Fact or Fiction?

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Particles & Exposure

In terms of environmental regulation, which PM0.8 concentration is more toxic?

- a mg/m^3 of sulfuric acid, or
- a mg/m^3 of zinc sulfate

The answer: there is no difference. Never mind that the sulfuric acid particle provides more than five times the relative irritant potency as shown in Table 1. This table, from Mary Amdur and her colleagues, reveals that the relative irritant potency of sulfates in animal testing spans two orders of magnitude.[1] Amdur *et al*. state, "The irritant potency of the sulfate species varies so widely that the term 'suspended sulfate' is toxicologically meaningless." However, as David Mage notes, "The EPA PM standards and the California sulfate standard treat an exposure to each PM sulfate, at the same AD (aerodynamic diameters), concentration, and averaging time, as having exactly the same human health effect."[2]

Table 1
Relative Irritant Potency of Sulfates
(0.1-0.8 μm mass median diameter)[a]

Species of sulfate	Relative irritant potency
Sulfuric acid	100
Zinc ammonium sulfate	33
Ferric sulfate	26
Zinc sulfate	19
Ammonium sulfate	10
Ammonium bisulfate	3
Cupric sulfate	2
Ferrous sulfate	0.7
Sodium sulfate[b]	0.7

a. Mary O. Amdur, John Bayles, Valerie Ugro and Dwight W. Underhill, "Comparative Irritant Potency of Sulfate Salts," *Environmental Research*, **16**, 1 (1978)
b. Mass median diameter of 0.1 um.

An article by David Mage with the catchy title, "A particle is not a particle is not a PARTICLE," in a recent epidemiology journal addresses this issue.[2] He says the following: "Since its inception, the U.S. Environmental Protection Agency (EPA) has, by necessity, been operating as if the health effects of ambient particulate matter (PM) are independent of the PM chemical composition, and only a function of the particles' aerodynamic diameters (AD), the mass concentration of the particles, and the averaging time of the exposure to the ambient PM. Although this may originally have been an expedient and practical executive decision for standard setting, in the absence of specific mixture toxicity composition information, it has spawned innumerable papers by authors who write as if they actually believe that all equal mass concentrations of ambient PM of identical AD have the identical toxicity." He goes on to point out, "At the same low dose units of ug/kg body weight/day, some substances can be inert (NaCl), some can be acutely toxic (NaCN), and some can be chronically toxic (NaF). Although this concept is well known to most toxicologists and apparently to most, if not all, air pollution health scientists, the EPA currently persists in treating all ambient PM species of a particular AD size range, save for water, as having the identical toxicity, whether they are like NaCl, NaCN, or NaF."[2]

Table 2
Dose Effectiveness Varies as Much as Toxicity[a]

Source	Grams inhaled per tonne emitted
US coal power plant	1
Vehicles	12
Neighborhood sources	100
Stove vented outdoors	600
Stove vented indoors	4,500
Cigarette-mainstream	1,000,000

a. Kirk R. Smith, "Place makes the poison," *Journal of Exposure Analysis and Environmental Epidemiology*, **12**, 167 (2002)

Mage concludes by suggesting that perhaps it is time for the EPA to consider

an approach that actually incorporates the relative toxicity of ambient PM species into the standard setting process.

Exposure

A related topic from a health standpoint is exposure. Kirk Smith notes that besides the oft-quoted "the dose makes the poison" from Paracelsus, present-day understanding of the importance of personal exposure indicates that "place makes the poison" needs to be considered.[3] Smith states: "The relative proximity of a pollution source to people has just as big an impact on its importance as a hazard as does the relative toxicity (including chemical nature and size distribution) of its emissions. The exposure effectiveness (or intake fraction) of common air pollution sources, for example, varies over nearly four orders of magnitude. A place-makes-the-poison perspective not only identifies new relationships and priorities among known sources, but also reveals an entirely new landscape of sources and potential control measures. It therefore, has profound economic and policy implications, which will be examined in the context of particle air pollution in different parts of the world."

Smith also notes: "The fraction of released pollutant reaching the breathing zone or actually inhaled greatly depends on the location/timing of the source emissions with respect to the places people spend time in contact with the pollutant." Table 2 shows that dose effectiveness ranges over six orders of magnitude, from active smoking, which is by definition 1.0 (100% of the released material is inhaled) to the average U.S. coal-fired power plant at 10^{-6}, where only 1.0 g/ton released is inhaled.[3]

Smith concludes by suggesting that, "Depending on the policy need, the 'event' of concern may not be mass of pollutant emitted, but incorporate such socially relevant denominators as 'grams inhaled per kilowatt hour electricity produced,' 'grams inhaled per meal cooked,' or 'grams inhaled per passenger-kilometer of transport.'"

One final item. Individual people have been observed to respond very differently to the same exposure of a given toxicant. Lauren Zeise notes, "The usual assumption in deriving dose response relationships for human carcinogenesis is that each person faces exactly the same risk of cancer, and that those particular individuals who actually develop cancer are determined by chance. This assumption may be more appropriate for laboratory animals in a given bioassay, which are far more homogeneous in genetic make-up and other environmental factors." [4]

Summary

In a previous column I discussed bioavailability and chirality and noted that these terms, which essentially mean that chemical analysis by itself does not determine the toxicity of some chemicals, need to be added to our understanding.[5] Particles and exposure are two other terms worthy of closer analysis. Neither is as simple or straight-forward as it may appear at first blush. *P&SF*

References

1. Mary O. Amdur, John Bayles, Valerie Ugro & Dwight W. Underhill, "Comparative Irritant Potency of Sulfate Salts," *Environmental Research*, **16**, 1 (1978)
2. David T. Mage, "A particle is not a particle is not a PARTICLE," *Journal of Exposure Analysis and Environmental Epidemiology*, **12**, 93 (2002)
3. Kirk R. Smith, "Place makes the poison," *Journal of Exposure Analysis and Environmental Epidemiology*, **12**, 167 (2002)
4. Lauren Zeise, "Assessment of Carcinogenic Risks in the Workplace," in *Chemical Risk Assessment and Occupational Health*, Editors, C. Mark Smith, David C. Christiani & Karl T. Kelsey, (Westport Connecticut, Auburn House, 1994), 119
5. Jack W. Dini, "How Toxic Are Toxic Chemicals in Soil?", *Plating & Surface Finishing*, **88**, 56 (April 2001)