SECTION VIII:

SUMMARY OF COMMENTS ON PROPOSED PARTICULATE MATTER NATIONAL AMBIENT AIR QUALITY STANDARDS

Introduction

On January 19, 2006, EPA published in the Federal Register proposed changes to the National Ambient Air Quality Standards (NAAQS) for particulate matter. These are the first changes proposed since 1997. The overall process for such a proposal is quite complex and involves preparation of a Criteria Document, pursuant to Clean Air Act Section 108; multiple drafts of an extensive policy assessment (the final version being over 500 pages in length, and generally cited as the "OAQPS Staff Paper"); a formal review of the Criteria Document and the Staff Paper by an EPA advisory committee; and completion of normal rulemaking materials, such as an Interim Regulatory Impact Analysis.

DOE is offering comments on several aspects of the proposed rule that we believe are essential to the protection of public health. The first general comment is that EPA has not fully considered a number of relatively recent reports (published after April 2002) that have a bearing on the rule, and that have methodologies and data that are superior both to earlier studies of health effects from particulate matter and to more recent studies that continue to use the earlier methodologies. The second is that, in aggregate, these excluded studies indicate that certain subspecies of fine particles appear to be far more relevant to protection of public health than fine particles in general. The third is that recent studies using more advanced methodologies generally find little or no association between either regional aerosols generally or a major component of regional aerosols in the eastern U.S. in particular (secondary sulfates), with adverse health effects. Lastly, there are concerns with certain studies which EPA cited as providing a significant basis for the proposed rule, the two most important ones of which are over a decade old, fail to monitor for important local pollutants, and use methodologies no longer current.

These issues are important, we believe, because a NAAQS that is not based on the latest scientific knowledge can result in standards leading to control of the wrong emission sources and the wrong pollutants. Such a standard can be met without adequately protecting public health.

Framing Issues

In considering the rule, we reviewed the statutory provisions that govern EPA's preparation of Criteria Documents and NAAQS, and the principal court decisions identified by EPA in the proposed rule's preamble. We note that Section 109 of the Clean Air Act states that Criteria Documents: "*shall accurately reflect the*

latest scientific knowledge useful in indicating the kind and extent of all identifiable effects on public health or welfare which may be expected from the presence of such pollutant in the ambient air". In practical terms, this means that exclusion of studies published after April 2002 is probably inappropriate, if those studies have meaningful contributions to the standard setting process.

We also note in Section 109 of the Act, that primary NAAQS should be set at levels such that when met: "*allowing an adequate margin of safety, are requisite to protect the public health*". Moreover, our reading of Whitman v. American Trucking Associations (531US457, Feb. 27, 2001) is that the term requisite "*means sufficient, but not more than necessary… -- that is, not lower or higher than is necessary – to protect the public health with an adequate margin of safety*". This decision also found that: "*Section 109(b)(1) directs the Administrator to set standards that are 'requisite to protect the public health' with 'an adequate margin of safety.' But these words do not describe a world that is free of all risk -- an impossible and undesirable objective. … The statute's words, then, authorize the Administrator to consider the severity of a pollutant's potential adverse health effects, the number of those likely to be affected, the distribution of the adverse effects, and the uncertainties surrounding each estimate. … They permit the Administrator to take account of comparative health consequences. They allow her to take account of context when determining the acceptability of small risks to health. And they give her considerable discretion when she does so.*" We believe this language provides ample discretionary authority for the Administrator to focus the NAAQS on those components of particulate matter that are primarily responsible for health effects associated with particulate matter, and to exclude components with little or no responsibility. EPA would appear to agree with this perspective, given the progressive narrowing of the standard over time from Total Suspended Particulate, to PM_{10}, to $PM_{2.5}$.

The remainder of this Summary will follow the organizational structure of Sections III through VI of the attached detailed comments.

<u>The Importance of Accurate Exposure Data</u>

Historically, the major tool for establishing a NAAQS for particles has been epidemiology. Epidemiological studies relate ambient pollutant concentrations to adverse effects in a statistical assessment of a large population of people. More recently, toxicology studies have also been useful in understanding health impacts of pollutants. Toxicology studies typically expose either cells or a small group of people or laboratory animals to relatively high concentrations of a substance to evaluate possible physical responses, such as changes in cytokine levels or in heart rhythm. In addition, there are also new studies with smaller numbers of subjects than traditional epidemiology studies, but which allow for more precise measures of responses of subjects to pollutants. Such studies

include panel and CAPs studies, among others, and might be thought of as a type of toxicology study, but one using ambient particles instead of exposures to particular atmospheres generated in a laboratory. The general rule is that all these types of studies should be used together, and that statistical correlations found through epidemiology are of limited value without a confirming explanation from toxicology and/or CAPs studies and panel studies of the statistical findings.

Most epidemiological studies conducted prior to the last revision of the NAAQS for particulate matter were based on "central monitoring," or representing the exposure of people in the study group (usually a country or city) with a single monitored concentration of each pollutant (from one monitor, or an average of monitor readings). Implicit in such a study design is the assumption that the concentration at this monitor accurately represents the exposure of the surrounding study group to air pollution that may be impacting their health. But this assumption depends on two additional assumptions: (1) that the particles measures include most to all of the health-relevant types of particles, and (2) that there aren't particle emissions relevant to health outcomes with large local variance, where the use of one measurement for all residents of the locality understates exposure of many to such emissions.

