FINAL REPORT

"Response of Individuals with Reactive Airway Disease to Atmospheric Pollutants Including Sulfates" (A6-216-30)

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ABSTRACT

Frequency and severity of day-time symptoms, night-time symptoms and medication requirements among a group of 34 volunteers with asthma were correlated to levels of pollutants and pollens and to meteorologic characteristics continuously recorded over a period of eight months, utilizing three analytic strategies:

(A) Correlations between several parameters of respiratory health and levels of sulfates were consistently noted among three of the 34 volunteers. Significant correlations were also noted among several additional volunteers in one or more of the respiratory health parameters.

Levels of sulfates correlated to levels of total oxidants, carbon monoxide and oxides of nitrogen but these correlations were not responsible for correlations observed between the respiratory parameters in volunteers and sulfate levels.

(B) The mean symptom and medication scores of panel members on days falling in the highest and in the lowest tertile of all sulfate levels (>10 $\mu g/m^3$ and <5 $\mu g/m^3$, respectively) were compared. The same three volunteers showed significant increases in respiratory symptoms and medication usage on days which were in the upper third of all sulfate levels.

(C) In the final analysis, the number of days on which the participant's symptom or medication score was above his/her mean was calculated for sulfate days above and below 10 $\mu g/m^3$, the upper tertile of all sulfate levels. The three consistent sulfate responders all had significantly fewer symptoms and medication needs on days which were below the 10 $\mu g/m^3$ sulfate cutpoint.

Although the number of individuals was necessarily small, the results of this longitudinal study suggest that as many as 9% of asthmatics may be sensitive to levels of sulfate in the ambient air and that reduction of sulfate levels to below 10 $\mu g/m^3$ would significantly reduce the frequency of symptoms and needs for medication in these individuals.

INTRODUCTION

In an effort to evaluate the relationship between air pollution and respiratory health several investigators have studied the relationship between symptoms, need for medication, and lung function in individuals with reactive airways disease such as asthma. These individuals can potentially be considered to be among the most susceptible to elevated levels of pollutants in the ambient air. Many factors, however, such as weather conditions and levels of pollens in the air, can confound attempts at correlating levels of pollutants with respiratory symptoms and function. Recently, Cohen, et al.,* reported the results of a study of 20 asthmatics who lived within one half-mile of a coal-fueled power plant having no abatement devices. The atmosphere in this area contained substantial quantities of particulates, sulfur dioxide and oxides of nitrogen. The investigators reported a relationship with levels of air pollution independent of weather conditions but were not able to separate out effects caused by specific pollutants.

Recently, considerable interest has been centered on the health effects of exposure to sulfates because of the use of catalytic converters for pollution control in automobiles and the use of high sulfur coals and oil. This paper reports the results of a study of symptoms, medication needs and peak flow values in a group of asthmatics living in an area within the Los Angeles air basin subject to high levels of sulfates and relatively low levels of photochemical oxidants.

MATERIALS AND METHODS

Selection of Study Site

Daily maximum hourly average concentrations of oxidants, SO_2, 24-hour total sulfates, and particulates monitored at each of the monitoring stations of the Southern California Air Quality Management District (SCAQMD) were compared. Stations were identified which reported periodic high levels of sulfates and low levels of photochemical oxidants. The area surrounding the Lennox monitoring station was selected as the study site because it met this criteria and because there was a group of cooperative allergists whose clinic was within three miles of the monitoring station. This area is located in the southwestern section of Los Angeles County, just east of Los Angeles International Airport and approximately five miles inland from the Pacific Ocean.

Selection of Study Subjects

Participants were selected from among patients attending the clinic in Inglewood. A roster of patients living within three miles of the SCAQMD monitoring station was drawn up. The files of these patients were reviewed by the allergists to verify that they suffered from atopic asthma. Patients meeting the clinical criteria were then phoned by the staff of the clinic to invite them to participate in a longitudinal study.

Patients indicating an interest in participating in the study were interviewed by the project coordinator. Patients were considered to be

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*Cohen, AA, et al: Asthma and air pollution from a coal-fueled power plant. Amer J Pub Hlth 62/9:181, June 1972

potential participants if they demonstrated reversibility of their disease (greater than or equal to 20% reversibility in forced expiratory volume in one second (FEV_1) with a methacholine challenge). All panelists were on maintenance dosages of daily medications and required additional medications for relief of symptoms.

