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Project Summary

Effects of Sulfuric Acid Mist Exposure on Pulmonary Function

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The effects of sulfuric acid particle concentration (mass/volume), particle size, and ambient temperatures on pulmonary function of young male nonsmokers were examined. Subjects repeated three times a sequence of 20-minute exercise (ventilation of approximately 30 l/min) and 20-minute sitting rest. Pre- and post-exposure pulmonary functions (forced vital capacity maneuvers, lung volumes, maximum voluntary ventilation, R_{aw} TGV and helium-oxygen FVC) were measured. During the exposure and at the 5th minute after cessation of each exercise period, forced vital capacity tests (air and helium-oxygen) were performed. Each subject was exposed in random order to filtered air or 233, 418 or 939 $\mu g/m^3$ particulate sulfuric acid. Particle sizes were MMD, 0.91-0.93 μm, geometric SD, 1.66-1.73. Two subject groups were studied in two different ambient conditions, i.e. approximately 22°C dry bulb, 55% relative humidity, and 35°C dry bulb, 85% relative humidity. Sulfuric acid concentrations were slightly higher during the hot environmental exposures. No significant changes in pulmonary functions related to sulfate were observed in subjects intermittently exercising in the cool environment. Metabolic measurements during exercise indicated a trend towards increased ventilation and oxygen uptake with duration of exposure. The only significant difference which was related to sulfate exposure was a higher respiratory rate compared to filtered air. Heart rates were similar under all conditions. In the hot humid environment, forced vital capacity decreased with time of exposure but was not related to pollutant exposure. The only significant interaction for pollutants across time was seen for FEF75%, where the post-exposure values were greater than the pre-exposure values under filtered air conditions but not during sulfate exposure. This observation was not corroborated by changes in FEF75-85%, which increased post-exposure under all conditions. Three subjects were studied during exposure to 1400 $\mu g/m^3$. No changes were observed. Predictable increases in heart rate, rectal temperature, ventilation and oxygen uptake were found but were not related to sulfate exposure, being simply the influence of the altered ambient conditions. Exposure to sulfuric acid mist in the 1 μm particle size range and in concentrations up to 1200 $\mu g/m^3$ had relatively minor effects on the cardiopulmonary system.

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This Project Summary was developed by EPA's Health Effects Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The increasing use of coal and petroleum products with high sulfur content has raised concern about the potential health effects of sulfur-containing air pollutants. Early studies found that humans exposed briefly (10-16 min) to sulfuric acid concentrations of 0.35 to 5 mg/m^3 and 4 to 40 mg/m^3 (particle size 1 μm) respectively, exhibited increased coughing, altered respiratory patterns and bronchoconstriction. However, more recent studies again exposed subjects briefly to 10, 100, and 1000 $\mu g/m^3$ to either sodium chloride or sulfuric acid aerosols (0.1 to 0.2 μm). These 10-minute exposures of either normal or asthmatic individuals did not induce any alterations in pulmonary functions. The effects on pulmonary functions of intermittently exercising subjects breathing sulfuric acid (75 $\mu g/m^3$, particle size 0.48-0.81 μm) were investigated. No convincing adverse short-term health effects were observed. Ten subjects inhaled via nasal mask 0.5 μm H_2SO_4 at 0, 100, 300 and 1000 $\mu g/m^3$ for one hour. Although no significant changes in respiratory dynamics were observed, bronchial mucociliary clearance was altered. Respiratory effects of sulfuric acid aerosol in normal subjects exposed for four hours to 100 $\mu g/m^3$ H_2SO_4 of particle size 0.1 to 0.3 μm were evaluated. The subjects performed two 15-minute bouts of exercise during the exposure period. No significant differences in pulmonary function were observed during or after the exposure. The conflicting results reported could have been related to the size of the aerosol particles utilized in the different experimental situations.

We examined the effects of sulfuric acid particle concentration (mass/volume) at an ambient temperature of 22°C and 55% relative humidity on pulmonary function of young male nonsmokers. All exposures were conducted in an environmental chamber. Eleven subjects thrice repeated a sequence of 20-minute exercise (ventilation approximately 30 liters/min) and 20-minute sitting rest during the 2-hour exposure. Pre- and post-exposure pulmonary function tests (forced vital capacity maneuvers, lung volumes, maximum voluntary ventilation, R_{aw}, TGV, and helium-oxygen FVC) were measured. During the exposure and at 2 minutes after cessation of each exercise period, forced vital capacity tests (air and helium-oxygen) were performed. Each subject was exposed in random order to filtered air or 233, 418, or 939 $\mu g/m^3$ particulate sulfuric acid. Mass median diameter (MMD) was 0.90-0.93 μm, and geometric SD was 1.66-1.73.

