BISHOP PAIUTE TRIBE
ENVIRONMENTAL MANAGEMENT OFFICE
AIR PROGRAM

SHORT TERM HEALTH IMPACTS OF HIGH PM EPISODES ON THE BISHOP PAIUTE RESERVATION

Prepared for
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ABSTRACT

This pilot study examines the impacts of high particulate matter concentrations on health for the Bishop Paiute Reservation, located 60 miles from the Owens Dry Lake, largest PM-10 source in the US. This may be the first such study for a Reservation population and of the health impacts of the dry lake. Instead of using conventional measures like mortality or hospitalizations, we focus on clinic visits yielding more observations. Using time series and Poisson models, we link daily visits to PM levels. We find weak impact of PM-10 on health despite high concentrations and modest impact of PM-2.5.

EXECUTIVE SUMMARY

This is a pilot study to examine the impacts of high particulate matter concentrations on health for the Bishop Paiute Reservation, located only 60 miles from the largest source of PM-10 in the US, the Owens Dry Lake. Located in a remote rural area on the Nevada-California border between the Sierra Nevada and the White Mountains, the Tribe has a population of 1350 enrolled members and the Reservation is comprised of 875 contiguous acres. To date, we have found no studies of the impact of particulate matter on health for Reservation populations and no quantitative studies of the impacts of the dry lake. This is because conventional methods mortality or hospital admissions are inappropriate for sparse rural populations, due to the small number of events. We therefore focus on clinic visits which yield more observations and capture common acute health problems.

The Bishop Paiute Reservation is a uniquely appropriate laboratory for this type of study. The Reservation is small and spatially compact. The native population is served by a single clinic, the Toiyabe Indian Health Project. The Tribe's air quality monitors are located in the same complex as the clinic. The air quality data are regularly validated internally and by outside audits and are known to be of good quality.

Using time series and Poisson models, we link the daily number of clinic visits to daily average and maximum levels of PM-10 and PM-2.5. We examine all visits, visits under age 5, visits age 65 and over, respiratory and circulatory visits to select those who may be more vulnerable. If particulate matter impacts health, we expect to see an increase in the number of visits two to

three days later. Our results are stable across both modeling approaches although we found few statistically significant results.

Despite high concentrations, we found weak evidence of the impact of PM-10 on circulatory visits, particularly 3-4 days after a high concentration episode and modest impact of PM-2.5 concentrations on pediatric visits at all lags. We were hampered by relatively small sample sizes because we had only one year of data, and the sample was further reduced by clinic closures and missing monitoring data. Nevertheless we believe that this approach bears further investigation because it provides a method for studying previously unexamined populations. We plan to add more years of data to the study in the near future to help establish the utility of the approach.

BACKGROUND

The National Ambient Air Quality Standards (NAAQS) were created with the goal of protecting health. However, the standards for PM-10 (particulate matter less than 10 microns in aerodynamic diameter) and for PM-2.5 (particulate matter less than 2.5 microns in aerodynamic diameter) refer to 24-hour concentrations. The PM-10 concentrations are set at the relatively high threshold of 150 μg/m³, and those for PM-2.5 are set at 35 μg/m³. Research suggests that there is no specific threshold for health impacts of particulate matter, i.e., impacts can be observed at low concentrations, and that short term high concentrations (that are not necessarily associated with exceedances of the NAAQS) also have a significant impact on health, particularly cardiac and respiratory illness.

The Bishop Tribe is located on the California-Nevada border in an area known as the Owens Valley. The Tribe is one of the five largest in California, in terms of population. The Bishop Reservation is located a mere 60 miles north of the Owens Dry Lake, the largest source of PM-10 in the nation. Measured concentrations on the dry lake have exceeded the federal standard by a factor of 75 and extremely high concentrations continue to be observed despite substantial mitigation efforts (100 exceedances were observed in 2006). The Bishop Paiute Tribe is in the area of potential impacts from the dry lake (Great Basin Unified Air Pollution Control District, 1998) and a recent study by the Tribe has confirmed that the dry lake probably has an impact in nearly half of high PM-10 concentrations days on the Reservation (Bishop Paiute Tribe, Air Program, presented at the 2006 National Tribal Environmental Science conference). Measured hourly PM-10 concentrations on the Reservation have exceeded 1,200 μg/m³ (Bishop Paiute Tribe, Air Program, data files).

In the Owens Valley, there are two primary sources of particulate pollution, smoke and dust. Dust is the primary source of PM-10 and originates from the Owens dry lake and other barren lands. It is associated with windy conditions. Smoke is the primary source of PM-2.5 and is generated by wildfires and wood burning for home heating (Bishop Paiute Tribe, 2002). Typically, higher PM-2.5 concentrations are associated with relatively calm winds and stable air. Levels of PM-10 are much higher, with exceedances of the Tribal and State of California 24-hour standard of 50 $\mu g/m^3$. Our prior work suggests that about half of the high PM-10 days on the Bishop Reservation are associated with wind events on the dry lake (Bishop Paiute Tribe, 2006).

LITERATURE REVIEW

At present, there are few or no studies of the impacts of the dry lake on any of the populations of the Owens Valley and we have found no studies of the impact of particulate matter on health for Reservation populations. One exception is Kittle, 2000, a study based on self reported health effects of Owens Valley residents who responded to newspaper ads, e-mail and other requests for information. Based on these self reports, Kittle found that valley residents were likely to report a range of respiratory problems following high dust episodes and the types of reported symptoms were similar to other studies of the impacts of particulate matter on health.

One of the reasons that there are few or no quantitative studies of rural areas or reservation populations is that conventional methods like studies of mortality or hospital admissions are inappropriate for sparse rural populations, due to the small population size and the small number of events involved, even when many years of data are combined. Similarly, large sample surveys do not provide coverage and detailed surveys of reservation populations are rare. This is a general problem for rural areas and has been raised as a concern when revisions of the NAAQS were proposed.

In addition, because particulate matter is defined by aerodynamic diameter and not by chemistry, generalizing results from urban industrial areas to rural areas is difficult. In the Owens Valley, PM-10 is primarily windblown dust from the Owens Dry Lake and other barren lands and PM-2.5 is primarily smoke from wildfires in the summer and wood burning for home heating in the winter – probably different from a standard urban mix. (See Bell, et al, 2008 for a study of heterogeneity.) Nevertheless, the impact of particulate matter on health is well-known and has been documented in many countries. A few of the most recent studies are cited here. The elderly and children have been shown to be particularly vulnerable and respiratory and cardiac conditions have been shown to be sensitive to the impact of particulate matter. In the case of children, the effects have included acute respiratory effects (O'Connor, et al, 2008, Wilhelm, et al, 2008) and allergic sensitization (Morgenstern, et al, 2008). In addition, low income populations may be at higher risk of adverse effects (Carder, et al, 2008). The cardiac and respiratory effects on adults, including some of the mechanisms are well-documented (see for example, Mills, et al, 2009, Peng, et al, 2008 and 2008a, Chuang, et al, 2008). Higher particulate matter concentrations have been found to decrease life expectancy (Pope, et al, 2010)

STUDY DESIGN

This study utilizes an innovative approach to examine the short term impacts of high particulate matter concentrations on health. The study uses daily counts of clinic visits as a measure of health. Specifically we examine the total number of visits, visits for children under age 5 and under, visits for persons 65 and over, visits for respiratory and visits for circulatory conditions (including cardiac conditions). These types of visits were chosen because we expect the young, the elderly, those with respiratory and those with circulatory conditions to be most vulnerable to high particulate concentrations. Broad diagnostic groups were selected to obtain a sufficiently large case base. The hope is that clinic visits would be sufficiently common that there would be sufficient variability in the daily number of clinic visits to overcome the small population base. Table 1 below summarizes the selection criteria.

TABLE 1. Selection criteria for counts of visits

Variable	Definition
Number of visits	Count of all visits in a day
Visits under age 5	Count of all visits by children aged 0 to 4 year in a day
Visits age 65 and over	Count of all visits by adults over age 65 in a day
Respiratory visits	Count of visits with a diagnosis using ICD-9 codes 460-519
Circulatory visits	Count of visits with a diagnosis using ICD-9 codes 390-459

This study is exploratory and intended as a pilot to determine whether clinic visits are an appropriate measure of health that can be used for small populations. The Bishop Paiute Reservation is a uniquely appropriate laboratory for this type of study. The Reservation is small and spatially compact. The native population is served by a single clinic, the Toiyabe Indian Health Project. The Tribe's air quality monitors are located in the same complex as the clinic. The air quality data are regularly validated internally and by outside audits and are known to be of good quality.

Hourly PM-10 data have been collected for the Bishop Paiute Reservation since 2003 and PM-2.5 was added in 2004. Data are collected hourly using TEOMs (tapered element oscillating microbalance) equipped with FDMS (filter dynamics monitoring system). The Reservation population is primarily served by a single clinic, operated by the Toiyabe Indian Health Project (TIHP). The tribal air monitors are located in the same complex as the clinic. The Reservation is only 875 acres, so the monitoring data are representative of conditions experienced by residents.

We then link the visits to daily levels of PM-10 and PM-2.5. The two measures used for each pollutant are the maximum hourly concentration in a 24-hour period and the 24-hour average. If either type of particulate matter has an impact on health, we hypothesize that we will see an increase in the number of visits two to three days later. Our initial intention was to focus on PM-10 because our prior work, presented at the 2006 National Tribal Environmental Science conference, had shown that at least half of the high PM-10 episodes on the reservation were associated with activity on the Dry Lake. However, we have also included information on PM-2.5 for comparison.

The results reported here are based on data from the Toiyabe Indian Health Project covering the period from October 1, 2006 to September 30, 2007. Obtaining data from the clinic's records proved to be more complex than expected because the data had to be extracted manually from claims data. However, clinic staff have been more than willing to assist with this detailed and tedious task and the quality of the data appears to be excellent.

Our analytic approach utilizes a combination of descriptive statistics to explore the structure of the data and to verify that sufficient variability exists for all of the measures of interest. Next we examine correlations among the measures of interest. Finally, we estimate two classes of models, one based on standard time-series methods and the other based on Poisson regression methods. Each modeling effort takes into account different aspects of the structure of the data. The time-series methods provide a better description of time-dependence in the various measures of visits while the Poisson models take into account the fact that visits are a count.

DESCRIPTIVE STATISTICS

Number of Visits

As shown in Table 1, between October 1st 2006 and September 30th 2007, the clinic had over 9,500 visits, with 39 visits in an average day and a range of 15 to 77 visits. On a typical day approximately 8 percent of visits are to children under age 5 and 28 percent of visits are to people age 65 and over. Eight percent of visits are for respiratory conditions and 5 percent of visits have a diagnosis relating to the circulatory system.

TABLE 1 – Descriptive Statistics for the Number of Visits October 1, 2006 to December 30, 2007

October 1, 2006 to September 30, 2007	Number of visits	Avg Daily Visits	Min Num Visits	Max Num Visits	Var Num Visits	Std Dev Num Visits
Total	9502	39	15	77	70.20	8.38
Under age 5	817	3	0	13	6.12	2.47
65 and over	2785	11	2	25	16.89	4.11
Respiratory	800	3	0	12	5.49	2.34
Circulatory	497	2	0	9	2.65	1.63

These results are shown graphically in Figure 1, below.

