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Developing Integrated Multistate Environmental Public Health Surveillance

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The UMDNJ Collaborative Project Working Group on Northeast US Ambient Air Quality and Adverse Birth Outcomes Surveillance*

Abstract

Environmental exposures cause substantial morbidity and mortality in the United States. A major goal of Centers for Disease Control and Prevention Environmental Public Health Tracking program is the development of a national network of health and environmental data with analytic

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tools for rapid evaluation of specific national or regional environmental health concerns. A six-state collaborative project in the northeast United States was established to assess the feasibility of such a system, assessing the possible association between ambient air quality and adverse birth outcomes. For this regional surveillance project, issues were discussed surrounding the design of a mutually acceptable protocol, obtaining human subjects' protection approvals, obtaining and organizing both the exposure and outcome data, analyzing the data both locally and regionally, and planning subsequent interventions to address identified public health concerns.

Keywords

air pollution; birth outcomes; epidemiology; environmental public health tracking; surveillance

Environmental exposures cause substantial morbidity and mortality in the United States, with air pollution alone responsible for tens to hundreds of thousands of deaths in the United States each year.^{1,2} Other local environmental health concerns include exposures to radon gas,^{3,4} contaminated drinking water supplies,^{5,6} pesticides,⁷⁻⁹ ionizing and nonionizing radiation,^{10,11} and contaminated soils,⁵ to name only a few. Yet, despite the great toll in adverse human health effects and even though most environmental exposures are preventable or amenable to substantial reductions, the public health data systems available in the United States to identify and characterize environmentally caused disease, and thus to limit the exposures, are viewed as inadequate.¹²

In response to these concerns, a Commission of the Pew Charitable Trust issued a provocative call to action.¹² Congress responded, providing targeted funding to the Centers for Disease Control and Prevention (CDC) for the establishment of the Environmental Public Health Tracking (EPHT) Program.¹³ This program facilitates focused public health, or epidemiologic, surveillance¹⁴ for the ongoing monitoring and identification of local disease or injury excesses attributable to environmental hazards and the dissemination of these data for the development of interventions to prevent and/or reduce the frequency and severity of these occurrences. The EPHT Program currently is funding 17 state and local health departments that are focusing on the provision of data and the conduct of surveillance activities, and four academic institutions that are examining methods development, research, and policy.

One specific goal of the EPHT Program is to establish a national EPHT computerized Network for nationwide public health surveillance to enable public health agencies to “determine disease impacts and trends, recognize clusters and outbreaks, identify populations and geographic areas most affected, and develop and assess the effectiveness of policy and environmental health interventions.”^{15(p17),16(p43)} To date, most projects have been initiated by, and focused on, a single city or state (<http://www.cdc.gov/nceh/tracking/network.htm>). One exception is the Public Health Air Surveillance Evaluation (PHASE) Project,¹⁷ in which Maine, New York, and Wisconsin health department staff collaborated on the evaluation and analysis of modeled ambient air quality data linked with hospitalization data. Even though this was a collaborative project, each state navigated its own data protection system. The lessons learned included the observation that although it

was possible to share Personal Health Information (PHI) at the geographic scale of 36 km² grid cells, the lack of finer resolution throughout the study area compromised the interpretability of the data and that administrative solutions for sharing the data, such as appointing colleagues from other states as unpaid employees to facilitate legal data access, can be successful if somewhat complex. Seeking more facile data-sharing arrangements, the PHASE Project team concluded that “additional work is necessary to define an appropriate, consistent, and linkable geographic and temporal resolution for health and hazard data in EPHT that maintains confidentiality.”¹⁸(p5) As with the project described herein, several other collaborative projects are in the early stages of implementation.

As another step toward a functional EPHT Network, the University of Medicine and Dentistry of New Jersey Academic Partnership for Excellence (UMDNJ APEX) in the CDC EPHT Program is coordinating a six-state collaboration in the northeast United States (Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York) to study the possible association between ambient air quality and adverse birth outcomes. Initially, exposure data for the project will be restricted to particulate matter less than 2.5 μm in diameter (PM_{2.5}) and ozone because these are the only air pollutants for which data currently are available from the Environmental Protection Agency (EPA) modeling work. Particulate matter less than 2.5 μm in diameter has been shown to be associated with adverse birth outcomes while results for ozone are less clear (Table 1).

