Office of Children's
Environmental Health

Protecting Our Chlidren: Assessing the Link between PM-10 Pollution and Childhood Asthma in Maricopa County

Children's Health Challenge Grant Project

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ADEQ
Arizona Department of Environmental Quality

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Summary

In 2006 the Arizona Department of Environmental Quality (ADEQ)) launched an effort to address the connection between particulate matter (PM10) air pollution and the growing incidence of asthma among children in Arizona through the use of the National Environmental Information Exchange Network (Exchange Network). Asthma is the most common chronic childhood disease in Arizona and a leading cause of absences from school for many Arizona children. Asthma also can contribute to long-term lung damage and other serious health impacts in children.

Using funds from an Exchange Network Challenge Grant provided by the U.S. Environmental Protection Agency (EPA), ADEQ worked with the Arizona Department of Health Services (ADHS) to develop a mechanism for exchanging and analyzing health and environmental information using a node infrastructure on the Exchange Network. The joint effort with ADHS had three goals: (i) develop a predictive model for asthma episodes and air quality thresholds in Maricopa County, (ii) examine correlations among data sets, and (iii) investigate the possibility of developing alert systems on the potential health effects of poor air quality.

Based on an initial assessment of needs, available data, and analytical capabilities for conducting air quality modeling and establishing environmental-health linkages, ADEQ engaged researchers at Arizona State University's (ASU) Ira A. Fulton School of Engineering and ASU's Center for Health Information and Research (CHIR) to design and conduct a study using emissions of particulate matter and meteorological data provided by ADEQ to create an air quality surface of PM10 levels over the metropolitan Phoenix area that could be compared with asthma incidence data over the same geographic area and time frame to determine the connection between elevated levels of PM10 pollution and increased incidences of asthma in children.

The study analyzed over 5,000 asthma events between January 1, 2005, and September 30, 2006, occurring among children in a selected study area. The study area covered 168 census tracts in a geographic area in metropolitan Phoenix generally bounded by Dunlap Road to the north, 52nd Street to the east, Elliot Road to the south and 75th Avenue to the west. Each census tract included in the study area was located within a five-mile distance from one of the permanent PM10 monitors in the Phoenix area.

When correlated with PM10 concentrations, the study showed a 13.7% increase in the probability of an asthma event occurring among children aged 5-18 years with changes in the daily average PM10 from the 25th to the 75th percentile. That percentile change is equivalent to a net increase of 26 $\mu g/m^3$ of PM10. In other words, the study revealed that the incidence of asthma events among children 5-18 years old increased by nearly 14% when levels of PM10 pollution increased to the 75th percentile in the study area.

Background

Since 2002, EPA has provided funding for agencies and partners to use the National Environmental Information Exchange Network to collaborate in areas of common interest. The Exchange Network is an Internet-based system used by state, tribal, and territorial partners to securely share environmental and health information with each other, with EPA, and with other designated partners. EPA's Challenge Grants have supported this objective in a variety of areas, including air and water quality and human health.

In 2003, at the direction of Governor Napolitano, ADEQ initiated the Children's Environmental Health Project with the goal of assessing and reducing environmental risks to children's health, including especially the connection between poor air quality and childhood asthma and other respiratory problems. As part of this effort, ADEQ submitted a grant proposal to EPA in 2005 seeking funding to link ADEQ's air quality data with health information from the Arizona Department of Health Services (ADHS) through the Exchange Network to enable the two agencies to evaluate potential relationships between air quality and asthma. Specifically, ADEQ, in partnership with ADHS and in collaboration with several local governments and public health advocacy groups, proposed leveraging Challenge Grant funding to build upon the Exchange Network node infrastructure in support of the following activities:

- Share and exchange quality assured hospital and emergency room admissions and ambient air quality data with the ADHS and other partners.

- Develop the data analysis tools necessary to complete a retrospective time series analysis of hospital admission and emergency room data and air monitoring data. This would allow for the detection of any statistically significant correlations between increased incidences of asthma in children and poor air quality conditions.

- Develop a model for predicting adverse impacts on childhood asthma from forecast air quality monitoring data. This model could also help gauge the effectiveness of current air quality programs in reducing childhood asthma.

- Develop tools to conduct asthma health warnings and alerts, using the Network node, for communication to the public, including schools, day care centers, hospitals and emergency rooms.