Patients demonstrating reversibility were invited to a group meeting where they were instructed in the technique of filling out the daily diary and of operating a Wright peak flow meter. Patients were subsequently followed for two weeks to determine if they could satisfactorily complete the daily diary and perform the peak flow maneuver. Individuals meeting this last criterion were then invited to participate in the study over a 8-month period. Participants were told that they would receive a stipend at the end of the study.

Daily Symptom and Medication Diaries

Participants were instructed to fill out a diary once in the morning for events occurring in the preceding evening and night and once at the end of the day for events occurring that day. The information to be recorded in the diary included:

1. Total number of asthmatic episodes or attacks of specific symptoms.

2. The severity of the event. Patients were asked to rate the severity of each symptom or attack on a scale of one to six, where one represented trivial or doubtful symptoms and six represented severe or intolerable symptoms. Information was requested for wheezing, breathlessness, chest tightness, cough sputum, nose stuffiness, number of attacks, etc.

3. Visits to doctors or emergency rooms.

4. Whether there was a requirement for intravenous medication and/or respiratory assistance (intermittent positive pressure breathing).

5. The dose and frequency of medication required for the symptoms or episode elicited above.

6. Peak flow rate determined by the portable Wright peak flow meter.

Scoring of Symptoms of Medication Needs

Daily symptom scores were graded on a basis of zero to six with zero indicating no symptoms and six indicating most severe symptoms. An asthma attack was defined as a noticeable respiratory change from normal in the opinion of the patient. Number of asthma attacks and symptom scores for the preceding night were entered on the top half of the diary upon waking in the morning and those for day symptoms entered on the bottom portion of the diary just before retiring at night.

Participants were instructed on the use of the Wright peak flow meter and recorded the best of three consecutive blows in the morning, noon and evening periods.

Medication needs were scored in the morning for the previous night and in the evening for that day as follows:

1 - normal maintenance medication, recommended number of doses (non-steroid)
2 - maintenance medications including steroid preparations
3 - additional medications not including steroids, or additional dosages of a maintenance medication, beyond those required for maintenance
4 - additional use of medications including steroids
5 - emergency room visit with administration of adrenalin or intermittant positive pressure breathing
6 - hospital stay or visit

In summary, medication scores of 1-2 represented baseline and scores of 3-6 indicated an increasing need for medication or treatment.

Evaluation of Participant Health

Participants were required to report to the allergy clinic twice monthly in order to have their daily diaries reviewed with the project director. Any individual failing to keep an appointment was immediately contacted by phone and rescheduled for a make-up appointment. The project coordinator evaluated the health status of each patient at these appointments and verified that the diaries were filled in correctly and adequately reflected the patient's health experiences over the previous two-week period. The project coordinator verified the medication requirements and inquired about new or additional medication in use since the previous period.

Monitoring of Pollutant Levels

Levels of oxides of nitrogen, ozone, total oxidant, carbon monoxide and SO_2 were continuously monitored by the Lennox station of the Southern California Air Quality Management District.* Oxides of nitrogen were measured using the colorimetric (Saltzman) reaction, ozone and total oxidant by analyzers calibrated against ultraviolet photometric standards, carbon monoxide by infrared non-dispersive spectroscopy, and SO_2 by the conductometric (H_2O_2) method. Twenty-four hour total sulfate levels were collected Monday through Friday at the monitoring station and analyzed using the AIHL Method #61. Total suspending particulates were measured using the high volume sampling method which gives 24 hour totals.

Monitoring of Pollen Levels

Levels of pollen in the study area were measured by a roto-rod pollen sampling device which was placed on the roof of the Lennox monitoring station. Samples were collected daily and were analyzed for pollens, molds, and particulate matter. Pollens were subclassified into 29 types (e.g., trees, grasses and weeds) and molds into 30 types. A coding system was implemented to organize this data in a more efficient manner. Pollen samples were collected from November 1977 through April 1978. Pollens were not collected during the first two of the eight months of study.

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*"California Air Quality Data," California Air Resources Board, Technical Services Division

RESULTS

Participants

Sixty-four patients of the allergy clinic in Inglewood were identified who resided within 3 miles of SCAQMD monitoring station. Fifty-two of the 64 patients met the clinical criteria by demonstrating reversibility of their disease with methacholine challenge, and were subsequently phoned by staff members. Thirty-eight individuals agreed to participate in the study and were entered into a two-week trial period, during which four patients were dropped for poor performance or reliability or for marginal study interest.