Results

No major changes in pulmonary function related to sulfate were observed in these subjects (Tables 1 and 2). The only measurement to show a significant interaction across time (pre - post) and sulfate concentration was $FEV_{1.0}$, which was significantly decreased with exposure to 939 $\mu g/m^3$ sulfate. The magnitude of the decrease was not considered to be of physiological significance. These results indicate that, even with the added stress of the increased depth and volume of ventilation associated with exercise, exposure to as much as 1 mg/m^3 of 1 μm sulfuric acid aerosol for 2 hours has little if any effect on standard tests of lung function. Many subjects noticed a dry or metallic taste in the air. At the highest concentration, throat irritation or dryness and cough were frequently noted. Eye irritation was reported by two subjects at 939 $\mu g/m^3$ of sulfate. Several individuals reported dizziness, fatigue, or headache, which were usually associated with exercise and had no relationship with sulfate levels in the ambient air.

Discussion

These data indicate that there was no significant effect of sulfuric acid aerosol in the 1-micron (0.9 μm) size range and in concentrations between 200 and 1000 $\mu g/m^3$ on the pulmonary function of young male nonsmokers. The results of the present study support previous studies of human exposure to sulfuric acid aerosols in the 0.3 to 0.5 μm size range at similar concentrations (100-1000 $\mu g/m^3$). However, they do not confirm studies in which subjects were exposed to larger aerosols. Subjects in the study described herein were not only exposed for longer periods; the quantity of inhaled aerosol was intentionally increased by having the subjects exercise so that their ventilatory volumes were intermittently increased up to 30 liters/ min. The increased prevalence of symptoms such as cough, dry throat, or throat irritation suggests that the sulfuric acid may have caused some irritation to the tracheal mucosa although not to a sufficient degree to induce functional changes. These symptoms were usually noted only when the subject took a deep or rapid inspiration and generally only at the beginning of the exposure period.

Conclusions

It is apparent that additional investigations involving long-term exposures (rest and exercise combinations), small and large particles, and various ambient humidities need to be conducted. Some attention must also be given to the mode of administration. Chamber studies which more closely simulate natural environments are preferred, but the interrelationship between such exposures and those utilizing oral or a combination of oral-nasal inhalation require clarification.

able 1. *Pulmonary Function Measurements in Subjects Exposed to Various Concentrations of H_2SO_4 (Pre & Post 2-Hour Exposures; Mean ± SD)*

		0 μg/m³	223 μg/m³	418 μg/m³	939 μg/m³
Forced vital capacity (L)	Pre	5.64 (±0.58)	5.65 (±0.55)	5.66 (±0.61)	5.65 (±0.61)
	Post[a]	5.58 (±0.56)	5.54 (±0.63)	5.59 (±0.63)	5.47 (±0.60)
$FEV_{1.0}$ (L)	Pre	4.47 (±0.46)	4.83 (±0.54)	4.72 (±0.55)	4.82 (±0.57)
	Post[b]	4.79 (±0.48)	4.80 (±0.57)	4.76 (±0.55)	4.72 (±0.57)
$FEV_{3.0}$ (L)	Pre	5.58 (±0.59)	5.61 (±0.57)	5.61 (±0.62)	5.62 (±0.63)
	Post[a]	5.55 (±0.57)	5.51 (±0.64)	5.54 (±0.63)	5.44 (±0.57)
Inspiratory capacity (L)	Pre	3.62 (±0.48)	3.58 (±0.49)	3.61 (±0.55)	3.54 (±0.50)
	Post[a]	3.48 (±0.45)	3.49 (±0.58)	3.49 (±0.46)	3.40 (±0.46)
Expiratory res. vol. (L)	Pre	2.02 (±0.45)	2.02 (±0.36)	2.05 (±0.47)	2.12 (±0.39)
	Post	2.10 (±0.45)	2.05 (±0.38)	2.12 (±0.45)	2.06 (±0.40)
Funct. res. capacity (L)	Pre	3.66 (±0.74)	3.68 (±0.73)	3.72 (±0.69)	3.74 (±0.74)
	Post	3.73 (±0.72)	3.76 (±0.70)	3.80 (±0.76)	3.76 (±0.73)
FEF25-75% 'L/s)	Pre	4.97 (±0.69)	5.14 (±0.89)	4.97 (±0.74)	5.11 (±0.88)
	Post	5.06 (±0.81)	5.36 (±1.11)	5.05 (±0.80)	5.29 (±1.08)
Max. volunt. vent. (L/min)	Pre	202 (±34)	206 (±35)	199 (±35)	211 (±35)
	Post	205 (±33)	202 (±41)	204 (±39)	209 (±32)
Airway res. 'L/s/cm H_2O)	Pre	1.67 (±0.39)	1.73 (±0.35)	1.75 (±0.52)	1.87 (±0.48)
	Post	1.76 (±0.58)	1.77 (±0.57)	1.64 (±0.46)	1.69 (±0.41)
FEF50% 'L/s)	Pre	5.57 (±0.77)	5.85 (±1.01)	5.97 (±0.85)	5.82 (±0.97)
	Post	5.63 (±1.03)	6.12 (±0.98)	5.84 (±0.96)	5.81 (±1.15)
FEF75% 'L/s)	Pre	2.80 (±0.65)	2.83 (±0.57)	2.83 (±0.68)	2.76 (±0.61)
	Post	2.93 (±0.80)	3.05 (±0.90)	2.88 (±0.77)	2.89 (±0.73)
FEF75-85% 'L/s)	Pre	2.12 (±0.59)	2.20 (±0.54)	2.29 (±0.61)	2.13 (±0.68)
	Post	2.22 (±1.02)	2.32 (±0.72)	2.32 (±0.70)	2.28 (±0.71)