We believe that the northeast United States is an appropriate area for testing this approach. Specifically, in Table 2, we show some characteristics of each participating state to emphasize both the appropriateness and importance of the combined and comparative analyses. In light of the observed variations, we anticipate finding some patterns common to most states and some patterns limited to one or a subset of states. The total number of births across states varies by more than 15-fold. Our analyses will include approximately twice as many births as the largest state and about 30 times as many as the smallest state. The states vary in terms of their environmental profiles of air pollution, number of superfund sites (data not shown), presence of arsenic in drinking water (data not shown), etc. Birth rates in all participating states are lower than the US average of 14.1 per 1 000 births, varying from 10.6 per 1 000 to 13.5 per 1 000 among women aged 15 to 44 years; the proportion of low-birth-weight births (LBW; <2 500 g) varies from 6.2 percent to 8.1 percent, a range that includes the national average of 7.9 percent, and the proportion of preterm deliveries (PTD; <37 weeks' gestation) varies from 9 percent to 12 percent, measures that all are lower than or equal to the national proportion of 12.2 percent. Given these variations, this project's approach can be used to focus on environmental concerns that are national and those that may not be national priorities but, because of the regional perspective, may be particularly well suited for effective and efficient regional or local public health interventions. The analyses also should identify differences within and among the states, especially with respect to environmental conditions, that warrant local attention and action. With the project results, one also should be able to identify and characterize situations in which environmental pollutants cross state lines, a situation that can be assessed only with multistate data. This collaborative project, if successful, will demonstrate one set of methods for analyzing and interpreting multistate, routinely collected health and environmental data,

one of the main goals of EPHT, and identifying some of the challenges in conducting such studies quickly and efficiently.

The UMDNJ Collaborative Project on Northeast US Ambient Air Quality and Adverse Birth Outcomes

This project is designed to demonstrate states' abilities to identify a common environmental health issue, establish and share consistent data, and collaboratively analyze the data to develop observations and conclusions of regional and local relevance for possible intervention. Given these goals, the project was designed to investigate a testable hypothesis that is regionally relevant, a national priority,³⁷ and has been studied previously in smaller studies^{38–40}: the possible association between ambient air quality and adverse birth outcomes. This topic is advantageous, in part, because among health records, birth data are less sensitive and thus easier to share (with appropriate confidentiality constraints). Given the larger sample size than those of most previous studies on this topic, this project's results should be more sensitive and reliable statistically than individual state studies.

Protocol development

Table 3 shows the steps followed in the development of this project. The idea for the project grew out of the EPHT and EPHT Network concepts. From these, researchers in the UMDNJ APEX chose a few possible hypotheses for investigation with state partners, discussed them informally with these partners, and then chose the assessment of the association of adverse birth outcomes with differences in ambient air quality as both the most relevant and likely to succeed. To implement the project the investigators need four types of data: (1) birth outcome data, available on birth certificates; (2) maternal and pregnancy history data to adjust for possible confounding, also available on birth certificates; (3) local sociodemographic data for neighborhoods, available from the US Census Bureau; and (4) exposure data, available from the US EPA. Although the latter two data types are readily available on the Web because they do not contain any PHI, the former two include PHI and thus require approval of the relevant institutional review boards (IRBs). On the basis of this project idea, the UMDNJ APEX solicited the participation of CDC-funded states in the northeast United States and all agreed to participate (Connecticut, Massachusetts, Maine, New Hampshire, New Jersey, New York). To finalize the specific goals and procedures of the project, we convened the UMDNJ Collaborative Project Protocol Working Group with volunteers from participating health departments. The group met once in person and several times through conference calls. Through discussions on the conference calls and via e-mail exchanges, issues were discussed, critiqued, and resolved. After 8 months of collaborative work, consensus was reached and the Collaborative Project Protocol Working Group presented a detailed protocol to the states' EPHT staff for final approval.

Throughout this process, the collaborators have stressed the importance of publishing findings in the peer-reviewed literature while honoring the PHI and other IRB considerations. Joint review and approval of publications has emerged as one of the most difficult aspects of the collaboration. We all agreed on the need to protect PHI and subjects' rights as addressed through the IRB process of the organization of each collaborator and

data owner. Furthermore, all agreed that each investigator and their parent organization should review any manuscript and provide any comments in writing within a reasonable time (eg, 4–6 weeks) regardless of whether they are participating as authors. The lead authors at the UMDNJ APEX will respond to all comments in writing, correct prior to publication any errors in the data that were identified by the participating states or others, and initiate follow-up discussions to resolve any differences in interpretation. The specific approach for addressing unresolved publication issues has yet to be worked out.