The remaining 34 patients completed the entire eight months of follow-up. The age-sex distribution of the participants is shown in Figure 1. There were twice as many males (23) as females (11). Seventy-one percent of the panel was Caucasian and 23% Black. In the following analyses participants were not separated by race or age since each individual was being compared to his or her self.

Forty-eight percent of the participants were born in the Los Angeles area. Seventy-three percent had resided within the study area for five years or longer. Only two of the 34 panelists had lived in the study area for less than one year. One male and one female participant reported being current smokers. All panelists resided within four miles of the Lennox monitoring station, the majority downwind from the station.

Correlation Between Outcome Measures

Day symptoms correlated with night symptoms at $r \geq .19$ ($P \leq .05$) in 97.1% of the participants and with medication scores in 82.4% of the participants (Table 1). The reported results of the peak flow manuever were noted to be more consistent than would be expected. Some variability in an individual's values from test to test would be expected even with highly correlated readings, given the variability of the test and of the individual's pulmonary status. The consistent values among many of the participants suggest that the test was not actually performed as reported. Therefore, results of peak flow manuevers have not been correlated to pollutant levels in the following analyses.

Because a day-of-the-week effect has been reported in several studies of asthmatics and pollutant levels are known to vary by the day of the week, the mean of all day-symptoms scores for a given day of the week was calculated and compared to the day-symptoms score means for each of the other days of the week for each individual. The mean of day symptoms, night symptoms, medication scores and peak flow values were not signficantly different for any one day of the week from all other days. Day-symptom scores were correlated to a day of the week in two of the 34 panelists and night-symptom scores in one of the 34 panelists. Therefore, no adjustment was made for day-of-the-week effect.

Correlations Between Pollutant Levels

The correlation coefficients for the nine pollutants measured at the Lennox monitoring station are shown for the first five months of the study period in Table 2. Daily sulfate levels were significantly ($P \leq .05$) correlated with two other pollutants; total oxidants ($r = 0.39$) and sulfur dioxide ($r = 0.42$). Sulfate levels were negatively correlated (at the $P \leq .05$ level) only to carbon monoxide ($r = -0.23$), nitric oxide ($r = -0.36$) and oxides of nitrogen ($r = -0.24$).

Correlations Between Levels of Sulfate and Pollens/Molds

The correlation coefficients between sulfates and pollens/molds which were present for 15 days or more during the five months of collection are shown in Table 3. Levels of sulfate were not significantly correlated to any of the pollens or molds collected at the Lennox station.

Correlations Between Levels of Sulfate and Weather Variables

The correlation coefficients between levels of sulfates and selected weather variables are given in Table 4. Sulfate levels were significantly correlated to a number of weather variablesbut only to daily minimum temperature and average dew point at $r > .25$.

Relationship Between Symptom/Medication Scores and Levels of Sulfates

To evaluate the relationship between patient symptom/medication usage and daily levels of sulfate pollutant, three analytic strategies were utilized:

(A) Correlations between symptoms, medication usage and daily sulfate levels

Correlation coefficients between symptom and/or medication scores and sulfate are given in Table 5. Positive correlations with sulfate levels greater than 0.25 were found with both symptoms scores and medications scores in two participants (#17 and #29), with day symptoms and medication scores in one participant (#34), with day symptoms in only one participant (#33), and with night symptoms only in one participant (#21). Two participants had correlations with medication score only (#7 and #25). A third (#2) had a positive correlation with medication score but a negative correlation with night symptoms. These participants had negative or non-significant correlations with NO_x and CO. Participant #25, one of those with a correlation to medication score only, paradoxically had significant positive correlations of symptoms with carbon monoxide, the oxides of nitrogen and particulates.

Negative correlations were found with both symptoms (day and night) and medication scores in one participant (#36) but this individual had a negative correlation with all pollutants. Two participants had negative correlations with day and night symptoms (#11 and #38). Both had positive correlations with oxides of nitrogen and carbon monoxide (which were inversely correlated with sulfate levels), perhaps explaining the apparent reduction in symptoms on high sulfate days. One participant (#2) had a negative correlation with night symptoms but an equally strong positive correlation with medication score and thus, #2 is difficult to evaluate.

In summary, strong positive correlations were found with sulfate levels in three participants (#17, #29, #34) and lesser correlations in several other participants. Two of the

participants with negative correlations of symptoms with sulfate levels had positive correlations with CO and NO_x (#11 and #38). A third had a strong negative correlation to sulfates but an equally strong positive correlation with medication score (#2). The fourth had negative correlations with all pollutants measured (#36).