Over the past several years, more sophisticated study designs have been formulated and executed. To take one example, some have combined mathematical modeling of wind speed and wind direction with monitored concentrations of emissions from several central monitoring sources, to derive an annual "pollution surface" for a facility or a locality. This "pollution surface" produces a better estimate of exposure than would averaging the concentrations from all the monitors and using this one value to reflect exposure for all residents of the locality.

The differences in exposure estimates for different people in the study area are most critical for pollutants that are local in origin, such as emissions associated with a major highway, versus pollutants that are regional in nature, such as those that may be transported and dispersed over hundreds of miles and which do not differ much in concentration over distances of tens of miles or more. Several of these more sophisticated studies point out that adverse impacts of locally variable pollutants (the exposure to which is not evaluated well by a central monitor) may be "transferred" to the regional pollutants for which central monitors do provide reasonable exposure information. The effect can be to conclude erroneously that the local pollutant is not statistically associated with a health impact, and that the regional pollutants are. For example,

- Kim et al, 2004, concluded: "…our results underscore the limitation of using central air monitoring stations for assigning population exposures. Concentrations of air toxics…or surrogates…should be more widely monitored."

- Delfino et al, 2005, found: "The main limitation of most epidemiological studies is exposure misclassification from dependence on central site rather than on personal or microenvironmental exposure data"

- Goldberg and Burnett, 2003, state: "... observed confounding effects were accentuated because of transference of causal effects from less-precisely to more-precisely measured variables."

- Ito et al, 2004, spell it out: "Thus, if a single monitor's or a few monitors' data are used to estimate the entire city's population exposure, then the potential health effects of individual PM species that have low monitor-to-monitor correlation such as EC would be masked or underestimated compared to PM species which have high monitor-to monitor correlation (e.g., sulfate)." [Note: EC = elemental carbon, thought to represent mostly diesel emissions in most localities.]

- Ito et al, 2004, also spell out how use of central monitor data to estimate effects of local emissions can misestimate and underestimate the effects of such emissions: "The implication is that, except for secondary aerosols [e.g., such as secondary sulfate and SOA], if these source apportioned PM were used in time-series analysis of mortality or morbidity data, the absolute health risk estimates (per unit mass concentration) for each source type could vary by several fold, depending on which monitor's data were used...It is possible that associations between a source-type and health outcome is distorted or not detected due to the error associated with the estimation of exposure for that source-type."

<u>Recent studies' conclusions regarding important sources of particulate matter</u>

Vehicular emissions

Recent studies of gradients of emissions (ultrafines, black carbon, vehicle-emitted sulfates, CO, absorption coefficient) near major roads, show that these emissions drop substantially (but at different rates) in close proximity to major roads, and find that most of these fresh emissions are of different chemical composition and size than PM at greater distances from such roads (Zhu et al, 2002a,b; Wichmann et al, 2005; Reponen et al, 2003; Delfino, et al, 2005; Sioutas et al, 2005).

Similarly, recent epidemiological and toxicological studies of the type which accurately assess exposure of subjects to local emissions associated with health impacts have consistently found that carbonaceous pollutants associated with motor vehicle emissions (e.g., polycyclic aromatic

hydrocarbons, quinones, alkanes, aldehydes, or general measures of vehicular carbonaceous emissions such as EC or black carbon) are linked with adverse health effects, and that other types of particulate matter (regional PM, secondary sulfates) appear not to be. Each of the epidemiology studies below uses one of the newer techniques to differentiate exposure to a type of pollutant among subjects in a study group; thus they are designed to better assess the impact of a locally emitted pollutant, the ambient concentration of which varies over short distances.

- New "highway gradient" cohort studies show substantially elevated risks of premature mortality (all cause, cardiovascular), relative to earlier studies examining associations only with fine PM mass, for those living within 100 meters of a major highway or within 50 meters of a major urban road, and thus exposed to the higher levels of fresh emissions near the roads (Hoek et al, 2002; Finkelstein et al, 2004, 2005). Hoek et al (2002) found a very large relative risk of 1.71 for cardiopulmonary mortality associated with total black smoke, most vehicular in origin. Finkelstein et al (2004) report that everything else equal, residence in close proximity to these roadways results in a shortening of live by 2.5 years.

- Other new cohort studies use central monitoring emissions data, meteorological data, and geostatistical modeling algorithms to create a modeled "PM surface" in Los Angeles, a location where a large proportion of particulate emissions is from vehicles. The researchers then use this PM surface to demonstrate similar risks of all cause and cardiovascular mortality as in the "highway gradient" studies immediately above (Jerrett et al, 2005a), or of increased carotid artery plaque (Kuenzli et al, 2005), suggesting that exposure to these emissions (or to emissions highly correlated with them, such as vehicular VOCs and SVOCs) can lead to adverse cardiovascular outcomes over time.

- Two studies use EPA data on HAPs to model cancer risks in the state of Maryland (Apelberg et al, 2005), or for the U.S. as a whole (Morello-Frosch and Jesdale, 2006). These studies show that the great majority of cancer risks from HAPs are from mobile sources – 88% of national risk if diesel emissions are included. In the state of Maryland, where diesel emissions were not included among cancer risks, mobile sources contributed 75% of cancer risks (50% from on-road sources, 25% from off-road), while point sources contributed less than 1% of cancer risks (point sources in Maryland do not include several known sources of carcinogenic PAHs, such as coking plants and integrated steel mills, but do include coal-fired power plants). The great majority of these risks were borne by those of lower income; this is the pattern of lung cancer mortality seen in the ACS studies.

