Focus: Environmental Distress Causes and Cures

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EPA May Go Beyond Law and Science in Setting NAAQS

Lucy Fraiser

Information from highly respected sources, such as the American Cancer Society,[1] indicates that only about 2 percent of cancer deaths in the United States are the result of exposures to carcinogenic agents in the workplace, community, and other settings. But the news about health risks from environmental exposures to air pollutants is almost constant. Although the US air quality has improved dramatically in the last 30 years, each recent review of a National Ambient Air Quality Standard (NAAQS) by the US Environmental Protection Agency (EPA) has resulted in a reduction in existing standards or replacement by a completely different and generally more stringent standard.

Only about 2 percent of cancer deaths in the United States are the result of exposures to carcinogenic agents in the workplace, community, and other settings.

The EPA lowered the eight-hour ozone (O_3) NAAQS from 80 parts per billion to 75 in 2008. The O_3 standard is under review now and, given the tone of the draft Policy Assessment for O_3, additional reductions appear imminent. The EPA established new one-hour NAAQS of 100 parts per billion and 75 parts per billion for nitrogen dioxide (NO_2) and

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Columns

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sulfur dioxide (SO_2), respectively, in 2010. In 2006, the EPA retained the annual NAAQS for fine particles less than 2.5 micrometers in diameter ($PM_{2.5}$) at 15 micrograms per cubic meter but reduced the 24-hour $PM_{2.5}$ standard from 65 micrograms per cubic meter to 35 and then promulgated a more stringent annual $PM_{2.5}$ standard in December 2012, lowering it from 15 micrograms per cubic meter to 12.

Each recent review of a National Ambient Air Quality Standard by the US Environmental Protection Agency has resulted in a reduction in existing standards or replacement by a completely different and generally more stringent standard.

Proponents of more stringent environmental regulation have continually offered the opinion that the significant positive benefits of reducing NAAQS to ever-lower levels are undisputed. However, for some recent decisions on NAAQS, there is good reason to believe that an adequate foundation in scientific merit is lacking.

Proponents . . . have continually offered the opinion that the significant positive benefits of reducing NAAQS to ever-lower levels are undisputed.

WHAT CONSTITUTES AN "ADVERSE HEALTH EFFECT" AND "MARGIN OF SAFETY"

The Clean Air Act (CAA) requires that primary NAAQS that are protective of public health, with an adequate margin of safety, and secondary NAAQS that are protective of public welfare to be established. "Public welfare" is defined as including "effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility and climate." Examples of what is intended by "public health" are not similarly provided, nor is a definition of what constitutes an "adequate margin of safety."

The CAA's silence on the definition of "public health" and "adequate margin of safety" has forced the EPA to make public health decisions without a clear definition of what constitutes an "adverse effect" or the degree of protection intended by the regulation.

Morton Lippmann, a participant in the EPA's Clean Air Scientific Advisory Committee reviews of Criteria Documents for NAAQS compounds between 1980 and 1987, opined on the EPA's interpretation of its statutory authority in setting NAAQS at the time the 1970 amendments to the CAA were enacted.[2] He believed primary standards are not intended to protect against all identifiable effects, but only those judged by the EPA administrator to be "adverse." However, because the primary NAAQS were intended by Congress to be precautionary and preventive, the EPA administrator is not free to define only those effects that are clearly harmful or for which there is a medical consensus about the degree of harm as "adverse." Lippmann further opined that a standard is statutorily sufficient when there is "an absence of adverse effect on the health of a statistically related sample of persons in sensitive groups from exposure to the ambient air."

The American Thoracic Society (ATS) has provided guidance on the distinction between "adverse" and "non-adverse" health effects. The ATS also acknowledges that the CAA suggests that the adequacy of any standard could be tested in a statistically representative sample of sensitive individuals.[3]

The ATS guidance indicates that healthy people may sustain transient reductions in pulmonary function with exposure to air pollutants but recommends that reversible loss of lung function only be considered "adverse" when it is accompanied by respiratory symptoms. The ATS further recommends that the following be considered "adverse": (1) any detectable level of permanent lung function loss attributable to air pollution, (2) air-pollution-related symptoms associated with diminished quality of life or with a change in clinical status (e.g., requiring medical care or change in medication), and (3) any effect on mortality.