Figure 1 – Number of Visits, Minimum, Maximum and Average

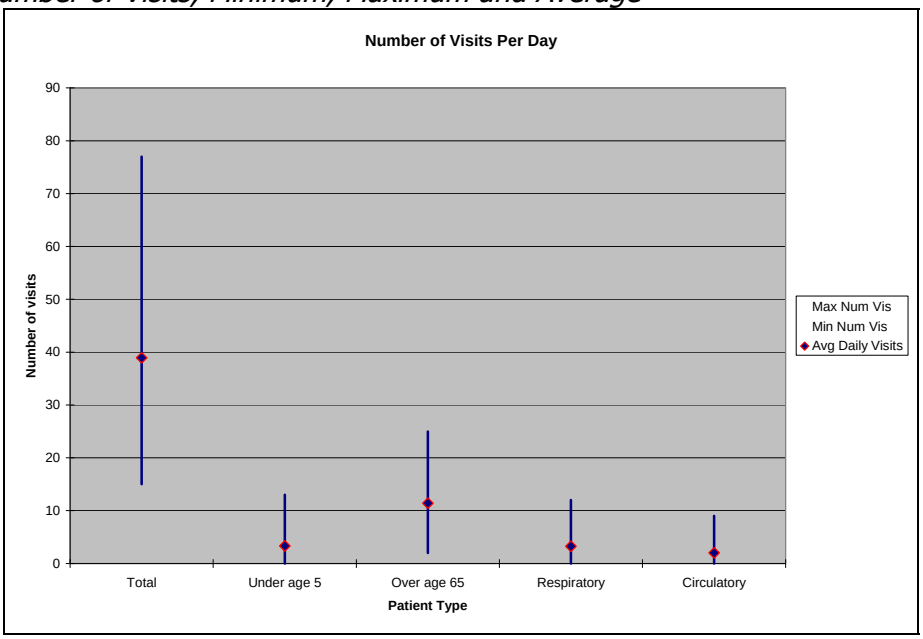
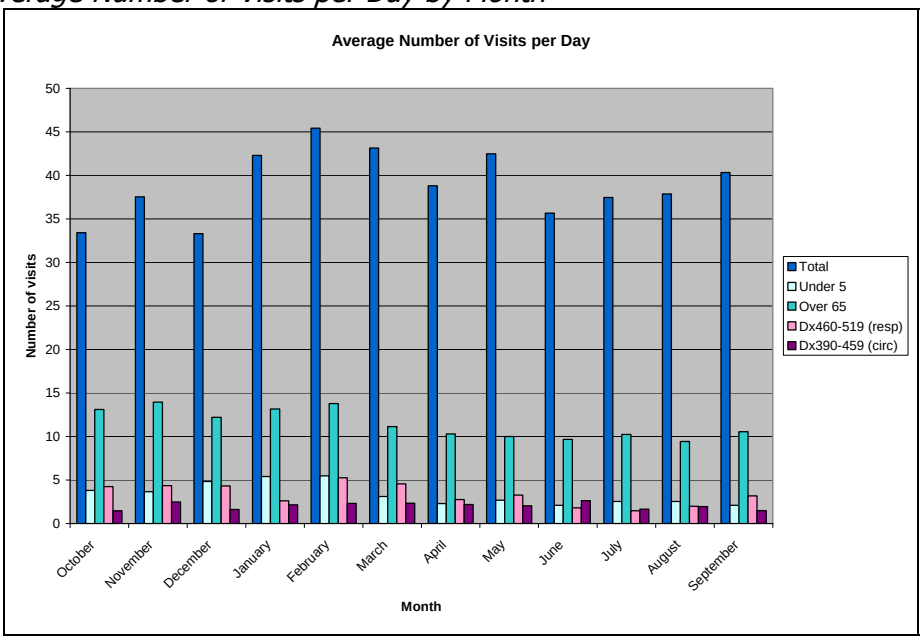


Figure 2, shows the average number of visits per day by month. There is some indication of a seasonal pattern, with December having the lowest number of visits per day, probably due to the holidays, and February having the most visits. Pediatric and visits by the elderly both peak during the winter months.

Figure 2 – Average Number of Visits per Day by Month



We investigated the daily variability of each type of visits using a time series plot, overlaid with a 7 point moving average. These results are shown in Figures 3, 4 and 5. These graphs help assure us that there is sufficient variability in each series for analysis. Because the daily number of visits is quite variable, the moving average is used to reveal the overall pattern.

Figure 3 – Time Series Plot of Total Daily Visits

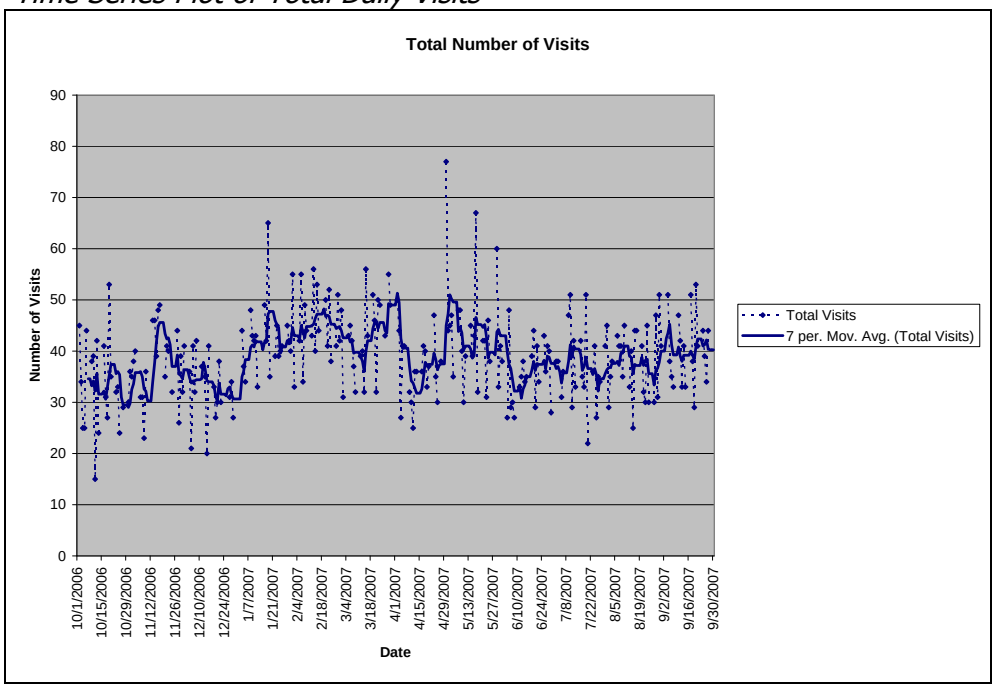


Figure 4 – Time Series Plot of the Number of Visits for Children under age 5 and Adults 65 and over

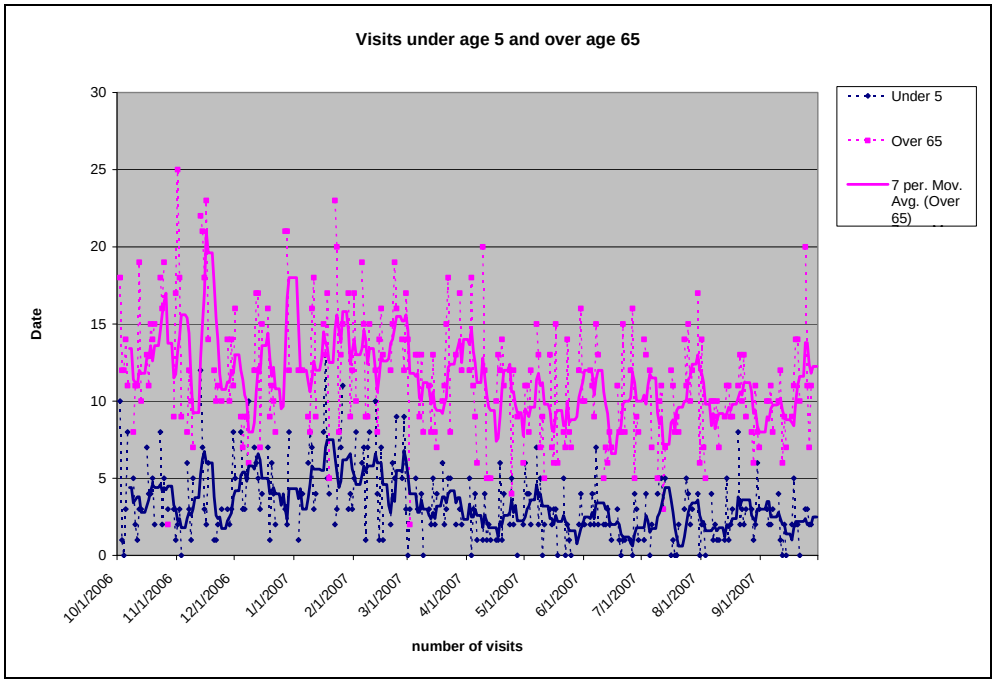
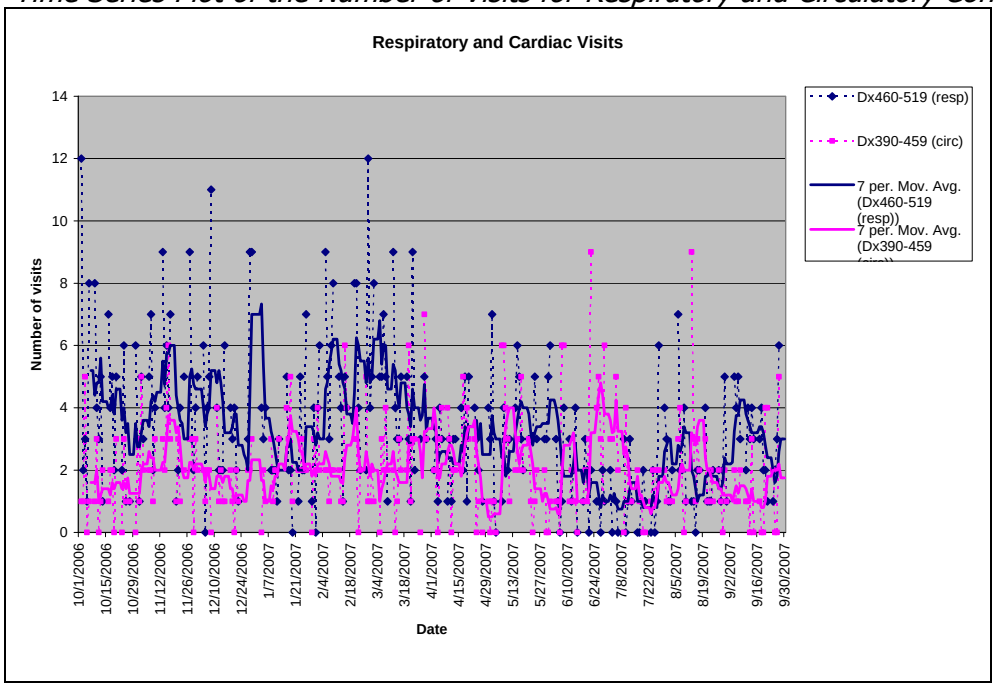


Figure 5 – Time Series Plot of the Number of Visits for Respiratory and Circulatory Conditions



Particulate Matter

Table 2 below shows the descriptive statistics for the particulate matter data. All measurements were taken at the monitoring station on the Bishop Paiute Reservation. Instruments are located on the roof of the Environmental Management Office which is in the same complex as the clinic.

Table 2 includes information for both PM-10 and PM-2.5. During the study period, the PM-10 sampler was down in December for several weeks for an upgrade. The highest hourly concentration of PM-10 was 710 $\mu g/m^3$. There were 17 hours where the concentration exceeded 200 $\mu g/m^3$, and 8 days where the concentration exceeded the Tribe's 24 hour standard of 50 $\mu g/m^3$. The PM-2.5 data are included for comparative purposes. In general, the PM-2.5 data are much less volatile than the PM-10 data, and, as expected levels are comparatively lower. There were only 5 hours above the proposed Tribal health standard of 70 $\mu g/m^3$, and no exceedances of the Tribal 24-hour standard of 35 $\mu g/m^3$. The maximum concentration was observed on July 4th and is associated with fireworks. The results are shown graphically below in Figures 6 and 7.

Table 2 – Descriptive Statistics for Particulate Matter October 1, 2006 to September 30, 2007

PM-10	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07
Average 24-Hr MC	16.8	23.8		28.4	15.9	18.1	18.4	25.8	28.1	29.5	28.8	30.4
Max 24-Hr MC	38.0	41.3		45.6	39.5	44.4	42.8	35.8	69.0	62.6	47.2	70.0
Max Hourly	246.6	376.8		173.6	337.0	250.3	189.1	145.1	294.1	416.6	331.7	710.5
Number of days over Tribal standard*									2	2		4
Number of hours over 200 ug/m3**	2	2			1	1			4	2		5
** Tribal standard is 50 ug/m3*												
*** Proposed Tribal stage 1 health alert*												
NOTE: PM-10 data for Nov and Dec. are incomplete due to system upgrade												
PM-2.5	**Oct-06**	**Nov-06**	**Dec-06**	**Jan-07**	**Feb-07**	**Mar-07**	**Apr-07**	**May-07**	**Jun-07**	**Jul-07**	**Aug-07**	**Sep-07**
Average 24-Hr MC	6.7	10.5	13.6	9.4	7.5	4.6	4.4	8.1	6.7	10.3	11.5	
Max 24-Hr MC	14.8	23.0	26.6	19.2	13.5	11.3	11.2	18.1	11.1	23.8	23.4	
Max Hourly	38.4	67.9	88.5	61.6	54.5	45.3	50.6	95.8	20.4	157.3	50.7	
Number of days over Tribal standard*												
Number of hours over 70ug/m3			2					1		2		
** Tribal standard is 35 ug/m3*												
NOTE: PM-2.5 data for Sept. are incomplete due to system maintenance												