- A study using geostatistical modeling in Oslo, Norway (population about 538,000 in 2006) to relate pollution levels to a person's home, shows significantly increased risks for total mortality, respiratory mortality, and ischemic heart disease mortality, in each of four time periods between 1974 and 1993 (Nafstad et al, 2004), for emissions the authors attribute to vehicles. Both this and an earlier companion study (Nafstad et al, 2003) show consistently elevated lung cancer risks for these four time periods, although the risks were significant only for the first time period (borderline thereafter).

- A new "intervention" study in Sao Paolo showed that mutagenicity of the city's air declined during a bus strike when city buses were idled by a strike (Carvalho-Oliveira et al, 2005). This reduction occurred despite high PM concentrations due to the increased use of cars during the strike days.

- Several studies relate childhood cancers to residence near sources of oil combustion or vehicular emissions (Knox, 2005a,b; Crosignani et al, 2004), and one does not (Reynolds et al, 2004). One study shows that benzo (a) pyrene DNA adducts increase with exposure of the expectant mother to increasing levels of PAHs in different geographic areas (Perera et al, 2005); this study and another notes the heightened susceptibility of the fetus to PAH-induced carcinogenicity due to such exposures (Bocskay et al, 2005).

- Many studies relate respiratory morbidity to close proximity to well trafficked roads, especially those with trucks (McConnell et al, 2006; Kim et al, 2004; Lin et al, 2002; others discussed in Grahame and Schlesinger, 2005).

Epidemiological studies which examine specific health endpoints, but improve upon the traditional use of central monitoring data by improving the estimation of exposure to local emissions, include:

- Gold et al (2005), a study where the monitors were located within 0.5 km of the study subjects' residences, and where both the residences and the monitor were closely adjacent to the same major urban road, allowing a more precise relationship between subject exposure and effect. The authors found that the mean BC level in the previous 12 hours before testing, and in the BC level 5 hours before testing, predicted ST-segment depression, but that fine PM mass, monitored at the same location, was not associated with ST-segment depression. A 2006 study, using ambient levels of pollution, shows in elderly volunteers that a measure of carbonaceous emissions from diesels is associated with ST-segment depression, but that other sources (such as metals and secondary sulfate) are not (Lanki et al, 2006).

- Two studies using concentrated ambient particles (CAPs) taken from close proximity to major highway in Toronto show that increased vasoconstriction (Urch et al, 2004) and increased blood pressure (Urch et al, 2005) in healthy human volunteers are related only to the carbonaceous particles, but not to other PM constituents, including metals.

- New studies of heart rate variability (HRV) show that ultrafine PM but not larger PM is associated with decreased HRV in humans, and that effects are more pronounced in the elderly (Chan et al, 2004; Chuang et al, 2005). Another study, where both the monitors for highway emissions (such as black carbon and CO) and the residences of the human subjects are located on the same major urban road (the same arrangement as with Gold et al, 2005 above), found that it is the carbonaceous (vehicular) emissions but not other fine PM emissions that are associated with the reduced HRV (Schwartz et al, 2005). These findings are consistent with two earlier studies of HRV, from 2000 and 2001, which find that representative days where fine PM levels and secondary sulfate levels are high have no effects on HRV (Creason et al, 2001; Godleski et al, 2000). Another recent study also found that removing from the analysis days during which secondary inorganic PM is high improved the association between fine PM and reduced HRV (Pope et al, 2004).

The results of Schwartz et al (2005), however, are not consistent with a new study which uses central monitor pollution data as a proxy for exposure for all those living up to 25 miles away, and which finds that it is fine PM mass but not vehicular emissions that are associated with the HRV endpoint (Rich et al, 2005). This study, although new, is representative of results from the older type of study which has poor exposure data for local emissions, and as a result more often than not finds regional emissions associated with health effects. Such findings appear to be the transference of potentially causal effects from “less-precisely to more-precisely measured variables” discussed at the beginning of our comments.

Recent toxicological studies have focused on specific types of particles which have the potency to cause significant intracellular damage. These studies provide toxicological explanations for the effects observed above. Some such studies include:

- Studies showing that PAHs from diesel exhaust have the ability to cause increased oxidative stress in cells, and that these effects are mimicked by fine PM in ambient Los Angeles air. Furthermore, the ultrafine PAHs have much greater ability to penetrate the cell wall, and thus cause far more oxidative damage, than do larger PM containing PAHs (Li et al, 2002a,b; Li et al, 2003; Cho et al, 2004). Oxidative stress is thought to cause inflammatory effects.

- A series of studies have established that (1) diesel emissions, (2) ambient air in Los Angeles (*in vitro* studies), and (3) ambient air in New York, concentrated approximately 10-fold (*in vivo* study), all cause inflammatory effects via the NF-κB pathway, a pathway which induces a strong cytokine response (Takizawa et al, 1999; Bonvallot et al, 2001; Ma et al, 2004; Yun et al, 2005; Shukla et al, 2000). As with the studies directly above, inflammatory effects are thought to be related to atherosclerotic plaque increases.

