7.2 EXPLORATION OF THE REGIONAL IMPACTS OF ATMOSPHERIC CONDITIONS BELOW THE TOP OF THE PYRAMID: THE CASE OF THE SEACOAST AREA IN NEW ENGLAND

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1. INTRODUCTION

To date, a significant focus of the discussion of the economic impact of air quality has been on the most severe impacts of poor air quality on human health, including the health care costs and economic consequences of deaths, prolonged hospitalizations and absence from work (Carpenter, et. al., 1979) (DSS, 2000) (Seethaler et. al., 2003). Much less is understood about the more common impact of atmospheric conditions on the general health of the population and on the regular day-to-day activities of individuals. With the more common occurrences, the impacts might be relatively minor, but quite significant for the economy overall as the impacts can be on large numbers of people and occur frequently. Even less well understood is the potential value of air quality information and forecasts (AQIF) in assisting individuals and organizations to avoid some of the potential costs associated with poor air quality. These later two considerations are the focus of this paper.

The discussion here and the research that this paper is based on are both exploratory. The key objectives are: (1) to expand the understanding of the public health and economic impacts of air quality; and (2) to consider the economic uses and value of air quality information and forecasts, including their application by private firms to avoid losses in worker productivity associated with poor air quality.

Hospital emergency room admissions are often the focus of research on the public health and economic impact of air pollution. However, this represents only a relatively small proportion of the potential adverse impact of poor air quality on individuals and organizations. Thurston (1997) suggests, for example, that hospital admissions account for less than one percent of all adverse impacts of poor air on quality. Thurston refers to hospital admissions as the "tip of the iceberg" and concludes that most of the adverse impact of poor air quality is from the loss of productivity and reduction in activities for individuals on days they suffer from symptoms such as watery eyes, coughing, and wheezing.

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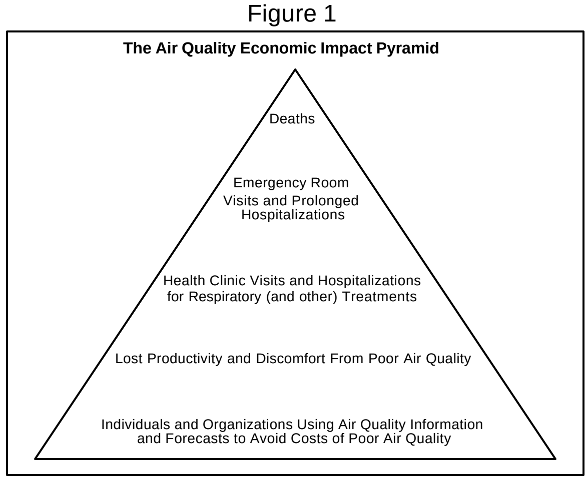
At the top of the iceberg, or what we call the "Air Quality Economic Impact Pyramid" (see Figure 1 below), are extreme adverse health affects resulting in deaths and requiring emergency room visits. Below that are adverse effects leading to hospital treatments and visits to health clinics and physicians. Below that are common aliments, which can cause discomfort and lead to declines in energy levels and work place productivity but do not require medical care. Finally, at the base are some relatively minor negative impacts, some of which have been reduced by ameliorative actions. The bottom of the pyramid effects have some cost, but lower costs than what they would have without use of air quality information and forecasts and associated changes in behavior.

Figure 1



The activities and consequences below the top of the pyramid are the focus here. They are not easy to document and research. The main contribution of this research is its consideration of multi-scales and use of different research data and methods to explore some of the "base" effects of poor air quality. The inquiry documents and measures air quality impacts requiring and not requiring treatments. It assesses the potential economic impacts of air quality with consideration of health clinic and hospital treatment data and also surveys of employees and of air quality information users.

The research that this paper is based on is focused on the New England region in the United States and summer months when air quality is considered to be most problematic in the region. However, the findings are relevant for other regions in the U.S. and elsewhere, particularly areas with an average annual number of poor air quality days higher than New England.

A key consideration of the inquiry is the effect of poor air quality on typical workers. Survey information is used (see details below) to examine the relationship between poor air quality and worker productivity. A broad cross-section of workers participated in the surveys. The workplaces were typical in that they were indoors, where the effects of air quality have been assumed to be relatively low compared to its affect on outdoor workers. However, individuals who work indoors have to be outdoors to drive and commute to work, and their exposure to poor air quality can continue at the indoor workplace and affect their productivity (Wargocki, P., et al., 2000).

The preliminary findings of the research, as reported here, are significant. An economic model used to assess the potential benefits from using air quality forecasts to avoid loses in productivity suggests that the potential value of AQIF is significant. The benefits can be considerable, especially if air quality information and forecasts are more broadly accessed and used than currently, particularly by commercial organizations and large employers.

The paper is broken down into five sections. First, the overall research that underlies the findings is presented. Second, results from a survey of recipients of AQIF are addressed. Third, the impact of air pollution on worker productivity is explored. Fourth, the relationship between respiratory hospital admissions and health care clinic appointments and air quality and pollen are investigated. Fifth, conclusions are presented. Sixth, future research priorities are presented.

2. RESEARCH

The research that underlies this paper has been focused on partnerships with four major health care organizations and selected major employers in the research region. The partnerships include access to health care data from health clinics and hospitals and information about employees from surveys at large organizations.

