

Particle Scavenging Coefficient Estimation

Atmospheric aerosol particles below the cloud line can be absorbed into rain droplets during precipitation events. This section will provide justifications that the estimation techniques in common use are sufficient for consideration of C-8 particulate scavenging.

There are numerous potential mechanisms by which particle scavenging can occur, including Brownian diffusion, interception, inertial impaction, thermophoresis, airflow turbulence and electrostatic attraction.^(1,4) These mechanisms involve phenomena which are basically governed by principles of conservation of mass, momentum, and electric charge.

Small particles have low inertia and are scavenged by the Brownian diffusion mechanism. The fall of the raindrops relative to the convection of small particles enhances the probability of collisions. Large particles tend to experience inertial impaction because of their significant inertial forces. Some intermediate sized particles will follow streamlines around raindrops and happen to graze the droplet, causing interception. Electrophoresis attraction results from oppositely charged raindrops and particles. Thermophoresis is caused by uneven heating of the particles in ambient temperature gradients and drives particles toward raindrops that are colder than their surroundings. Finally, scavenging by turbulence ensues from relative motions between particles and raindrops that are produced by velocity gradients in turbulent air or uneven response of particles and raindrops to local turbulent accelerations.⁽³⁾ In each of these mechanisms, the fundamental phenomena are a function of physical characteristics of the particles, such as size and weight, rather than chemical properties.

The efficiency of a single raindrop in scavenging particles is described by the so-called collection Kernel, K_p , which is the effective volume swept out by the raindrop in unit time.⁽⁴⁾ The collection kernel can be expressed as

$$K_p = A * |V_t - v_t| * E_p$$

where A is a function of only the diameters of the particle and the raindrop and denotes the geometric cross-sectional area of a pair of impacting bodies oriented perpendicular to their fall direction; V and v are the fall speeds of the raindrop and the particle and are functions of their respective diameters; and E_p is the collection efficiency of the particles by the raindrop, defined to be the ratio of the actual cross-section for particle capture to the geometric cross-sectional area. Again, the efficiency of scavenging is a function only of physical characteristics of the particle, such as diameter, and the raindrop, rather than the chemical properties.

In the work of Jindal and Heinold⁽²⁾, which is the commonly used method of calculating scavenging coefficients in the ISC User Guidance Manual, they were

able to improve on work of previous authors and provide a parameterization method which could be applied to any known particle size distribution from an emission source. Their single value parameterization was able to reproduce previously accepted scavenging coefficients with considerable accuracy and was valid for particle sizes up to 10 microns. Based on sampling data presented in this report, 100% of the particles emitted from the Washington Works are less than 5 microns, well within the correlation range of the Jindal parameterization methods.

Considering

- a) dependence of particle scavenging coefficients on the physical characteristics of the particle, such as diameter, size and weight, and
- b) the mechanistic phenomena are physical in nature having to do with physical collisions of particles with raindrops,

there is no reason to assume C-8 particle scavenging will depend on any other characteristics than physical particle size distribution.

References:

1. Hinds, W.C., "Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles", 1982, Wiley & Sons, New York.
2. Jindal, M., and Heinold, D., Development of Particulate Scavenging Coefficients to Model Wet Deposition from Industrial Combustion Sources, Air & Waste Management Association, 84th Annual Meeting, Paper 91-59.7, 1991.
3. Jylha, K., The Scavenging of Air Pollutants by Precipitation, and its Estimation with the Aid of Weather Radar", Academic Dissertation, Department of Meteorology, University of Helsinki, 2000.
4. Pruppacher, H.R., and Klett, J.D., "Microphysics of Clouds and Precipitation", 2nd Ed., 1997, Kluwer.