- Another study shows diesel exhaust particles can create oxidative stress with properties inherent to the particle, which cannot be reduced by acid or solvents – these chemical species are thought to be semiquinones (Pan et al, 2005).

- Another study found that submicron size particles caused a number of effects, and that lipid peroxidation was associated with organic and elemental carbon content of the PM (Huang et al, 2003).

- Diesel PM was found to cause more intense and more sustained inflammation because the PM appears to bind and concentrate the cytokine IL-8 (Seagrave et al, 2004). In addition, this study reports on an earlier study showing that diesel PM caused changes in low-density lipoprotein, as step toward the buildup of atherosclerotic plaque, reinforcing the findings of the preceding toxicological study (Huang et al, 2003), and the epidemiological study of Kuenzli et al (2005), finding increases in carotid artery plaque in those areas of Los Angeles with higher PM levels.

- Several studies found mutagenicity associated with various vehicular emissions (McDonald et al, 2004a). One found that vehicular ultrafine PM can cause oxidative DNA damage to bicyclists in traffic, and that this damage is thought to be involved in both mutagenicity as well as cardiovascular and pulmonary disease (Vinzents et al, 2005). Another study found chromosomal aberrations in cord blood to be associated with prenatal exposure to airborne PAHs (Bocskay et al, 2005).

- Campen et al (2006) found that fresh diesel emissions can cause vasoconstriction in the blood vessels of mice, and that filtering the diesel emissions to remove PM doesn't change the vasoconstrictive properties of the emissions. These are the effects found in the CAPs studies of Urch et al (2004, 2005). Further analysis suggests that alkanes and aldehydes may be responsible for these effects. Campen et al (2006) also finds, in live mice engineered to have properties of atherosclerosis, decreases in heart rate and T wave depression, consistent with myocardial ischemia in humans, due to exposure to either filtered or unfiltered diesel emissions.

Again, these are among the many effects found in the more advanced epidemiological studies, such as those of Schwartz et al (2005), Gold et al (2005), and Lanki et al (2006), among others.

- McDonald et al (2004b) demonstrates that fresh diesel emission from a properly operated contemporary diesel engine causes inflammation (as measured by TNF-α, IL-6, and IFN-γ), resistance to infection, and oxidative stress *in vivo*. However, when the same engine is operated with the new catalyzing particle trap (required for certain new diesels in 2007) and the ultra low sulfur diesel fuel needed to avoid poisoning the catalyst, all of these health effects no longer occur. The authors demonstrate that concentrations of most VOC, SVOC, and PM emissions are sharply reduced, in many cases by over 95%.

It is important to note that several of the above studies – those which both had accurate exposure estimates for local pollutants, and which could compare different pollutants in the same study on an "apples to apples" basis – showed not only that carbonaceous vehicular particles were associated with adverse health impacts, but secondary sulfates or regional fine PM mass were not.

Industrial sources

Three recent studies (two epidemiological, one toxicological), using advanced exposure methodologies, have recently addressed health impacts associated with ambient air nearby a Canadian steel mill complex. Prior to these studies, there has not been as much research about the health effect of ambient pollutants from major industrial sources as there has been with regard to vehicular or regional emissions. However, some emissions, such as those from coke ovens, have traditionally been known to be highly toxic. For example, Cohen and Pope (1995) found that the relative risks of death from respiratory cancer for coke oven workers from 1953 through 1970 was as high as 15.72, for the most highly exposed workers. This compares to the risk of mortality from lung cancer in the second ACS study (Pope et al, 2002) of 1.06 (for a 10 $\mu g/m^3$ increase in particulate matter), a few hundred times less risk.

More recent studies of the Canadian steel complex have used a modeled gradient approach to estimate changing human exposure to emissions from the plants (represented by TSP or TSP and SO_2), and identified large and statistically significant relative risk (RR) factors for all-cause, cardiovascular, and cancer mortality associated with the higher exposures for residences closer to the complex [Finkelstein et al (2005), Jerrett et al (2005b)]. Commenting on significant associations of RRs of 1.34 for men and 1.27 for women for increases of 10 $\mu g/m^3$ in fine PM within the gradient of the steel complex (after taking socioeconomic characteristics into account), Jerrett at al concluded: "Viewed in the context of other findings, our results suggest intra-urban exposure gradients

may associate with larger health effects than in earlier studies using inter-urban exposure contrasts." [e.g., studies such as the ACS study]

The third study found that exposure to ambient air near the steel complex caused mice to have elevated heritable mutation rates, but that mice exposed to rural air from 30 km distant did not develop have elevated rates (Somers et al, 2004). Use of HEPA filters sharply reduced the elevated rates when used on ambient air near the complex. Since mutagenesis is strongly related to carcinogenesis, these findings reinforce those of the studies above. Somers et al found that daily levels of PAHs in ambient air near the mill were 33 times higher than in the rural setting.

Residual oil

There have been a large number of toxicology studies of residual oil fly ash (ROFA), most at high doses, and many using instillation as a means of administering ROFA to rodents' lungs. Many of these studies took place in the 1997-2004 timeframe. These studies have generally found a large variety of adverse effects. The effects are believed to be due to high concentrations of V and Ni in ROFA, usually in a primary sulfate form, which appear to act synergistically.