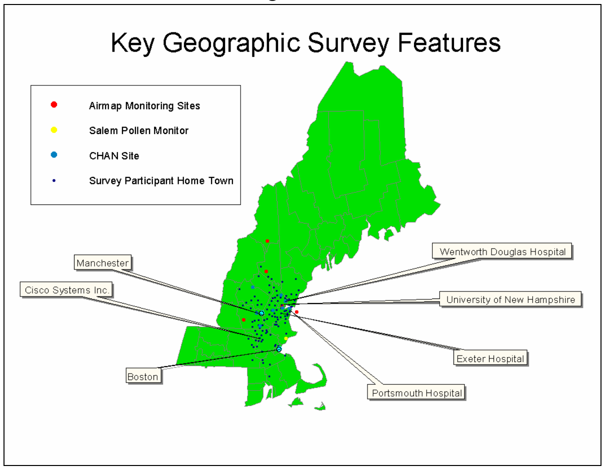
The surveys of employees focus on changes in behavior, health and productivity associated with changes in atmospheric conditions. Survey participation included approximately 500 workers in the New England region.

The detailed hospital and health clinic patient data is used, as presented below, to test correlation of treatments to air quality factors. The focus is on asthma-related conditions and treatments that are considered significantly affected by air quality.

The research draws on the unique air quality data available in the Seacoast region of New Hampshire, Massachusetts and Maine. The data is available from the University of New Hampshire's Atmospheric Investigation, Regional Modeling, Analysis and Prediction (AIRMAP) program and other sources.

The map below (Figure 2) details the locations of the main air quality monitoring sites and research partner organizations.

Figure 2



2.1 *Partnerships*

The research team established partnerships with the three major hospitals in southeastern New Hampshire -- Exeter Health Resources, Portsmouth Regional Hospital, and Wentworth-Douglass Hospital. The seacoast area of New Hampshire was targeted because: (a) it could provide some new information about air quality impacts outside of a major city; (b) it typically has the poorest air quality during the summer compared to in-land; and (c) the detailed air quality data available from the AIRMAP program.

Up to three years of detailed data was collected and analyzed from the hospitals. Also, at each of the hospitals some employees volunteered to participate in a Summer 2004 Employee Survey (employee survey) regarding productivity at the work place.

The research team also partnered with the New Hampshire Community Health Access Network (CHAN). CHAN is a not-for-profit organization of New Hampshire health care "safety net" providers. CHAN is comprised of eight community and primary health centers. With CHAN data the potential "below the tip of the iceberg" (i.e., less severe, not requiring hospitalization) impacts of poor air quality could be considered. CHAN provided detailed historical patient data -- on visits to and usage of their health facilities.

The main large employer research partner was Cisco Systems through its New England headquarters in Massachusetts. Cisco employees volunteered for the employee survey and management agreed to work with the research team on assessing how the company and its employees could benefit from air quality information and forecasts.

Cisco was selected for several reasons. The company is well known for its efforts to minimize the negative societal impact of its operations. This includes sensitivity to the environmental impact of its company offices in New England and elsewhere. Furthermore, the company and its senior managers were interested in exploring how to inform and alter work practices to avoid potential productivity losses associated with poor air quality. Additionally, from a business development perspective the company was prospectively interested in the potential for broader societal application of air quality information and forecasts. This could be to promote telecommuting to reduce productivity loss on poor air quality days, and could increase demand for Cisco's Internet and networking products.

2.2 *Surveys*

A preliminary survey in the Summer of 2003 of respondents to the EPA Region 1 (New England) air quality forecast alert program was completed to get information about the very bottom of the pyramid. The purpose was to gain insights on who currently receives air quality forecasts and what behavioral and organizational changes, if any, recipients make in response to the information they receive.

The purpose of the Summer of 2004 Employee Surveys was to evaluate the relationship between exposure to different air quality conditions and worker productivity. Subjects were enrolled in the study during research team visits to participating employers and through solicitations via email. The participating employers included Cisco Systems, Wentworth-Douglass Hospital, Portsmouth Regional Hospital, Exeter Health Resources, the New Hampshire Department of Environmental Services and the University of New Hampshire.

2.3 *Hospital and Health Clinic Patient Data Analysis*

Partnerships with the hospitals provided, not only a pool of employees to solicit for the employee survey, but along with CHAN data an opportunity to investigate the relationship between variations in air quality and health care treatments.

3. FINDINGS: EPA SURVEY

By enrolling in the EPA's Air Quality Alert program, participants receive -- by e-mail or fax -- a notification from the EPA that the next day's air quality is forecast to be unhealthy or when air quality levels reach high levels.

In the Summer of 2003, when the EPA survey was undertaken, the notification list had approximately 1,900 participants: 1,300 for email alerts and 600 for faxes. The response rate to the survey was approximately 12 percent.

Respondents identified themselves in one of three categories: individuals, who use the air quality alerts for themselves; commercial organizations; and non-commercial organizations, such as schools, day cares, summer camps or medical facilities. Seventy-six percent of respondents were individuals, 22 percent from non-commercial organizations, and 2 percent from commercial organizations.

The majority of individuals learned about the program through the EPA's web site, while the majority of non-commercial organizations learned about the program through letters from the EPA and the EPA's web site. The commercial organizations learned of the program through letters from the EPA and other state-level environmental management agencies.

An important question of the respondents was whether or not they altered their behavior and/or organizational practices in response to an air quality alert. Almost all, 97 percent, of the individual respondents did something to protect their own health. Over two-thirds of the non-commercial organizations took specific steps to protect the health of those under their care when they received air quality alerts. All the commercial respondents also implemented changes during a bad air spell. This included changes to outdoor worker schedules and reductions in their physical activity. It also included organizational efforts to reduce emissions and to increase employee awareness of poor air quality and its negative impacts. Figures 3 and 4 document what each group did in response to an air quality alert.

