Rural Fugitive Dust and Health: Comments on EPA's Proposed PM_{10} Fugitive Dust Policy Docket Number A-87-01

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EXHIBIT 1

EXECUTIVE SUMMARY

The EPA proposed policy statement on Particulate Matter Fugitive Dust Policy (52FR24716-24723) presents concerns of "commenters" that rural fugitive dust may pose a health hazard requiring controls. One such "commenter" was the California Air Resources Board (Ref. 1). The CARB comments fall into three specific areas:

1. That rural PM_{10} "nearly approaches (the) health risk posed by urban PM_{10}."
2. That as much as 50% of total rural dust is "fine particles".
3. "Rural fugitive dust appears to transport substances that are just as hazardous...(as) urban fugitive dust."

The concerns expressed by CARB and then echoed by Region IX EPA but not by any other commenters are not supported by the available facts.

1) In assuming that rural and urban PM_{10} are equivalent in terms of health risk, CARB ignores the profound chemical and physical differences. Health effects are generally attributed to particles less than 2.5 microns (probably less than 1 micron) which are chemically active. Health effects are not found with fugitive dust particles between 2.5-10 microns.

2) If PM_{10} concentrations approach the standard, this will normally occur in correlation with high TSP concentrations. During such episodes of wind blown dust, the less than 10 micron portion is still harmless fugitive particles which do not play a substantial role in health risk.

3) The presence of "toxic" substances in rural fugitive dust may be theoretically possible but dose and exposure are negligible. Control of spores, silica and natural asbestos is impractical and any alleged health effects are undocumented. Rural fugitive dust metals concentrations are miniscule and are or will be controlled through specific NAAQS, NESHAPS, NSPS as appropriate to protect public health from significant risk. Current pesticide practices dictate low application concentrations and rapidly decomposing compounds. Significant exposures beyond the treated field are unlikely and controlled through other government programs.

In summary, there is no evidence to conclude that rural fugitive dust contributes to health effects. On the contrary, health effects are related to

particles of less than 1 micron size of anthropogenic origin which are chemically active. Whatever harmful constituents there may be in rural fugitive dust are of insignificant dose and are controllable as appropriate under other regulatory mechanisms as noted above. Therefore, EPA's prior judgment that rural fugitive dust is benign was correct and is not controverted by any evidence yet available.

PREFACE

In addressing the issue of a PM-10 standard in relation to fugitive dust, Dr. Bernard Goldstein, EPA's previous administrator for Research and Development, raised the question, "How does one control mother nature..? (Ref. 2) A more fundamental question is whether one needs to control mother nature. But this is essentially what some areas of the US may be required to do if fugitive dust is considered to have the same degree of toxicity (and offer the same degree of exposure) as the particulate matter found in industrialized urban areas.

Particulate matter is used as a surrogate indicator of airborne aerosols (solid and liquid particles) which are presumed to include constituents that have health effects. Particulate matter less than 10 microns (PM_{10}) in size is the current basis of the National Ambient Air Quality Standards. In actuality, 10 microns is the 50% cut point and larger particles (probably up to a maximum of 14-15 microns) affect the mass concentration measurements. Fine particles are usually defined as less than 2.5 microns and coarse particles are the 2.5-15 micron range (These definitions are an artifact of the sampling technique not directly related to health effects). Total suspended particulate matter (TSP) is measured with a high volume sampler and was the basis of the old NAAQS. Misuse of particulate matter definitions is frequent and care must be taken. Fine particles does not mean PM_{10}, for instance. PM_{10} therefore has both fine and coarse fractions. Rural measurements of PM_{10} therefore include fugitive dust which is predominantly coarse particles. This distinction is important since violations of the PM_{10} NAAQS in rural settings would be expected to contain a high percentage of coarse fugitive dust particles which, because of their larger size (as opposed to fine particles), will dominate the mass measurement.

Because of the health concerns some commenters have raised regarding fugitive dust, this report attempts to address what is known about the health risks associated with exposure to fugitive dusts. A review of the published scientific literature on this subject offered little direct information on health effects. However, much information was found regarding the role of fine versus coarse particulate matter. Coarse particulate matter is the primary constituent of fugitive dust. Careful review of the health studies concerning particulate matter and discussions with some of the nation's pre-eminent air pollution health researchers confirmed that studies on the health effects from exposure to fugitive dusts have not been performed because of (1) the relatively low concentrations in the ambient environment, (2) their relatively large particle size (>2.5 μm), and (3) their composition (primarily the earth's crustal material). Still, in order to address the fugitive dust issue, a summary report of several key studies on fine and coarse particles is presented. The work of Covert and Frank, (Ref. 3) the 1982 Criteria Document (Ref. 4) for particulate matter and sulfur oxides, and the most recent epidemiological material on particulate matter comprise the body of this assessment.