There are now some new epidemiological studies which directly compare the effects of ROFA vs. those of secondary sulfates, the emission with which ROFA is most likely to be confused in an epidemiological study because both emissions contain sulfate. For example:

- In the CAPs study of Maciejczyk and Chen (2005), inflammatory effects were associated only with the 2% of $PM_{2.5}$ in the ROFA factor. These effects are thought to be associated with the buildup of plaque due to exposure to CAPs in genetically altered mice in a companion study. The secondary sulfate factor, containing 65% of the $PM_{2.5}$, was not associated with inflammatory effects, but did contained the secondary organic aerosols (SOA) normally found in the eastern U.S. in summertime air masses – the OC loading (0.68) was identical to the S loading. The lack of effect from the 65% of the particulate matter contained in the secondary sulfate factor during this six month study is consistent with the review study of Schlesinger and Cassee (2003), which found no adverse effects from secondary sulfates at ambient or high ambient levels.

- ROFA emissions but not coal emissions or secondary sulfate are associated with hospital admissions for heart and lung disease (Janssen et al, 2002) or with daily all-cause mortality rates (Grahame and Hidy, 2004).

Other studies continue to find adverse effects from ROFA or from the metals normally found mostly in ROFA:

- Sorensen et al (2005) find that personal exposure to V and Cr, but not to concentrations of other soluble metals (Fe, Cu, Ni, and Pt), is associated with increased oxidative stress. V and Ni are the major metals normally present in ROFA.

- A 2006 toxicology study shows that the ROFA is more harmful to obese, pre-diabetic animals than to lean, non-diabetic animals, providing possible evidence for epidemiological findings that diabetics may be more at risk for cardiovascular disease than the population as a whole (Proctor et al, 2006).

These studies show the importance of clearly identifying whether sulfate exposure in an epidemiological study is primary V and Ni sulfate (associated with ROFA and oil combustion) or secondary sulfate (associated with SO_2 emissions from coal combustion and other sources).

Secondary sulfates

Secondary sulfates are important to the NAAQS because they comprise up to half the mass of fine particulate in ambient air in rural parts of the eastern US (EPA Interim Regulatory Impact Analysis, Jan 17, 2006). Because they are "secondary", i.e., formed in the atmosphere over time from emitted SO_2, they tend to be broadly and evenly dispersed rather than concentrated in proximity to an emission source. As a result, a central monitor can accurately reflect exposure to secondary sulfates and to regional fine PM (including secondary organic aerosols, SOA), even though it may not accurately assess exposure to pollutants from local sources.

Ito et al (2004) found that among three monitors in New York City, $PM_{2.5}$ and secondary sulfate aerosols were highly correlated, but that emissions from traffic were poorly correlated. Ito et al (2004) spelled out in detail some consequences of poor correlation of measurements for local traffic emissions:

> "Thus, if a single monitor's or a few monitors' data are used to estimate the entire city's population exposure, then the potential health effects of individual PM species that have low monitor-to-monitor correlation such as EC would be masked or underestimated compared to PM species which have high monitor-to monitor correlation (e.g., sulfate)."

In addition, Goldberg and Burnett (2003) state:

> "... observed confounding effects were accentuated because of *transference* of causal effects from less-precisely to more-precisely measured variables."

Now, a number of new studies (mostly from 2004 or later) which (1) examine local pollutants as well as secondary sulfates or regional fine PM, and (2) use the newer subject exposure techniques identified earlier, have been published and are reviewed in the attached detailed comments. Virtually all of these studies show that while vehicular, residual oil, industrial, or urban fine PM other than secondary sulfate are associated with the health effects observed, secondary sulfate and/or regional fine PM (secondary sulfate plus SOA) are <u>not</u> associated with the adverse health effect under consideration, whether these are:

- cardiovascular effects such as inflammation, heart rate variability, and ST-segment depression;
- daily morbidity or mortality;
- mutagenicity/carcinogenicity; or
- respiratory effects.

These studies include Maciejczyk and Chen, 2005; Gold et al, 2005; Lanki et al, 2006; Schwartz et al, 2005; Creason et al, 2001; Godleski et al, 2000; Urch et al, 2004, 2005; Gent et al, 2003; Grahame and Hidy, 2004; Ebelt et al, 2005; Somers et al, 2004. The early source apportionment study by Janssen et al (2002) comes to similar conclusions, as does the required reanalysis of Laden et al (2000) by Schwartz (2003).

Thus we suggest that the reason for this disparity among types of studies is precisely that suggested by Ito et al (2004) and Goldberg and Burnett (2003): effects may be transferred from local pollutants to more accurately monitored regional ones, in the studies which do not accurately account for exposure to harmful local emissions, but not in the ones that do more accurately account for exposure to local pollutants.

Finally, it is important to know what other governmental studies have found. The most recent scientific report of the effects of particulates on health from the Netherlands concludes:

> "…it does seem to be clear that sea-salt aerosol and the secondary inorganic fractions, such as sulphate and nitrate aerosol, have little importance to the direct health effects of particulate matter…" (Netherlands Environmental Assessment Agency, 2005).

It should be noted, however, that many studies which still use central monitoring data without any attempt either to procure more accurate data with regard to the exposure of subjects to local emissions, or to model the data to obtain better exposure estimates, still may find associations with fine PM and/or secondary

sulfate as opposed to local vehicular emissions (although there are exceptions, such as Wellenius et al, 2005).