Requesting the data

To obtain the data, UMDNJ APEX staff began to request the data state by state using the protocol as the basis for the request. This involved working through each state's EPHT staff to contact the data owner/flight attendant within each health department (eg, Office of Vital Records), discussing the project with them, soliciting and responding to relevant comments, and then similarly discussing the request with the IRB or other human subjects' protection group. Once they all agreed that they understood the project, that the data could be made available if IRB approval was obtained, and that the project was potentially approvable, the UMDNJ APEX staff began filing the relevant applications. This project has been approved by the UMDNJ—Robert Wood Johnson Medical School IRB, as this is the home institution of the principal investigator. Once this initial approval was obtained, we began to request the data from each participating state. With each application to a state IRB, the IRB has requested copies of all paperwork from the IRBs that have already approved the project. In addition, each has slightly different requirements for how to request data, the justifications needed, and other related details. Addressing each of these issues in a thorough manner took a substantial amount of time and sensitivity to the concerns of all involved. Once the data are acquired, the UMDNJ APEX staff will begin the data analysis phase of the project. To date, applications have been made and approved by New Hampshire for all births from 2000 to 2002 and are in various stages of processing with all the other states.

Data and methods

Births—For outcomes, the project will use standard birth certificates to determine for each birth the frequency of a variety of outcomes that have been used in previous studies: LBW (<2 500 g), very LBW (<1500 g), high birth weight (>4000 g), PTD (<37 weeks), very PTD (<32 weeks), term LBW (LBW and PTD ≥ 37 weeks), intrauterine growth retardation (<10% for specified gestational age), and sex ratio.

Exposures and confounding variables—For exposures, we will use EPA's modeled daily levels for airborne particulates (PM_{2.5} 24-hour daily average) and ozone (8-hour maximum) for each 12 × 12-km or 36 × 36-km grid (depending on location) and routine air monitoring data. The specific data were developed for the CDC EPHT PHASE project.¹⁷ Environmental Protection Agency researchers combined the ambient air quality data at this scale with data from its Community Multiscale Air Quality modeling system for the eastern United States in a hierarchical Bayesian space-time statistical model. With the EPA assistance, this project will use these data as our primary exposure measure. The alternative is to use data collected routinely from each state's ambient air quality monitoring program. One advantage of using the modeled data is that they are more comprehensive

geographically than the limited number of ambient air monitors in each state. Individual data for each residence are not available. One disadvantage of the modeled data is that they are estimates based on certain modeling assumptions rather than being actual measurements of ambient concentrations. To determine whether the monitoring data yield similar results and thus could be used in states not yet within the EPA modeling region, subsequent analyses are planned using the monitoring data. Because the EPA-modeled data currently are available only for 2001, this project will analyze air quality from 2001 only, but include all births that may have been exposed (ie, date of conception from about April 2000 through births in September 2002).

For possible confounding variables, we will use data from the birth certificates, as available, including maternal sociodemographics (eg, age, race, education, marital status, payer of prenatal care, medical conditions, smoking history, alcohol use, drug use, occupation, previous neonatal death, previous LBW infant, maternal weight gain), reproductive factors (eg, gender, parity, prenatal care, season of birth, pregnancy complications), neighborhood characteristics from the US Census (eg, income, housing, crowding, racial composition, residential stability), and possibly meteorological data (temperature, humidity, dew point temperature). We cannot evaluate the quality and accuracy of these data, and the values of certain data items are unknown (ie, missing) more frequently than others.^{41–44}

Analytic methods—It is necessary to link the maternal residence at delivery to the exposure data and US Census data to conduct the desired analyses. One concern that arose is that not all states are willing to release either individual addresses or specific locations (geocoded latitude and longitude) of maternal residences. To facilitate this project without violating the states' data release policies, we developed two approaches. For states that provide maternal residential location, we will link the data directly. For those that do not release those data, the health departments themselves will do the linkage internally, strip the geographic location information, and provide us with a dataset of birth certificate records already linked to the exposure and census data, without having to provide us maternal residential location.