Figure 6 – Monthly PM-10 Concentrations, October 2006 to March 2007

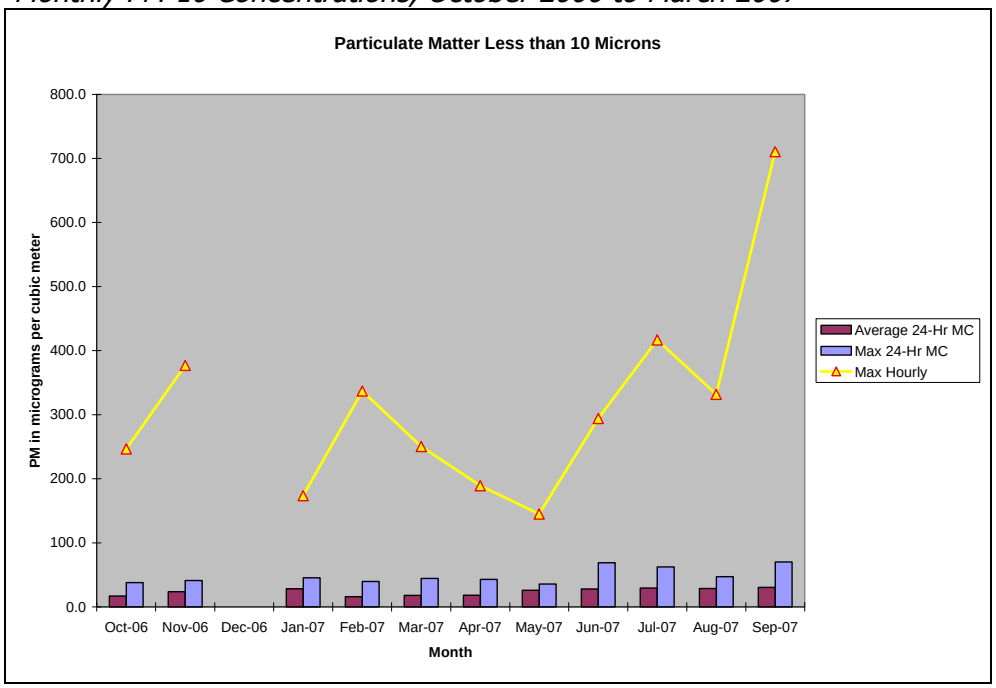
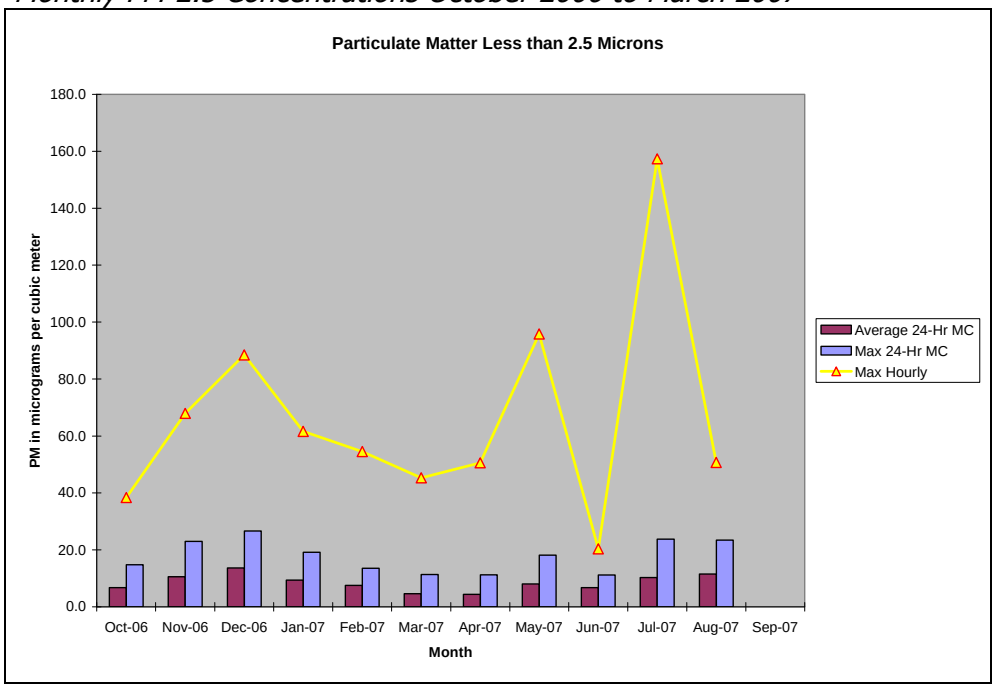


Figure 7 – Monthly PM-2.5 Concentrations October 2006 to March 2007



In order to more completely assess the variability of the PM-10 data relative to the PM-2.5 information, we constructed scatter diagrams of the daily and the maximum concentrations. These are show in Figures 8 and 9. Both series show considerable variability particularly at the higher concentrations.

Figure 8 – Scatter Diagram of Average versus Maximum PM-10 concentrations

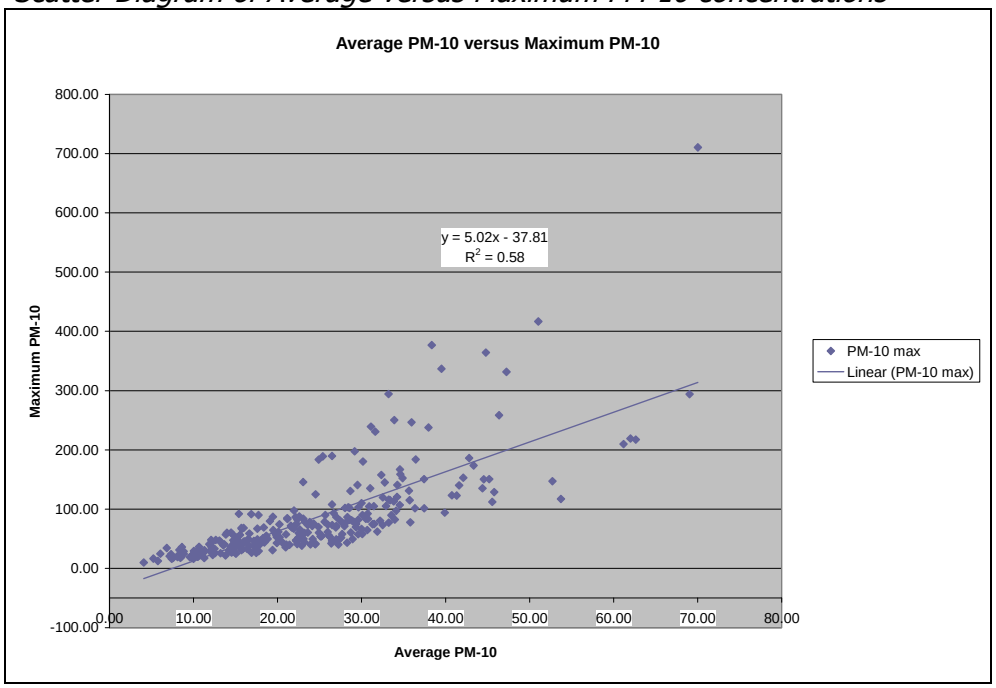
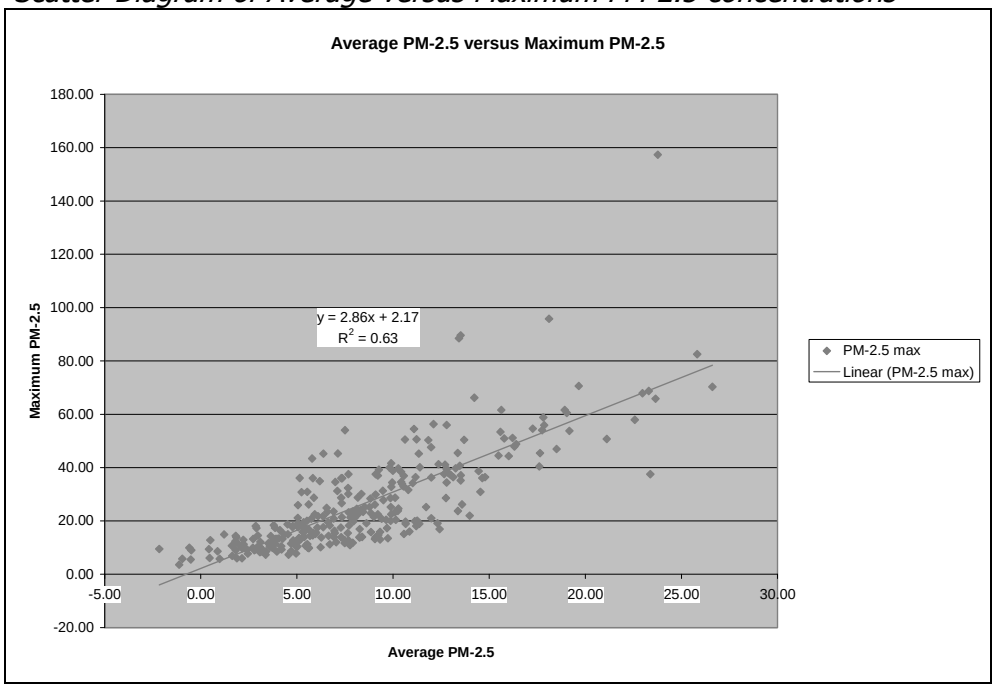


Figure 9 – Scatter Diagram of Average versus Maximum PM-2.5 concentrations



PRELIMINARY TIME SERIES RESULTS

Missing data: Handling weekends and holidays

Because the clinic operates Monday through Friday and is closed for standard holidays, there is a natural structure to the data, leading to missing values. This particularly affects any of the

times series estimates such as the autocorrelation functions. To handle this structure, we adopted the following strategy.

1. For variables based on clinic visits, we deleted weekends, holidays and days when the clinic was closed (days with zero visits).
2. For variables measuring 24-hour average air quality, we used the average of days when the clinic was closed and the first day the clinic was open. (For example, for Monday, we use the average of the 24-hour averages for Saturday through Monday.)
3. For variables measuring the hourly maximum, we used the maximum of the days when the clinic was closed and the first day the clinic was open. (For example, for Monday, we use the maximum of the hourly maxima for Saturday through Monday.)

We conducted sensitivity analyses to evaluate the impact of this approach and verified that the changes were not substantially variance altering and did not alter substantive conclusions. In addition, the time series models include a variable indicating days that follow a weekend or holiday to account for potentially higher visits following periods when the clinic is not open, and the Poisson models treat days within a week as a cluster.

Autocorrelation functions

Prior to beginning modeling we examined the autocorrelation functions of each series studied. We considered lags up to 4 days. The results are shown in Table 2 and are plotted in Figure 10. Correlations that are significant at the 0.05 level are indicated in bold in the table and the associated points are highlighted in the graphs.

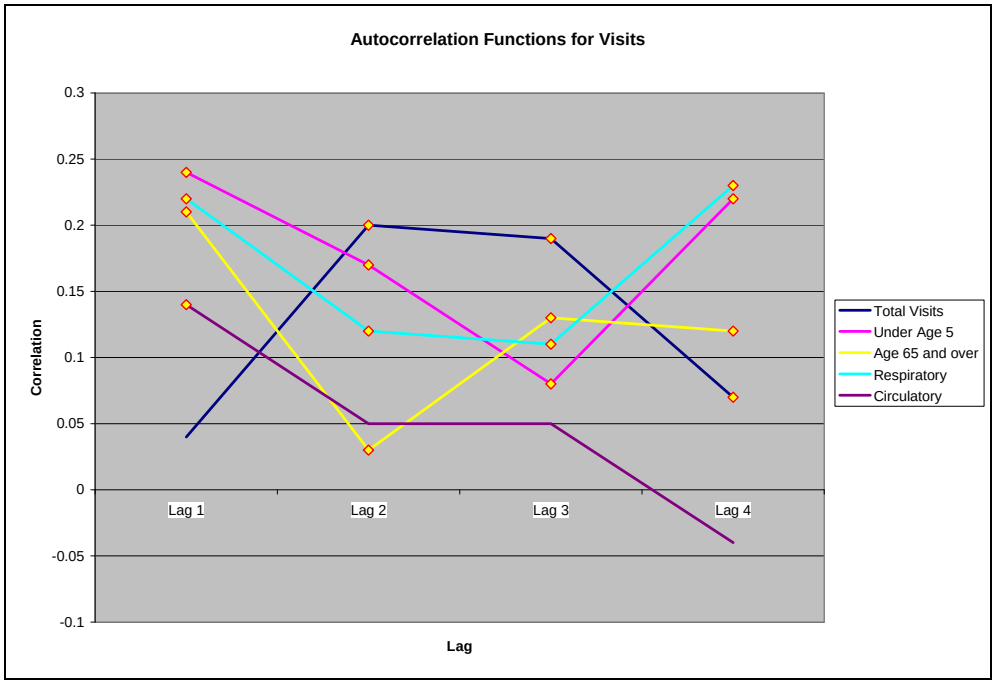
Table 3. Autocorrelation functions for visits

Variable	Lag 1		Lag 2		Lag 3		Lag 4	
	Correlation	p	Correlation	p	Correlation	p	Correlation	p
Total Visits	0.04	0.50	**0.20**	0.007*	**0.19**	0.003*	0.07	0.004*
Under Age 5	**0.24**	0.0001*	**0.17**	0.00*	**0.08**	0.00*	**0.22**	0.00*
Age 65 and over	**0.21**	0.0009*	**0.03**	0.004*	**0.13**	0.001*	**0.12**	0.0006*
Respiratory	**0.22**	0.0006*	**0.12**	0.0005*	**0.11**	0.0004*	**0.23**	0.00*
Circulatory	**0.14**	0.03*	0.05	0.06	0.05	0.11	-0.04	0.16

*NOTE: * significant at the .05 level.*

All of the series except total visits show evidence of significant first order autocorrelation with the exception of total visits which seems to have at least a second order process. To standardize models across all dependent variables, initial modeling uses an order 2 process.