Sulfate levels were correlated to levels of total oxidants and SO_2: two of the three participants with strong correlations with sulfates also had a correlation with total oxidants (#34 and 29), and one of the three was apparently sensitive to SO_2 (#34). However, the correlation with total oxidants and SO_2 were lower than with sulfates in all cases.

(B) High sulfate days compared to low sulfate days

A second analysis involved examination of differences in mean symptom and medication scores on high sulfate days (>10 $\mu g/m^3$) and low sulfate days (<5 $\mu g/m^3$), using T-test analysis for significant differences between the means. (These levels represented the limits of the upper and lower tertiles of all sulfate days.) Participants with a difference resulting in a T value >3.0 are given in Table 6. Participants #17 and #29 had large differences in both symptom and medication scores on high vs. low sulfate days, a finding similar to that using a correlation >0.25 (Table 5). Differences for participant #34 included day symptoms and medications, the same categories found to be associated using the correlation coefficient. The three participants with negative correlations to sulfate (#38, #36, #11) also had differences in T scores ≥3.00. Participant #38, who had a small negative correlation with symptoms, demonstrated a negative difference with T values just above 3.0 for night symptoms. Generally, results using this analysis were similar to those found using a correlation coefficient ≥0.25 and also identified the same three participants as having increased symptom and medication needs associated with elevated sulfate levels.

(C) Deviations from mean symptom/medication scores on days above and below 10 $\mu g/m^3$ sulfate

In the third analysis the mean symptom and medication scores for each individual over the entire study period were calculated, and the number of days on which the participant's symptom or medication score was above his/her mean was calculated for days on which sulfate levels were above and below 10 $\mu g/m^3$, the upper tertile of all sulfate levels. The chi-square for the difference in proportion of days with symptoms above an individual's mean on high sulfate days and low sulfate days is shown in Table 7. The same three apparently sensitive individuals (#17, #29, #34) had a greater proportion of symptom and medication scores above the mean on sulfate days above 10 $\mu g/m^3$ and in the same parameters as previously stated. The same negative responders were also identified. A graphical comparison

of the three responders and three of the nonresponders are shown in Figure 2. The mean symptom score is designated by a line parallel to the abscissa. A second line drawn parallel to the ordinate corresponds to the threshold level of 10 $\mu g/m^3$ of sulfate. For the responders there are more points in either the lower left or upper right quadrants indicating a relationship to sulfate levels.

Several other participants not previously identified had differences in the proportion of either day or night symptoms above the mean on elevated sulfate days. Participant #33 had a difference for day symptoms as he did for the correlation analysis (Table 5). This analysis suggests that those asthmatics sensitive to sulfate would have significantly fewer symptoms and medication needs if sulfate levels were maintained below the 10 $\mu g/m^3$ cutpoint. (Note: Twenty-four hour sulfate levels ranged between 1.5-38.1 $\mu g/m^3$ over the study period. For purposes of analysis only, days with sulfate levels $\leq$ 5 g/m^3 or $\geq$10 g/m^3 were considered to represent low sulfate days or high sulfate days respectively, because these cutpoints represented the lowest and highest third of all sulfate exposures measured over the study period.)

DISCUSSION

Three participants among the 34 studied were consistently sensitive to levels of sulfates in the ambient air according to the three analytic strategies used. These three had correlation coefficients greater than 0.25 between sulfate levels and symptom/medication scores and a higher frequency of symptoms and medication needs on days on which sulfate levels were above 10 $\mu g/m^3$. Other participants demonstrated weaker relationships between respiratory symptoms and sulfate levels.

One of the major problems confronting these types of panel studies is the well established association between levels of total oxidants and SO_2 with levels of sulfate. We observed this association in the present study. Two of the three participants were observed to be sensitive to levels of total oxidants and one of the three was apparently sensitive to SO_2. The participants having day symptoms which correlated with total oxidant or SO_2 had higher correlations of sulfates with day symptoms and medications. These analyses suggest that these three individuals were responding to sulfate levels rather than co-variates of sulfate.

Four participants apparently had an improvement in symptoms and/or a reduced need for medication on high sulfate days. One of these individuals concurrently had an equally strong positive association with medications (greater need). Two had positive correlations with levels of carbon monoxide and oxides of nitrogen to which levels of sulfate were negatively correlated. It is possible that these individuals may have been sensitive to levels of carbon monoxide and oxides of nitrogen. The fourth individual had a negative correlation with all pollutants and is difficult to evaluate. In summary, inverse associations with sulfates were weak and inconsistent compared to the positive associations among the three participants sensitive to sulfate levels.