Our goal is to work with the staff of each state health department in analyzing their own data. Each state will have the choice of conducting analyses with or without the assistance of the UMDNJ APEX staff or requesting that UMDNJ APEX staff conduct the analyses first. Following initial data-screening evaluations (eg, frequencies, outlier detection, distributional considerations), these semiecologic data (ie, individual birth outcome, sociodemographic, reproductive history, and behavior data but aggregate exposure and neighborhood data) will be analyzed using standard statistical approaches, such as logistic (multiplicative) regression⁴⁵ and linear (additive) regression.⁴⁶ Then the UMDNJ APEX will conduct both meta-analyses and pooled analyses⁴⁷ using data for all six states. These analyses will allow the investigators to assess how similar the relationships are across states, which could be helpful in developing and implementing interventions. It will enable identification of states that differ, if any, and might suggest specific follow-up investigations to determine why they differ and what can be done to improve the outcomes. Meta-analysis will provide a measure of heterogeneity of results across states, providing information on how influential each state is in determining the average regional associations, but this method is limited by the ways in

which confounders can be considered. The pooled analysis, which is both more rigorous and more cumbersome to conduct, will allow a more direct comparison across states, although our experience suggests that the results are likely to be quite similar to the meta-analysis results.

We also plan to explore the use of case-over analysis methods⁴⁸ as demonstrated by our EPHT partners in the PHASE study for asthma and air pollution, applying them to acute reproductive outcomes such as preterm delivery.

To ensure consistency and facilitate the analysis within each health department, the UMDNJ APEX staff are developing standard SAS⁴⁹ programs (SAS Institute Inc, Cary, North Carolina; <http://www.sas.com/>) that can be used with any health department's data. The only anticipated modification will be to adjust the input statement to accommodate each state's data format and structuring/labeling of data categories. In addition, UMDNJ APEX staff will develop additional programs to conduct meta-analyses and pooled analyses.

Discussion

This report provides a summary of the preliminary steps in a multistate regional collaboration under the CDC EPHT Program. This collaboration is of local and regional public health relevance and another step in the transition from the individual partner surveillance activities to national-scale collaborations involving most or all EPHT Network partners. We believe that many of the difficult and controversial administrative and scientific issues likely to arise in a nationwide assessment can be more easily identified and resolved first through the collaboration of a few states rather than with all state and city EPHT programs at once. The lessons learned from this effort, and other multipartner collaborations, will provide important information and guidance for the implementation CDC's EPHT Network.

One reason for choosing the specific topic for this project, in addition to the more limited concerns over confidentiality for these data relative to other health data, is that there are several previous studies of the possible association of air pollution with adverse birth outcomes (Table 1). Those studies have resulted in a somewhat inconsistent body of studies suggesting a small, positive risk for LBW,^{40,24} and somewhat weaker associations for PTD⁴⁰ and IUGR.⁴⁰ Although some may suggest that effects from weak associations should not be top priorities for further investigation, we argue that they are worthy of further investigation because the exposure of concern, elevations of ambient air pollutants, is common throughout the United States (and the world) and thus may reflect a large attributable risk and public health impact directly amenable to intervention. Our multistate approach, with relatively fine scaled geographic data, enables us to evaluate local and regional variations in levels of air pollutants to identify areas of greatest concern and allows for crossborder assessments, when pollutants cross geopolitical boundaries.

There are five important results we seek from our project. First, because of the larger size and greater geographic extent of the project, the results obtained may be more appropriate for etiologic generalization than previous studies. Second, we believe that the individual

states' results, and their comparison with regional results, will be of particular utility for each state in evaluating its reproductive health status and considering possible assistance programs independent of, or in collaboration with, neighboring states. Third, our comparison of ambient air monitoring data with the US EPA modeled data may provide guidance for developing appropriate and relatively easy-to-calculate air quality metrics for future studies, given the limitations of the epidemiologic data and methods. Fourth, on the basis of the quantitative results, we will assess the utility of this approach for developing and targeting interventions to reduce adverse birth outcomes, both regionally and locally. These interventions could include a variety of strategies, such as methods for limiting exposures, possibly by intervening earlier in the pregnancy, and providing more comprehensive prenatal care. Fifth, positive findings at relatively low levels of PM_{2.5} or ozone also may support in strengthening state and federal standards for those pollutants.