In short, our understanding of the literature is that with the exception of certain central monitor studies which we believe use study designs which are no longer current, studies conducted over the past few years with more accurate exposure methodologies consistently find that secondary sulfates and the secondary organics (SOA) which travel in eastern U.S. air masses with secondary sulfates, appear not to cause harm at today's levels.

Metals

As noted earlier, metals in residual oil fly ash (ROFA), such as primary vanadium (V) and nickel (Ni) sulfate emissions, have been studied at length, using different methodologies. With the exception of the metals in ROFA, study of various other metal emissions appears to have been done with less systematic organization than would have been desirable, due in part to their ubiquity in urban environments, intermixed with many other ambient emissions. Other metals which have been suggested as possibly harmful at contemporary ambient levels include Fe, Zn, and Cu (which are widespread in urban areas because of their presence in erosion products from vehicles, tires, and/or brakes, or presence in lubricating oils). Pb was once used in gasoline for anti-knock properties in compounds with Br and is part of brake wear today; both Pb and Br are still found in roadside and urban environments, even though the phaseout of Pb in gasoline was completed several years ago. Metals of concern which may not be as widespread would include Cr and Cd.

Of metals other than V and Ni, Fe appears not to be associated with widespread adverse effects, based upon a number of CAPs and toxicology studies, including toxicology studies of both soluble and insoluble iron at levels thousands of times higher than found in typical ambient air (see attached detailed comments). Evidence appears to be incomplete with regard to Cu, Zn, Cd, and Cr.

Analysis of recent studies with contrary findings

The body of evidence reviewed above suggests that fine particulate matter associated with vehicular emissions, residual oil combustion and certain industrial facilities emitting known carcinogens (steel and coking complexes, especially those in operation before mandated emission reductions) are associated with adverse health effects, and that certain other particles appear not to be harmful (e.g., secondary sulfates, and secondary organics which travel in eastern U.S. air masses with them).

Older studies and some newer studies maintain, however, directly or indirectly, that $PM_{2.5}$ is harmful *per se* and that the benefits to public health are not much different, regardless of what types of $PM_{2.5}$ are controlled. Other new studies

may identify two different "factors" in a factor analysis, and then combine the data in these two factors to create a new, single factor, despite evidence from other studies that one of the factors may be harmful and that the other may not be. A third type of study may have already combined two such factors in its choice of variables, perhaps not recognizing that different particulate emissions from more than one source (but with some compounds in common) are present, thus preventing analysts from attempting to determine whether there are different and independent effects associated with either factor. A number of these studies are reviewed in detailed in the attached detailed comments. Our overall conclusion for the group is that their basic designs preclude them from providing information approaching the value of studies with more sensitive exposure assessment capabilities, or with methodologies capable of distinguishing among different sources or types of PM.

Proposed Coarse PM Rule

Our review of available evidence suggests that EPA is correct to focus on anthropogenic urban contributions to coarse PM as the most likely cause of health effects which might stem from exposure to coarse PM. Partly this is due to the types of emissions (e.g., emissions such as PAHs which can adsorb onto coarse PM, as well as other coarse emissions attributable to vehicles and roadways), and partly this is because urban areas are where the great majority of people live.

Studies cited by EPA as critical to the proposed rule

The 24-hour average standard

The Preamble states that the proposed 24-hour standard of 35 $\mu g/m^3$ is based on number of studies, but cites one in particular as supporting the chosen level for the standard:

> "More specifically, there is a strong predominance of studies with 98th percentile values down to about 39 $\mu g/m^3$ (in Burnett and Goldberg, 2003) reporting statistically significant associations with mortality, hospital admissions, and respiratory symptoms."

Apparently, the proposed standard was based upon the finding in Burnett and Goldberg of affects as low as 39 $\mu g/m^3$, with the standard set 4 $\mu g/m^3$ below the Burnett and Goldberg finding.

With regard to the Burnett and Goldberg (2003) study, the following observations are made:

- It would appear to be inappropriate to base a fine PM standard on a study (Burnett and Goldberg, 2003) which did not examine whether inclusion of gases in the model would drive the fine PM associations to insignificance.

This would be true in any case, but especially in the case where the prior version of this study (which had to be reanalyzed due to statistical issues common to many studies using particular software) showed that effects of gases were more important than those of fine PM.

- More importantly, a follow-up study by the same authors (Burnett et al, 2004), using appropriate statistical packages but with eight more years of data and 50% more cities, found that there were *no* significant associations between the same indicator of $PM_{2.5}$ as in Burnett and Goldberg (2003) and daily mortality. Furthermore, this study found large and significant associations between daily mortality and a gas (NO_2) – which the authors state is mostly the product of vehicular emissions (80% to 90%) in Canada, where the study was conducted. When the indicator of $PM_{2.5}$ is included in models with NO_2, the size of the NO_2 association increases, but the size of the $PM_{2.5}$ association, already insignificant, decreases further.