INTRODUCTION

An assessment of the health effects of fugitive dusts, including the PM_{10} range requires information on various factors. These include factors important to determining exposure, dose, and toxicity. This assessment addresses these factors by considering first the importance of particle size and chemical composition in determining respiratory uptake and retention in the biological system; second, the physical and chemical properties of fugitive dust; and third, the toxicological effects from exposure to fugitive dusts.

FACTORS AFFECTING RESPIRATORY UPTAKE AND BIOLOGICAL DOSE

Ultimately, the nature of the biologic response to airborne particles, elicited by either brief or prolonged exposure, is a function of the dose. Dosage, particularly as it affects local sites within the respiratory system, is determined by a complex interplay between the particle and host. As noted in the comprehensive review by Dr. Robert Frank, a current member of CASAC, and Dr. David Covert, some of the commonly recognized determinants of dosage apart from the ambient concentration are:

- Physical properties of the particle, including size, shape, and density.
- Mode of breathing: The nose is a more efficient scrubber of particles than the mouth, thereby shifting the site of deposition.
- Pattern of ventilation and flow profiles within airways: slow breathing increases the time for particles to deposit by diffusion and sedimentation; rapid breathing associated with turbulent flow increases the likelihood for inertial impaction. (A maneuver commonly used to increase the total uptake of therapeutic or bronchoconstrictive aerosols is a rapid, deep inspiration followed by breath holding.)
- Size and shape of the airways.

How evenly the dosage is distributed within different regions of the lung reflects the distribution of mechanical properties and ventilation. In healthy individuals the rate of deposition of monodispersed particles in the periphery of the lung during breath holding, a measurement used to assess the size of airspaces, appears to be uniform from one occasion to the next, but varies among individuals. The clearance rate of insoluble particles from the lung also tends to be more consistent within than among individuals. Both findings underscore the role of factors inherent in the lung that determine the level of exposure to particulate matter.

A discussion of the behavior and deposition of fugitive dust particles in the respiratory system also requires consideration of their chemical

properties. While particle size and density, which determine aerodynamic diameter, primarily govern the deposition efficiency of aerosol particles within the respiratory system, chemical parameters are also important. Chemical composition determines not only the toxicity but also the hygroscopic (water soluble) nature of the particles, thus their potential for reaction with gaseous compounds before and after inhalation.

In general, the atmospheric size distribution of particulate matter is the sum of two or three separate modes of particles that have different sources, sinks, and physical and chemical properties. An example of an atmospheric volume-size distribution is presented in Figure 1. The bimodal form shown is typical of that found in the atmosphere. However, the total volume concentration of the area under the bimodal curve may vary by a factor of 10 or more with time at a specific location or between locations at a particular time. The relative magnitude of the two modes may vary by a factor of about 2, depending on the history of the air mass, but the volume-mean sizes of the fine and coarse modes remain between 0.2 to 0.6 μm and 5.0 to 10 μm, respectively. The minimum in the volume-size distribution which separates the two modes occurs consistently between 1.0 and 2.0 μm.

According to the discussion by Covert and Frank (Ref. 3), the chemistry of the particles in these two modes is markedly different and can be related to their sources. The major fraction of particle mass in the fine mode is due to combustive processes associated with human activities, such as fossil fuel power plants, vehicles, industrial processes, domestic heating and hydrocarbon emissions. The emissions consist of gases-sulfur dioxide (SO_2), sulfur trioxide (SO_3), nitrogen oxides (NO_x); hydrocarbons and nuclei mode sized particles: heavy metals such as lead (Pb), vanadium (V), and manganese (Mn); and graphitic carbon (soot). In the atmosphere these compounds react in combination with water vapor, ammonia (NH_3), and sunlight, all of which

