Regional Multimedia Distribution of Nanomaterials and Associated Exposures

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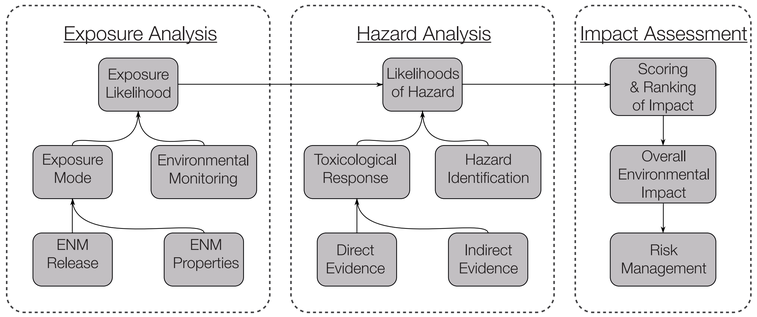
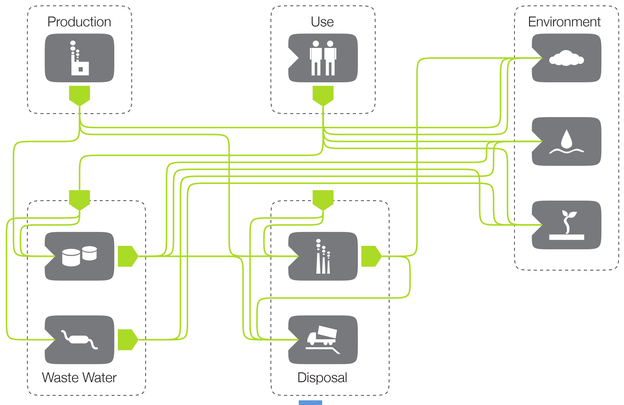
Abstract

Evaluation of the potential impact of engineered nanomaterials (ENMs) in the environment requires information regarding levels of anticipated exposure concentrations. Accordingly, a generalized modeling framework of the multimedia environmental distribution of nanomaterials (MendNano) was developed to estimate the environmental distribution of ENMs subject to various release scenarios. As an integral part of MendNano, a life cycle environmental assessment for the release of ENMs (LearNano) modeling tool was developed to enable estimation of ENM release rates (if such are unavailable) to the environment.

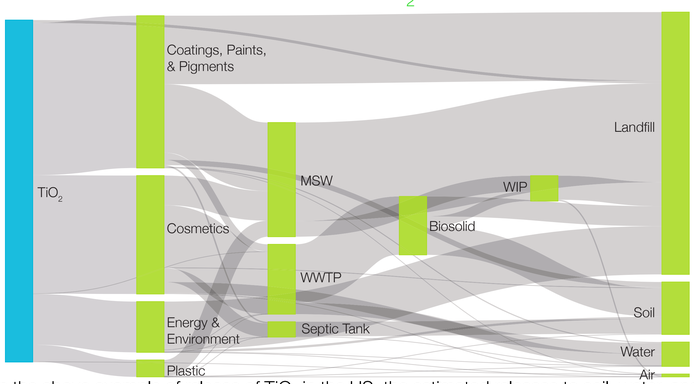


Life Cycle Environmental Assessment for the Release of Nanomaterials (LearNano)

Source release rates are determined by tracking the mass of ENMs from production, through the various technical compartments (i.e., waste water treatment, septic systems, waste incineration), to eventual release to the various environmental compartments (i.e., air, water, soil) or to landfills. The ENM transfer between two adjoining compartments is then determined by a transfer coefficient (which can be ENM, application and/or region specific) that dictates the ENM fraction that enters the "source" compartment and then transfers to the "target" compartment.