Finally, in evaluating the utility of this project as a model for a national network, a number of lessons already have been learned. One of the biggest challenges is obtaining data from multiple states for the combined analyses, either prelinked or with identifiers. This requires coordination with state health department EPHT staff, data owners, and human subjects' protection staff, and is taking substantially more staff time than anticipated. In applying for data access, we provide a detailed protocol outlining all of the planned analyses. If additional analyses are desired, it will be necessary to reapply to the human subjects' protection groups for approval of those specific activities. Although useful as a demonstration project, the process we are following does not lend itself to the rapid evaluation of surveillance data in EPHT-like programs. In addition, as states have different data release policies, there is a need to devise different strategies for linking the birth outcome data to the exposure and confounder data. Some data will be linked by us using geographic location information. For others, the UMDNJ APEX staff will provide exposure/confounder data with geographic locations, and they will be linked by states to birth outcomes, the geographic locations will be removed, and the linked data will be returned. To fulfill the stated goals of EPHT, city and state health and environmental surveillance data would have to be made available far more quickly, in consistent formats, for regional or nationwide analyses, as issues of concern arise, with the capability for more direct linking to exposure and census data. Although the information technology solutions are straightforward, data-sharing agreements, implementation of consistent data formats, and relatively recent surveillance data would have to be in place and provided well in advance of use rather than in response to identification of a particular problem or concern. Otherwise, the preparation of the data and approval for use might be so involved as to render the process insufficiently responsive from a public health perspective. Methods for developing such data resources have been pioneered by the CDC (eg, the National Center for Health Statistics; CDC Wonder), although without the level of geographic specificity, potential identifiability, and rapid availability that would be required to make this resource optimally useful for a timely response. Addressing these data needs is an important challenge for EPHT. We also are pleased that we were able to develop a process for jointly writing up the results of the collaborative work. This often is a major impediment in collaborative work.

While this study has been under way, a study was published examining the association between ambient air quality and adverse birth outcomes in two of our six collaborating

states.²⁴ The investigators found a small but statistically significant excess of LBW associated with an interquartile range increase of exposure PM_{2.5} during gestation (OR = 1.05; 95% CI, 1.02–1.09). There still is value in our project as it will consider six rather than only two states; has more ambitious analytic goals, including meta-analyses and pooled analyses; and, as noted above, involves working directly with state health departments to identify a common environmental health issue, establish and share consistent data, and collaboratively analyze the data to develop observations and conclusions of regional and local relevance for possible intervention. Although some of the goals could be achieved with the data and results from the Bell et al study, we see value in the processes and procedures reported here that go considerably further in demonstrating the utility and importance of EPHT for state and city health departments, and potential pitfalls.