Figure 1

Atmospheric Aerosol, Volume Size Distribution

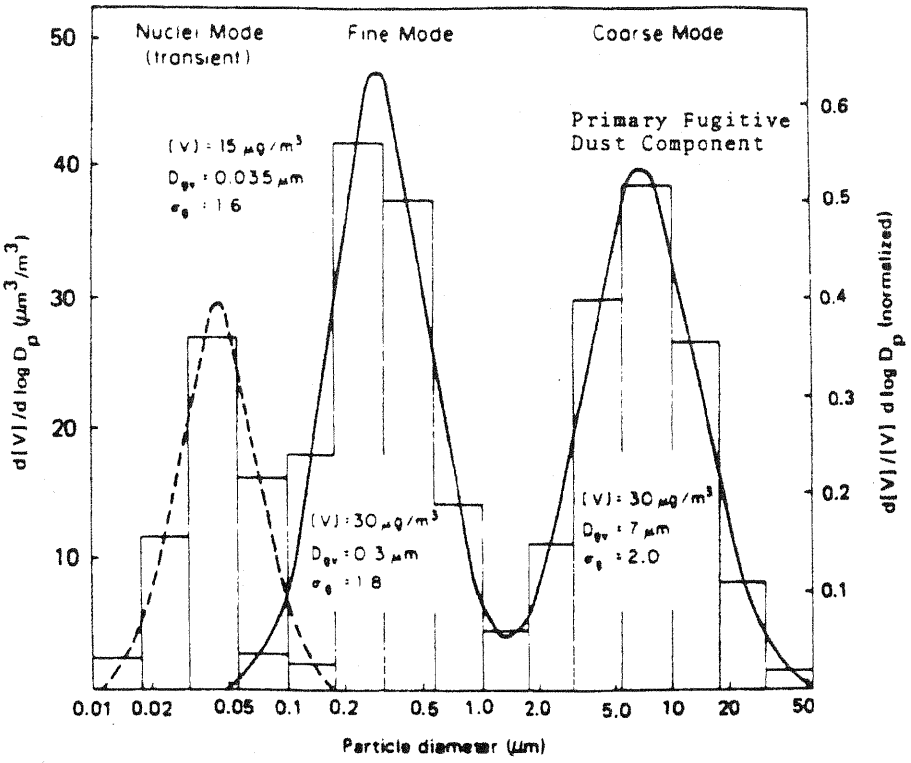

FIGURE 1 Atmospheric aerosol, volume size distribution. Abscissa: particle diameter D_p (μm) on a logarithmic scale. Ordinate: (left) incremental particle volume (expressed as concentration) per increment of particle size d[V]/d log D_p ($\mu m^3/cm^3$); (right) normalized volume scale d[V]/[V] d log D_p.

Adapted from Covert and Frank (1980)

occur naturally, as well as with ozone (O_3), which occurs naturally but also is a product of photochemical reactions initiated by pollutants. Sulfate and nitrate compounds, and a wide range of hydrocarbons (organic acids, aldehydes, and salts) are formed.

While it is difficult to generalize about the physical and chemical properties of such a complex mixture as atmospheric aerosols, certain aspects of the fine mode particles have become clear in the last few years. Our present understanding of the structure of these particles is that they consist of a solid water-insoluble core composed of graphitic carbon, hydrocarbons, and heavy metals, which is surrounded by a solid (or liquid) layer of water-soluble organic and inorganic salts and/or acids. Their density is generally between 1 and 1.5 g/cm^3. The water-soluble layer may comprise 50 to 90% of the mass of the particle.

The mass of material in the coarse particle mode is more evenly divided between anthropogenic and natural sources than in the fine mode. The primary sources of the coarse mode are soil and sand from the earth's surface, which are raised by the wind either alone (natural) or in conjunction with agricultural, mining, or transportation activities (anthropogenic). The chemical composition of these particles is generally similar to that of the earth's crust. It includes silicates (SiO_2), aluminum (Al), magnesium (Mg), and iron (Fe). Near the coastline, sea salt, which is predominantly sodium chloride (NaCl) in a size range of 3 to 5 μm, can contribute to the mass of the coarse mode. At times, pollens (>10 μm) add to the mass of this size mode.

The physical structure of the particles in the coarse mode is more irregular than that of the fine mode particles. They vary in shape from cubes (NaCl) to plates. Their densities range between 2 and 3 g/cm^3. Thus, their aerodynamic diameter is ~1.5 times their geometric volume mean diameter. They are also less homogeneous chemically. A summary of the sources, chemical composition, and physical and chemical properties of the fine and coarse modes is presented in Table 1. Although little information was found for the biological component of coarse mode rural particulate matter, the US EPA reported on the results of a study of fourteen cities by Bradway and Record (Ref. 5) that biological material (primarily pollen, leaves, and other plant material) accounted for less than two percent of the weight of the total coarse fraction (Table 2). As seen in Figure 2, the coarse mode will deposit primarily in the nasopharyngeal region with a high efficiency of 50 to 100%. The fine mode will deposit primarily in the pulmonary region with a much lower efficiency of 20 to 40%.

ORIGIN AND COMPOSITION OF FUGITIVE DUST

According to the US EPA (1982) (Ref. 4), a substantial portion of TSP, usually more than half, is accounted for by coarse or supercoarse particles, and a great portion of this mass is mineral dust, also called "crustal material" in many of the papers reporting chemical analytical data. There is growing opinion that this major component of TSP is contributed almost entirely by agitation of soil in some way, and this component is commonly called fugitive dust. One of the major sources for fugitive dust generation is vehicle traffic; the motion of vehicles can reentrain silt (fine soil particles) that has been deposited by settling from the air, washing from nearby areas in rain, or falling from vehicle tires.