Recommendation

Although the number of individuals was necessarily small, the results of this longitudinal study suggest that as many as 9% of asthmatics may be sensitive to levels of sulfate in the ambient air and that reduction of sulfate levels to below 10 $\mu g/m^3$ would significantly reduce the frequency and severity of symptoms and needs for medication in these individuals.

TABLE 1

CORRELATION COEFFICIENTS (r) BETWEEN PARTICIPANT SYMPTOM AND MEDICATION SCORES

Patient ID	Day Symptom Score to Night Symptom Score	Day Symptom Score to Medication Score
13	r = .543*	r = .69*
14	.858*	.00
20	.906*	.47*
23	.807*	.21*
3	.515*	.62*
4	.249*	.38*
7	.564*	.01
12	.295*	.57*
25	.755*	.22*
5	.567*	.54*
39	.294*	.51*
15	.000	.00
16	.672*	.69*
24	.829*	.55*
30	.580*	.37*
38	.599*	.21*
31	.626*	.24*
40	.461*	.44*
21	.783*	.62*
17	.852*	.34*
35	.517*	.18*
34	.543*	.27*
36	.848*	.27*
41	.447*	.14
26	.812*	.31*
27	.186*	.25*
2	.406*	.48*
18	.585*	.31*
32	.602*	.22*
9	.747*	.51*
11	.645*	.13
29	.454*	.33*
33	.341*	-.03 (Neg)
6	.635*	.26*
(Proportion with r > .19 and p ≤ .05)	33/34 = 97.1%	28/34 = 82%

*Significant; $p \leq .05$ ($\alpha = .05$)

TABLE 2

CORRELATION COEFFICIENTS (r) AMONG 9 SELECTED POLLUTANTS**
MEASURED AT THE LENNOX MONITORING STATION

Correlation Matrix

	PARTICULATE	SULFATE	AVE-TOX	AVE-CO	AVE-CO1	AVE-SO_2	AVE-NO_2	AVE-NO	AVE-NO_x
PARTICULATE	1.00								
SULFATE	0.19	1.00							
AVE-TOX	0.23*	0.39*	1.00						
AVE-CO	0.48*	-0.15	0.09	1.00					
AVE-CO1	0.39*	-0.23*	-0.03	0.95*	1.00				
AVE-SO_2	0.31*	0.42*	0.02	0.38*	0.30*	1.00			
AVE-NO_2	0.50*	0.13	0.20*	0.88*	0.86*	0.50*	1.00		
AVE-NO	0.38*	-0.36*	-0.03	0.90*	0.88*	0.20*	0.75*	1.00	
AVE-NO_x	0.44*	-0.24*	0.04	0.94*	0.92*	0.31*	0.87*	0.98*	1.00

*Significant $p \leq .05$ ($\alpha = .05$)

**Correlation coefficients based on the 1st 5 months of data collection

TABLE 3

CORRELATION COEFFICIENTS (r) BETWEEN SELECTED POLLENS/MOLDS* AND SULFATE (mg/m^3)

Pollen/Mold	Frequency-No. of Days Pollen/Mold Occurred	Correlation Coefficients (r) with Sulfate (mg/m^3)
Aceraceae	0	r = —
Fagaceae	4	—
Hamamelidaceae	1	—
Juglandaceae	2	—
Leguminosae	1	—
*Oleaceae	43	-.069
Platanaceae	0	—
Salicaceae	0	—
Tiliaceae	0	—
*Ulmaceae	25	-.005
Urticaceae	1	—
Myrtaceae	8	—
Pologonaceae	0	—
Plantaginaceae	0	—
Cyperaceao	0	—
Amaranthaceae	9	—
Ambrosia	11	—
Artemosia	9	—
*Gramineae	15	-.017
*Other	46	-.053
*Cupressaceae	17	-.035
*Pinaceae	35	-.085
*Basidiomycetes	107	-.048
*Ascomycetes	16	-.053
*Fungi Imperfecti	103	.046
Penicillium	2	—
*Aspergillus	17	.060
*Hormodendrum	59	.062
*Alternaria	61	.058
Algal cells	9	—
Fern	14	—
*Moss like	26	-.008
*Helminthosporium	19	-.022

*Correlation Coefficients (r) were calculated only for those pollens/molds which were present on ≥ 15 days of the 5 month collection period.