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TABLE 1

Previous studies of selected birth outcomes resulting from common air pollutants

Pollutant	Location	Birth, y	Number of births	Confounder adjustment	Exposure metric	Effect estimate for gestational period ^a			Reference
						1st trimester	2nd trimester	3rd trimester	
Low birth weight									
TSP	Czech Republic	1991	78 148	MC ^b , PC ^c , MD ^d	50 µg/m ³	1.15 (1.07–1.24)	1.12 (1.04–1.21)	1.11 (1.00–1.22)	Bobak ¹⁹
	Czech Republic	1986–1998	223 929	SF ^e	50 µg/m ³	1.04 (0.96–1.12) ^f			Bobak ²⁰
	South Korea	1996–1997	276 763	MC ^b , PC ^c , MD ^d	By quartile ^g	1.04 (1.00–1.08)	Not reported	0.95 (0.90–0.99)	Ha ²¹
	China	1988–1991	74 671	MC ^b , PC ^c	100 µg/m ³	Small negative assoc	Small negative assoc	1.10 (1.05–1.14)	Wang ²²
PM ₁₀	Canada	1998–2000	74 284	SF ^e , MC ^b , PC ^c	By quartile ^h	1.03 (0.94–1.14)	1.00 (0.90–1.10)	0.94 (0.85–1.05)	Dugandzic ²³
	United States	1999–2002	358 504	MC ^b , PC ^c , MD ^d	By quartile ^h	1.03 (0.99–1.06) ^f			Bell ²⁴
	South Korea	1996–1998	388 105	MC ^b , PC ^c	By quartile ^g	1.06 (1.01–1.10) ^f			Lee ²⁵
	United States	1994–1996	89 557	MC ^b , PC ^c , MD ^d	10 µg/m ³	0.93 (0.85–1.00)	0.93 (0.85–1.02)	0.96 (0.88–1.06)	Maisonet ²⁶
PM _{2.5}	United States	1999–2002	358 504	MC ^b , PC ^c , MD ^d	By quartile ^h	1.05 (1.02–1.09) ^f			Bell ²⁴
	California	2000	18 247	MC ^b , MD ^d	10 µg/m ³	–38.2 g (–54.9 to –21.6) ^f			Parker ²⁷
O ₃	Canada	1998–2000	74 284	SF ^e , MC ^b , PC ^c	By quartile ^h	0.98 (0.86–1.12)	1.04 (0.91–1.18)	1.01 (0.88–1.16)	Dugandzic ²³
	South Korea	1996–1997	276 763	MC ^b , PC ^c , MD ^d	By quartile ^g	0.92 (0.88–0.96)	Not reported	1.09 (1.04–1.14)	Ha ²¹
	Canada	1985–1998	229 085	MC ^b , PC ^c , MD ^d	10 ppb	1.04 (0.95–1.13) ⁱ	Not reported	1.01 (0.92–1.11) ^j	Liu ²⁸
	Preterm delivery								
TSP	Czech Republic	1991	78 148	MC ^b , PC ^c , MD ^d	50 µg/m ³	1.18 (1.05–1.31)	1.11 (0.97–1.26)	1.12 (0.97–1.28)	Bobak ¹⁹
	China	1988	25 370	MC ^b , PC ^c , MD ^d	100 µg/m ³	1.10 (1.1–1.20) ^f			Xu ²⁹
PM ₁₀	Australia	2000–2003	28 200	SF ^e , MC ^b , PC ^c , MD ^d	By quartile ^g	1.15 (1.06–1.25)	Not reported	1.04 (0.92–1.16) ^k	Hansen ³⁰
	Korea	2001–2002	52 113	MC ^b , PC ^c	By quartile ^l	1.27 (1.04–1.56)	Not reported	1.09 (0.91–1.30)	Leem ³¹
	United States	1989–1993	97 518	MC ^b , PC ^c , MD ^d	50 µg/m ³	1.15 (1.04–1.26)	Not reported	1.09 (1.00–1.19)	Ritz ³²
PM _{2.5}	United States	1997–2001	187 997	MD ^d	50 µg/m ³	Not reported	Not reported	1.07 (0.98–1.18) ^j	Sagiv ³³
	Australia	2000–2003	28 200	SF ^e , MC ^b , PC ^c , MD ^d	By quartile ^g	1.09 (0.97–1.23)	Not reported	0.95 (0.85–1.06) ^k	Hansen ³⁰
	United States	2003	2 543	MC ^b , MD ^d	>21.36 µg/m ³	1.07 (0.85–1.35)	Not reported	Close to null ^m	Ritz ³⁴

Pollutant	Location	Birth, y	Number of births	Confounder adjustment	Exposure metric	Effect estimate for gestational period ^a			Reference
						1st trimester	2nd trimester	3rd trimester	
O ₃	Australia	2000–2003	28 200	SF ^e , MC ^b , PC ^c , MD ⁴	By quartile ^g	1.26 (1.10–1.45)	Not reported	1.06 (0.89–1.26) ^k	Hansen ³⁰
	Canada	1985–1998	229 085	MC ^b , PC ^c , MD ⁴	10 ppb	0.98 (0.89–1.03) ^j	Not reported	0.93 (0.86–1.00) ^j	Liu ²⁸
	United States	1989–1993	97 518	MC ^b , PC ^c , MD ⁴	4.80 pphm	No consistent effects	Not reported	No consistent effects	Ritz ³²
	United States	2003	2 543	MC ^b , MD ⁴	>3.54 pphm	0.92 (0.70–1.20)	Not reported	Close to null ^m	Ritz ³⁴
Intrauterine growth retardation									
TSP	Czech Republic	1991	78 148	MC ^b , PC ^c , MD ⁴	50 µg/m ³	0.89 (0.75–1.06)	No significant assoc	No significant assoc	Bobak ¹⁹
PM ₁₀	Czech Republic	1994–1996	1 943	MC ^b , PC ^c , MD ⁴	20 µg/m ³	1.50 (1.15–1.96) ^j	No assoc found ⁿ		Dejmek ³⁵
PM _{2.5}	Czech Republic	1994–1996	1 943	MC ^b , PC ^c , MD ⁴	20 µg/m ³	1.34 (0.98–1.82) ^j	No assoc found ⁿ		Dejmek ³⁵
O ₃	Canada	1985–1998	229 085	MC ^b , PC ^c , MD ⁴	10 ppb	1.02 (0.95–1.08)	1.08 (1.01–1.15)	0.99 (0.93–1.06)	Liu ²⁸
	United States	1975–1987	3 901	MC ^b , PC ^c	17 ppb	Not reported	1.2 (1.0–1.3)		Salam ³⁶