TABLE 1

Chemical Composition and Sources of Atmospheric Aerosol Size Modes

Mode	Source	Chemical compounds or classes of compounds	General physical and chemical properties
Accumulation	Combustion of fuels; gas to particle conversion; photochemical oxidation	SO42-, NO3-, NH3+, H+, hydrocarbons, graphite carbons, heavy metals (Pb, As, Vn)	Water soluble (hygroscopic); low density, 1-1.5; near spherical shape
Coarse	Wind-blown dust; grinding processes	Silicates; carbonates, ferric oxides, Al, Mg+, Ca2+, pollen, fly ash	Less water soluble (non-hygroscopic); high density, 2-2.5; more irregular shape

Covert and Frank (1980)

TABLE 3

Fourteen-City Study - Microscopic Identification of Coarse Materials Collected in Urban Atmospheres

Location	Wt. % of Component			
	Minerals	Combustion products	Biological material	Miscellaneous (rubber tire debris)
Oklahoma City	88	8	1	4
Denver	81	7	1	11
Miami	79	8	1	12
St. Louis	75	21	1	4
Washington, DC	70	23	5	2
Baltimore	69	25	3	3
Birmingham	66	22	2	10
Philadelphia	64	33	1	2
Providence	64	22	1	13
Seattle	60	27	3	10
San Francisco	52	29	3	16
Cincinnati	51	44	1	4
Cleveland	51	40	1	8
Chattanooga	36	35	16*	13

*Anomalously large amounts of plant material(pollen, leaf fragments, etc.)

Source: US EPA (1982) from Bradway and Record (1976)

Figure 2

Deposition-Size Distribution

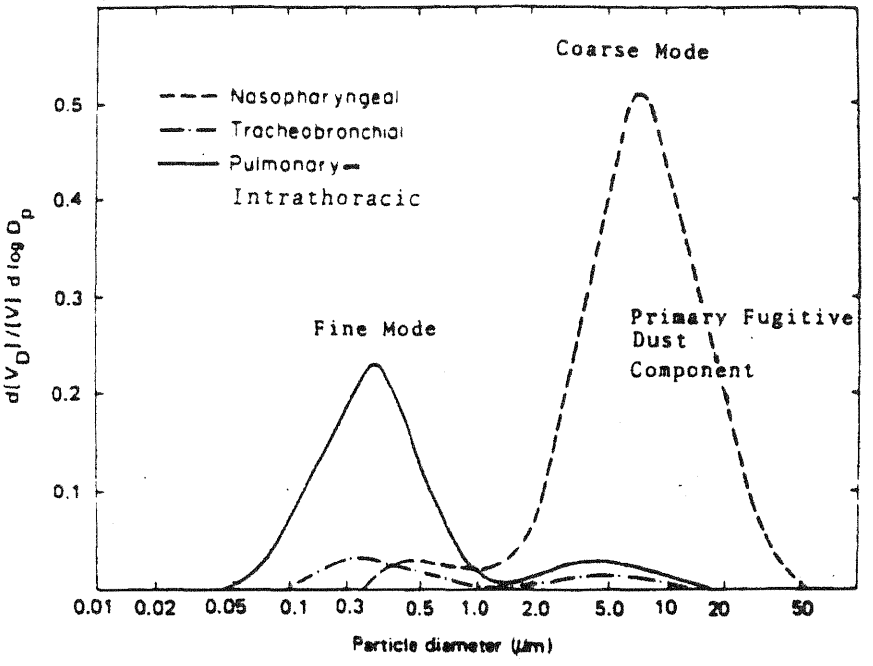

FIGURE 2 Deposition-size distribution. Abscissa: particle diameter D_p (μm). Ordinate: increment of aerosol volume deposited per increment of particle size, $dV_D/F\ d \log D_p$ ($\mu g/m^3$), where V_D = particle volume deposited.

Adapted from Covert and Frank (1980)

In an assessment of particle source influence on TSP in western States, fugitive dust from anthropogenic disturbance of soils accounted for 53 to 95 percent of TSP emissions (with exceptions near point sources) and 31 to 50 percent of TSP concentrations (with 2 exceptional at critical receptor locations in 20 inland western cities (Ref. 6). Additionally 25 to 50 percent of TSP concentrations were background, i.e., not attributable to man-made emissions.

Figure 3 shows the traditional division of fugitive dust sources for 1976 in terms of emissions. It is clear that soils are the main constituent with unpaved roads and agricultural operations being predominant combined to constitute 94.3% of all emissions.