Figure 10. Autocorrelation functions for visits



Cross Correlations of Particulate Matter and Number of Visits

To investigate the health impacts of high particulate concentrations, we examined the time series cross correlation of each of the PM series and health. We considered lags of up to 4 days to allow time for clinic visits to be scheduled. In these correlations, the visits of each type are correlated with PM values on the same day (lag 0), the previous day (lag 1), and so on up to PM values 4 days prior (lag 4). If particulate matter has an impact on health, we expect to see an increase in the number of visits two to three days following the high PM episode. This will appear as a positive correlation at lags 2 or 3.

The results are shown in Tables 4a through 4d and graphically in Figures 11a through 11d. Only two sets of cross correlations stands out as statistically significant – those between visits for children under age 5 and the maximum PM-2.5 concentration (Table 4d) which are positive and those between respiratory visits and the average PM-10 concentration (Table 4a) which are negative. In the tables, values that are significant at the .05 level are in bold. In the graphs, the corresponding points are highlighted with a yellow diamond outlined in red. In reviewing these results, it is important to keep in mind that they describe bivariate relationships and do not take into account the full structure of the data. The discussion below is organized by PM measure because there appeared to be more consistency by type of exposure than by type of visit.

<u>Visits and Average PM-10</u>

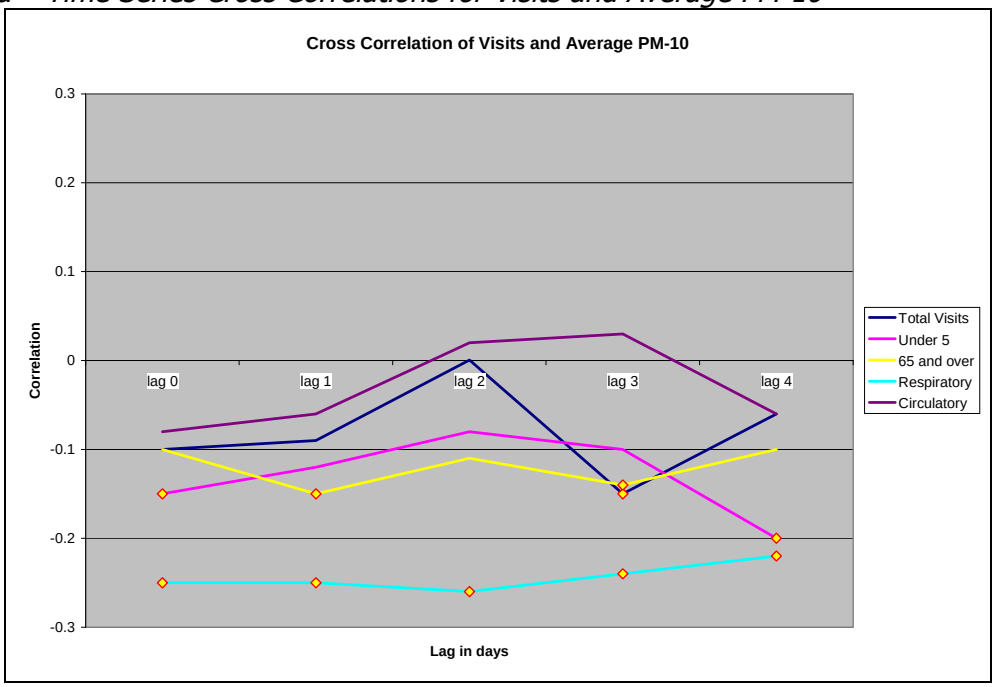
In general, the correlations between visits and average PM-10, shown in Table 4a and Figure 11a, are weak and negative. As noted above, the most striking finding is a consistent negative correlation between respiratory visits and average PM-10. The relationship is difficult to interpret and is repeated for the other PM measures with the exception of maximum PM-2.5, although it does not reach conventional levels of statistical significance.

Table 4a – Time Series Cross Correlations for Visits and Average PM-10

Average PM-10	lag 0		lag 1		lag 2		lag 3		lag 4	
	Corr.	p	Corr.	p	Corr.	p	Corr.	p	Corr.	p
Total Visits	-0.10	0.17	-0.09	0.22	0.0006	0.99	**-0.15**	0.04*	-0.06	0.40
Under 5	**-0.15**	0.03*	-0.12	0.11	-0.08	0.30	-0.10	0.16	**-0.20**	0.006*
65 and over	-0.10	0.19	**-0.15**	0.04*	-0.11	0.14	**-0.14**	0.05*	-0.10	0.17
Respiratory	**-0.25**	0.0003*	**-0.25**	0.0005*	**-0.26**	0.0002*	**-0.24**	0.001*	**-0.22**	0.002*
Circulatory	-0.08	0.25	-0.06	0.37	0.02	0.78	0.03	0.72	-0.06	0.43

*NOTE: * significant at the 0.05 level.*

Figure 11a – Time Series Cross Correlations for Visits and Average PM-10



Visits and Maximum PM-10

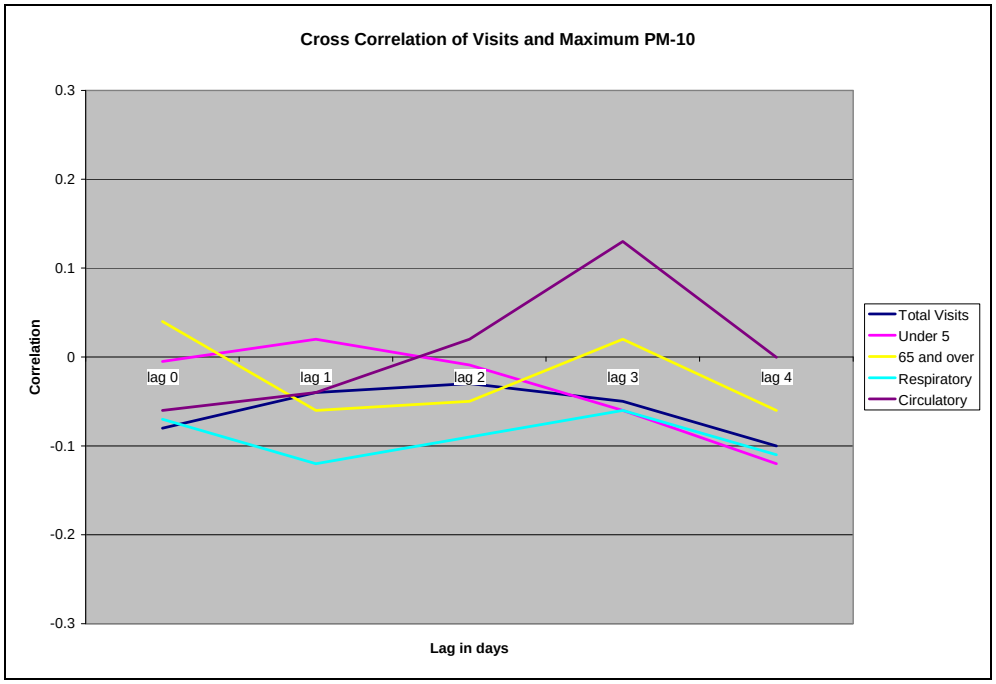
The correlations between visits and maximum PM-10 are shown in Table 4b and Figure 11b below. None of the correlations reach conventional levels of statistical significance. However, circulatory visits do show a modest if not quite significant positive association with maximum PM-10 at lag 3.

Table 4b – Time Series Cross Correlations for Visits and Maximum PM-10

Maximum PM-10	lag 0		lag 1		lag 2		lag 3		lag 4	
	Corr.	p	Corr.	p	Corr.	p	Corr.	p	Corr.	p
Total Visits	-0.08	0.29	-0.04	0.58	-0.03	0.72	-0.05	0.50	-0.10	0.18
Under 5	-0.005	0.95	0.02	0.73	-0.009	0.91	-0.06	0.38	-0.12	0.11
65 and over	0.04	0.58	-0.06	0.43	-0.05	0.47	0.02	0.78	-0.06	0.44
Respiratory	-0.07	0.34	-0.12	0.11	-0.09	0.20	-0.06	0.41	-0.11	0.13
Circulatory	-0.06	0.42	-0.04	0.61	0.02	0.73	0.13	0.08	-0.0003	1.00

*NOTE: * significant at the 0.05 level.*

Figure 11b – Time Series Cross Correlations for Visits and Maximum PM-10



Visits and Average PM-2.5

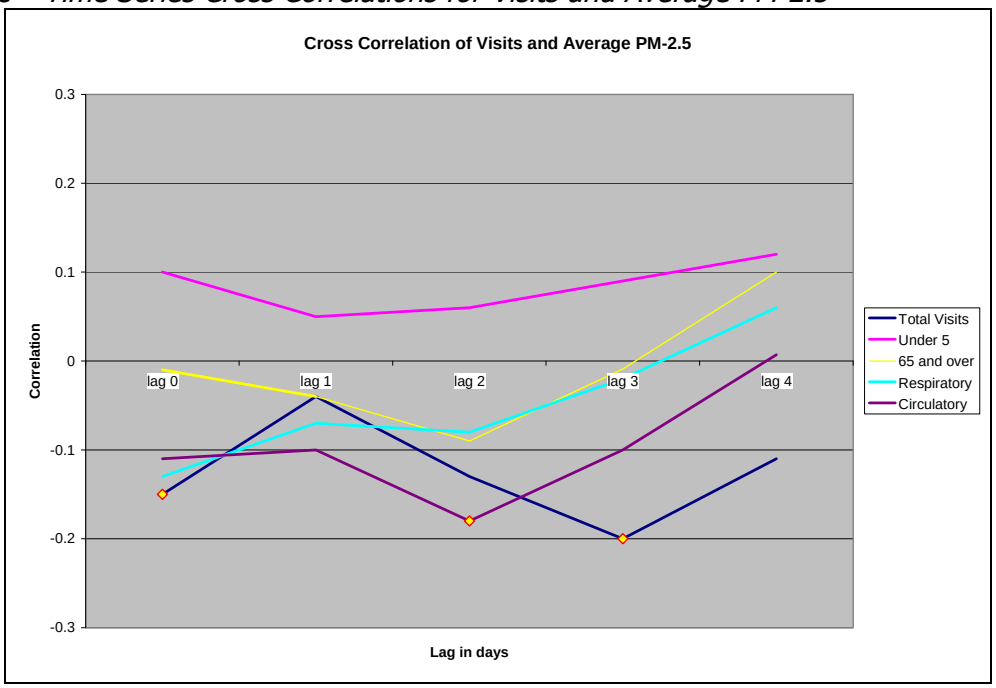
The correlations of visits and average PM-2.5 are shown in Table 4c and Figure 11c below. Again few of the correlations reach conventional levels of significance, except a few negative correlations that remain difficult to interpret. More striking, if not significant, is the consistent positive association of pediatric visits and average PM-2.5, although the correlations are modest and not significant in conventional terms. This finding is repeated with pediatric visits and maximum PM-2.5 and does reach conventional levels of significance.