[a]*Post < Pre overall - no difference across sulfate concentrations.*
[b]*Pre (FA, 418) < Pre (223, 939); Pre (939) > Post (939).*

able 2. *Pulmonary Function Measurements During 2-Hour Exposure to H_2SO_4 (Mean ± SD)*

		0 μg/m³	223 μg/m³	418 μg/m³	939 μg/m³
Forced vital capacity (L)	Pre	5.35 (±0.54)	5.25 (±0.55)	5.30 (±0.54)	5.28 (±0.59)
	25	5.21 (±0.61)	5.25 (±0.56)	5.20 (±0.58)	5.20 (±0.59)
	65	5.24 (±0.62)	5.21 (±0.56)	5.24 (±0.56)	5.17 (±0.61)
	105	5.16 (±0.62)	5.23 (±0.57)	5.17 (±0.53)	5.13 (±0.62)
$FEV_{1.0}$ (L)	Pre	4.65 (±0.49)	4.53 (±0.51)	4.51 (±0.57)	4.55 (±0.57)
	25	4.48 (±0.54)	4.43 (±0.64)	4.43 (±0.59)	4.49 (±0.55)
	65	4.53 (±0.58)	4.45 (±0.53)	4.52 (±0.49)	4.44 (±0.55)
	105	4.52 (±0.52)	4.56 (±0.64)	4.53 (±0.53)	4.48 (±0.57)
$FEV_{3.0}$ (L)	Pre	5.33 (±0.56)	5.22 (±0.56)	5.28 (±0.55)	5.26 (±0.59)
	25	5.18 (±0.61)	5.19 (±0.60)	5.12 (±0.59)	5.16 (±0.59)
	65	5.23 (±0.63)	5.17 (±0.59)	5.19 (±0.56)	5.15 (±0.62)
	105	5.13 (±0.61)	5.20 (±0.54)	5.14 (±0.54)	5.10 (±0.20)
Inspiratory capacity (L)	Pre	3.48 (±0.48)	3.39 (±0.57)	3.43 (±0.43)	3.43 (±0.54)
	25	3.25 (±0.59)	3.23 (±0.58)	3.34 (±0.49)	3.29 (±0.46)
	65	3.29 (±0.43)	3.32 (±0.55)	3.31 (±0.49)	3.21 (±0.49)
	105	3.19 (±0.42)	3.36 (±0.60)	3.26 (±0.45)	3.22 (±0.48)
FEF25-75% (L/s)	Pre	4.92 (±0.79)	4.91 (±0.83)	4.75 (±0.97)	4.90 (±0.83)
	25	4.73 (±0.83)	4.82 (±1.21)	4.64 (±0.97)	4.90 (±0.84)
	65	4.90 (±1.01)	5.13 (±1.05)	4.81 (±0.89)	4.84 (±0.95)
	105	5.05 (±0.83)	5.10 (±1.30)	4.90 (±0.89)	5.02 (±0.80)

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Table 2. *(continued)*

		0 μg/m³	223 μg/m³	418 μg/m³	939 μg/m³
FEF50%	Pre	4.80 (±0.83)	4.99 (±0.78)	4.69 (±0.99)	4.92 (±0.85)
(L/s)	25	4.73 (±0.81)	4.76 (±1.14)	4.54 (±0.94)	5.00 (±0.86)
	65	4.88 (±0.98)	4.98 (±0.84)	4.76 (±0.91)	4.92 (±0.89)
	105	5.05 (±0.80)	5.03 (±1.08)	4.83 (±0.93)	5.00 (±0.92)
FEF75%	Pre	2.53 (±0.61)	2.66 (±0.70)	2.40 (±0.74)	2.54 (±0.58)
(L/s)	25	2.51 (±0.71)	2.50 (±0.65)	2.49 (±0.84)	2.56 (±0.57)
	65	2.53 (±0.84)	2.64 (±0.77)	2.47 (±0.72)	2.52 (±0.68)
	105	2.65 (±0.73)	2.66 (±0.87)	2.63 (±0.78)	2.59 (±0.66)

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***Donald H. Horstman** is the EPA Project Officer (see below).*

The complete report, entitled "Effects of Sulfuric Acid Mist Exposure on Pulmonary Function," (Order No. PB 81-208 977; Cost: $9.50, subject to change) will be available only from:

National Technical Information Service
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