Hi, I’m Toni Richards, the air quality specialist for the Bishop Paiute Tribe. Today I’m going to talk to you about a pilot study that I carried out on the impact of particulate matter on health. For this study I had help from a former colleague John Adams, a statistician that I worked with for many years. He did all of the consultation at no cost to the Tribe.
The bishop reservation is only 60 miles from the largest source of PM-10 in the nation. PM-10 refers to particles that are smaller than 10 microns. These particles are small enough that they can lodge in the lung and at high concentrations they can aggravate respiratory problems. They have also been associated with exacerbating cardiac problems.

Monitors around the lake have measured particulate levels that exceeded the federal level by a factor of 75. The lake is 110 square miles and the amount of dust released is measured in tons.

In our area, PM-10 is primarily wind-driven dust
WHERE IS THE BISHOP PAIUTE TRIBE?

- On the California-Nevada Border
- In the “deepest valley” at 4,000ft between the Sierra Nevada and White Mountains
- 200 miles South of Reno
- 270 miles East of Las Vegas
- 300 miles North of Los Angeles

The bishop reservation that is located in a remote area, about 2 or 300 miles from any metropolitan area.

The dry lake covers 110 square miles and is evident even on a map with this large scale.
In 2006, I carried out a small study to find out how often high PM days on our reservation were associated with activity on the Dry Lake.

This was a fairly comprehensive study that combined multiple years of data from all of the tribes down the valley between us and the Dry Lake + information on dry lake activity collected by the Great Basin Unified Air District. These are the folks who are in charge of monitoring on the lake.

The conclusion from that study was that about half of our high concentration episodes were associated with dry lake activity.
The tribe monitors for both PM-10 and PM-2.5 and the sources are described above. When I went to look at health impacts of PM-10, I decided that I might as well use information on both PM-10 and PM-2.5 since both are known to have an impact on health, though my expectation was that PM-10 would be more important.
As you can see, since 2004, the tribe has experienced fairly high levels of both PM-10 and PM-2.5.

I've used hourly maxima to characterize our high concentration events because the events are typically weather-driven and fairly short-lived, though intense.

2006 and 2007 are highlighted because our study is from October 1, 2006 to September 30, 2007.
BACKGROUND

- Few or no studies of the impacts of the dry lake
- No studies of the impact of particulate matter on Reservation populations

WHY?

- Can’t use standard methods (mortality / hospitalizations) on sparse rural populations

Before starting the study, I looked in the literature for other studies that addressed the impact of particulate matter on health.

I found that while there is substantial evidence of health impact, with some studies indicating no minimum threshold, and there is also evidence of impacts from short term exposure, there are no quantitative studies of the impact of the dry lake and I could find no studies of reservation populations (this was a couple of years ago).

The reason for this is simple, the population in our area is sparse and there aren’t enough of the events of the type that are usually used, like death or hospitalization to make for a meaningful study.
Therefore I decided to focus on something much more common like clinic visits. The Toiyabe Indian Health Project’s clinic is located in the same complex as our monitors and serves the Bishop Reservation. Clinic visits are much more common than hospitalizations and are associated with common acute medical problems. I hoped that they would yield a reasonable data base.

I decided to use one year’s worth of data for a start, estimating I would get at least 200 observations, and that this would probably be a large enough sample to detect large effects with some certainty.

I looked at all visits, then separated out types of visits where I expected the impact to be larger. These included: visits to the young and the elderly who might be more vulnerable and visits for respiratory and cardiac conditions that have been shown to be sensitive to particulate matter.

I examined the effect both types of PM and studied both the daily hourly maximum and the 24-hour average.

The data are for the clinic’s fiscal year starting in October 2006.
HOW DID WE GET THE DATA?

- **Particulate Matter**
  - Hourly and daily data from our monitors
  - TEOM / FDMS
  - Continuous monitors

- **Health Data**
  - From the Toiyabe Indian Health Project
  - Manually abstracted from claims by their staff

All of the Bishop Tribe’s ambient monitors have data available in near real time. The monitors are checked regularly and have regular external audits. In addition, the data are manually validated. The Tribe participates in the TrEx network.

We expected that obtaining health data would be the most difficult part of the project and allowed extra time and had all kinds of contingencies. However, this turned out to be relatively simple, possibly because of the general interest in the topic. There were no privacy issues because all we asked for was a count of events so there was no identifying information.

The clinic staff were exceptionally helpful particularly considering that the data abstraction had to be done by hand. The data appeared to be consistent and of high quality.
I followed the usual procedure of carefully exploring the data using graphical methods and descriptive statistics to check data quality.

The descriptive work was followed up by conventional statistical methods that included looking at the correlation of variables to see if visits in a 4-day period increased following high particulate concentrations.