**P ≤ .05 (α.05); No problem or mold was significantly correlated with S04 level.

TABLE 4

CORRELATION COEFFICIENTS* (r) BETWEEN SULFATE AND SELECTED WEATHER VARIABLES

VARIABLE	CORRELATION WITH SULFATE (r)
Temperature (^{o}F)	
Daily Max.	.11
Daily Min.	.31*
Daily Ave.	.25*
Ave. Dew Pt. (^{o}F)	.39*
Rain (in.)	-.25*
Pressure (in.) (daily ave.)	-.13
Wind	
Direction	.13
Ave. Speed (m.p.h.)	-.18*
Fastest Speed (m.p.h.)	-.27*

* $P \leq .05$ ($\alpha = .05$)

TABLE 5

PARTICIPANTS WITH CORRELATION COEFFICIENTS $\geq$ 0.25 ($P \leq .05$)

BETWEEN SYMPTOM AND/OR MEDICATION SCORES AND

SULFATE AND/OR OTHER POLLUTANTS

Participant	Sulfate to Symptoms		Sulfate to Medication	other pollutants to symptoms				
	Day	Night	Score	total oxid.	Part.	SO_2	CO	NO_x
17	.35	.32	.45	-.01*	-.21*	-.04*	-.42	-.48
29	.37	.28	.26	.20	-.05*	.04*	.02*	-.13*
34	.39	.14*	.34	.26	.10*	.20	.11*	.07*
7	.04*	.11*	.35	-.17*	-.11*(N)+	.18	-.12*	-.18*
13	.13*	.06*	.20	-.07*	-.13*	-.05*	-.40	-.41
21	.17*	.28	.01*	-.01*(N)	.03*(N)	.16*	-.04*	-.04*
25	.05*	.17*	.25	.10*	.29	.12*	.57	.55
33	.28	-.07*	.10*	.04*	.14*	.16*	.06*	.08*
2	.06*	-.30	.34	.10*	.09*	-.08*	.11*	.13*
11	-.36	-.37	-.04*	.10*	.09*	-.06*	.22	.21
36	-.22	-.20	-.32	-.20*	-.16*	-.32	-.28	-.23
38	-.20	-.21	-.11*	.22*	.26(N)	.13*	.28	.25

* $P \geq .05$

+ = night symptoms only

TABLE 6

DIFFERENCE* BETWEEN MEAN SYMPTOM AND MEDICATION SCORES ON DAYS WITH SULFATES <5 mg/m^3 AND ON DAYS WITH SULFATES >10 mgs/m^3

Participant	Day symptoms	Night Symptoms	Medications
17	5.4	5.2	3.2
29	4.8	4.4	2.7
34	2.4	1.6+	5.0
7	1.7+	2.5	3.5
20	3.3	-.3+	1.1+
2	.4+	-4.9	3.7
11	-5.5	-4.2	.1+
36	-2.1	-1.7+	-3.1
38	-2.7	-3.3	0.0+

*T value $\geq$ 3.00

+ = p >.05

TABLE 7

DIFFERENCE IN PROPORTION OF DAYS WITH SYMPTOM AND MEDICATION SCORES ABOVE AN INDIVIDUAL'S MEAN SCORE FOR DAYS WITH SULFATE LEVELS ABOVE AND BELOW 10 mgs/m^3

Participant	Day symptoms		Night Symptoms		Medication	
	X^2	P<	X^2	P<	X^2	P<
17	17.1	.00	18.8	.00	11.4	.00
29	3.7	.06	4.6	.03	14.6	.00
34	7.9	.01	.3	.66	9.5	.00
13	2.8	.09	4.5	.04	7.1	.01
27	1.7	.19	5.6	.02	2.2	.14
32	2.0	.16	4.8	.03	5.1*	.02
33	14.6	.00	0.0	1.00	0.0	1.00
35	4.7	.03	1.0	.34	0.0	1.00
2	1.8	.19	22.8*	.00	13.5	.00
11	24.4*	.00	17.3*	.00	0.0	1.00
38	4.0*	.05	4.5*	.04	3.8	.05
23	0.9	.34	0.6	.48	4.3	.04
7	3.1	.08	1.2	.27	5.8	.02
40	0.2	.66	.2	.66	6.6*	.01
36	2.8	.09	2.6	.11	11.8*	.00
41	0.0	.92	0.3	.58	4.07	.04

*T value is negative - showed greater proportion of symptom or medication days above the mean on low sulfate days ($\leq$ 10 $\mu g/m^3$)