While previous ATS guidance[4] hinged the distinction between "adverse" and "non-adverse" effects on medical considerations, the most recent ATS guidance[5] places increased emphasis on quality-of-life measures as indicators of adversity and formally acknowledges the concept that minute individual risks may be significant from a population standpoint, even if no individual experiences a level of exposure that is associated with clinically relevant consequences. This guidance seems to have opened the door to considering increasingly benign and isolated effects that occur in very few test sub-

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jects in controlled human studies as relevant in the NAAQS setting process.

KEY SUPPORT FOR RECENTLY REDUCED PRIMARY NAAQS

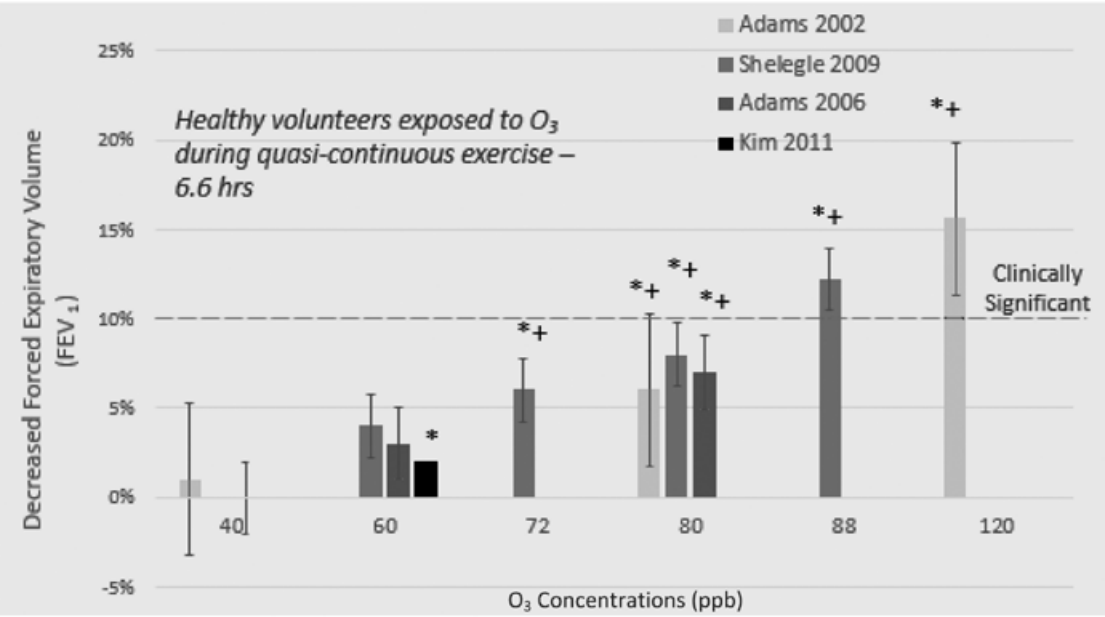
Controlled human exposure studies evaluating effects on lung function provide the primary support for the one-hour NAAQS for SO_2 and the eight-hour O_3 NAAQS.

Ozone

The EPA is currently considering lowering the existing eight-hour O_3 NAAQS of 75 parts per billion to a level between 60 parts per billion and 70 parts per billion because of concerns about the adequacy of its health protectiveness. One of the early effects of O_3 exposure is transient lung-function decrements, which has been demonstrated in controlled human exposure studies in young healthy adults exposed to O_3 while engaging in moderate, semicontinuous exercise for more than six hours. **Exhibit 1** summarizes the results of the controlled human studies that the EPA is relying on in its current, ongoing O_3 NAAQS review. There are more short-term O_3 studies than those shown in Exhibit 1, but only four controlled human studies have evaluated short-term O_3 exposures below 80 parts per billion. These are the studies that provide the primary basis for the EPA's questions about the adequacy of the current eight-hour NAAQS of 75 parts per billion.

Forced expiratory volume in one second (FEV_1), a measure of how much air a person can exhale during a forced breath, and respiratory symptoms were selected as critical health endpoints for judging the respiratory effects of O_3. The EPA has outlined a graded classification for lung-function changes in which changes in FEV_1 were graded as mild, moderate, or severe for reductions of less than 10 percent, 10–20 percent, and greater than 20 percent, respectively.

Exhibit 1. Evidence for O_3-Induced Lung-Function Decrements



* statistically significant.
* + statistically significant + respiratory symptoms.