Table 4c – Time Series Cross Correlations for Visits and Average PM-2.5

Average PM-2.5	**lag 0**		**lag 1**		**lag 2**		**lag 3**		**lag 4**	
	Corr.	**p**	**Corr.**	**p**	**Corr.**	**p**	**Corr.**	**p**	**Corr.**	**p**
Total Visits	**-0.15**	0.04*	-0.04	0.54	-0.13	0.07	**-0.20**	0.006*	-0.11	0.12
Under 5	0.10	0.19	0.05	0.50	0.06	0.38	0.09	0.22	0.12	0.09
65 and over	-0.01	0.88	-0.04	0.54	-0.09	0.22	-0.009	0.90	0.10	0.17
Respiratory	-0.13	0.07	-0.07	0.33	-0.08	0.28	-0.02	0.77	0.06	0.44
Circulatory	-0.11	0.13	-0.10	0.18	**-0.18**	0.02*	-0.10	0.19	0.007	0.92

*NOTE: * significant at the 0.05 level.*

Figure 11c – Time Series Cross Correlations for Visits and Average PM-2.5



Visits and Maximum PM-2.5

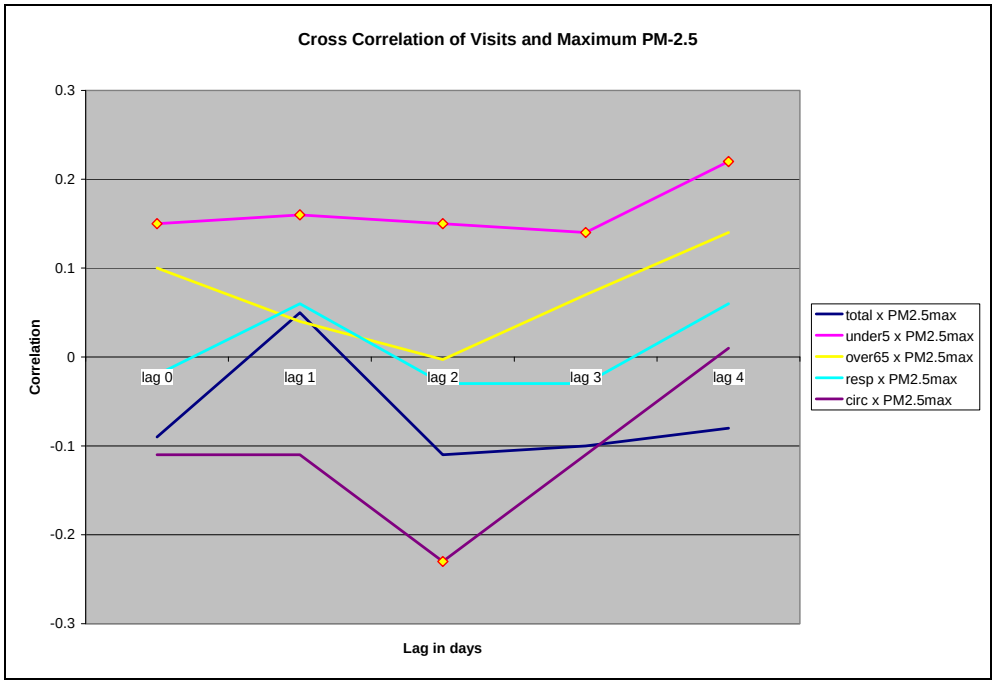
The correlations between visits and maximum PM-2.5 are shown in Table 4d and Figure 11d below. As we have noted, there is a consistent significant positive correlation between pediatric visits and maximum PM-2.5. This is one of the strongest findings so far. However, it is important to recognize that these are bivariate results and do not account for the structure of the data.

Table 4d – Time Series Cross Correlations for Visits and Maximum PM-2.5

Maximum PM-2.5	**lag 0**		**lag 1**		**lag 2**		**lag 3**		**lag 4**	
	Corr.	**p**	**Corr.**	**p**	**Corr.**	**p**	**Corr.**	**p**	**Corr.**	**p**
total x PM2.5max	-0.09	0.18	0.05	0.53	-0.11	0.14	-0.10	0.17	-0.08	0.28
under5 x PM2.5max	**0.15**	0.04*	**0.16**	0.02*	**0.15**	0.04*	**0.14**	0.05*	**0.22**	0.002*
over65 x PM2.5max	0.10	0.17	0.04	0.62	-0.003	0.97	0.07	0.34	0.14	0.06
resp x PM2.5max	-0.02	0.82	0.06	0.39	-0.03	0.72	-0.03	0.71	0.06	0.39
circ x PM2.5max	-0.11	0.14	-0.11	0.12	**-0.23**	0.001*	-0.11	0.13	0.01	0.86

*NOTE: * significant at the 0.05 level.*

Figure 11d – Time Series Cross Correlations for Visits and Maximum PM-2.5



PRELIMINARY MODELING RESULTS – TIME SERIES MODELS

We initiated modeling using conventional time series methods to explore the structure of the data and to take a close look at time-dependence. However, as noted earlier, these models, like the correlation functions just examined to not take into account the fact that visits are a count. This may be particularly important when visits are restricted to specific age groups or diagnoses. The final modeling using Poisson methods takes into account this aspect of the data.

Structure of the data – Second order autoregressive process

We initiated modeling by examining the data structure using a second order autoregressive process with an indicator variable for days that follow a weekend and/or a holiday. We elected to use a second order model because total visits appeared to follow a second order process and to maximize comparability across the various measures of clinic visits.

$$visits_t = \alpha + \beta\ Weekend/Holiday + \mu_t$$
$$where\ \mu_t = + \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \varepsilon_t$$

These initial results are used to verify that the structure of the data is adequately captured and are used for global hypothesis tests in the distributed lag model that follows. These analyses are limited to days that have complete information for the full distributed lag model to maximize comparability and enable hypothesis testing.

The approach we have chosen appears to provide a reasonable description of the various types of clinic visits, with the exception of circulatory visits. For the other measures of visits, the indicator for days following a weekend and/or holiday is positive and statistically significant and the error terms seem to be adequately represented by a second order autocorrelation process.

We hypothesize that model is less adequate for circulatory visits in part because circulatory visits may be dominated by routine visits for follow-up and only have a small component of acute episodes. In addition, there are typically few circulatory visits on a given day (an average of 2, as shown in Table 1). However, pediatric and respiratory visits are also relatively rare and the model is more successful.

Table 5 – Second Order Autoregression with Indicator for Weekends and/or Holidays

	Coefficient	Standard Error	p
Total Visits			
Constant	38.520	1.365	0.00
Weekend/Holiday	**4.097**	0.872	0.003*
Autoregression			
Lag 1	-0.012	0.091	0.89
Lag 2	**0.220**	0.840	0.009*
$\mathbf{X^2}(3)$	**18.57**		0.0003*
Under age 5			
Constant	2.784	0.300	0.00
Weekend/Holiday	**1.102**	0.319	0.001*
Autoregression			
Lag 1	**0.208**	0.078	0.008*
Lag 2	**0.149**	0.064	0.02*
$\mathbf{X^2}(3)$	**27.18**		0.00
Age 65 and over			
Constant	10.638	0.438	0.00
Weekend/Holiday	**1.735**	0.742	0.02*
Autoregression			
Lag 1	**0.278**	0.078	0.00*
Lag 2	-0.080	0.087	0.36
$\mathbf{X^2}(3)$	**14.09**		0.003*
Respiratory			
Constant	3.100	0.322	0.00
Weekend/Holiday	**0.768**	0.324	0.02*
Autoregression			
Lag 1	**0.228**	0.083	0.006*
Lag 2	0.152	0.098	0.12
$\mathbf{X^2}(3)$	**18.57**		0.0003*
Circulatory			
Constant	1.953	0.192	0.00
Weekend/Holiday	0.116	0.285	0.68
Autoregression			
Lag 1	0.141	0.083	0.09
Lag 2	0.011	0.079	0.89
$\mathbf{X^2}(3)$	2.97		0.40
Number of observations	178		

Distributed Lag Models

Following the estimation of the base model, we estimated a distributed lag model of the form:

$$visits_t = \alpha + \beta_1 PM_t + \beta_2 PM_{t-1} + \beta_3 PM_{t-3} + \beta_4 PM_{t-4} + \beta_5 Weekend/Holiday + \mu_t$$

where $\mu_t = \rho_1 \mu_{t-1} + \rho_2 \mu_{t-2} + \varepsilon_t$

and t indexes days

We estimated this model individually for each of the dependent variables:

Total visits
Visits under age 5
Visits age 65 and over

Respiratory visits
Circulatory visits

And for each dependent variable, we examined the following independent variables, also individually.

Average PM-10
Maximum PM-10
Average PM-2.5
Maximum PM2.5

As discussed earlier, all models include an indicator variable for days that follow a weekend or holiday, as discussed earlier, the error term follows a second order process. The results are shown in Tables 6a through 6d below and graphically in Figures 12a through 12d. As before significant results are highlighted.

The significance of each coefficient is noted in the tables, as is the overall model X^2. A second likelihood ratio test compares a base model that includes only the indicator variable for the day after a weekend or holiday to the full model that includes the PM variables. The focus is on regularities across the various PM and visit measures with the goal of addressing the overall utility of the approach. There are some differences in the sample between the cross correlations and the full model due to missing data on the covariates.

Response of Visits to Average PM-10

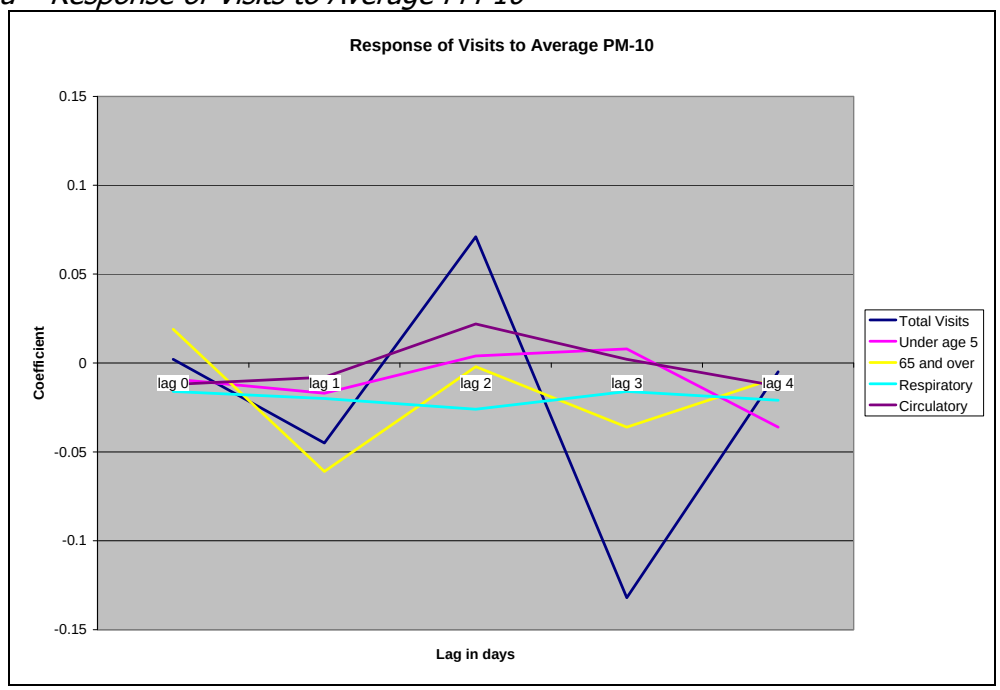
These results are shown in Table 6a and Figure 12a. As noted earlier in the cross correlation results, the estimates of the effect of average PM-10 on visits do not reach conventional levels of significance. However, there are consistent positive coefficients for total visits, visits under age 5 and respiratory visits at lag 2, suggesting a possible health response.

Table 6a – Distributed Lag Models for Visits and Average PM-10

	Coefficient	**Standard Error**	**p**
Total Visits			
Constant	41.204	2.615	0
PM10avg	0.002	0.061	0.97
Lag 1	-0.045	0.079	0.57
Lag 2	0.071	0.066	0.28
Lag 3	-0.132	0.073	0.07
Lag 4	-0.005	0.065	0.94
Weekend/Holiday	**4.153**	1.4	0.003*
Autoregression			
Lag 1	-0.011	0.093	0.91
Lag 2	**0.206**	0.082	0.01*
X^2(8)	**23.68**		0.002*
Likelihood ratio test PM -- **X^2**(5)	5.64		0.34
Number of observations	178		
Under age 5			
Constant	4.065	0.737	0
PM10avg	-0.009	0.016	0.55
Lag 1	-0.017	0.016	0.28
Lag 2	0.004	0.015	0.78
Lag 3	0.008	0.018	0.66
Lag 4	-0.036	0.02	0.07
Weekend/Holiday	**0.995**	0.328	0.002*
Autoregression			

	Coefficient	Standard Error	p
Lag 1	**0.177**	0.075	0.02*
Lag 2	**0.14**	0.07	0.05*
X^2(8)	**30.8**		0.0002*
Likelihood ratio test PM -- **X^2**(5)	7.7		0.17
Number of observations	178		
65 and over			
Constant	12.766	1.159	0
PM10avg	0.019	0.029	0.51
Lag 1	-0.061	0.034	0.07
Lag 2	-0.002	0.028	0.94
Lag 3	-0.036	0.031	0.26
Lag 4	-0.008	0.027	0.76
Weekend/Holiday	**2.05**	0.735	0.005*
Autoregression			
Lag 1	**0.289**	0.079	0.00*
Lag 2	-0.153	0.087	0.08
X^2(8)	**24.85**		0.002
Likelihood ratio test PM -- **X^2**(5)	9.43		0.09
Number of observations	178		
Respiratory			
Constant	5.583	0.685	0
PM10avg	-0.016	0.015	0.3
Lag 1	-0.02	0.016	0.21
Lag 2	-0.026	0.02	0.19
Lag 3	-0.016	0.018	0.39
Lag 4	-0.021	0.019	0.26
Weekend/Holiday	**0.675**	0.331	0.04*
Autoregression			
Lag 1	0.134	0.086	0.12
Lag 2	0.054	0.105	0.61
X^2(8)	**21.35**		0.006*
Likelihood ratio test PM -- **X^2**(5)	**13.78**		0.02*
Number of observations	178		
Circulatory			
Constant	2.19	0.515	0
PM10avg	-0.012	0.011	0.29
Lag 1	-0.008	0.013	0.55
Lag 2	0.022	0.012	0.07
Lag 3	0.002	0.009	0.83
Lag 4	-0.013	0.014	0.37
Weekend/Holiday	0.082	0.315	0.8
Autoregression			
Lag 1	0.14	0.105	0.18
Lag 2	0.021	0.085	0.8
X^2(8)	7.6		0.47
Likelihood ratio test PM -- **X^2**(5)	4.83		0.44
Number of observations	178		