Figure 4 is from the Harvard Six Cities Study (Ref. 7). It shows monthly average concentrations of fine and coarse fractions, inhalable particles (<15 microns, IP) and total sulfate mass. The cities were selected on the following basis:

- Steubenville and St. Louis: exceed both SO_2 and TSP standards
- Watertown and Harriman: high but less than standard concentrations of SO_2 and TSP
- Portage: low SO_2 and low TSP
- Topeka: low SO_2 and TSP concentration exceeding the standards.

The figure shows a very different pattern in Topeka than the other more eastern cities. In Topeka the IP mass is dominated by and tracks the coarse particle fraction while fine particles do not track the total mass. This is indicative of fugitive dust situations and while not strictly rural, shows the pattern we would expect in rural fugitive dust areas. In the other cities the total IP mass pattern is dominated by fine particle concentrations (see Harriman and Steubenville) or fine and coarse track together (see Portage).

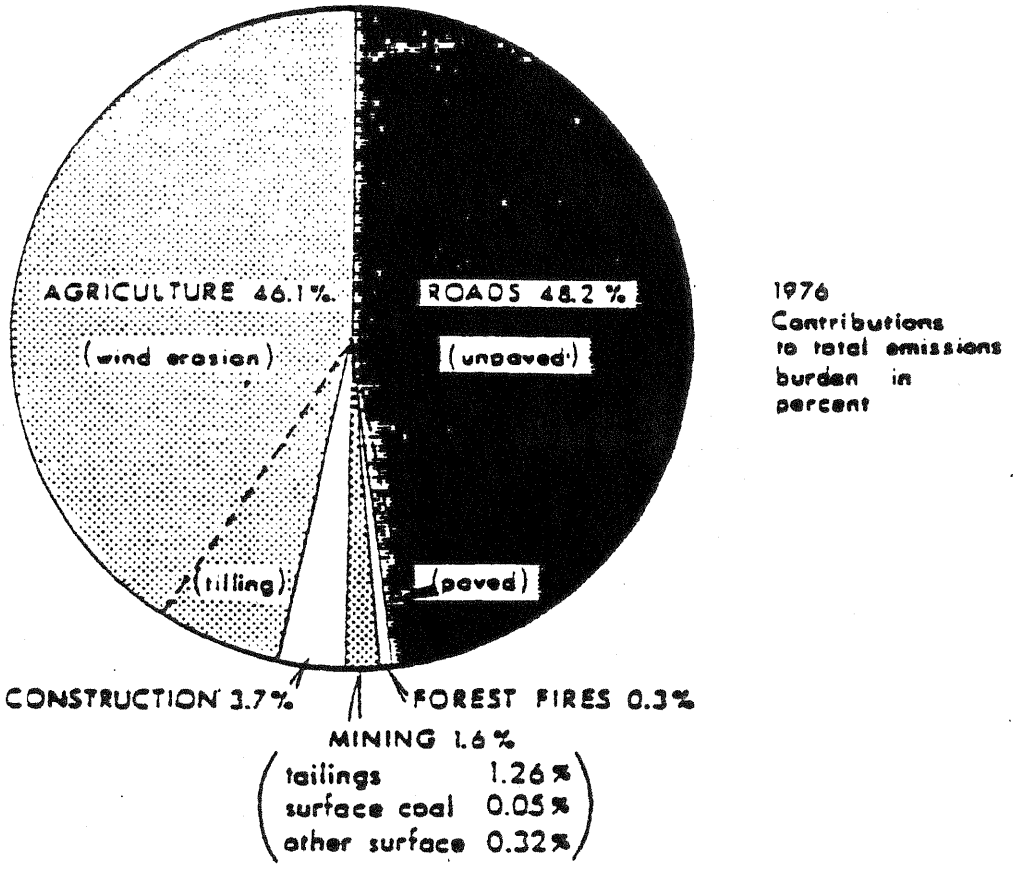

Figure 3. Categories of Particulate Emissions from Open Sources in the U.S

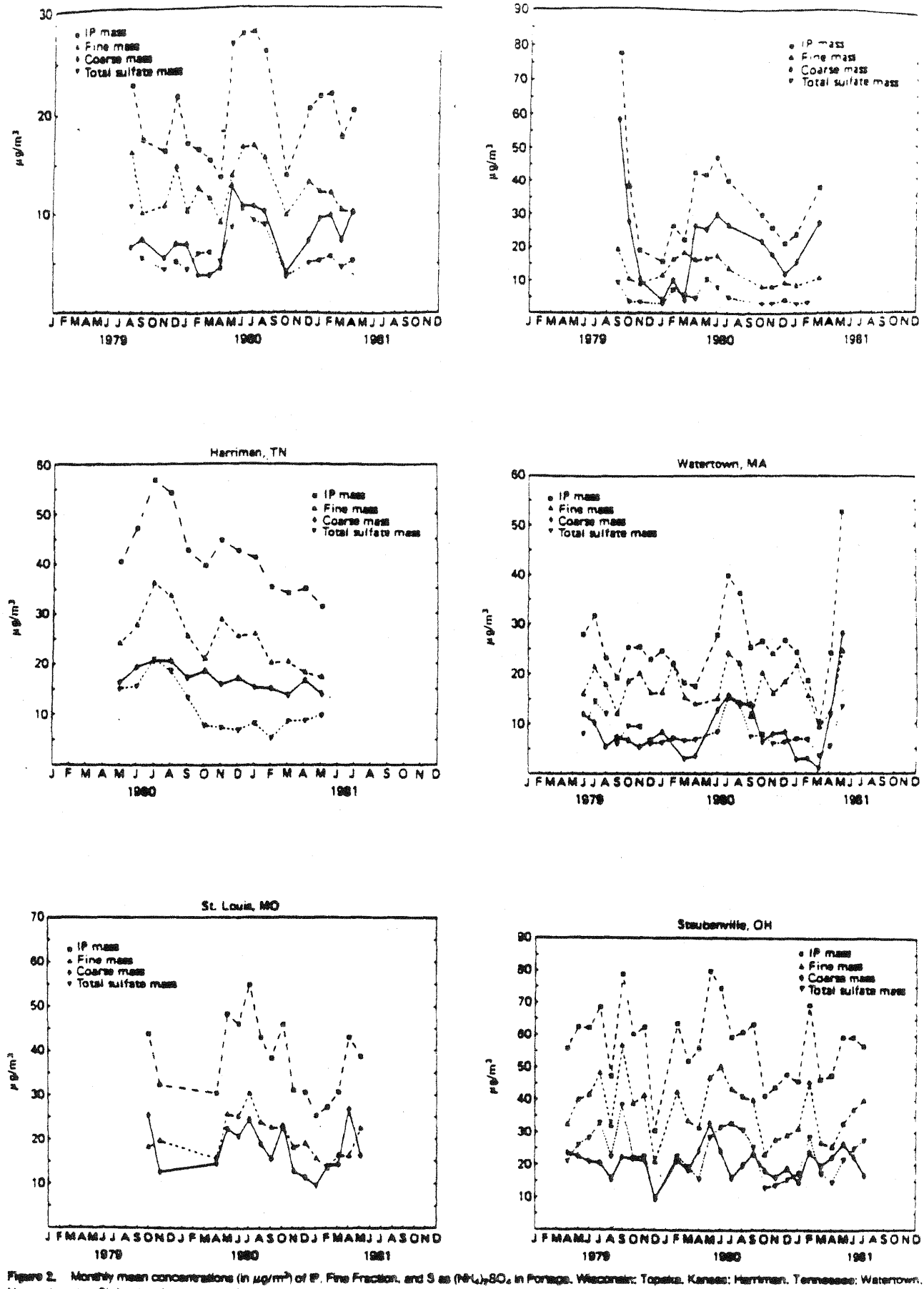

Figure 2. Monthly mean concentrations (in $\mu g/m^3$) of IP, Fine Fraction, and S as $(NH_4)_2SO_4$ in Portage, Wisconsin; Topeka, Kansas; Harriman, Tennessee; Watertown, Massachusetts; St. Louis, Missouri; and Steubenville, Ohio.

Figure 4 (Ref. 7)

The California Air Resources Board (Ref 1) has suggested that "fine particles often constitute over 50 percent of total rural dust" and that "agricultural tillage is the largest direct source of PM_{10} emissions in California." CARB concludes that "rural (primarily agricultural) sources of PM_{10} may provide for a much greater proportion of the population's actual exposure to fine particles than previously believed." There is confusion in these statements concerning the definitions of fine particles and PM_{10} implying that they are equivalent. A review of CARB's cited reference (Ref 8) reveals that it is an extensive review of fugitive dust from only agricultural operations. The emission factors developed for agricultural soil preparation in the study indicate that 10% of fugitive dust emissions are fine particles (<2.5 microns) and that 25% are inhalable particles (<15 microns). This is in direct contradiction to the CARB statement that 50% of total rural dust is "fine particles."