Release rates of TiO_2 to the US

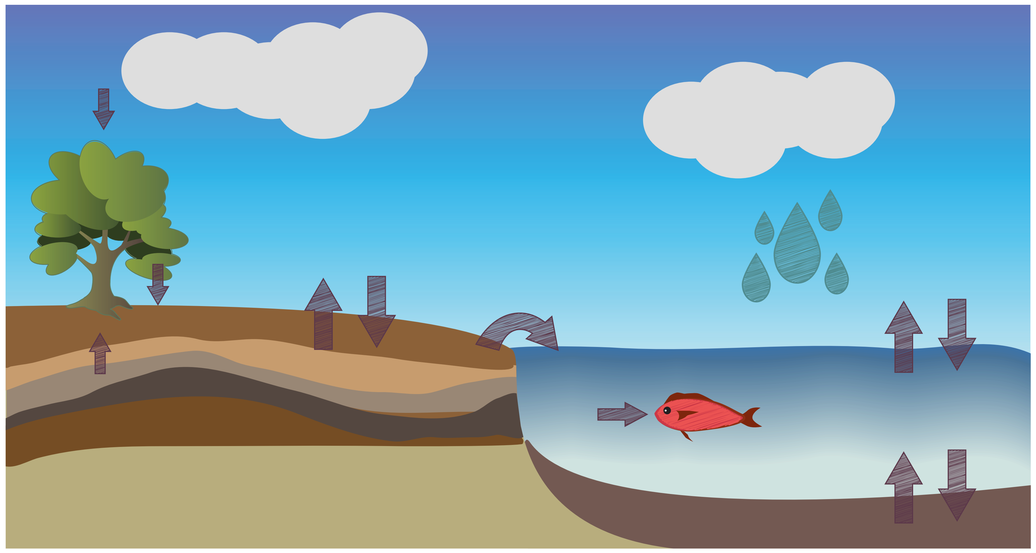


In the above example of release of TiO_2 in the US, the estimated releases to soil, water, and air are 611.2, 283.8, and 33.2 T/y, respectively. However, the release to soil that maybe distributed regionally is debatable, since application of biosolids are typically localized. Estimation of local/regional release rates can be scaled based on a suitable scaling ratio (e.g., population or GDP).

Keller, A. A.; Lazareva, A. Predicted Releases of Engineered Nanomaterials: From Global to Regional to Local. Environ. Sci. Technol. Lett. 2014, 1, 65–70.

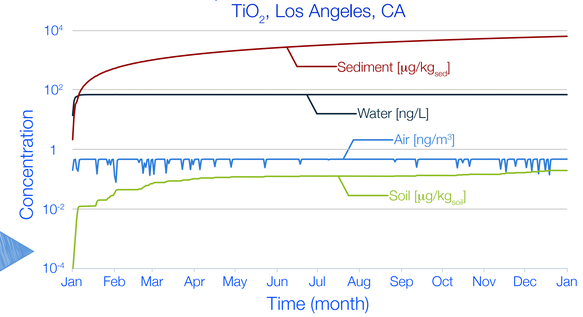
Multimedia Environmental Distribution of Nanomaterials (MendNano)

MendNano considers the environment as a collection of compartments and sub-compartments. Fundamental intermedia transport processes (e.g. dry deposition, rain scavenging, resuspension, runoff, sedimentation, dissolution) link adjoining compartments while accounting for the particle size distribution. Simulations with MendNano require relevant properties of the ENM under consideration, regional geographical and meteorological parameters (i.e., size of regions, temperature, wind speed, rain rates, etc.), ENM transport process parameters and source emissions.