Abbreviations: assoc, association; g, grams; MC, maternal characteristics; MD, meteorologic data; O₃, ozone; PC, pregnancy characteristics; PM₁₀, particulate matter 10 µm in size; PM_{2.5}, particulate matter to 2.5µm in size; SF, socioeconomic factors; and TSP, Total suspended particles.

^aIf no OR is reported, the author's description is used.

^bMC may include age, race, education, occupation, maternal weight gain, medical conditions, smoking history, alcohol use, prior pregnancies.

^cPC may include sex, parity, adequacy of prenatal care, pregnancy complications, birth weight, gestational age.

^dMD may include temperature, dew point temperature, humidity, season.

^eSF may include income, housing, residential stability.

^fEntire pregnancy.

^gPer interquartile range increase.

^hContinuous based on interquartile range.

ⁱFirst month.

^jLast month.

^kLast 90 days prior to birth.

^lHighest quartile compared to lowest quartile.

^mSix weeks before birth.

ⁿMonths 2 to 9.

TABLE 2

Characteristics of births and maternal characteristic in 2003 for collaborating states and US births

	United States	Connecticut	Maine	Massachusetts	New Hampshire	New Jersey	New York
Birth characteristics^a							
Total live births	4 089 950	42 873	13 855	80 184	14 393	116 983	253 714
Birth rate (per 1 000 women 15–44 y)	14.1	12.3	10.6	12.5	11.2	13.5	13.2
Sex, male, %	51.2	51.3	51.7	51.2	50.6	51.1	51.3
Preterm delivery (<37 wk), %	12.2	9.7	10.1	10.7	9.2	12.1	11.4
Low birth weight (<2 500 g), %	7.9	7.5	6.5	7.6	6.2	8.1	7.9
Maternal characteristics^a, %							
Younger (15–19 y)	10	7	8	6	6	6	7
Older (>34 y)	14	22	14	23	18	22	20
White	79	83	96	82	95	73	72
Black	15	12	1	11	2	17	19
High school graduate	73	87	88	88	89	84	80
Smoked during pregnancy	9	6	16	8	13	8	8
Unmarried at time of birth	35	30	34	28	25	29	37
Late (3rd trimester) or no prenatal care	4	2	2	2	1	5	5
Ranking of states' air quality (percentiles)^b							
Emissions of PM _{2.5}	NA	10th	20th	30th	10th	20th	80th
Exceeding air quality standard for O ₃ (8 h)	NA	90th	30th	20th	10th	60th	80th
Exceeding air quality standard for O ₃ (1 h)	NA	70th	50th	10th	0th	70th	80th

Abbreviations: O₃, ozone; PM₁₀, NA, not applicable; particulate matter 10 μ m in size; PM_{2.5}, particulate matter to 2.5 μ m in size.

^aNational Vital Statistics Reports. (2005). Births: final data for 2003. 54(2). <http://www.cdc.gov/nchs/nvss.htm>

^bScorecard: The pollution information site. <http://scorecard.org>

TABLE 3

Flow chart of activities

	Pew	CDC	EPA	States	UMDNJ
Develop concept of EPHT and EPHT Network	X				
Implement EPHT and plan for EPHT Network		X			
Develop hypothesis consistent with EPHT/EPHT Network	X	X		X	X
Develop project protocol to test hypothesis about air quality and adverse birth outcomes				X	X
Request institutional review board approvals for implementing protocol					X
Request data for implementing protocol				X	X
Compile and organize outcome, exposure, and confounder data			X	X	X
Conduct analyses for individual states' data				X	X
Conduct meta—and pooled analyses					X
Interpret results of analyses		X	X	X	X
Consider policy implications of project results and possible interventions and follow-up studies		X	X	X	X

Abbreviations: CDC, Centers for Disease Control and Prevention; EPA, Environmental Protection Agency; EPHT, Environmental Public Health Tracking.