The proposed 24-hour $PM_{2.5}$ standard is based upon the 98th percentile value from Burnett and Goldberg (2003) of "about 39 $\mu g/m^3$." If this study is inappropriate for standard setting, in light of the above, what is the next highest 98th percentile value from other studies of this type referenced in the proposed rule? The January 17 FR notice does not give this value, but if the next lowest significant values are around 44 to 46 $\mu g/m^3$, as we understand might be the case for the Lipfert et al (2000) and Sheppard et al (2003) references[1], then it might make sense for the 24 hour standard to be set based upon these studies, as opposed to that of Burnett and Goldberg (2003). Since these studies apparently find 98th percentile effects at levels about 5 $\mu g/m^3$ higher than in Burnett and Goldberg (2003), this might suggest that the 24-hour $PM_{2.5}$ standard be higher than the proposed standard by about this same amount. However, before using these studies to set standards for $PM_{2.5}$, it is important to scrutinize them with the same care as afforded above to Burnett and Goldberg (2003).

Annual average standard

The Proposed Rule puts great emphasis on two studies (the Six Cities and the ACS studies, published in 1993 and 1995, respectively):

> "For mortality, the Criteria Document places greatest weight on the reanalyses and extensions of the Six Cities and ACS studies, finding that these studies provide strong evidence for associations with fine particles…notwithstanding the lack of consistent results in other long-term exposure studies." [2]

[1] 71FR at page 2649, left hand column.
[2] 71FR notice at page 2642, middle column

A thorough assessment of these studies thus would be appropriate.

An important part of such an assessment would be to understand how the information about mortality from local sources – mainly vehicular, but also including some industrial sources and residual oil emissions – is included or otherwise implicitly treated in the results of these studies. However, because these studies did not monitor for important local particulates, such as PAHs or black carbon, which have large local variance, these studies cannot address the health impacts of such pollutants. If local emissions are responsible for large health impacts, but are not taken into account in studies such as these, then associations with regional pollutants may simply represent the transfer of associations from less-well monitored pollutants to better monitored pollutants, as suggested by Ito et al (2004) and by Goldberg and Burnett (2003). We believe that certain of the conclusions of each study, however – even without monitoring for local PM emissions such as PAHs and elemental carbon (EC) – points to evidence of the dominant effects of local pollutants.

The main conclusion of the Six Cities study (Dockery et al, 1993) is that the city with the highest fine PM and sulfate levels, Steubenville, OH, has significantly elevated mortality risks compared to those in the city with the lowest concentrations of these PM types. Steubenville at the time of the study was a major steel and coke oven center, with 600 acres of coke ovens nearby, 11 steel-making facilities in Steubenville proper, and more facilities 4 miles upriver in Weirton. Similarly, the locality with the second highest mortality risks, St. Louis, was also a major coking and steel center at the time of the study (1979-1988). It seems far more likely that specific emissions from these facilities – including emissions the U.S. government has labeled as carcinogenic, which "natural intervention" studies have also shown to be harmful, and which gradient studies of a steel complex in Canada (Finkelstein et al, 2005; Jerrett et al, 2005b) have shown to be associated with highly elevated all-cause, cardiovascular, and lung cancer mortality – are more likely to be harmful, rather than widespread emissions which toxicology and other epidemiology tests suggest would cause little harm.

The 2006 follow-up analysis, using the same study design but with many more years of data and the use of different monitors in later years, confirmed the same pattern found in the first study, for the first of two time periods (roughly the same time period as in the 1993 study). In the second, more recent time period (not in the first study), reduced mortality rates demonstrate the benefit of reducing emissions such as those found in earlier time frames in the industrial areas of places like Steubenville. However, reductions in mortality were uneven among the localities. In particular, Boston had a very small reduction in pollution but a very large reduction in mortality, to the point where the mortality risks in Boston for this time period were significantly *reduced* relative to those in Portage, the city with the lowest levels of fine PM. This reduction in mortality risks in Boston may possibly reflect the large reduction in monitored emissions from residual oil

power plants during this second time period – none of the other localities featured much use of this type of fossil fuel. However, because the Six Cities study didn't monitor specific emissions that could be used to determine which types of particles may be most harmful to public health, for either time frame, we cannot answer the question of why a locality with higher fine PM emissions would have lower mortality risks – we can only point to the other studies herein which show the importance of residual oil for these effects.

The ACS study, as with the Six Cities study, neither monitors for important local types of PM such as PAHs or black carbon, nor utilizes data expressing well the actual exposure of residents to local pollutants; therefore, it cannot address directly or well the health effects of such pollutants. However, available information from the original analysis, from two reanalyses, and especially from the variety of newer studies of the health effects of local emissions (including gradient studies), helps us understand how the health impacts of local pollution sources might show up in the ACS results, even without specific emissions from these sources being monitored. Specifically, the information from these newer studies allows us to understand how confounding – due to SO_2 and educational levels – appear to demonstrate that different people may have been exposed to different local pollutants with different toxicities in the ACS studies.

SO_2 emissions can be a proxy for the many emissions from a large steel complex (Finkelstein et al, 2005). Emissions from such complexes, including PAHs, metals, and likely many other specific chemicals of concern, have been shown to cause harm. In contrast, EPA has found that SO_2 emissions at today's levels are unlikely to be harmful (the NAAQS for SO_2), and the review article by Schlesinger and Cassee (2003) found that secondary sulfates are unlikely to be harmful at ambient or high ambient levels. The founder of the Ames test for mutagenicity, Dr. Bruce Ames, states that ammonium sulfate is in the growth medium for the bacteria used in the assays, and thus is unlikely to be mutagenic or carcinogenic (Ames, 2003).