Activities Conducted Under the Grant

Background Analysis

ADEQ contracted with Arizona State University's (ASU) Mechanical and Aerospace Engineering, Center for Environmental Fluid Dynamics and the ASU Center for Health Information and Research (CHIR) to create a team to accomplish the goals of the Challenge Grant. Representatives of ADEQ, ADHS, and ASU formed an advisory committee that met frequently to determine the course of the analyses, review results, and generate conclusions.

The group successfully guided the efforts of the Exchange Network node installation, mapped particulate matter (PM10)[1] concentrations via air modeling and monitoring studies, selected and processed asthma incidence data and examined the relationship of the health data to the air quality data. In addition, experts from the University of Arizona and the Arizona Asthma Coalition provided feedback on project direction.

The Exchange Network Node

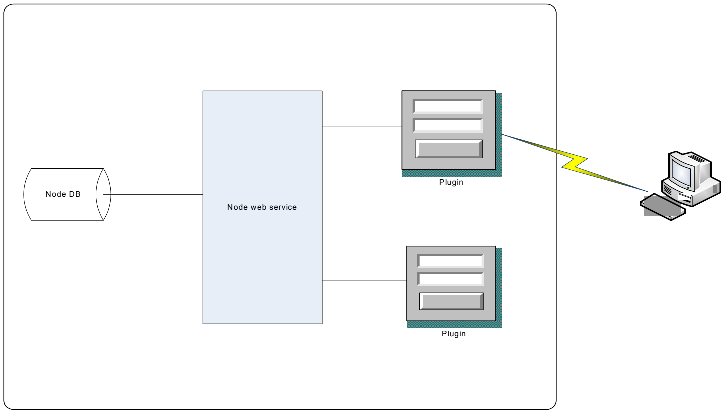
To achieve the information exchange needs of this project, a Central Data Exchange (CDX) node was created at ADEQ based on a standard created by EPA. The standard for the CDX node has been defined by the EPA for the sharing of data from partners to the EPA, as well as partner to partner. The basic functionality provides node-to-node communication and allows the transfer of data in a variety of formats. It also enables communication between a node and a client when one of the users does not have a node. (See Figure 1 below).

The CDX node is an internet application enabling the transfer of data between approved users consisting of 3 main parts:

- The node server, which provides the main functionality
- Plug-ins, which are extensions to the server which manage the transmission of specific data flows. Typically, each data flow will have its own plug-in which will define the transfer process and the data content for the flow. Plug-ins may be simple, offering basic automatic transfer or they may provide a user interface which allows the user to select specific data to transfer.
- The database component. This holds the data which is to be transferred. This is loaded by the sender prior to use and will, in the ADEQ case, be taken from the Agency data bases.

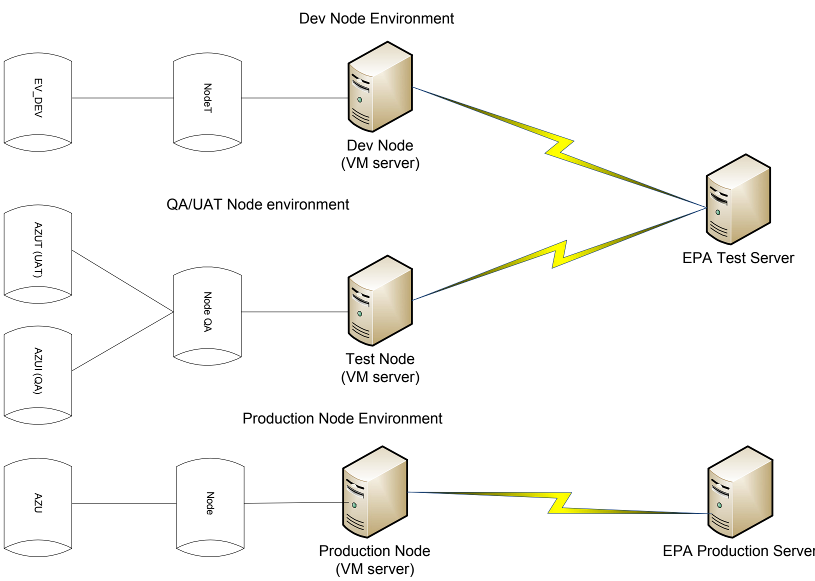
[1] EPA groups particulate matter into two categories based on size: fine particles 2.5 micrometers or less in diameter (PM2.5) and all inhalable particles up to 10 micrometers in diameter (PM10). PM10 includes PM2.5.