Sources: Adams, W. (2002). Comparison of chamber and face-mask 6.6-hour exposures to ozone on pulmonary function and symptoms responses. *Inhalant Toxicology*, *14*, 745–764; Schelegle, E., Morales, C., Walby, W., Marion, S., & Allen, R. (2009). Hour inhalation of ozone concentrations from 60 to 87 parts per billion in healthy humans. *American Journal of Respiratory Critical Care Medicine 180*, 265–272; Adams, W. (2006). Comparison of 6.6 h exposures to 0.04–0.08 ppm ozone via square-wave and triangular profiles on pulmonary responses. *Inhalant Toxicology*,*18*, 127–136.

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A moderate decrease in FEV_1 of greater than or equal to 10 percent has been judged by the EPA to be a clinically relevant change. As shown in Exhibit 1, FEV_1 decrements are not accompanied by respiratory symptoms (required to be considered "adverse") until O_3 concentrations reach 72 parts per billion and clinically relevant lung-function decrements (decrease of at least 10 percent) do not occur until O_3 concentrations reach 88 parts per billion.

Clinically relevant lung-function decrements . . . do not occur until O_3 concentrations reach 88 parts per billion.

The EPA acknowledges that group mean changes in lung function, such as those shown in Exhibit 1, are small following exposures to O_3 concentrations in the range of 60–70 parts per billion. But the EPA still argues that some sensitive individuals experience clinically meaningful decrements at these levels because in each study summarized in Exhibit 1, one or two subjects experienced greater than or equal to 10 percent decreases in FEV_1. However, this conclusion is entirely dependent upon the assumption that a 10 percent decrease in FEV_1 represents a clinically relevant benchmark.

This assumption is questionable for several reasons. Many studies have demonstrated that there is a high degree of spontaneous day-to-day and diurnal variation in FEV_1 and that a 10 percent drop in FEV_1 is within the range of normal variation, even in healthy individuals that are neither exercising nor exposed to pulmonary irritants.[6] In its justification of the 10 percent decrease in FEV_1 as the threshold for clinical relevance, the EPA states that some asthmatics would choose to self-limit activities and might require additional or more frequent use of asthma medication. However, there are many studies[7] that dispute this statement, indicating instead that asthma symptoms and medication use, as well as "quality-of-life" indicators, such as self-reported activity restriction, are poorly correlated with pulmonary function tests such as FEV_1.

Sulfur Dioxide

The most immediate effect of SO_2 exposure on the respiratory system is bronchoconstriction. FEV_1 and airway resistance (sRAW) were selected as the primary critical health endpoints for judging the respiratory effects of SO_2. For SO_2, the EPA judges a moderate decrease in FEV_1 to be clinically relevant but considers a 15 percent decrease to be the threshold (as opposed to the 10 percent threshold used for O_3).

Exhibit 2 summarizes the results of several controlled human studies that evaluated the effect of short-term SO_2 exposure in exercising asthmatics on lung function, as measured by decrease in FEV_1, and that were relied upon by the EPA in establishing the one-hour SO_2 NAAQS in the 2010 NAAQS review. There are other controlled human studies that evaluated SO_2-induced decreases in FEV_1, but those in Exhibit 2 represent the ones for which the EPA's raw data were made available. The studies in Exhibit 2 are representative of the others in terms of results. None of the Linn studies reported whether the decrements were statistically significant or whether they were accompanied by respiratory symptoms, but as the exhibit shows, the group mean decreases in FEV_1 did not reach the 15 percent threshold level required to be considered clinically relevant in any of the studies until SO_2 concentrations reached 600 parts per billion.

In addition to classifying FEV_1 changes, the EPA has also outlined a classification system for sRAW, in which increases in sRAW of less than 100 percent, 100–200 percent, and greater than 200 percent are graded as small, moderate, and large, respectively. The EPA considers a moderate increase in sRAW as the threshold for clinical relevance. **Exhibit 3** summarizes the results of controlled human studies on the effect of short-term SO_2 exposure in exercising asthmatics on lung function measured as an increase in sRAW. As shown in the exhibit, a statistically significant and clinically relevant group mean increase in airway resistance (greater than 100 percent) was observed at a concentration of 500 parts per billion, but not below. A statistically significant increase in airway resistance large enough to be considered clinically relevant (greater than 100 percent) that was also accompanied by respiratory symptoms (required to be considered adverse) was only reported in one study, and it was not observed until the SO_2 concentration reached 1,000 parts per billion.