Figure 3

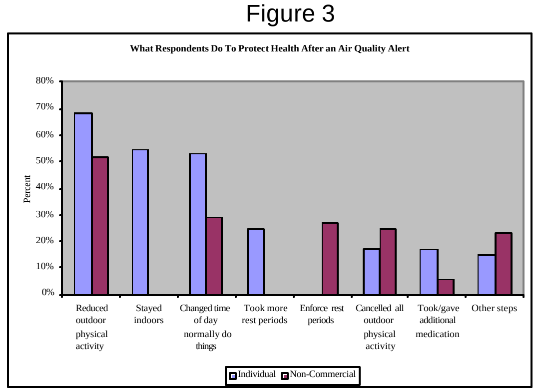
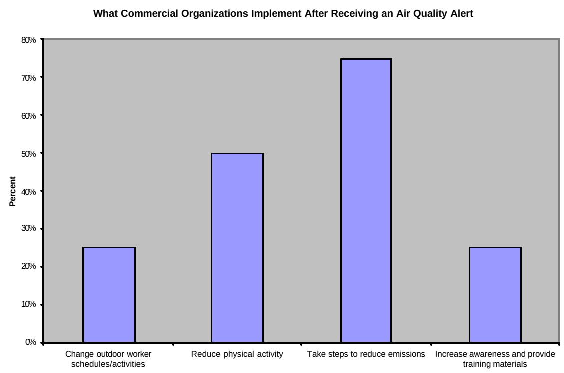
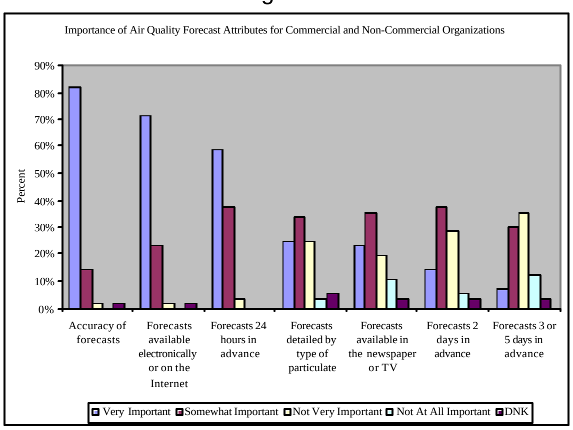


Figure 4



The commercial and non-commercial organizations were asked to assess the importance of air quality forecast attributes. This was in an attempt to discover how current forecasts might be improved to better meet the needs of this group. Figure 5 displays the results.

Figure 5



Of most importance to respondents were accurate forecasts available electronically and at least 24 hours in advance. Less important were extended (more than 3 days out) forecasts. Surprisingly, the availability of AQIF from traditional media sources was not a high priority.

The EPA survey documents that air quality information and forecasts can be useful to individuals and organizations. It also suggests how those that receive AQIF can and do take actions to reduce the negative costs and consequences of poor air quality.

The EPA survey also highlights that significant outreach and education about AQIF needs to occur. This is suggested by the very low numbers of private corporations subscribing to the EPA Air Quality Alert in New England. There is much need to persuade new users, particularly private corporations, about AQIF. To do this will require convincing corporate decision makers that air quality information can be valuable to their organizations.

To further these ends, and more generally expand knowledge on how AQIF may be used beneficially, the EPA survey was supplemented with employee surveys. The main objective of the employee surveys was to explore the impact on worker productivity of poor air quality.

Of particular note, among employee survey respondents, only about one in seven reported accessing air quality information every day. In contrast, almost nine of every ten received weather-related information. Forty percent of respondents reported never accessing air quality information, while only one percent indicated never using weather-related information.

4. SUMMER 2004 EMPLOYEE SURVEY

The specific goal of the Employee Survey was to evaluate the relationship between exposure to different air quality conditions and worker productivity. The University of New Hampshire's Survey Center administered the surveys. All surveys were Internet-based.

The summer was targeted because it is typically considered the season in New England with the poorest air quality, particularly with high levels of ozone, particulate matter and smog.

An initial survey provided background demographic and health information of participants. Seven weekly surveys monitored productivity changes with variance in air quality through the summer of 2004. Participants were emailed once a week from July 23 through September 2 to complete the online weekly survey as air quality conditions varied. The total number of survey participants was 470.

The initial (baseline) survey included questions on place of work, commuting patterns, time spent outdoors, pre-existing respiratory conditions and location of residence. The mean age of respondents was 43, and fifty percent of the respondents were between the ages of 34 and 51. The survey data was used to test whether higher concentrations of particulate matter ($PM_{2.5}$ ug/m3), ozone (O_3 ppb) and tree pollen had a significant affect on worker productivity.

Measurements of $PM_{2.5}$ were taken from a monitoring station in Portsmouth, New Hampshire. O_3 was measured at Thompson Farm, in Durham, New Hampshire, and tree pollen was measured at a station in Salem, Massachusetts. Time series atmospheric data were averaged over relevant time intervals based on the periods of impact of individuals' health and well-being. $PM_{2.5}$ and O_3 concentrations were averaged over 24-hour time periods. Tree pollen was transformed into 3-day averages.

Exposure for each subject, in the cases of $PM_{2.5}$ and O_3, was based on the 24-hour average concentration prior to the time of their response to the survey, while tree pollen exposure was based on the 3-day average prior to when the survey was answered.

Statistical tests supported that higher $PM_{2.5}$ and O_3 concentrations were both significantly associated with declines in worker productivity. Tree pollen was not related to declines in worker productivity.