Next I carried out 2 types of modeling, one based on time series methods, called distributed lag models. This type of model does a good job of taking into account time-dependence in the data. However, since the number of visits in a day is a count and the number of visits in a day is small, I also used what are called Poisson models to make sure that the standard errors were appropriately calculated.
So let’s look at some basic information
The clinic sees about 40 patients on an average day, as few as 15 and as many as 75
In a typical day, 3 visits are for patients under age 5 and 11 are for patients age 65 and over
Also on a typical day, 3 cases are for respiratory conditions and 2 are for circulatory conditions
The small number of daily visits turned out to require special consideration for statistical modeling. They also restrict our ability to consider particular medical conditions, like asthma.
In the year we examined, particulate matter varied quite a bit from month to month, with maximum hourly concentrations exceeding 700 micrograms per cubic meter.

As with most stations, our particulate monitors had some down time. In December of 06 we upgraded our PM-10 monitor.
PM-2.5 also showed considerable variable. Our highest value in most any year is on the 4th of July, but high values are reached both in the winter months due to wood burning for home heating and in the summer due to wildfires. As with PM-10 we have some missing data in September of 07 for another system upgrade.
This slide gives the equations that define the structure of the time series models that we used.

The distributed lag model says that visits on a given day depend on particulate matter concentrations for the current day and the previous 4 days.

What we are looking at is whether the number of clinic visits increases in response to high particulate concentrations.

We also take into account that visits are higher after the clinic is closed and high visits one day are associated with high visits the next day.

We estimated this model for PM-10 and PM-2.5, and for each type of particulate we used both the 24 hour average and 24 hour max (so 4 versions of the particulate measures models).

And for each type of visit (all, pediatric, 65 and over, respiratory and circulatory)

This yields a matrix with a total of 20 models.

This model is fairly comprehensive but does not take into account the small number of events for pediatric, circulatory and respiratory visits.
**FINAL MODELING:**

*Poisson Regression*

- The number of visits follows a Poisson distribution with clustering within weeks
  
  \[ \text{Visits}_{wt} = \text{exposure}_t \exp(\beta \text{PM}_t + \beta_1 \text{PM}_{t-1} + \beta_2 \text{PM}_{t-2} + \beta_3 \text{PM}_{t-3} + \beta_4 \text{PM}_{t-4} + \mu_{wt}) \]

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

  \[ = 0 \text{ otherwise} \]

  \( t \) indexes days and \( w \) indexes weeks

  and \( \text{exposure}_t = 1 \) (unknown) by assumption

- The coefficients \( \exp(\beta) \) compare the ratio of visits on days where PM increased by 1 microgram to those where it did not. Values >1 indicate a positive effect.

This slide gives the equations that define the structure of the Poisson model we estimated.

As before we are looking at whether the number of clinic visits responds to particulate matter concentrations in the previous few days.

In this case we take into account clustering of visits within weeks and estimate standard errors using robust methods. It allows us to test the sensitivity of the time series results to distributional assumptions.

We did this because the number of visits each day is small and the time series model might make it look like results are statistically significant when they are not.
I am only showing you the final set of estimates for the Poisson model which should be the most statistically correct.

In general, the Poisson and time series results are fairly consistent, though often the effects are not statistically significant and the effects are small. Keep in mind that this is an exploratory study and we are looking for patterns.

These are the results for PM-10 which we think is the best measure of dust from the dry lake.

The graph on the left shows the response for each type of visit to 24-hour average particulate matter concentrations, and the one on the right looks at just the maximum hourly concentration each day.

Each line represents a particular type of visit.

Dark blue is total visits
Pink is pediatric
Yellow is over 65
Turquoise is respiratory
And dark red is circulatory

The vertical axis is the value of the coefficient
A coefficient that is over 1.00 means that visits increase in response to high particulate concentrations. Statistically significant effects are shown by a yellow diamond with a red outline.

The horizontal axis is the lag in days. Zero is the same day.

The main observation here is that circulatory visits seem to respond to PM-10 at later lags, so about 2 days after a high concentration event.
This set of graphs shows the results for PM-2.5.
The layout is the same as for PM-10.
We added PM-2.5 to the analysis somewhat as an afterthought because we had the information readily available, although our main interest was PM-10.
The main finding is the response of pediatric visits respond to the daily maximum PM-2.5 at all lags. This is the pink line.
Keep in mind that the effects are small are the study is exploratory.
I need to emphasize that this is a pilot study that uses a new approach that may be uniquely suited for sparse rural populations.

The study was frustrating to the extent that strong, clear results were not obtained despite quite high PM concentrations.

Nevertheless, the results are somewhat encouraging in that they are fairly consistent results across modeling approaches and there is some modest evidence of positive impact of PM on health as measured by clinic visits.
The sample size using a single year of data is not as large as we would have liked due to days the clinic was closed and missing PM data due to equipment upgrades. The effects we have found are small for the most part. We are hoping to add another year of data to see if we can improve our ability to detect even these small effects. Thank you for your attention and patience.