Figure 12a – Response of Visits to Average PM-10



Response of Visits to Maximum PM-10

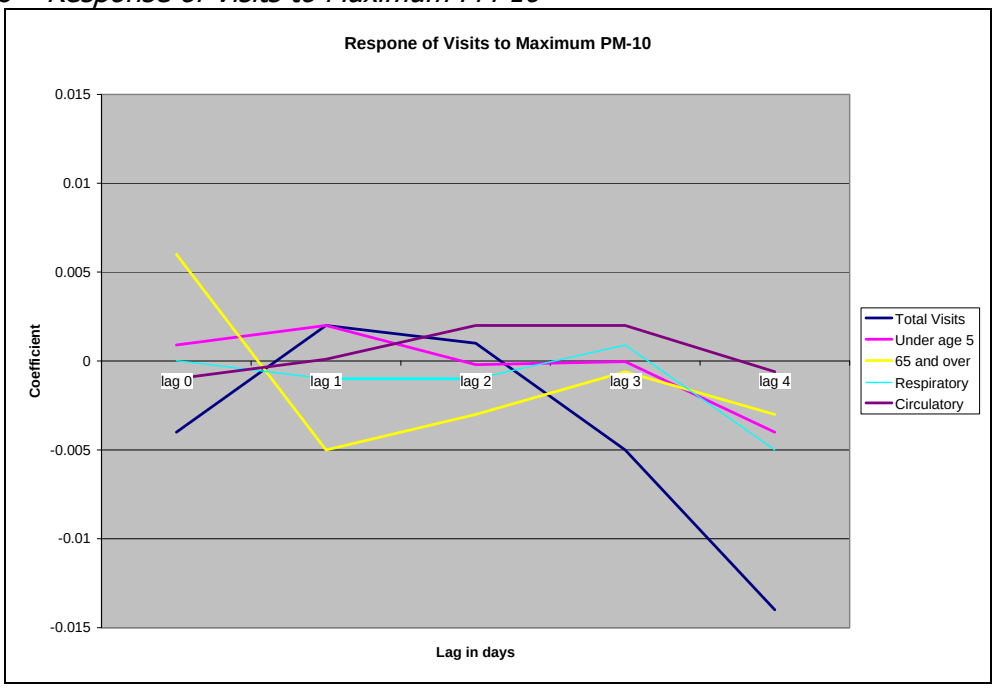
These results are shown in Table 6b and Figure 12b. There is some evidence of a weak positive response of total visits and visits under age 5 at lag 1, of total visits and circulatory visits at lag 2 and circulatory and respiratory visits at lag 3 to maximum PM-10. However, none of the effects either taken individually or as a group reach conventional levels of statistical significance. Based on anecdotal evidence, we had hypothesized that this would be where we might observe the strongest health effects. However, these effects did not materialize.

Table 6b – Distributed Lag Models for Visits and Maximum PM-10

	Coefficient	**Standard Error**	**p**
Total Visits			
Constant	40.348	2.023	0
PM10max	-0.004	0.009	0.62
Lag 1	0.002	0.012	0.86
Lag 2	0.001	0.011	0.92
Lag 3	-0.005	0.011	0.64
Lag 4	-0.014	0.01	0.19
Autoregression			
Lag 1	-0.024	0.09	0.78
Lag 2	**0.214**	0.084	0.01*
Weekend/Holiday	**4.2**	1.401	0.003*
$\mathbf{X^2}(8)$	**22.69**		0.003*
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	3.2		0.67
Number of observations	178		
Under age 5	**Coefficient**	**Standard Error**	**p**
Constant	2.95	0.54	0
PM10max	0.0009	0.002	0.62
Lag 1	0.002	0.002	0.49
Lag 2	-0.0002	0.002	0.93
Lag 3	-0.00004	0.002	0.98
Lag 4	-0.004	0.003	0.19
Weekend/Holiday	**1.04**	0.351	0.003*

	Coefficient	Standard Error	p
Autoregression			
Lag 1	**0.186**	0.081	0.02*
Lag 2	**0.164**	0.076	0.03*
$\mathbf{X^2}(8)$	**33.52**		0
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	3.63		0.6
Number of observations	178		
65 and over	**Coefficient**	**Standard Error**	**p**
Constant	11.095	1.01	0
PM10max	0.006	0.004	0.18
Lag 1	-0.005	0.004	0.24
Lag 2	-0.003	0.004	0.56
Lag 3	-0.0006	0.005	0.9
Lag 4	-0.003	0.004	0.54
Weekend/Holiday	**1.672**	0.775	0.03*
Autoregression			
Lag 1	**0.302**	0.081	0.00*
Lag 2	-0.11	0.088	0.21
$\mathbf{X^2}(8)$	**19.98**		0.01
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	3.94		0.56
Number of observations	178		
Respiratory	**Coefficient**	**Standard Error**	**p**
Constant	3.696	0.589	0
PM10max	0.00002	0.002	0.99
Lag 1	-0.001	0.002	0.66
Lag 2	-0.001	0.002	0.56
Lag 3	0.0009	0.002	0.63
Lag 4	-0.005	0.003	0.14
Weekend/Holiday	**0.734**	0.351	0.04*
Autoregression			
Lag 1	**0.22**	0.095	0.02*
Lag 2	0.136	0.103	0.18
$\mathbf{X^2}(8)$	**18.28**		0.02*
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	4.48		0.48
Number of observations	178		
Circulatory	**Coefficient**	**Standard Error**	**p**
Constant	1.742	0.402	0
PM10max	-0.001	0.001	0.3
Lag 1	0.0001	0.002	0.94
Lag 2	0.002	0.002	0.31
Lag 3	0.002	0.002	0.25
Lag 4	-0.0006	0.003	0.83
Weekend/Holiday	0.151	0.31	0.63
Autoregression			
Lag 1	0.141	0.098	0.15
Lag 2	0.028	0.087	0.74
$\mathbf{X^2}(8)$	8.03		0.43
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	3.06		0.69
Number of observations	178		

Figure 12b – Response of Visits to Maximum PM-10



Response of Visits to Average PM-2.5

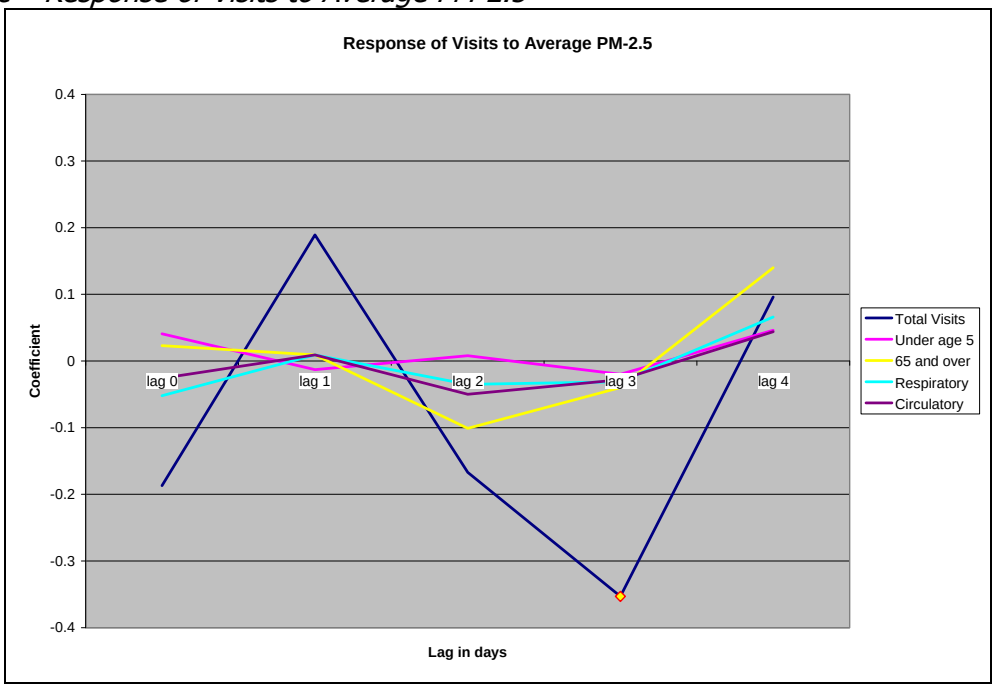
These results are shown in Table 6c and Figure 12d. There is some response of total visits to average PM-2.5 at lag 1. All of the effects are small. In addition, all of the coefficients are consistently positive at lag 4. Again, there is little evidence of statistically significant positive effects, with some negative effects reaching conventional levels of significance. The positive effects for pediatric visits have all but disappeared, possibly due to reductions in sample size caused by missing covariate data.

Table 6c – Distributed Lag Models for Visits and Average PM-2.5

	Coefficient	**Standard Error**	**p**
Total Visits			
PM2.5avg	-0.187	0.156	0.23
Lag 1	0.189	0.166	0.26
Lag 2	-0.167	0.182	0.36
Lag 3	**-0.353**	0.164	0.03*
Lag 4	0.096	0.151	0.53
Autoregression			
Lag 1	0.058	0.101	0.57
Lag 2	**0.239**	0.081	0.003*
Weekend/Holiday	**3.684**	1.448	0.01*
$\mathbf{X^2}(8)$	**25.63**		0.001*
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	**14.32**		0.01*
Number of observations	179		
Under age 5			
Constant	3.042	0.75	0
PM2.5avg	0.041	0.044	0.35
Lag 1	-0.013	0.048	0.78
Lag 2	0.008	0.046	0.86
Lag 3	-0.02	0.045	0.66
Lag 4	0.046	0.044	0.29
Weekend/Holiday	0.563	0.385	0.14
Autoregression			
Lag 1	**0.204**	0.088	0.02*

	Coefficient	Standard Error	p
Lag 2	0.128	0.074	0.09
X^2(8)	14.99		0.06
Likelihood ratio test PM -- **X^2**(5)	2.69		0.75
Number of observations	179		
65 and over			
PM2.5avg	0.023	0.075	0.76
Lag 1	0.009	0.066	0.9
Lag 2	-0.101	0.083	0.22
Lag 3	-0.04	0.081	0.62
Lag 4	0.14	0.081	0.08
Weekend/Holiday	**2.32**	0.768	0.003*
Autoregression			
Lag 1	**0.308**	0.076	0.00*
Lag 2	-0.115	0.075	0.12
X^2(8)	**21.94**		0.005
Likelihood ratio test PM -- **X^2**(5)	5.79		0.33
Number of observations	179		
Respiratory			
PM2.5avg	-0.052	0.043	0.23
Lag 1	0.009	0.043	0.83
Lag 2	-0.035	0.043	0.44
Lag 3	-0.031	0.038	0.41
Lag 4	0.066	0.039	0.09
Weekend/Holiday	0.733	0.373	0.05
Autoregression			
Lag 1	**0.17**	0.083	0.04*
Lag 2	0.113	0.101	0.26
X^2(8)	**15.53**		0.05*
Likelihood ratio test PM -- **X^2**(5)	5.5		0.36
Number of observations	179		
Circulatory			
Constant	2.475	0.333	0
PM2.5avg	-0.026	0.029	0.37
Lag 1	0.009	0.034	0.78
Lag 2	-0.05	0.029	0.08
Lag 3	-0.028	0.034	0.41
Lag 4	0.044	0.028	0.12
Weekend/Holiday	0.333	0.252	0.19
Autoregression			
Lag 1	0.062	0.088	0.48
Lag 2	0.054	0.092	0.56
X^2(8)	8.94		0.35
Likelihood ratio test PM -- **X^2**(5)	9.74		0.08
Number of observations	179		

