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Nanotechnology: Implications for the Environment

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Nanotechnology holds the promise of impacting our world on a very large scale. Nanotechnology refers to materials that are 1 to 100 nanometers (nm) across, which is approximately ten thousand times smaller than the diameter of a human hair. Although particles of this size occur naturally (e.g., viruses, volcanic ash, some natural aquatic polymers and aerosols) or as byproducts of human activity (exhaust particulates, silica dust), the term nanotechnology generally refers to materials that are purposefully manufactured, such as the "buckyball", a fullerene composed of C-60. There is a wide range of potential applications for nanotechnology, and it is likely that the industry will continue vigorous growth and globally become a trillion dollar industry by 2015.

Nanotechnology presents a challenge to regulators and the environmental industry due to the diversity of potential products and their rapid development. We will discuss current thoughts as to the most appropriate regulatory approach. There are questions as to whether current environmental regulations are sufficient or if nanotechnology-specific regulations are necessary. There is also some concern that over-regulation could limit research into this technology that holds so much promise for a variety of valuable and useful applications.

Nanomaterials come in a variety of compositions, sizes, and structures—all of which are likely thought to influence fate and transport behavior. By design, the physical properties of nanomaterials differ from larger particles of the same chemical composition. Moreover, some of these properties—for example, their hydrophobicity, zeta potential, etc.—might be expected to change over time in the natural environment. To a first approximation, the factors that control colloidal transport in aquatic environments may limit nanoparticle transport because of their similarity in size (colloids are 5 to 200 nm). However, because of the small size of nanomaterials, aerial dispersion is likely to be as important a risk vector as subsurface movement.

While nanotechnology may ultimately present new environmental challenges, it is increasingly relied on as a useful tool in solving old (and new) environmental problems. The high surface area and tailored reactivity of nanoparticles make them ideal candidates for environmental catalysis and contaminant removal. For example, nanoparticles are being used to break down volatile organic compounds (VOCs) and dense nonaqueous-phase liquid (DNAPL), and to remove arsenic from drinking water. The high specific reactivity of nanoparticles might also be applied in the future to remove/break down such emerging contaminants as perchlorate and NDMA—contaminants that tend to have health impacts at the parts per billion or parts per trillion level.

Understanding the surface properties of nanoparticles is critical to maximizing the economic impact of nanotechnology and to minimizing its environmental impact. Anticipating secondary waste streams is also important to minimizing the environmental footprint of nanotechnologies. We will show how each of these factors can be used to roughly predict the environmental face of nanotechnology in the future.

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