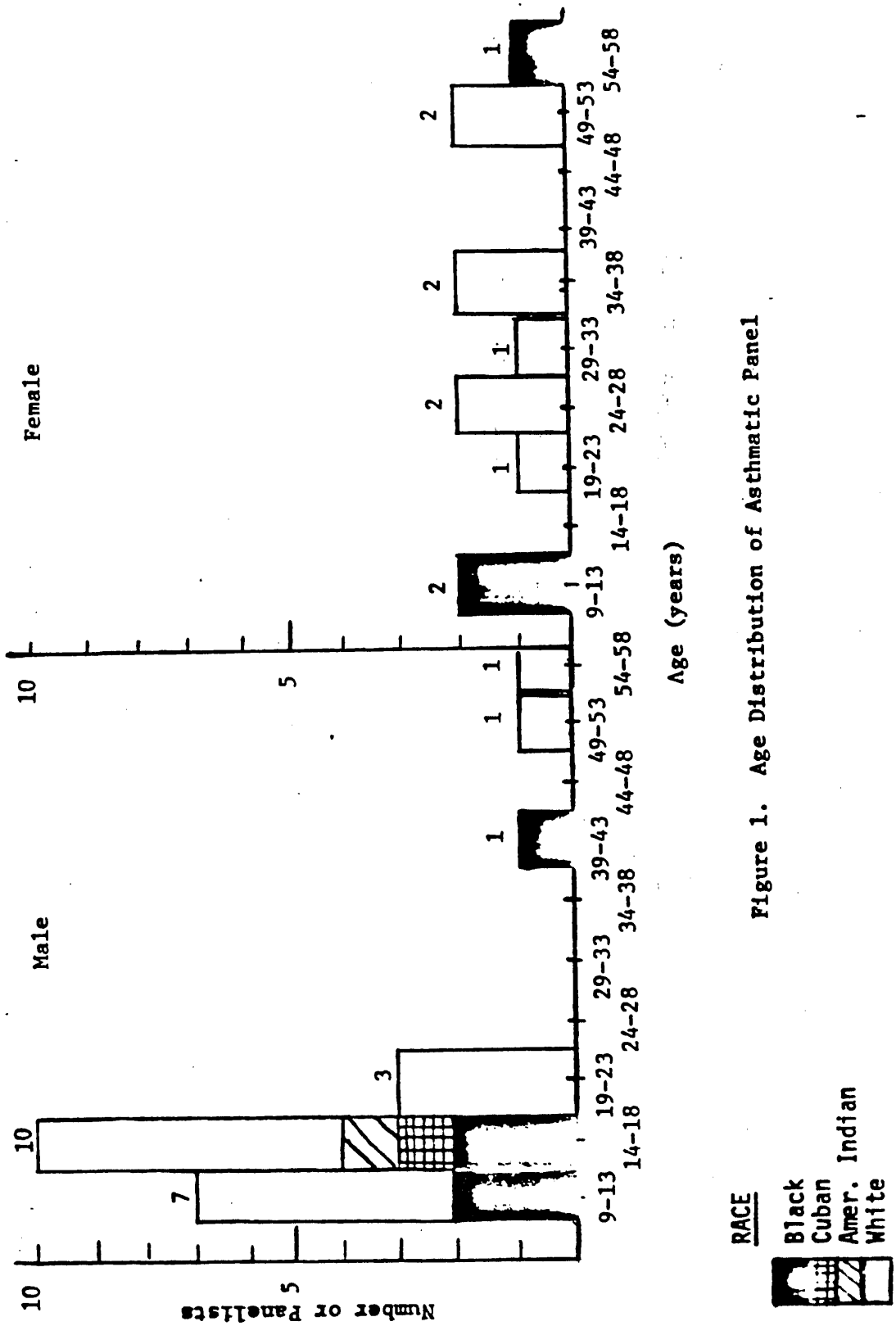
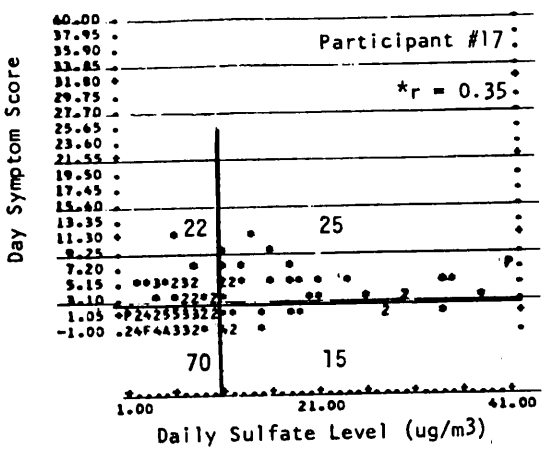
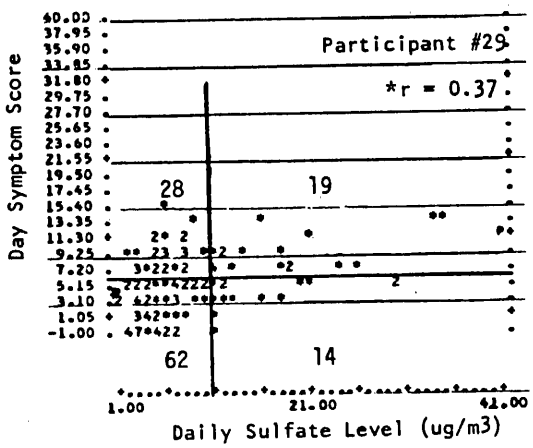