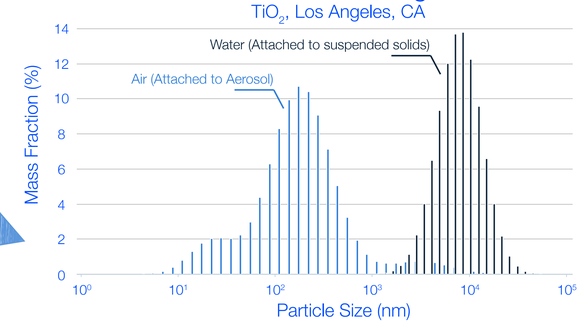
ENM Temporal Concentration Profiles

TiO_2, Los Angeles, CA



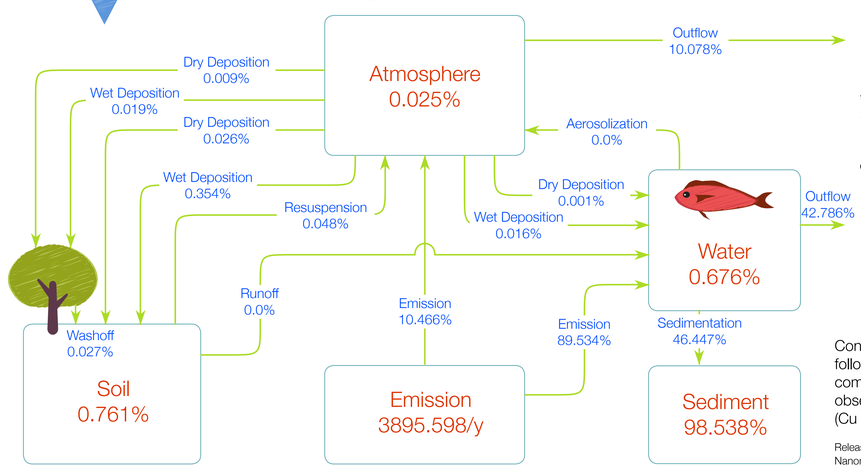
Mass Distribution Among Size Bins

TiO_2, Los Angeles, CA



Intermedia Transport Rates and Mass Distribution

TiO_2, Los Angeles, CA

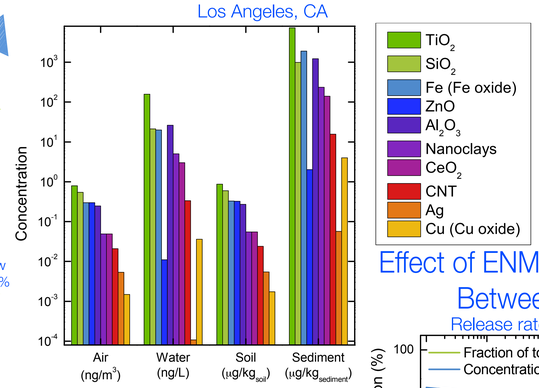


When ENMs are released primary to air and water, the majority of their mass accumulation in the environment is to the soil and sediment, respectively. It is noted that predicted environmental chronic exposure concentration levels are generally significantly lower than the level of concentrations deployed in toxicity studies, although one must acknowledge that there can be local "hot-spots" of high ENM concentrations.

Liu, H. H.; Cohen, Y., Multimedia Environmental Distribution of Engineered Nanomaterials. Environmental Science & Technology. 2014, 48, 3281-3292

Predicted Environmental Concentrations

Los Angeles, CA



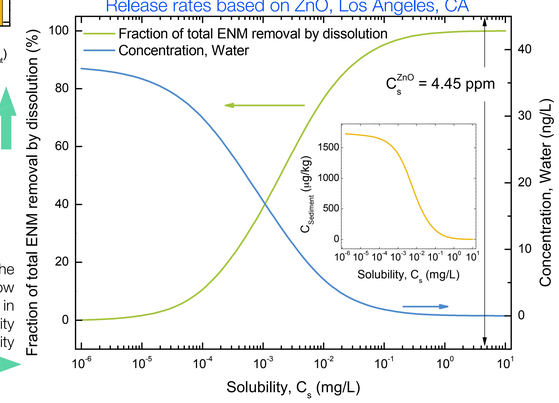
Concentration rankings of ENMs in air and water follow the order of release rates to the respective compartments, with exception ENMs that exhibit observable solubility (i.e., Fe (Fe oxide), ZnO, Ag, Cu (Cu oxide).

Release rates based on: Keller et al. Global Life Cycle Releases of Engineered Nanomaterials. J. Nanopart. Res. 2013, 15, 1– 17.

Dissolution has a minor impact on ENMs loss from the water column (<5%) when the ENM solubility is below ~$5x10^{-5}$ mg L^{-1}. The concentration of suspended ENMs in water decreases, by ~3 orders of magnitude, as solubility increases from <10^{-6} mg L^{-1}, to 4.45 mg L^{-1} (i.e., solubility of ZnO at pH 8).

Effect of ENM Dissolution on its Distribution Between Water and Sediment

Release rates based on ZnO, Los Angeles, CA



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