During the summer of 2004 in New England, particulate matter and ozone concentrations were the highest on July 23. This corresponds to the survey date on which the highest number of respondents reported feeling less productive. (See Figures 6 and 7 below.) Between July 23 and August 5, particulate matter and ozone concentrations declined, as did productivity losses. After August 5 both concentration measures of air quality increased along with reports of productivity losses. The last two survey dates, August 26 and September 2, were characterized by the lowest concentrations of ozone and particulate matter, and the lowest reported productivity declines. The overall trend in the percentage of workers feeling less productive follows the trend in particulate matter and ozone concentration. This suggests a positive correlation between declines in worker productivity and these air quality measures.

Figure 6

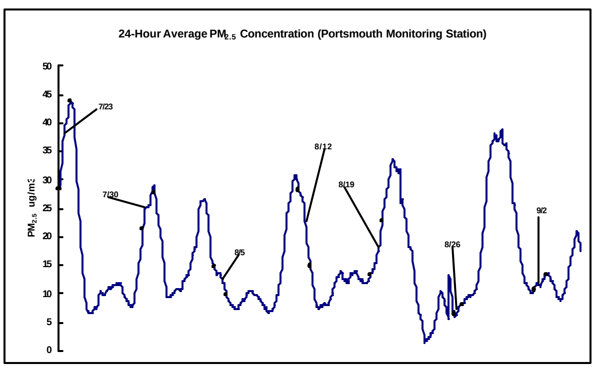
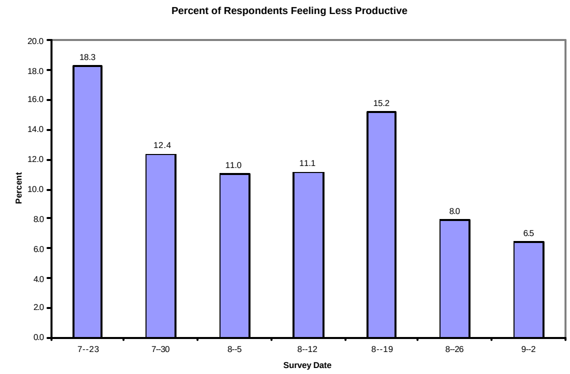


Figure 7



The observations above concerning the relationships between measures of air quality and worker productivity are supported by statistical tests in which productivity was regressed on each measure of air quality. Logistic regression models were used to relate worker productivity to particulate matter, ozone and also to total tree pollen, another hypothesized factor. Parameter estimates, see Figure 8, for each of the three potential explanatory variables considered are all significant. Parameter estimates for both ozone and particulate matter are positive, indicating that higher concentrations are correlated with higher probabilities of decreased productivity. The parameter estimates for tree pollen were inconsistent with the hypothesis that it would have negative effect on worker productivity.

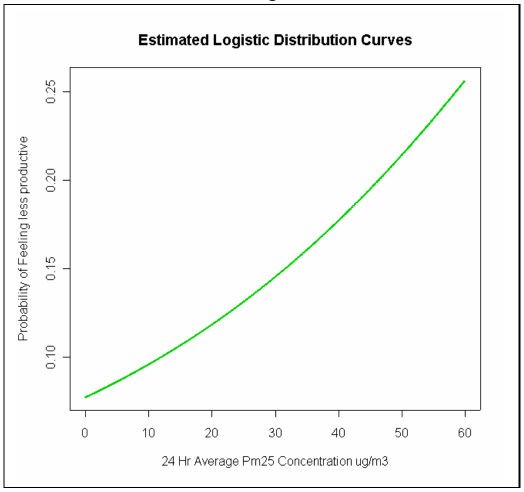
Figure 8

Parameter	DF	Estimate	Std Error	Likelihood Ratio 95% CI		Chi-Square	P-value
Productivity ~ PM25							
Intercept	1	-2.478	0.1402	-2.7574	-2.2074	312.32	<.0001
PM25	1	0.0235	0.006	0.0118	0.0352	15.6	<.0001
Productivity ~ O3							
Intercept	1	-2.675	0.1998	-3.0536	-2.2699	176.87	<.0001
O3	1	0.022	0.0063	0.0097	0.0342	12.38	0.0004
Productivity ~ Tree Pollen							
Intercept	1	-1.7425	0.084	-1.9095	-1.5801	430.31	<.0001
Tree Pollen	1	-0.0257	0.0058	-0.0375	-0.0146	19.4	<.0001

The logistic regression parameters can be used to construct an estimated logistic distribution curve describing the probability of a worker in the sample feeling less productive at various levels of a particular measure of air quality. Assuming that the underlying population of workers in New England is similar to the sample of workers in the survey and that other factors driving productivity declines are not highly confounded with air quality related effects on worker productivity, the results could aid managers in deciding when to act to mitigate air quality related productivity decreases.

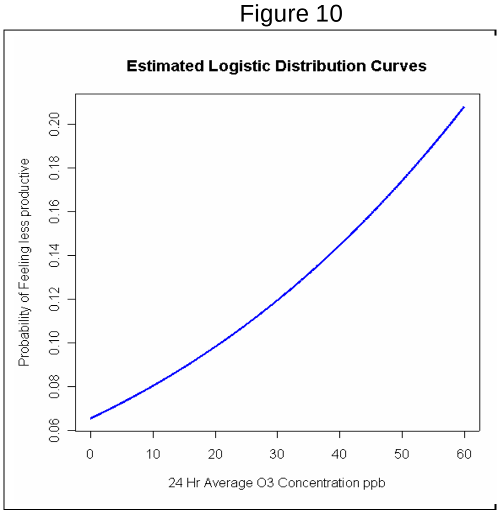
The estimated logistic distribution for particulate matter predicts that for 24-hour average concentrations in the range 0 to 60 ug/m3, the probability of a worker feeling less productive will range from eight percent to 25 percent, as Figure 9 shows. (The range of observed $PM_{2.5}$ levels during the study period was limited. Relatively low predicted probabilities outside of this range are subject to wider prediction intervals.)