Figure 12c – Response of Visits to Average PM-2.5



Response of Visits to Maximum PM-2.5

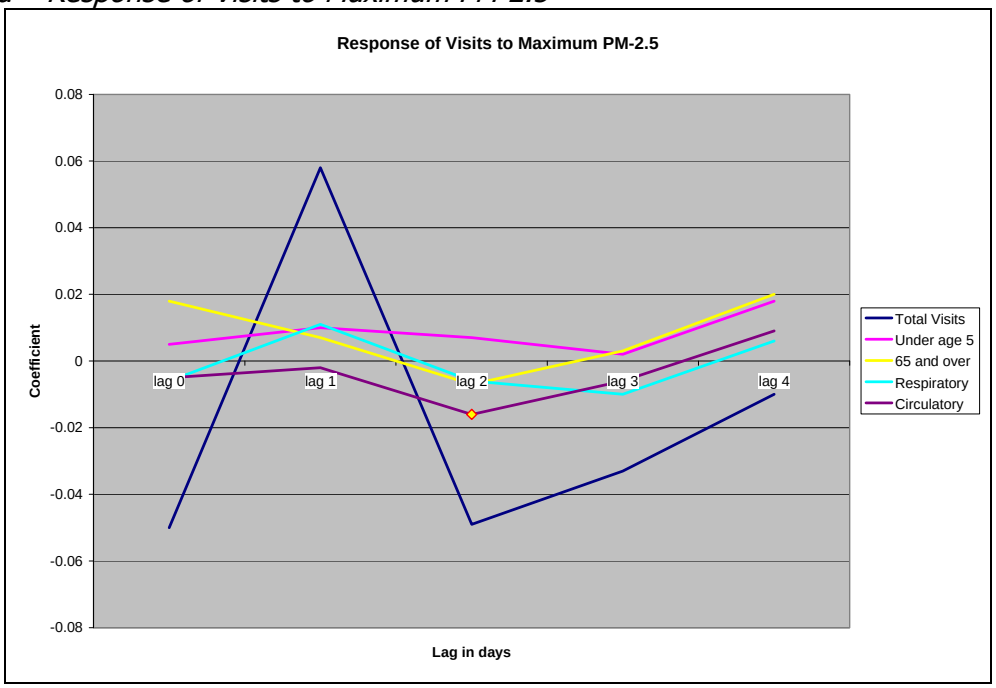
These results are shown in Table 6d and Figure 11d. There is a positive response of total visits, visits under age 5, visits age 65 and over and respiratory visits at lag 1, and a positive response of visits under age 5, visits age 65 and over, respiratory and circulatory visits at lag 4 to maximum PM-2.5. As with the other covariates, there are few cases of statistical significant and none involve a positive coefficient. One encouraging finding is the persistence of the positive effect of maximum PM-2.5 on pediatric visits.

Table 6d – Distributed Lag Models for Visits and Maximum PM-2.5

	Coefficient	**Standard Error**	**p**
Total Visits			
Constant	40.533	2.284	0.00
PM2.5max	-0.05	0.041	0.23
Lag 1	0.058	0.042	0.16
Lag 2	-0.049	0.031	0.11
Lag 3	-0.033	0.033	0.32
Lag 4	-0.01	0.04	0.8
Autoregression			
Lag 1	0.085	0.098	0.38
Lag 2	**0.235**	0.078	0.003*
Weekend/Holiday	**3.711**	1.472	0.01*
$\mathbf{X^2}(8)$	**21.65**		0.006*
Likelihood ratio test PM -- $\mathbf{X^2}(5)$	9.63		0.09
Number of observations	179		
Under age 5			
Constant	2.326	0.687	0.001
PM2.5max	0.005	0.009	0.55
Lag 1	0.01	0.009	0.28
Lag 2	0.007	0.013	0.57
Lag 3	0.002	0.011	0.83
Lag 4	0.018	0.012	0.12
Weekend/Holiday	0.562	0.387	0.15
Autoregression			

	Coefficient	Standard Error	p
Lag 1	0.17	0.088	0.05
Lag 2	0.094	0.08	0.24
X^2(8)	13.88		0.08
Likelihood ratio test PM -- **X^2**(5)	6.69		0.24
Number of observations	179		
65 and over			
Constant	10.09	0.982	0
PM2.5max	0.018	0.016	0.24
Lag 1	0.007	0.021	0.72
Lag 2	-0.007	0.019	0.71
Lag 3	0.003	0.022	0.9
Lag 4	0.02	0.018	0.27
Weekend/Holiday	**2.204**	0.826	0.008*
Autoregression			
Lag 1	**0.293**	0.078	0.00*
Lag 2	-0.124	0.074	0.09
X^2(8)	**20.89**		0.007*
Likelihood ratio test PM -- **X^2**(5)	4.15		0.53
Number of observations	179		
Respiratory			
Constant	3.344	0.712	0
PM2.5max	-0.006	0.013	0.67
Lag 1	0.011	0.01	0.23
Lag 2	-0.006	0.013	0.65
Lag 3	-0.01	0.008	0.24
Lag 4	0.006	0.01	0.51
Weekend/Holiday	**0.856**	0.39	0.03*
Autoregression			
Lag 1	**0.188**	0.086	0.03*
Lag 2	0.12	0.102	0.24
X^2(8)	**15.92**		0.04*
Likelihood ratio test PM -- **X^2**(5)	4.16		0.53
Number of observations	179		
Circulatory			
Constant	2.629	0.346	0
PM2.5max	-0.005	0.007	0.44
Lag 1	-0.002	0.006	0.74
Lag 2	**-0.016**	0.008	0.04*
Lag 3	-0.006	0.007	0.43
Lag 4	0.009	0.006	0.13
Weekend/Holiday	0.291	0.346	0.27
Autoregression			
Lag 1	0.049	0.088	0.58
Lag 2	0.034	0.09	0.7
X^2(8)	10.21		0.25
Likelihood ratio test PM -- **X^2**(5)	**13.01**		0.02*
Number of observations	179		

Figure 12d – Response of Visits to Maximum PM-2.5



FINAL MODELING RESULTS

Poisson Model

To better take into account the fact that the number of visits is a count variable, we re-estimated the models assuming that the number of visits follows a Poisson distribution. We treated weeks as a clustering variable to take into account the natural grouping of clinic visits. This is an alternative approach to the inclusion of the second order autoregressive process and the indicator variable for days that follow a weekend or holiday. In addition, we employed robust methods for calculating the standard errors. This alternate specification allows us to verify the sensitivity of the time-series results to distributional assumptions. The model is described the equation below.

$$Visits_{wt} = exposure_t\,(\exp(\beta_1 PM_t + \beta_2 PM_{t-1} + \beta_3 PM_{t-3} + \beta_4 PM_{t-4})) + \mu_{wt}$$

$$corr(\mu_{wt}, \mu_{vs}) = \rho \quad \text{if } v=w$$

$$\text{and} \quad = 0 \quad \text{otherwise}$$

where t indexes days and w indexes weeks

$$\text{and } exposure_t = 1 \text{ (unknown) by assumption}$$

We present these results with the coefficients in exponentiated form so that they are incident rate ratios. IRRs that are greater than one represent an increase in the number of visits in response to higher PM concentrations and those that are less than one represent a decrease in the number of visits. So $exp\beta_t$ is the ratio of incidence rate of visits where a 1 microgram increase in PM has occurred at lag t, to the incidence rate of visits without such an increase. Because we have assumed exposure = 1, the incidence rate is equal to the count of visits.

As before, statistically significant coefficients are highlighted.

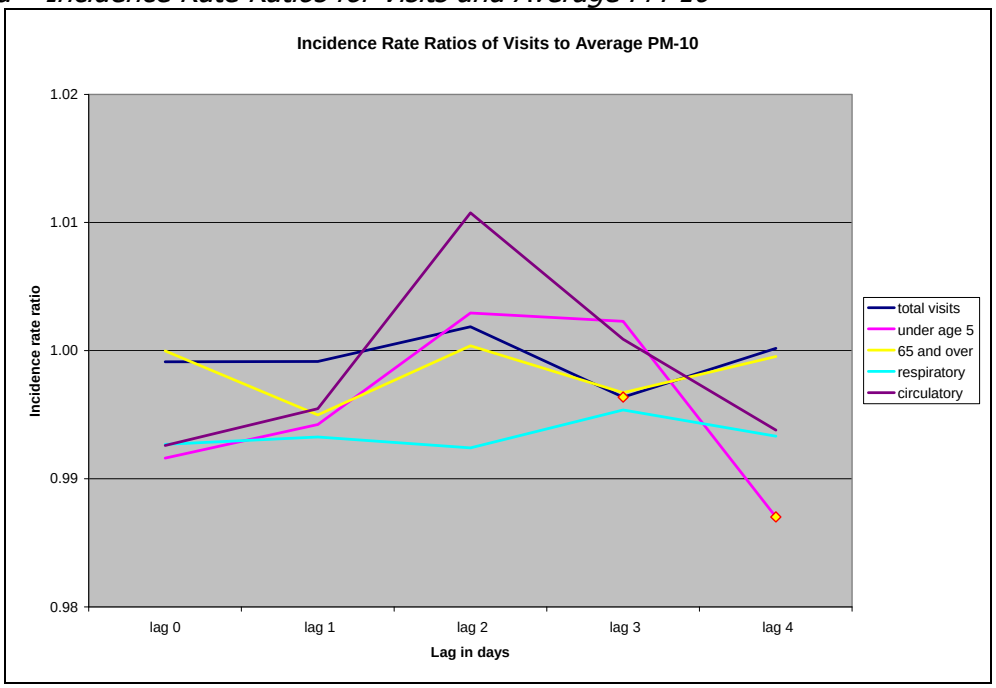
Response of Visits to Average PM-10

These results are shown in Table 7a and Figure 13a and correspond to the distributed lag results in Table 6a and Figure 12a. Only a few IRRs reach conventional levels of statistical significance, and these indicate a decrease in visits when average PM-10 increases. Overall, the effects are small. There is a positive effect of average PM-10 on total, pediatric and circulatory visits at lag 2 and a positive effect of pediatric and circulatory visits at lag 3. As in the distributed lag model, respiratory visits show a consistent negative response to average PM-10.

Table 7a – Poisson Models for Visits and Average PM-10

	IRR	**Standard Error**	**p**
Total Visits			
PM10avg	0.9991	0.0018	0.62
Lag 1	0.9991	0.0013	0.51
Lag 2	1.0019	0.0015	0.22
Lag 3	**0.9964**	0.0018	0.05*
Lag 4	1.0002	0.0017	0.91
$\mathbf{X^2}(5)$	6.03		0.30
Number of observations	178		
Under age 5			
PM10avg	0.9916	0.0056	0.13
Lag 1	0.9942	0.0059	0.33
Lag 2	1.0029	0.0055	0.59
Lag 3	1.0023	0.0055	0.67
Lag 4	**0.9870**	0.0048	0.01*
$\mathbf{X^2}(5)$	**16.37**		0.006
Number of observations	178		
Age 65 and over			
PM10avg	1.0000	0.0026	0.99
Lag 1	**0.9950**	0.0024	0.04*
Lag 2	1.0004	0.0032	0.91
Lag 3	0.9967	0.0023	0.16
Lag 4	0.9995	0.0022	0.84
$\mathbf{X^2}(5)$	10.55		0.06
Number of observations	178		
Respiratory			
PM10avg	0.9927	0.0062	0.24
Lag 1	0.9933	0.0058	0.25
Lag 2	0.9924	0.0054	0.16
Lag 3	0.9954	0.0057	0.42
Lag 4	0.9933	0.0043	0.12
$\mathbf{X^2}(5)$	**26.67**		0.0001*
Number of observations	178		
Circulatory			
PM10avg	0.9926	0.0057	0.20
Lag 1	0.9955	0.0087	0.60
Lag 2	1.0108	0.0063	0.08
Lag 3	1.0009	0.0102	0.93
Lag 4	0.9938	0.0070	0.38
$\mathbf{X^2}(5)$	4.84		0.44
Number of observations	178		

Figure 13a – Incidence Rate Ratios for Visits and Average PM-10



Response of Visits to Maximum PM-10

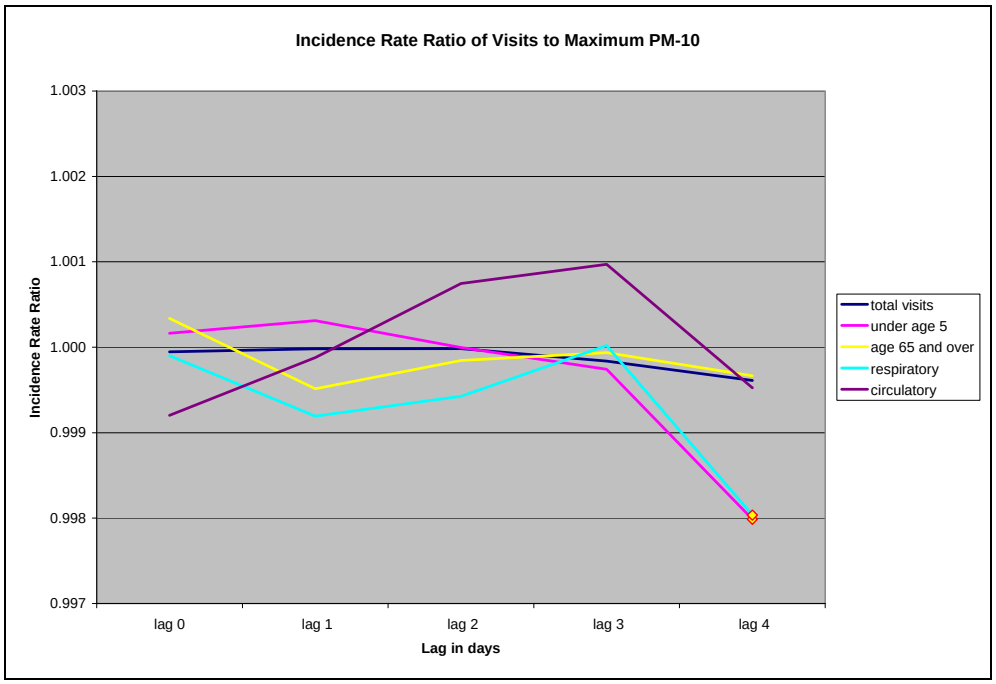
These results are shown in Table 7b and Figure 13b and correspond to the distributed lag results in Table 6b and Figure 12b. As with average PM-10, the effects are small and tend not to reach conventional levels of significance. The few effects that are significant indicate a negative impact of PM-10 on visits. Only circulatory visits who a positive effect at lags 2 and 3, mimicking the distributed lag results.