Figure 1 - Control Data Exchange Web Service Infrastructure



ADEQ created a full infrastructure to enable the CDX node to become operational, which is a key element of EPA's information sharing strategy. This included three servers linked to servers housing ADEQ's Oracle databases. The general structure is shown in Figure 2, below. The CDX servers were implemented using Virtual Machine technology. This approach gave ADEQ additional flexibility during the testing and implementation process.

Figure 2 - ADEQ CDX Node Environments[2]



[2] ADEQ has three environments for the CDX node:

- A development environment in which new applications and plug-ins are created;
- A Quality Assurance (QA) / User Acceptance Testing (UAT) environment which is used to test new applications; and
- A production environment, which is used to communicate with the EPA and other users/partners.

This is an industry standard configuration for software development. The environments are functionally identical.

Children's Health Node-to-Client Data Transmission Process

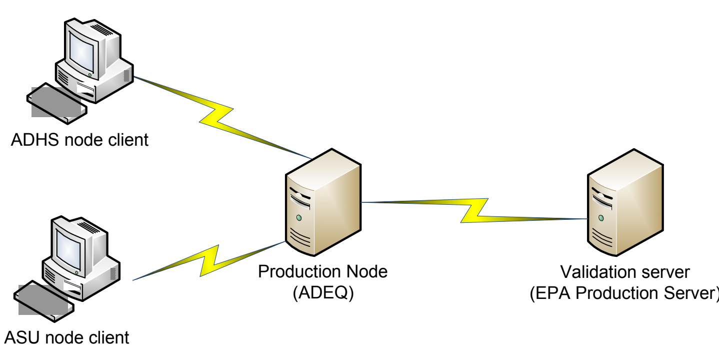
The basic process uses the node clients to transmit data to the ADEQ server where it is passed to the receiving user. While the EPA validation server takes no part in the transmission process, it validates the users, thus giving them access to the network.

Under the Exchange Network Challenge Grant project, data was supplied from two State sources, ADEQ and ADHS, and transmitted to ASU. Because only ADEQ has the node server, it was necessary for all data transmissions to pass through the ADEQ node. (See Figure 3 below). Access to the CDX node requires that the users have an ID and password provided by the EPA. When connecting to the ADEQ node, the EPA node must be available in the network for verification purposes.

To send data from ADHS to ASU:

- ADHS creates a data file. This may be plain text, encrypted, zipped, etc.
- ADHS logs on to the ADEQ server and uploads the file to the server.
- The system notifies ASU via email that the file is available and provides a transaction ID.
- ASU logs on to the node server and downloads the file.

Figure 3 –Node to Client Data Transmission Process



To ensure the privacy and security of the health information transmitted under federal Health Insurance Portability and Accountability Act (HIPAA) rules, an encryption guideline was presented in a document to the participating agencies detailing steps to both encrypt as well as optionally compress the data files. Use of this procedure insures privacy for individual personal health information when this information is used in statistical group health analysis. The document outlined the process including how and when encryption keys should be shared. When followed, only the sending and receiving agencies can view the contents of the file. Without this privacy protection in place, the data could not be exchanged.

Air Quality Monitoring and Modeling

To develop reliable gridded concentrations of PM10 throughout the metropolitan Phoenix area suitable for linking asthma incidences, ASU researchers used the MM5/SMOKE/CMAQ modeling system, which incorporates meteorological and PM10 emissions data. Different time periods during 2005 and 2006 with high and low particulate pollution levels were included in the study design. These design days were identified by conducting preliminary statistical analyses relating daily average PM10 concentrations to asthma diagnoses, and were selected in part based upon the completeness of available air quality and health data.

The hourly and daily simulated concentrations were compared with data from five permanent monitoring sites with continuous PM10 instruments. "Continuous" monitors collect meteorological and air pollution data in real-time and report those data as hourly averages. Hourly and daily measurements from the five permanent central-city monitoring sites[3] were then interpolated using a technique called the Inverse Distance Weighting method onto a 168-census tract grid. This method allows the use of a small number of monitoring stations to interpolate over the study area.

To ensure the reliability of the data, four additional temporary monitoring stations were deployed from November 2007 to March 2008 during this project.[4] Furthermore, continuous PM10 monitors began operating in 2006 and 2007 at two additional monitoring sites, Greenwood and South Phoenix, respectively.[5] These six additional sites filled in gaps in the geographic coverage of the PM network in areas with high numbers of asthma cases. (See Figure 4).