Figure 9



The logistic regression predicted that for 24-hour average ozone concentrations between 0 and 60 ppb, the corresponding probability of a worker feeling less productive ranged from approximately seven percent to 20 percent. (See Figure 10)

Figure 10



With both ozone and $PM_{2.5}$, more accurate probability statements pertaining to higher particle concentrations depend on future studies over a wider range of air quality conditions.

Using an economic impact model and considering how air quality forecasts could be used to avoid some of the loss of worker productivity from poor air quality, the net annual benefit to the New England region in avoided loss in short-term profits in a typical year (with 10 poor air quality days a year) is estimated at about $0.5 million. This is the estimated annual value of air quality forecasts in New England. In areas with many more poor air quality days in a typical year and greater concentrations of workers, such as many urban areas in the Pacific Rim, the annual benefits of air quality forecasts could be significantly higher.

The cost avoidance from use of AQIF could come from adjusting work schedules and allowing for work at home based on prevailing and forecasted air quality conditions. During a bad air quality spell during the summer in New England, for example, workers could be encouraged and supported to work from home and/or choose to commute to and from work during times of the day when air quality was not at its worst.

There are approximately seven million workers in New England, and average per capita income is just under $37,000. Given 275 working days per year, the daily value of worker product would be just over $941,000,000. If we approximate the differential for typical workers experiencing decline in productivity between the highest and lowest ozone day at 1/8th of all workers (or 12.5 percent) and only a modest 10 percent reduced productivity during 10 average annual bad air quality days in New England, the worker product lost to bad air would be almost $118,000,000. If 20 percent of that loss could be avoided by accurate air quality forecasts, the worker productivity savings would be more than $23,000,000. Given that the ratio between total output in private firms and net income in the U.S. averages two percent, the air quality forecasts might increase profits by almost $471,000 in New England annually. In the context of the conceptual model, this $471,000 represents what New England employers would be willing to pay for air quality forecasts.

A simple calculation, with New England representing approximately five percent of total employment in the United States, estimates the value of air quality forecasts in the United States would be just under $10 million. Private frms should be willing to pay this amount for air quality forecasts.

The estimates of economic benefits from air quality forecasts are only for short-term annual improvements in corporate profitability resulting from avoiding declines in worker productivity associated with poor air quality. The estimates do not take into account short- and long-term benefits to private firms and their employees from avoiding medical costs and lost days at work and other costs that could be avoided.

5. HOSPITAL AND HEALTH CLINIC PATIENT DATA ANALYSIS

5.1 *Air Pollution and Asthma*

Moving up the economic impact of poor air quality pyramid, evidence exists that poor air quality has an adverse effect on human health. Garty et al. (1998)

showed that a high correlation exists between emergency room visits of asthmatic children and environmental factors. Over 60 percent of the variance in emergency room visits was explained by NO_X, SO_2, and O_3 concentrations and 69 percent by the combination of air pollutants and weather parameters.

Morgan, G., S. Corbett, et al. (1998) also examined the effects of outdoor air pollutants on daily hospital admissions in Sydney, Australia. They found that an increase from the tenth to the ninetieth percentile in daily maximum one-hour concentration of nitrogen dioxide was associated with an increase of 5.3 percent in childhood asthma admissions. Exposure to high levels of PM_{10} is also documented as having a negative impact on human health. Using daily records of asthma emergency room visits from eight hospitals in Seattle, Schwartz, J., et al. (1993) concluded that for persons under age 65, a significant relationship exists between admission and PM_{10} exposure on the previous day.

5.2 *New England Hospital and Health Clinic Patient Data Analysis*

Data on hospital admissions and visits were obtained from partnering hospitals. The data included information on age, gender, race, admission date, zip code, and charges for patients diagnosed with a respiratory illness. Each hospital data set covered different time periods: April 2001 to March 2004 for Wentworth-Douglass Hospital, July 2001 to May 2004 for Portsmouth Regional Hospital, and October 1997 to June 2004 for Exeter Health Resources.

Monthly admissions for asthma (ICD 9 code 493) were counted. The totals as well as the subtotals corresponding to each age category were noted. Using the age variable, patients were grouped in six categories: less than 5 years, 5 to 17 years, 18 to 24 years, 25 to 34 years, 35 to 54 years, 55 to 64 years, and over 65 years. In order to compare admissions for these different age groups, Census Bureau estimates of New Hampshire population by age group were used to calculate an annualized rate of admissions per 10,000 people. The following formula was used:

*Annualized rate per 10,000 = (N/Pop)*12*10000*
N is the monthly number of admission per age group
Pop is the New Hampshire population of that age group.

CHAN health patient data also provided respiratory treatment data. The data include information on patients' visits at six New Hampshire clinics for a period of six years (1997-2003). The same methodology for the hospital data was used to look at asthma-related clinic visits.

To explore the potential link between the asthma-related admissions and clinic visits and air quality indicators (from Thompson Farm and Salem, Massachusetts' monitoring sites), the hospital data and air quality data sets were plotted on the same graph. The (yearly) cumulative sum of daily asthma admissions and the cumulative sum of daily concentration of air quality indicators of O_3, SO_2, and CO_2 were graphed together. The objective was to identify whether the changes in the slopes of the curves (inflection points) were related, and use that to ascertain whether any of the air quality indicators might be considered as explaining changes (increases) in asthma admissions.