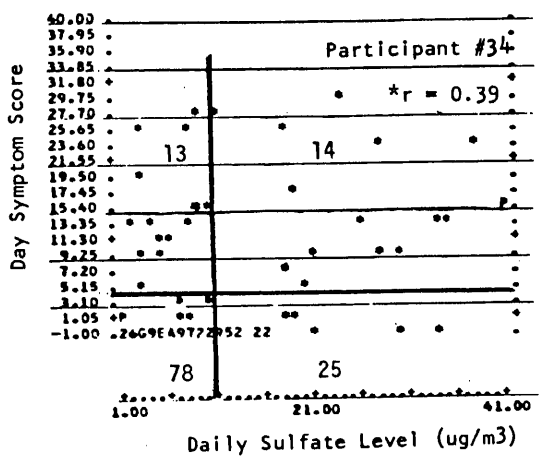
Figure 1. Age Distribution of Asthmatic Panel

Figure 2. Graphical Comparison of Sulfate Responders and Non-Responders

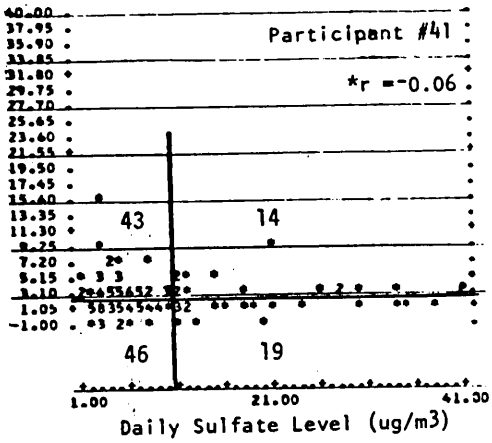
Sulfate Responders

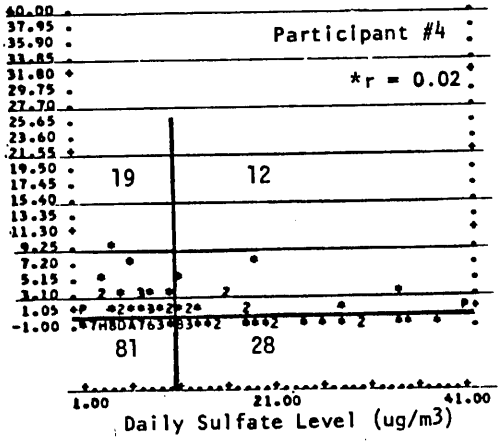


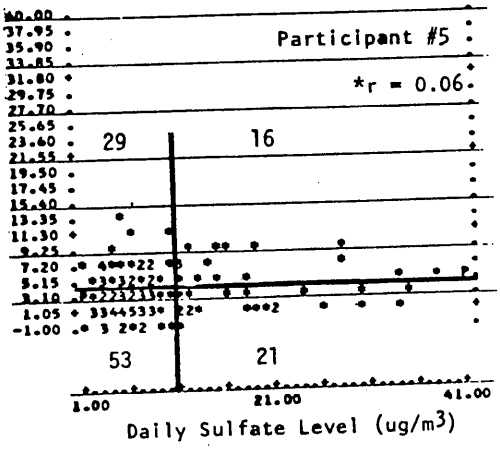




Non-Responders







* Correlation coefficient (r) between day symptoms and daily sulfate