Surprisingly, on the basis of these studies, the EPA concluded that respiratory effects were

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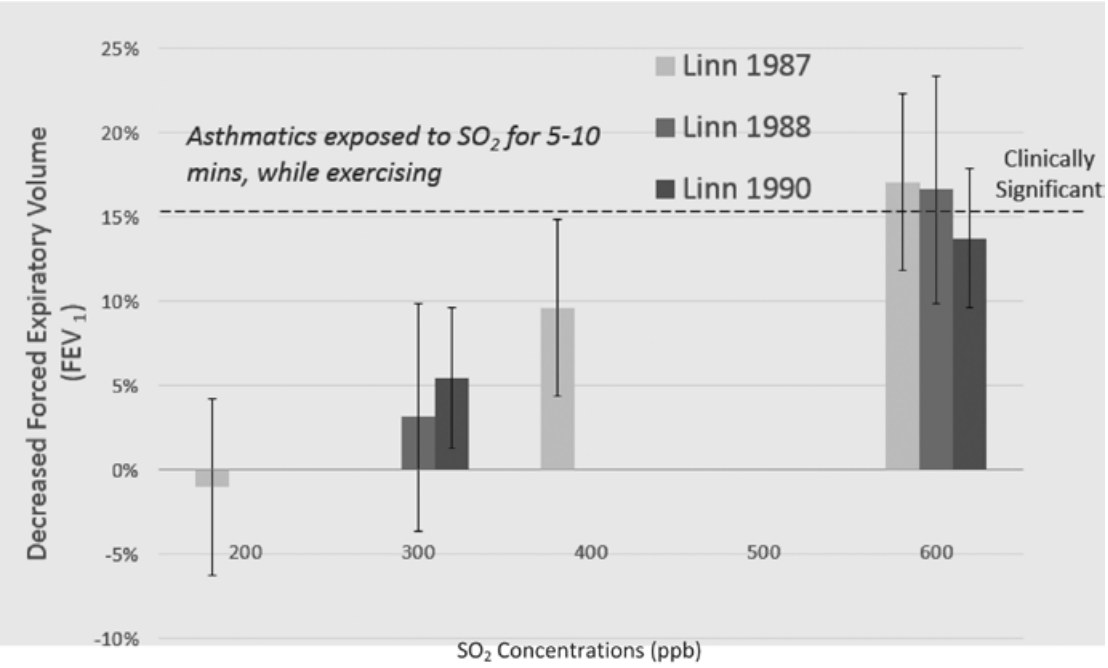
Exhibit 2. Evidence for SO_2-Induced Lung-Function Decrements, Measured as Decreases in FEV_1



Respiratory symptoms not reported.
Statistical significance not reported.

Sources: Linn, W., Avol, E., Peng, R., Shamoo, D., & Hackney, J. (1987). Replicated dose-response study of sulfur dioxide effects in normal, atopic, and asthmatic volunteers. *American Review of Respiratory Diseases, 136*, 1127–1134; Linn, W., Avol, E., Shamoo, D., Peng, R., & Hackney, J. (1988). Effect of metaproterenol sulfate on mild asthmatics' response to sulfur dioxide exposure and exercise. *Archives of Environmental Health, 43*, 399–406; Linn, W., Shamoo, D., Peng, R., Clark, K., Avol, E., & Hackney, J. (1990). Responses to sulfur dioxide and exercise by medication-dependent asthmatics: Effect of varying medication levels. *Archives of Environmental Health*, *45*, 24–30.

consistently observed following five-to-ten-minute exposures to SO_2 at concentrations of more than 200 parts per billion in asthmatics engaged in moderate to heavy levels of exercise. Again, while the group mean lung-function decrements were small, the EPA argued that a few sensitive individuals experienced clinically relevant decreases in FEV_1 (greater than or equal to 15 percent) or increases in sRAW (greater than 100 percent). From that five-to-ten-minute 200 parts per billion SO_2 level, the EPA calculated an hourly concentration of 75 parts per billion and set that level as the one-hour SO_2 NAAQS. However, the symptoms observed at 200 parts per billion were mild and occurred in only a small number of participants (i.e., effect was not consistently observed).