5.3 *Asthma and Ozone, SO_2 and CO_2*

Three air quality indicators, daily maximum one-hour ozone, daily mean SO_2, and daily maximum CO_2, and the Exeter Health Resources data were analyzed using the "slope and comparing points of inflection" method. Exeter Health Resources data was explored because it was the hospital for which the most historical information was available.

None of the air quality indicators seemed to explain the points of inflection (kinks) in asthma admissions. As Figures 11 and 12 show, asthma treatment inflection points (kinks) occur around the same date regardless of cumulative ozone or CO_2 levels. The preliminary conclusion is that no link exists between asthma admissions at Exeter Health Resources and the air quality indicators considered.

Figure 11

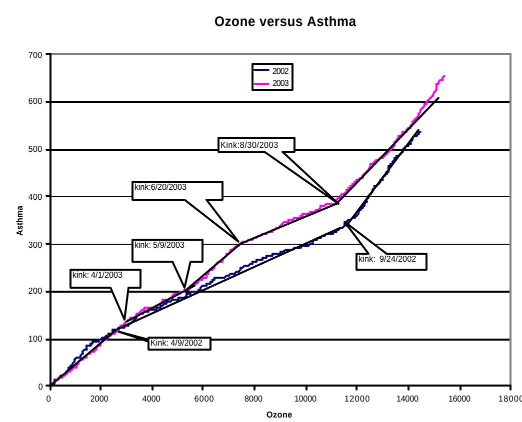
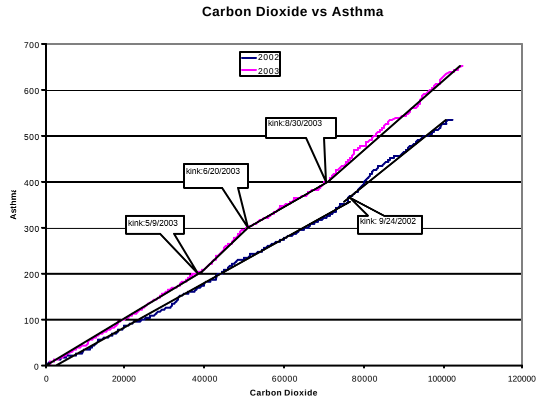


Figure 12



5.4 *Asthma and $PM_{2.5}$*

The analysis of asthma hospital admissions and clinic visits was restricted by the lack of $PM_{2.5}$ data. For the years 2002 and 2003, $PM_{2.5}$ data were not collected in the counties surrounding Exeter Hospital. The closest collection sites were located in Manchester, NH (Hillsborough County). The data for the year 2002 was incomplete, with only seven months of data from May to mid-December, and several missing days in between. Thus, the analysis included only data for one year (2003) for $PM_{2.5}$ and three local hospitals (Wentworth-Douglass, Portsmouth, Exeter) and two clinics in the CHAN network (Clinic A and B).

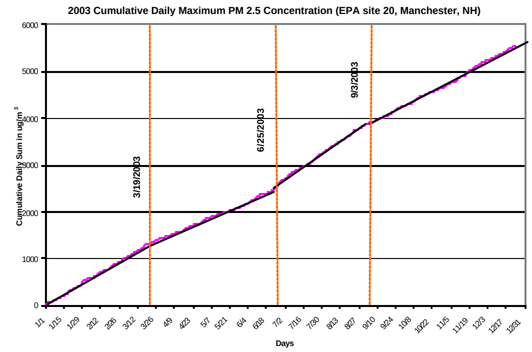
Analyses of cumulative daily asthma admission for each of the three hospitals and the two clinics revealed that the second and third week in September 2003 corresponded to a significant increase in the number of asthma admissions and visits. Figure 13 summarizes the dates for each hospital and clinic.

Figure 13

	WD	Portsmouth	Exeter	Chan Clinic A	Chan Clinic B
2003	9/2	9/14	9/10	9/14	9/22

When the cumulative daily maximum concentration of $PM_{2.5}$ is graphed for the year 2003, there seems to be an increase in the concentration of particulate matter in the first week of September. (See Figure 14)

Figure 14



As the above graph shows, 9/3/2003 represents a "kink" in the curve which indicates a change in the daily concentration of $PM_{2.5}$.

A possible hypothesis is that this change in the first week of September in the concentration of $PM_{2.5}$ leads to an increase in the number of asthma treatments in the following weeks, namely weeks 2 and 3 in September. The other "kinks" in the graph of $PM_{2.5}$, 3/19/2003 and 6/29/2003, do not always correspond to "kinks" in the asthma curves. (Figures 15 through 19 present the cumulative daily asthma curves for the health care partners.)