HEALTH EVALUATIONS

Detailed assessments on the health risks to populations resulting from exposures to airborne particles have been presented by numerous researchers. Invariably, it is the fine mode, urban aerosols that are associated with possible health effects. A multidisciplinary study on airborne particles initiated by Harvard University and funded by Department of Energy addressed this concern (Ozkaynak et al., 1985a) (Ref. 9). These investigators concluded that the most toxic substances in ambient air are highly concentrated in the fine particle mass (<2.5 μm). It is especially the fine particle fraction

of ambient aerosols that includes carcinogenic or toxic metals, organic, and acidic components resulting from automobile and other combustion emissions (Ref. 10 and Ref. 11). Other epidemiological analyses from Harvard also indicate that variations in ambient fine particle and sulfate mass are more important to public health than variations in the levels of coarse particles (Ref. 12; Ref. 13; Ref. 10). The cumulative results from numerous studies "suggest that it is the fine particle mass fraction or its toxic constituents...rather than inhalable particles (<15 μm) or TSP, that should be focused on in studies of human health effects" (Ref. 14).

Pengelly et al. (Ref. 15) conducted a massive study on 3,500 elementary school children in Hamilton, Ontario, Canada on the effects of environmental factors on respiratory health. Because of a substantial gradient in particle concentration and size over the study area, this investigation was designed, in part, to separate out the effects of fine versus coarse particles. Outside of the Six-Cities study, this is the only study reported in the scientific literature to measure the effects of particle size. The investigators found that the only statistically significant association was that between decrements in pulmonary function and exposure to fine particles. There was, therefore, no statistically significant association between coarse particles and pulmonary function.

In reviewing epidemiological research on particulate matter, Pengelly et al. also noted that

> "there is a good theoretical basis for the hypothesis that particle size and chemical composition are important determinants of (particulate matter) toxicity...The results of this study support the idea that the fine fraction of the aerosols is the most important, when considering the impact on the respiratory health of children."

Information on nontraditional components of fugitive dusts, pesticides and virulent spores, was scarce in the reported scientific literature. According to a comprehensive review by Mulla, Mian, and Kawecki (Ref. 16), pesticides are found in detectable concentrations throughout the inhabitated and noninhabitated world. They result from applications in the home, garden, greenhouse, and agriculture and exist in most of the foods we consume. The vapor pressure of many pesticides is such that in hot arid areas, such as those of the Southwest, they are more likely to volatilize. Invariably, some pesticide will adsorb on the surface of the agricultural dusts, but because these dust particles tend to be in the coarse mode, they are not transported long distances under typical weather conditions. When they are, they are most likely diluted to barely detectible concentrations. Also, because most pesticides are applied in repeated short-term periods, the dose from the transport of dust-laden pesticides appears to be negligible.

The most likely exposures to pesticides are those indoors. A recent report by EPA (Ref. 17) looked at pesticide exposure indoors versus outdoors in a pilot study. The pesticide exposures from household and garden pesticide use were generally higher indoors than outdoors. Further, little information is available on baseline concentrations of pesticides away from agricultural areas.

The information on biological contaminants is even poorer. At present information on the amounts and types of biological materials is not available, and the virulence of viable organisms varies tremendously. Again baseline data for virulence of viable organisms is not known (Ref. 17). If long-range transport of biological contaminants does occur (unsubstantiated claims of a 1977 San Francisco episode), it is rare and totally uncontrollable.

CONCLUSIONS

Fugitive dust is a type of particulate matter that consists primarily of coarse materials primarily from soils. Because this dust is formed mechanically by comminution or disintegration processes, the size of the dust particles vary considerably, from 2.5 μm aerodynamic diameter to 100 μm, with maximum concentrations occurring in the 5 to 50 μm range. Biological materials such as pollen and spores make up a small percentage of the coarse particles. Particles less than 2.5 μm are termed "fine" particles. Typically, fine particles are formed by the combustion of fuels and from the conversion of toxic gases in the atmosphere. Fine particles also tend to have high water solubilities and low densities, unlike the more highly dense, less water soluble coarse particles. Ultimately, these properties determine the innocuousness or the toxicity of the inhaled particulate matter.

Medical research has shown that the smaller, fine particles are the potentially toxic fraction of particulate matter. Because of their size, usually between 0.1 and 1 μm, they are able to penetrate deeper into the respiratory system, reaching the intrathoracic or pulmonary region. The greater water solubility (hygroscopicity) of the particles less than 1 μm causes them to grow in size after entering the deep lung, thereby increasing their deposition efficiency. This same solubility also enhances their ability to react in the biological system. These basic fundamentals of "particle toxicology" have directed the focus of medical research over the past decade. As such, studies on the health effects from exposure to fugitive dust in ambient air generally are not conducted, since knowledgeable scientists do not consider ambient air exposure to the coarse, natural crustal particles to be harmful.