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[3] The five permanent sites are Central Phoenix (CP), Durango Complex (DC), West 43rd Avenue (WF), West Phoenix (WP) and the Supersite (SS1). (See Figures 4 and 5).

[4] The four temporary sites were Maryvale (MRV), Valley Garden Center (VGC), Weaver's Auto Service (WVR) and Community Service (CSR). (See Figure 4).

[5] With the two new continuous monitors and the four temporary monitoring stations, the ASU team was able to use a more sophisticated method, known as "ordinary Kriging" to confirm the soundness of the Inverse Distance Weighting interpolations. Because Kriging requires data from more than ten monitoring stations, however, it was not used in the health-particulate matter correlation studies.

Figure 4 - Central Phoenix Continuous PM10 Monitoring Sites

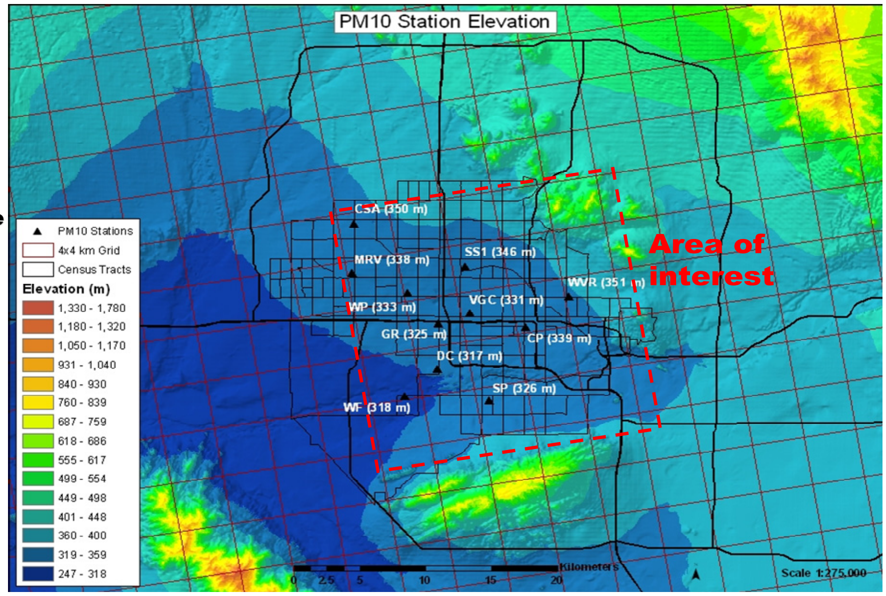
Monitors

Permanent:

CP - Central Phoenix
DC - Durango Complex
WF - West 43rd Avenue
WP - West Phoenix
GR – Greenwood
SP – South Phoenix
SS1 - Supersite

Temporary:

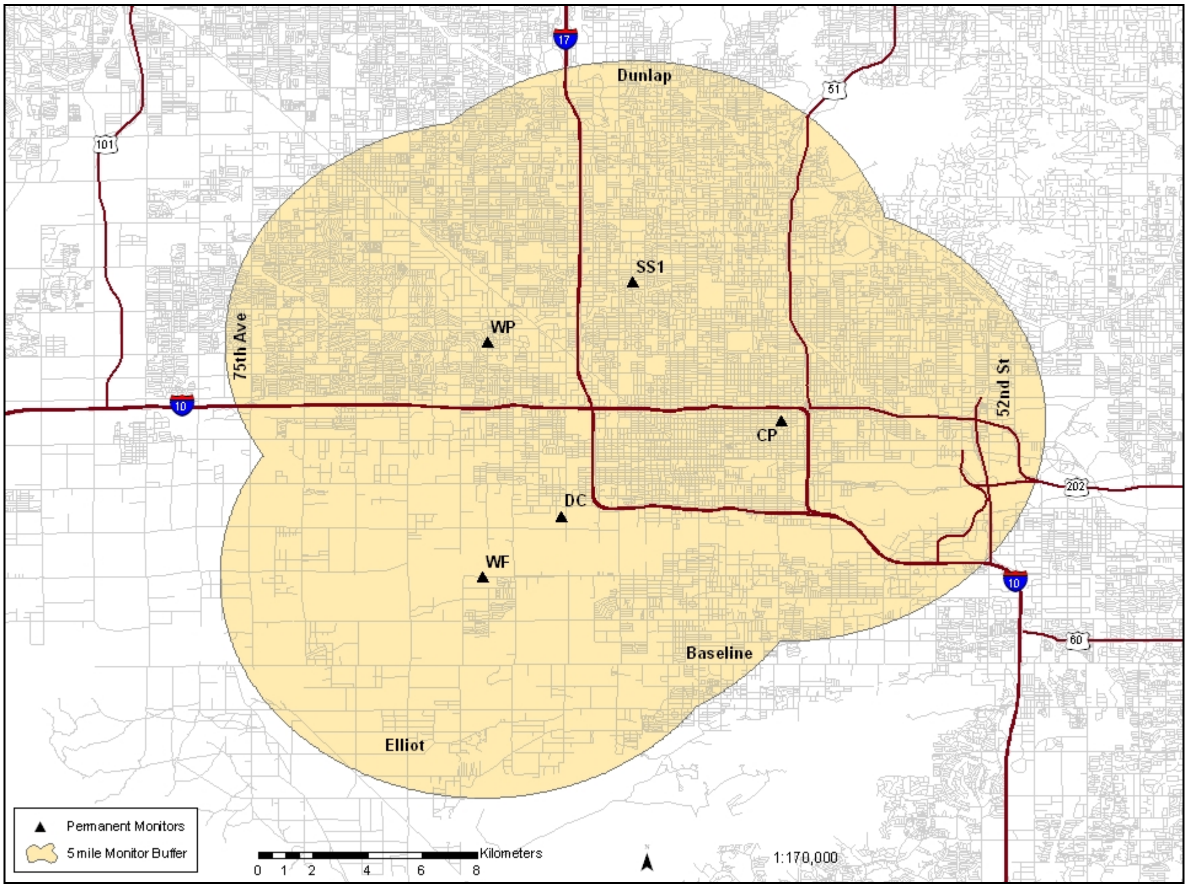
MRV - Maryvale
VGC - Valley Garden Center
WVR - Weaver's Auto Service
CSA - Community Service



The Study Area

The study area for relating asthma incidences with PM10 concentrations was an irregularly shaped closed curve with four distinct lobes delimited by a five-mile distance from each of the five permanent PM10 monitors, encompassing168 census tracks in central Phoenix. (See Figure 5 below). The study area was centered near 35th Avenue and McDowell Road and was bounded by Dunlap Road to the north, 52nd Street to the east, Elliot Road to the south, and 75th Avenue to the west. (See Figure 5).

Figure 5 – The study area



With support from ASU's CHIR, ADHS first conducted a preliminary, high-level analysis of air quality monitoring data for PM10 and asthma incidence from hospital discharge data to determine the statistical relationship, if any, between poor air quality and higher rates of asthma.[6] Preliminary analyses using data from CHIR's Arizona Health Query helped researchers define the demographic groups, sample size, and data cleaning strategies that were subsequently applied to the final analyses conducted using data from ADHS.[7]

Researchers next evaluated ADHS asthma incidence data occurring within the 168 census tracts from January 1, 2005, through September 30, 2006, a period for which complete air monitoring records were available. Asthma events were included in the dataset for all incidents occurring within a census tract with its centroid within the 5-mile radius of an ambient air monitoring site. Multiple steps

[6] The data included discharge data from hospitals outside the study area since it was based on patient address and not the facility location.

[7] The Arizona Health Query is an integrated database containing health information on Arizona adults and children that includes information about medical visits and costs, patient characteristics, physician, health plan enrollment, and Medicaid eligibility.

were taken to “clean” the data to ensure that only unique asthma incidents were included. Asthma incidents were described by age group, day of the week, month, and place of service (emergency department and inpatient admission) resulting in a dataset containing approximately 5,000 asthma incidents among children aged 0-18 years.

Air-Asthma Data Linkage

The health data were linked by census tract with the PM10 concentrations derived from the gridded air quality data. In addition to reviewing daily PM10 levels on the asthma “event” day, 24-hour averages of PM10 from one to seven days before the event were used in the statistical analysis (these variables are referred to as “lag times”). A case-crossover analysis was conducted to detect the effects of PM10 for each asthma incident while accounting for several confounding variables, such as seasonality, day of the week, patient-level covariates (e.g., age, gender, ethnicity), and the presence of other pollutants in the air at the time the data were collected (e.g., ozone). This type of analysis associates a reference time period as a control for each case. Consequently, each patient was treated as a matched case-referent pair with control exposures obtained from the same patient in different time periods.

