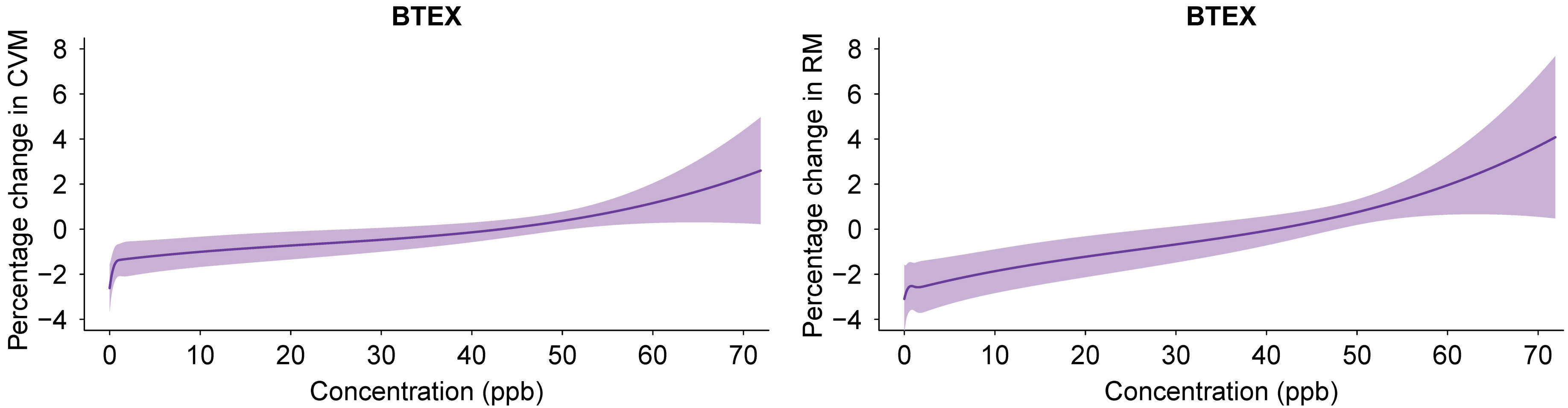


Figure S3. Exposure-response curves for associations of BTEX with cardiovascular and respiratory mortality. The y-axis represents the percentage change in daily mortality at a certain concentration relative to the median concentration. The x-axis represents concentrations BTEX.