Just as minute amounts of various pollutants are found in every part of the world, including pristine areas, so are traces of chemical substances

detected in soils of the United States, the source of fugitive dust. From market basket surveys, it is evident that trace amounts of pesticides are found in nearly all food categories, but at levels considered not harmful to human health. If trace amounts of pesticides were detected in a "transported" fugitive dust sample, the concentrations probably would be such as to approximate background, grocery-store levels. Additionally, the widespread use of home and garden pesticides makes it nearly impossible to trace the origin of a specific pesticide. Without a sufficient dose (defined as the concentration of a substance times the duration of exposure), even so called "toxic" substances are innocuous.

Finally, biological materials were shown to make up a very small percentage of coarse particles, and they comprise an even smaller fraction of total fugitive dusts. Certain virulent spores endemic to the southwestern United States can be carried by the wind, just as pollen and other allergens are carried. But these naturally occurring plant materials are part of the natural environment and likely will not be affected one way or another by EPA's decision on the rural fugitive dust policy. As Dr. Goldstein said, "How does one control mother nature?"

Fugitive dust is inert chemically (being mostly soils) and has no demonstrable health effect. Contaminants which might be attached to fugitive dust (which is less unlikely because of the soils chemical inertness) are small in concentration and concomitant dose and are either uncontrollable or controlled better through other mechanicsms than PM_{10} standards attainment.

REFERENCES

1. California Air Resources Board, Comments on Rural Fugitive Dust Policy, July 2, 1985, EPA Docker A-87-01.

2. B. Goldstein, Improving the Scientific Basis for Risk Management Decisions for Particulate Matter in Arosols, Lee et al., (Eds) Lewis Publisher, Inc. Chelsea, MI (1986).

3. Covert, D.S. and N.R. Frank Atmospheric Particles: Behavior and Functional Effects in Physoilogy and Pharmacology of the Airways. J.A. Nadel (Ed.) Marcel Dekker, Inc. New York (1980).

4. US EPA Air Quality Criteria for Particulate Matter and Sulfur Oxides. ECAO: EPA-600/8-82-0296 Research Triangle Park, NC (1982).

5. Bradway, R.M. and F.A. Record - National Assessment of the Urban Particulate Pro Chem. Vol II - Particle Characterization EPA-450/3-76-025. Research Triangle Park, NC (1976).

6. Axetell, K. Assessment of non-traditional source impacts in the western U.S. in Specialty conference and the Technical basis for a Size Specitic Particulate Standard Proceedings. APCA Pittsburg PA (1980).

7. Spengler, J.D., Thurston, G.D.: "Mass and Elemental Composition of Fine and Coarse Particles in Six U.S. Cities," JAPCA, Volume 33, No 12 p 1162. December 1983.

8. California Air Resources Board (1981): "The Role of Agricultural Practices in Fugitive Dust Emission" June 1981, available from NTIS - PB81-219073.

9. Ozkaynak, H. J. Spengler, A. Garsd, and E. Thurston. Assessment of Poopulation Health Risks Researching from Exposures to Airbone Particles in Aerosols. Lewis Publishers, Inc. Chelsea, MI (1986).

10. Ozkaynak, H., G. D. Thurston and A. Schatz. "Relationships between Human Morbidity and Ambient Pollution: Preliminary Findings." Paper no. 84-1.6, presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, CA (1984).

11. Thurston, G. D., H. Ozkaynak and A. Schatz. "A Chemical Characterization and Source Apportionment of the IP Network Fine Particle Data," presented at the 77th Annual Meeting of the Air Pollution Control Association, San Francisco, CA (1984).

12. Garsd, A., and H. Ozkaynak. "Mortality Risks due to Air Pollution: Time Series Analysis of 13 Years of Data from New York City," cited in, Aerosols, Lewis Publisher, Inc. Chelsea, MI (1986).

13. Ozkaynak, H. and J.D. Spengler, "Analysis of Health Effects Resulting from Population Exposures to Acid Precipitation Precursors." Environ. Health Persp. 64:45-55 (1985).

14. Ozkaynak, H., J. D. Spengler, and G D. Thurston. "Consideration of Risk Analysis Methods in the Revision of the Primary Standards for Ambient Particles," presnted at the 78th Annual Meeting of the Air Pollution Control Association, Detroit, MI (1985).

15. L. Pengelly, C. Goldsmith, A. Kerigan, W. Furlong, and s. Toplack. The Hamilton Study: Effect of Particle Size on Respiratory Health in Children, Aerosols, Lewis Publishers, Inc. Chelsea, MI (1986).

16. Mulla, M., Li Mian, J. M. Kawecki. Distribution Transport, and fate of the Insecticide, Melathien and Parathien in the Environment: Residue Reviews Vol 81. Springer-Verlag, New York (1981).

17. US EPA EPA Indoor Air Quality Environmental Plan. Appendix A. EPA/600/8-87-014. June 1987.