Studies have shown that, like FEV_1, sRAW varies substantially between individuals, which can lead to isolated effects that occur in only a few individuals and are most likely unrelated to exposure. Bethel[8] reported that baseline (i.e., pre-exercise and pre-exposure) sRAW values collected on two consecutive days from 28 volunteers varied by as much as 53 percent and that 11 of the 28 volunteers experienced differences of greater than or equal to 25 percent. The range of variability in baseline sRAW values provides further evidence that lung function can vary appreciably due to factors unrelated to exposure to air pollutants. Linn and his coauthors[9] reevaluated results from their earlier study[10] and found FEV_1 decreases of greater than or equal to 15 percent in five subjects, *increases* of greater than or equal to 15 percent (opposite direction expected) in five other subjects, and an overall group mean response that was not different from the control group.

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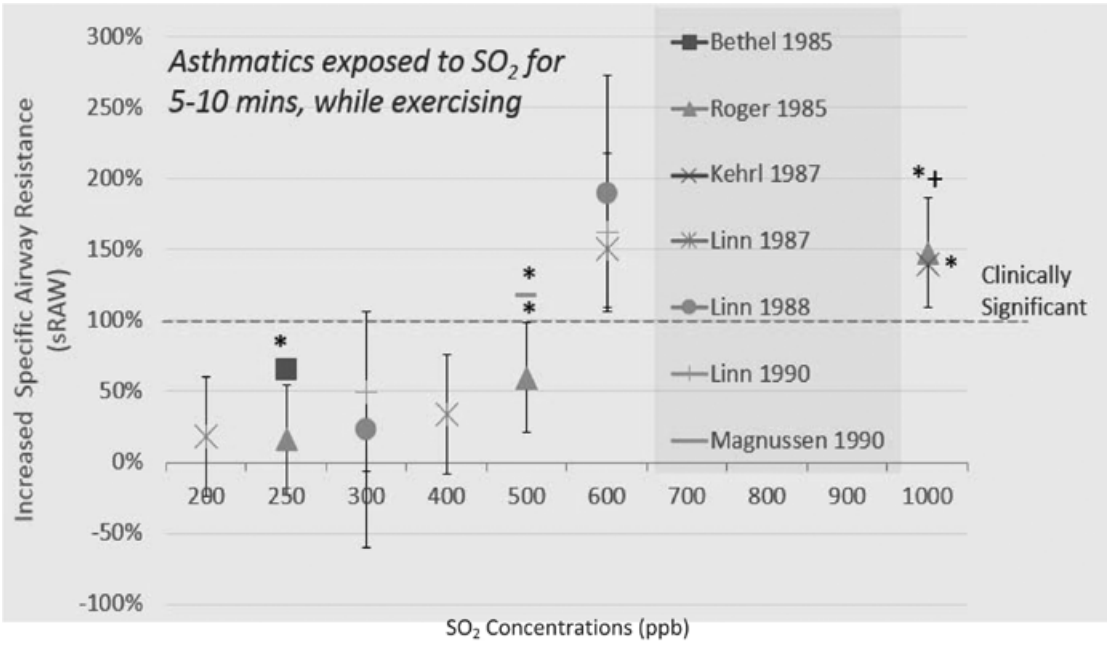
Exhibit 3. Evidence for SO_2-Induced Lung-Function Decrements, Measured as Increases in sRAW



* statistically significant.
* + statistically significant + respiratory symptoms.

Sources: Bethel, R., Sheppard, D., Geffroy, B., Tam, E., Nadel, J., & Boushey, H. (1985). Effect of 0.25 ppm sulfur dioxide on airway resistance in freely breathing, heavily exercising, asthmatic subjects. *American Review of Respiratory Diseases*, *131*, 659–661; Roger, L., Kehrl, H., Hazucha, M., & Horstman, D. (1985). Bronchoconstriction in asthmatics exposed to sulfur dioxide during repeated exercise. *Journal of Applied Physiology*, *59*, 784–791. Kehrl, H., Roger, L., Hazucha, M., & Horstman, D. (1987). Differing response of asthmatics to SO_2 exposure with continuous and intermittent exercise. *American Review of Respiratory Diseases*, *135,* 350–355; Linn, W., Avol, E., Peng, R., Shamoo, D., & Hackney, J. (1987). Replicated dose-response study of sulfur dioxide effects in normal, atopic, and asthmatic volunteers. *American Review of Respiratory Diseases*, *136*, 1127–1134; Linn, W., Avol, E., Shamoo, D., Peng, R., & Hackney, J. (1988). Effect of metaproterenol sulfate on mild asthmatics' response to sulfur dioxide exposure and exercise. *Archives of Environmental Health*, *43*, 399–406; Linn, W., Shamoo, D., Peng, R., Clark, K., Avol, E., & Hackney, J. (1990). Responses to sulfur dioxide and exercise by medication-dependent asthmatics: Effect of varying medication levels. *Archives of Environmental Health*, *45*, 24–30.