The time-stratified design used a 28-day period with three additional dates falling on the same day of the week as the case. (See Figure 6). In Figure 6 below the original case data is shown alone at the left while the right chart shows the case data supplemented with the three additional control days falling within the 28-day period.

Air quality on the control days was compared to the case days. With an appropriate time-stratified period, the case-crossover analysis controlled for long-term trends, seasonal effects, and various epidemiologic covariates that change slowly with time by design (e.g., lifestyle behaviors, diet). Conditional logistic regression analysis was conducted with the Statistical Analysis System (SAS), widely used statistical software.

Figure 6 – Air-Asthma Data Linkage: Time stratification with 28-day Stratum

Date	Day	Event
1/1/2004	Thursday	Case
1/2/2004	Friday	Case
1/3/2004	Saturday	Case
1/4/2004	Sunday	Case
1/5/2004	Monday	Case
Date	Day	Event
1/1/2004	Thursday	Case
1/2/2004	Friday	Case
1/3/2004	Saturday	Case
1/4/2004	Sunday	Case
1/5/2004	Monday	Case

Original Data

Stratum	Date	Day	Event
1	1/1/2004	Thursday	Case
1	1/8/2004	Thursday	Control
1	1/15/2004	Thursday	Control
1	1/22/2004	Thursday	Control
2	1/2/2004	Friday	Control
2	1/9/2004	Friday	Control
2	1/16/2004	Friday	Case
2	1/23/2004	Friday	Control
…	…	…	…
5	1/5/2004	Monday	Case
5	1/12/2004	Monday	Control
5	1/19/2004	Monday	Control
5	1/26/2004	Monday	Control

Case-Crossover Data

Results and Findings

The retrospective analysis of ambient PM10 concentrations and asthma incidence data showed a positive correlation between elevated levels of PM10 (i.e., poor air quality) and high asthma incidence in the metropolitan Phoenix area.

Among children ages 5-18 years there was a 13.7% increase in the occurrence of an asthma event when the PM10 concentration increased by 36.4 µg/m^3 (the change in daily average PM10 from the 25^{th} to 75^{th} percentile).

This represents a stronger effect than seen in other studies, where in some instances such site specific, comprehensive health and air quality data may not have been as readily available.

There were no observed effects among children ages 0-4, likely due to the difficulty in accurately diagnosing asthma among very young children and in many cases the very young are kept indoors more frequently than older children.

Upon linkage of the air quality data to ADHS health data, PM10 concentrations were found to have statistically significant associations with asthma incidence at the 95% confidence level.

Conclusions and Next Steps

The current study shows a significant increase in the likelihood that children may experience an asthma event with a relatively small PM10 increase in ambient air. These findings suggest that the at-risk population overall is greater than previously observed and that sensitive populations in particular may need greater protections than the asthma warning systems and other safeguards currently in place. Public health messages should be developed and targeted to children 5-18 years of age, parents of asthmatic children, and other sensitive populations to supplement current warning efforts.

The weather and pollution prediction modeling system (CMAQ/MM5/SMOKE) used by the researchers generally performed well at predicting PM10 concentrations across the 168 census tracts of the study area. As more data support the need for, and inform decisions about, the development of new warning systems, the Exchange Network node could serve as a valuable tool in helping health and environmental agencies publish warnings that can be used by schools, hospitals, child care providers, the general public and others.

While this study successfully accomplished its major goals, it also laid the groundwork for additional studies to further validate the analytic results presented here. The study identified additional variables to be incorporated into future model iterations and helped build capacity and partnerships among agencies and the university that will provide ongoing benefits toward improved collaboration for Arizona's public health.

Moreover, by using the fully functional Exchange Network node to share health and environmental information, similar studies can be done in other parts of the state, using modeled data for other pollutants such as PM2.5, ozone or a combination of pollutants. Depending on the availability and completeness of data, the model also could be adjusted to evaluate different health outcomes related to poor air quality.

Arizona already employs several programs aimed at reducing children's exposure to environmental hazards, including ADEQ's School Bus Idling Program and the air quality flag programs in Maricopa County and Yuma. This study adds to the underlying information supporting these and other programs and provides a further basis for a partnership between ADEQ, ADHS and other groups throughout the state, such as schools, hospitals, child care centers and other state agencies and facilities. The study also presents strong evidence that ADEQ should continue to provide assistance and advice to help school officials, parents and others protect children against the impact of air pollution conditions and take action to prevent the onset of asthma or other serious health problems.