Figure 15

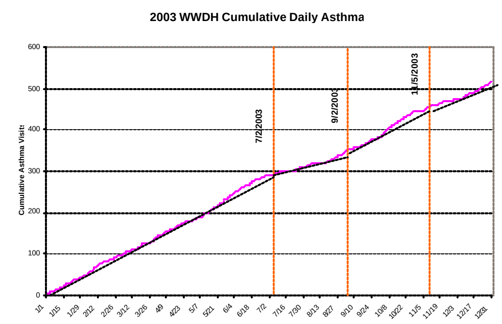


Figure 16

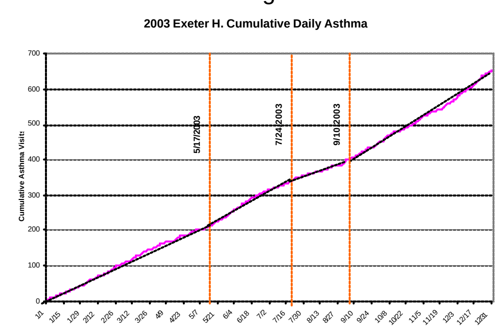


Figure 17

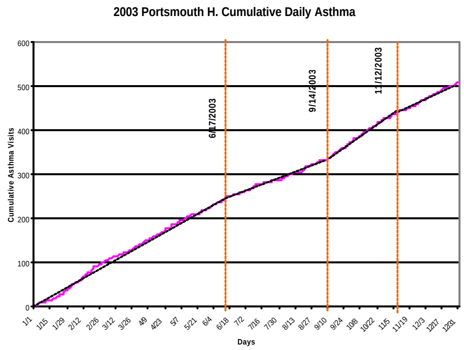


Figure 18

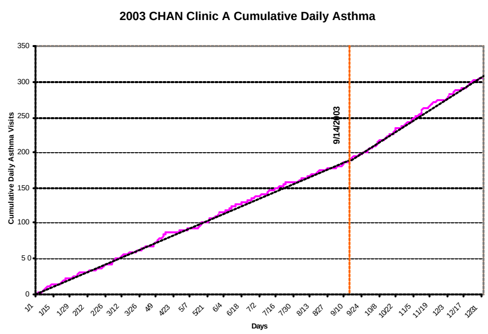
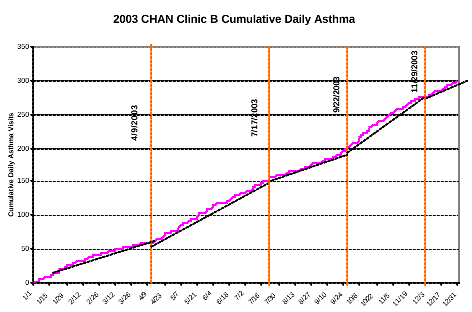


Figure 19



5.5 *Asthma and Pollen*

The pollen data from Salem, MA contain over 25 different species of pollen (allergenic and non allergenic) collected from April to September for the years 2002 and 2003. The allergenic pollens included in the analysis are: morus (mulberry), cupressaceae (juniper family, cedar), ambrosia/franseria (ragweed), juglans (walnut, butternut), artemisia (sage), and quercus (oak).

This analysis of pollen data and asthma admissions and visits focused on the years 2002 and 2003 because these are the only two years for which a complete set of both hospital/clinic data and pollen data are available.

By graphing the cumulative daily asthma admissions and visits, an approximate date each year when a change in the admission trend occurs for each hospital and the clinics was identified. That change is represented by a "kink" in the curve of the cumulative asthma admissions. Figure 20 summarizes the occurrence date for each year and each hospital:

Figure 20

	WD	Portsmouth	Exeter	CHAN Clinic A	CHAN Clinic B
2002	9/20	9/21	9/26	9/22	9/20
2003	9/2	9/14	9/10	9/14	9/22

This method of identifying a date for the change in the trend is approximate but, on average, the change in the trend occurred earlier in 2003 than in 2002.

A bar graph of daily count of pollen for the year 2002 and 2003 identifies two species of pollen with peak season in August and September: ragweed and sage. (See Figures 21 and 22.)

Figure 21

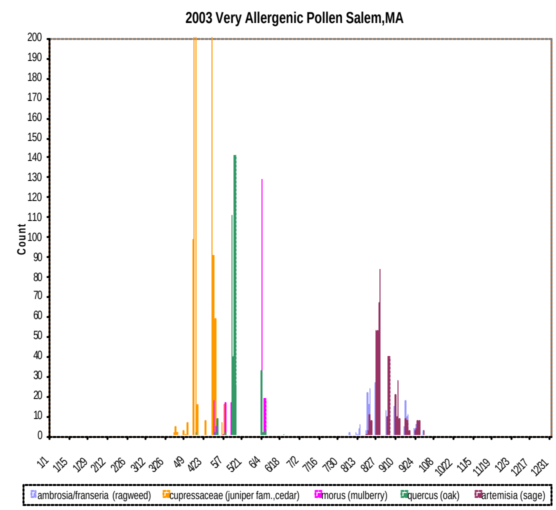
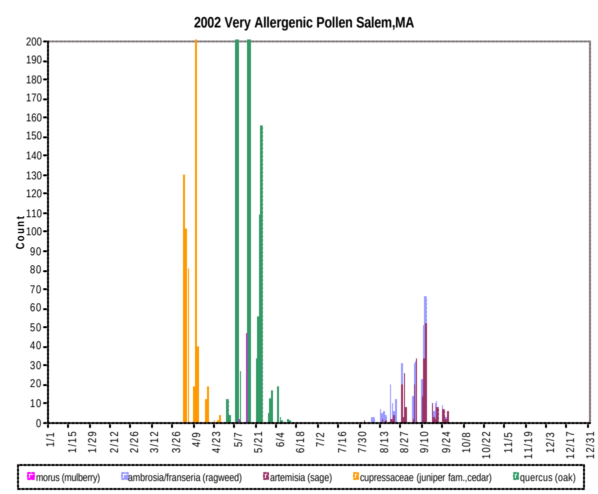


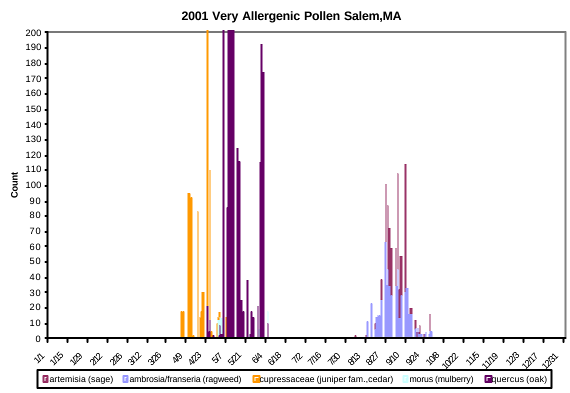
Figure 22



Figures 21 and 22 show that the peak in the pollen season for both ragweed and sage occurred earlier in 2003 than 2002.