Thus when both SO_2 and sulfate are included in the reanalyses of Krewski et al (2000) and of Jerrett et al (2003), and the SO_2 effects stay significant, but substantially reduce the sulfate and $PM_{2.5}$ effects and drive them to insignificance, the interpretation most supported by toxicology is not that the SO_2 is simply a precursor for secondary sulfate, but rather that higher levels of SO_2 are a proxy for other, harmful emissions that have not been monitored, as elaborated upon by Moolgavkar (2005). Emissions such as PAHs, present in emissions from coke ovens and steel complexes, are carcinogenic (US Department of HHS [2002]; Cohen and Pope [1995]); thus the associations in the ACS study between fine PM and sulfate with lung cancer (before they are driven to insignificance by inclusion of SO_2 in the reanalyses) may actually reflect higher PAH exposure in the more highly polluted areas, mainly in areas with large point industrial point sources at the time of the study. Further, associations between $PM_{2.5}$ and lung cancer is also likely to reflect exposure to vehicular carcinogens

(again including PAHs but also including other HAPs) for those who live closest to major roads and are exposed to the emissions of greater numbers of vehicles (Apelberg et al, 2005; Morello-Frosch and Jesdale, 2006).

Emissions specifically from vehicles have been found to cause cardiovascular harm in either the long term (Hoek et al, 2002; Finkelstein et al, 2004; Finkelstein et al, 2005) or short term (Burnett et al, 2004; Peters et al, 2004; Urch et al, 2004; Urch et al, 2005; Lanki et al, 2006; Gold et al, 2005; Schwartz et al, 2005).

Why do those with better than HS education levels have no associations with fine PM emissions for risks of cardiovascular mortality in the ACS update (Pope et al, 2002)? The most likely reason is that the less educated are exposed to higher emissions from known sources of harmful emissions (major industrial facilities [Jerrett et al, 2005b; Finkelstein et al, 2005] and well trafficked roads [Green et al, 2003; Guinier et al, 2004; Grahame and Schlesinger, 2005]). However, almost everyone in the eastern U.S., of any income or educational level, is exposed to regional emissions including secondary sulfates and weathered secondary organics. Those who are exposed to these emissions, but do not live in close proximity to major roads and industrial sources, have no increased mortality risks in the ACS studies – for either all-cause, cardiovascular, or lung cancer. The most parsimonious interpretation, and one supported by toxicology as well as more modern epidemiology, is that the elevated and significant mortality risks of the less well educated has to do with the types of emissions to which they are exposed preferentially. These emissions are primarily the local emissions from major roadways and in major cities, and in the past (perhaps to an extent in the present) from major industrial facilities such as coking and steelmaking.

In light of the analysis above, we find that the statements about the ACS study in the Proposed Rule, specifically those on pages 2652 (starting toward bottom of middle column) and ending on page 2653 of 71FR are accurate and well-stated. Proposed research needs, in response to the Administrator's request for comments on pg. 2653, top left column, are addressed above.

Additional studies cited by EPA as important to setting the primary NAAQS in the proposed rule are addressed in the attached detailed comments.

Conclusions

The current proposed NAAQS for particulate matter were based on the best information available at the time the Criteria Document was closed to inclusion of new studies. Due to a combination of factors, including the discovery of a statistical flaw in the software used in many epidemiological studies (necessitating the lengthy reanalysis of these studies), the revision of these standards was delayed by several years, during which EPA did not reopen its process to consideration of additional published studies (with the exception of allowing the reanalyses of the pre-cutoff date studies with statistical flaws into the process, and one or two other studies).

The preamble to the proposed rule invites commenters to express their views on EPA's use of the April 2002 "cut-off" date and on the value and relevance of epidemiological and toxicological studies published since that date. We believe that if the standards are revised in a manner that is "requisite to protect the public health" and "reflect the latest scientific knowledge" then they must fully incorporate a number of recent studies that were not considered in the proposed rule. Our comments summarize the findings of these studies which, in general, attribute particulate matter related health effects to vehicular-related emissions; primary sulfate compounds involving certain metals, such as Ni and V (residual oil emissions); and emissions of carbonaceous and other particles from certain industrial facilities; and not to secondary sulfates or to secondary aerosols.

We do not believe that these studies support a reduction in the annual average standard for $PM_{2.5}$, although they might support a standard for widespread carbonaceous fine particles from vehicles, or a standard leading to reduction of other more local constituents of fine particulate matter (e.g., ROFA). We believe that a simple reduction in the $PM_{2.5}$ standard would lead to further reduction in secondary sulfates, and these studies suggest that would provide little if any benefit to public health. We would also offer that the 2003 study EPA cites as central to the level of the proposed 24-hour average standard for $PM_{2.5}$ was updated by a more comprehensive study a year later by the many of same authors. The update used data from the same 8 cities as the first study and the same methodology, but used added data (in terms of years, and 4 additional localities) and included gases, not just PM. The updated study came to conclusions that in essence reversed the conclusions of the first study, e.g., particles were not associated with adverse health effects, but a gas the researchers stated was primarily a vehicular emission (and thus a possible proxy for other vehicular emissions) was so associated. Since the 2003 study results have been reversed by the newer study, we suggest that the proposed 24-hour standard should reflect that reversal.