Comparable changes in sRAW occurred with a similar frequency.

Just as the lung-function improvements seen in a few individuals exposed to 200 parts per billion do not indicate a beneficial effect of SO_2, the small lung-function decrements after low-level SO_2 exposure do not represent an "adverse" effect of SO_2.

CONCLUSIONS

There have been recent efforts to formalize processes for characterizing the weight of the scientific evidence and judging the strengths and limitations of individual studies that may affect the overall interpretation of the results. Nevertheless, there has been inconsistency in the way the EPA has interpreted health effects studies used to support its decisions on setting NAAQS. The examples given here are but a few of those inconsistencies.

There has been inconsistency in the way the EPA has interpreted health effects studies.

Clearly, Congress did not intend that only healthy persons would be protected by the NAAQS. The legislative history of Section 109 of the CAA indicates that a primary standard is to be set at "the maximum permissible ambi-

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ent air level . . . which will protect the health of any [sensitive] group of the population," and that for this purpose "reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group."[11] Based on this interpretation and similar interpretations by Lippmann[12] regarding the statutory authority given to the EPA by the CAA in setting NAAQS, it is unclear how far the EPA should go in terms of protecting "hyper-susceptible individuals" and against effects that are not clearly "adverse." Nonetheless, the trend has been for the EPA to consider increasingly benign and isolated effects that occur in very few test subjects as relevant in the NAAQS-setting process.

The trend has been for EPA to consider increasingly benign and isolated effects that occur in very few test subjects as relevant.

In contrast to the ATS's recommendations,[13] the EPA often considers a moderate decrease in lung function or symptoms alone to be "adverse" in setting NAAQS. Presumably, this policy is at least partly based on the EPA's assertion that these effects would interfere with normal activities and/or require additional or more frequent use of asthma medication. This tendency may be related to the ATS's recently increased focus on "quality-of-life" measures as indicators of adversity. However, as previously discussed, there are many studies disputing that lung-function tests (e.g., FEV_1) are good predictors of "quality-of-life" indicators, symptoms, or asthma medication use.[14]

Focusing on the response of hypersensitive individuals in the test group . . . appears to go beyond the original intent of the CAA.

In addition, by focusing on small decreases in FEV_1 or increases in sRAW that only occur in a few sensitive individuals, justifications for lowering the NAAQS are being based on what most likely represents normal variation in pulmonary function tests rather than clearly "adverse" effects associated with exposure to air pollutants. Furthermore, focusing on the response of hypersensitive individuals in the test group, rather than responses in a representative sample of sensitive groups, appears to go beyond the original intent of the CAA. It is clear from the inconsistencies described in this article that more objective and specific criteria for weighing the scientific evidence and judging the strengths and limitations of individual studies need to be established so that judgments about reducing NAAQS are made based on truly "adverse" health effects in representative samples of sensitive subpopulations.

NOTES

1. American Cancer Society. (2014). *Cancer facts and figures 2014*. Retrieved from http://www.cancer.org/research/cancerfactsstatistics/cancerfactsfigures2014/.
2. Lippmann, M. (1989). The influence of responses in susceptible populations in establishing standards for ambient air pollutants. In M. J. Utell & R. Frank (Eds.), *STP1024 Susceptibility to Inhaled Pollutants* (pp. 6–20). Philadelphia, PA: American Society for Testing and Materials. Retrieved from http://www.astm.org/DIGITAL_LIBRARY/STP/SOURCE_PAGES/STP1024.htm.
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11. S.Rep. No. 91–1196, 91st Cong., 2d Sess. 10 (1970) as referenced in 71 Fed. Reg. 2620–2708 (January 17, 2006).
12. See Note 2.
13. See Notes 3 and 4.
14. See Note 7.

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