Unlike the pollen for the years 2002 and 2003, where a clear peak existed, the year 2001 does not show a single peak. An episode of high sage and ragweed pollen occurred roughly between August 26 through September 12, a span of about three weeks, as shown in Figure 23.

Figure 23



Consequently, no correlation can be drawn between the increase in the number of asthma admissions in 2001 and the pollen season in 2001. However, of interest is not only the timing of the pollen peak in relation to the increase in the fall admissions, but also the magnitude of the pollen season in relation to the increase in asthma admissions. Is a big pollen season associated with a larger increase in the fall peak? The year 2001 had a bigger ragweed and sage pollen season compared to 2002 and 2003. And, proportionally, the increase in the fall admission in 2001 at Exeter and CHAN Clinics A and B was bigger than that of 2002 and 2003. 2001 data is unavailable for Wentworth-Douglass and Portsmouth.

The results for 2002 and 2003 support the hypothesis that pollen may be a trigger for asthma. In 2003, the increase observed in the hospital admissions and visits occurred earlier than that of 2002. And similarly, the peak in the ragweed and sage pollen season occurred earlier in 2003 than in 2002.

The previous analysis of $PM_{2.5}$ and asthma data indicates a potential link between asthma and $PM_{2.5}$ in the fall, and more specifically in September.

With the data currently available, distinguishing the effect of pollen versus $PM_{2.5}$ on asthma is not possible.

The hospital and health clinic data analysis provides more information about the third level of the economic impact of air quality pyramid. It supports that the effects of air quality on hospitalizations and health clinic visits are significant, as is the effect of air quality on public health.

Being able to identify and anticipate periods of high particulate matter and pollen can help to ameliorate the detrimental impact on public health. Forecasts of extended spells of high particulate matter and pollen can help individuals and organizations adjust their operations and day-to-day activities to reduce the costs of poor air quality. For example, hospitals and health clinics can better prepare for high admissions and visits from asthmatics and adjust their staffing accordingly. Individuals can plan their outdoor activities and reduce their physical activities during periods of expected high particulate matter and pollen.

Future research will attempt to quantify the potential value in avoided public health and health care costs of particulate matter and pollen information and forecasts in the Seacoast region and New England.

6. CONCLUSIONS

This paper and inquiry has taken a “bottom and up the pyramid” approach to exploring the economic and health effects of poor air quality.

The numbers and percentages of individuals and organizations receiving air quality information remains very low relative to those receiving weather information on a regular basis. This will have to be overcome -- through education, outreach and marketing efforts -- to achieve the most significant economic benefits from AQIF.

The EPA Survey findings suggest that people and organizations that do receive air quality information and forecasts do make changes in their behavior to protect their health, the well-being of others and productivity of workers.

Moving up the pyramid, we identify negative productivity effects of poor air quality -- with correlations between higher levels of exposure to $PM_{2.5}$ and O_3 and decreased worker productivity -- among large employers of indoor worker. The summer season cost in New England alone in short-term profitability loss is estimated to be $0.5 million.

Finally, relationships exist between health clinic visits and hospital admissions for asthma with $PM_{2.5}$ and sage and ragweed.

The exploratory inquiry presented here indicates that there can be significant benefits from encouraging greater use of AQIF. It would be beneficial to encourage greater use of AQIF by a broad range of individuals and organizations. This includes encouraging more commercial organizations, like Cisco Systems and hospitals and health clinics, to access and use AQIF on a regular basis.

In order to capture the attention of potential users, however, a strong case has to be made that AQIF can provide useful and economically valuable information. We contribute to this process here. Still, further research on this important topic is required.

7. FUTURE RESEARCH PLANS

In an effort to gain further insights on the potential economic value of AQIF our research plans include follow-ups on the analysis presented above.

To capture how air quality events in the non-summer months may impact health and productivity, survey participants from the Summer 2004 Employee Survey will be asked during the Spring and Fall to complete Internet-based surveys regarding general health and productivity at the workplace. This data will be used to correlate with a variety of air quality factors to gain additional seasonal perspectives on the public health and economic impact of air quality in New England.

In addition, to get a more representative sample of workers during major air quality events during the summer of 2005, a random phone survey of 300 households in New England will be undertaken. This survey will document changes in general health and activities at work associated with changes in air quality among a broader population.

Case studies will also be developed with institutional research partners. The case studies will investigate the air quality impact on business operations, and identify specific beneficial applications of air quality information and forecasts. The case study assessments will be initiated with a forum at each partner's location, presenting results from the Summer 2004 Employee Survey and hospital and health clinic analysis. They will then involve facilitated structured discussion about the opportunities to use air quality information and forecasts to improve operations and reduce costs related to poor air quality.

With the hospital and health care treatment data, the research team is focusing on following up on the preliminary analysis and findings, by: (a) analyzing data from five (other) clinics in the CHAN network and (b) correlating a wider set of air quality factors with data from the partner hospitals and CHAN.

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