Table 7b – Poisson Models for Visits and Maximum PM-10

	IRR	**Standard Error**	**p**
Total Visits			
PM10max	0.99995	0.00016	0.74
Lag 1	0.99998	0.00017	0.91
Lag 2	0.99998	0.00021	0.94
Lag 3	0.99984	0.00028	0.56
Lag 4	0.99961	0.00025	0.13
$\mathbf{X^2}(5)$	3.73		0.59
Number of observations	178		
Under age 5			
PM10max	1.00016	0.00083	0.84
Lag 1	1.00031	0.00074	0.67
Lag 2	1.00000	0.00077	1.00
Lag 3	0.99974	0.00097	0.79
Lag 4	**0.99799**	0.00100	0.04*
$\mathbf{X^2}(5)$	4.48		0.48
Number of observations	178		
65 and over			
PM10max	1.00034	0.00026	0.20
Lag 1	0.99951	0.00040	0.22
Lag 2	0.99985	0.00045	0.73
Lag 3	0.99994	0.00031	0.84
Lag 4	0.99966	0.00036	0.35
$\mathbf{X^2}(5)$	3.84		0.57

	IRR	Standard Error	p
Number of observations	178		
Respiratory			
PM10max	0.99990	0.00100	0.92
Lag 1	0.99919	0.00079	0.31
Lag 2	0.99942	0.00092	0.53
Lag 3	1.00002	0.00127	0.99
Lag 4	**0.99803**	0.00086	0.02*
$\mathbf{X^2}(5)$	7.83		0.17
Number of observations	178		
Circulatory			
PM10max	0.99920	0.00094	0.40
Lag 1	0.99988	0.00080	0.88
Lag 2	1.00075	0.00107	0.49
Lag 3	1.00097	0.00092	0.29
Lag 4	0.99952	0.00068	0.48
$\mathbf{X^2}(5)$	2.94		0.71
Number of observations	178		

Figure 13b – Incidence Rate Ratios for Visits and Maximum PM-10



Response of Visits to Average PM-2.5

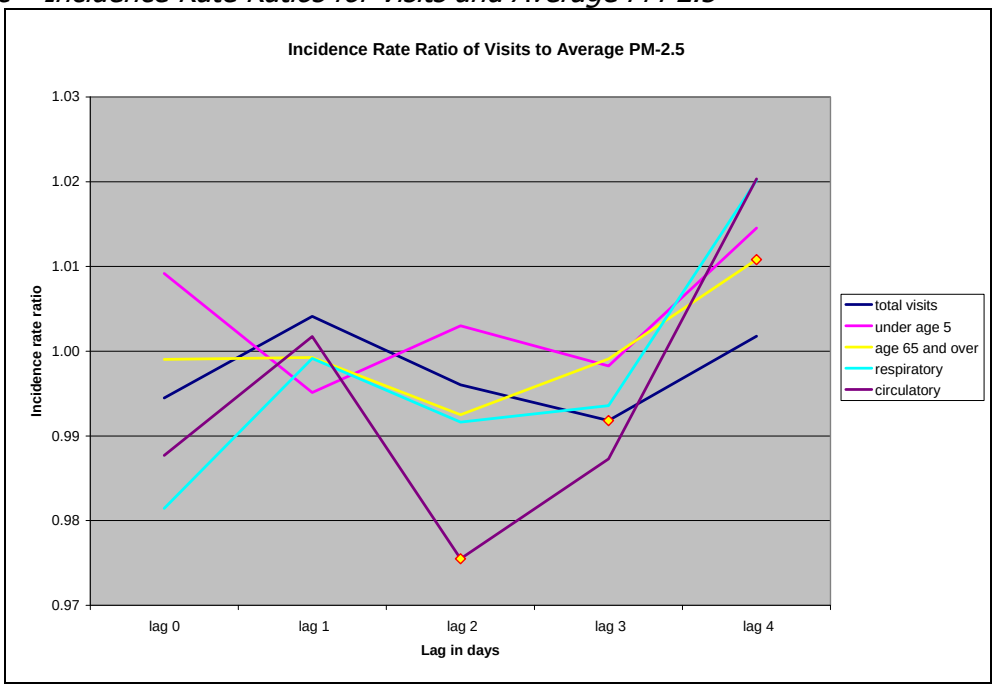
These results are shown in Table 7c and Figure 13c and correspond to the distributed lag results in Table 6c and Figure 12c. Unlike the results for PM-10, there is some indication that average PM-2.5 has some impact on the number of visits. One coefficient – for visits age 65 and over at lag 4 – does reach conventional levels of significance, although the impact is small. In addition, the coefficients for all types of visits are positive at lag 4.

Table 7c – Poisson Models for Visits and Average PM-2.5

	IRR	Standard Error	p
Total Visits			
PM2.5avg	0.9945	0.0032	0.08
Lag 1	1.0041	0.0033	0.20
Lag 2	0.9960	0.0029	0.17

	IRR	Standard Error	p
Lag 3	**0.9918**	0.0030	0.01*
Lag 4	1.0018	0.0044	0.69
X^2(5)	**16.60**		0.005*
Number of observations	179		
Under age 5			
PM2.5avg	1.0092	0.0094	0.33
Lag 1	0.9951	0.0096	0.61
Lag 2	1.0030	0.0119	0.80
Lag 3	0.9982	0.0100	0.86
Lag 4	1.0145	0.0097	0.13
X^2(5)	6.34		0.27
Number of observations	179		
65 and over			
PM2.5avg	0.9990	0.0052	0.85
Lag 1	0.9993	0.0050	0.88
Lag 2	0.9925	0.0051	0.14
Lag 3	0.9991	0.0073	0.90
Lag 4	**1.0108**	0.0049	0.03*
X^2(5)	5.91		0.32
Number of observations	179		
Respiratory			
PM2.5avg	0.9815	0.0103	0.08
Lag 1	0.9992	0.0106	0.94
Lag 2	0.9916	0.0110	0.45
Lag 3	0.9936	0.0109	0.56
Lag 4	1.0202	0.0131	0.12
X^2(5)	5.92		0.31
Number of observations	179		
Circulatory			
PM2.5avg	0.9877	0.0112	0.28
Lag 1	1.0017	0.0104	0.87
Lag 2	**0.9755**	0.0122	0.05*
Lag 3	0.9873	0.0114	0.27
Lag 4	1.0203	0.0106	0.05
X^2(5)	**13.39**		0.02*
Number of observations	179		

Figure 13c – Incidence Rate Ratios for Visits and Average PM-2.5



Response of Visits to Maximum PM-2.5

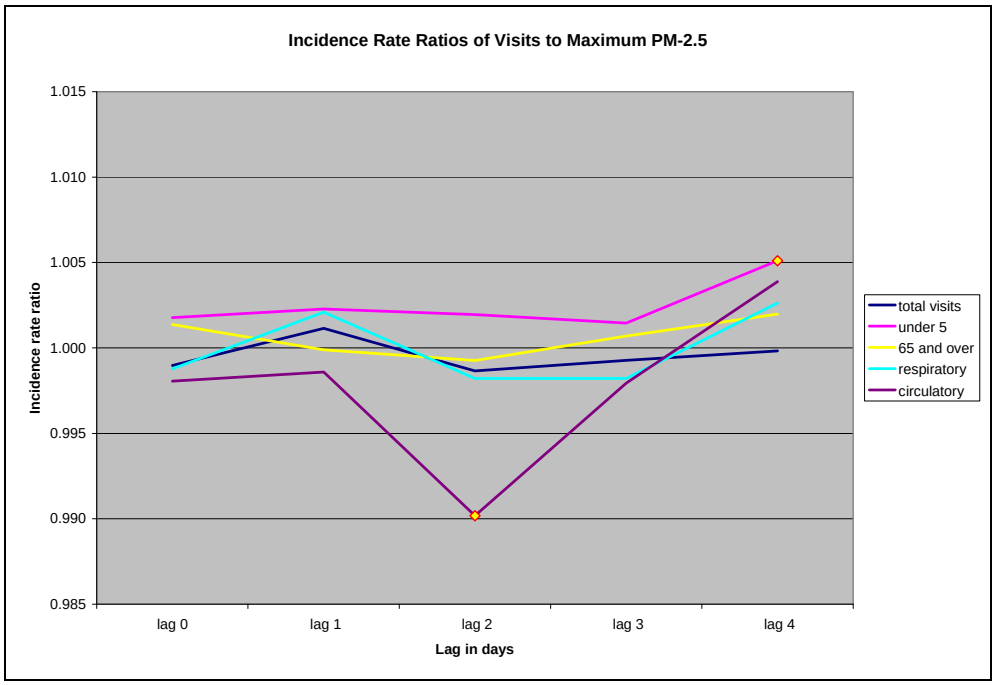
These results are shown in Table 7d and Figure 13d and correspond to the distributed lag results in Table 6d and Figure 12. As with average PM-2.5, there is some indication that maximum PM-2.5 has some impact on the number of visits. The effect is consistently positive at all lags for pediatric visits, and reaches conventional levels of significance at lag 4.

Table 7d – Poisson Models for Visits and Maximum PM-2.5

	IRR	**Standard Error**	**p**
Total Visits			
PM2.5max	0.9990	0.0007	0.13
Lag 1	1.0011	0.0006	0.07
Lag 2	0.9987	0.0009	0.12
Lag 3	0.9993	0.0008	0.34
Lag 4	0.9998	0.0008	0.83
$\mathbf{X^2}(5)$	**14.89**		0.01*
Number of observations	179		
Under age 5			
PM2.5max	1.0018	0.0020	0.37
Lag 1	1.0023	0.0018	0.22
Lag 2	1.0020	0.0015	0.20
Lag 3	1.0015	0.0021	0.49
Lag 4	1.0051	0.0013	0.00
$\mathbf{X^2}(5)$	**52.98**		0.00*
Number of observations	179		
65 and over			
PM2.5max	1.0014	0.0013	0.28
Lag 1	0.9999	0.0010	0.91
Lag 2	0.9993	0.0011	0.51
Lag 3	1.0007	0.0012	0.56
Lag 4	1.0020	0.0014	0.14
$\mathbf{X^2}(5)$	4.35		0.50
Number of observations	179		

	IRR	Standard Error	p
Respiratory			
PM2.5max	0.9988	0.0021	0.56
Lag 1	1.0021	0.0021	0.32
Lag 2	0.9982	0.0020	0.37
Lag 3	0.9982	0.0030	0.55
Lag 4	1.0026	0.0028	0.34
$\mathbf{X^2}(5)$	3.59		0.61
Number of observations	179		
Circulatory			
PM2.5max	0.9981	0.0029	0.51
Lag 1	0.9986	0.0026	0.58
Lag 2	**0.9902**	0.0032	0.002*
Lag 3	0.9979	0.0028	0.46
Lag 4	1.0039	0.0023	0.09
$\mathbf{X^2}(5)$	**26.55**		0.0001
Number of observations	179		

Figure 13d – Incidence Rate Ratios for Visits and Maximum PM-2.5



LESSONS LEARNED

This study is a pilot to determine the value of examining clinic visits as a measure of health that may be responsive to air quality. Our results offer some modest evidence of the usefulness of this approach. We investigated two modeling approaches, one based on conventional time series methods and the other using a Poisson model that takes into account the fact that the dependent variable is a count. Our results are broadly consistent across the two approaches. We did not find evidence of the impact of PM-10 episodes on health despite proximity to the Owens Dry Lake, and rather high hourly concentrations, except possibly for circulatory visits. We did find some modest impact of PM-2.5 concentrations on pediatric visits, although these do not always reach conventional levels of statistical significance. This result may bear further investigation. In general, our results are consistent with prior research. We were hampered by

relatively small sample sizes because we had only one year of data, and the sample was further reduced by clinic closures and missing monitoring data due to equipment maintenance.

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