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Surface Chemistry and Stability of Nanostructured Materails in Natural Aquatic Environments

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List of nanostructures and the related materials

Nanostructure	Chemical Composition	Potential Application	Structural Parameter
Mesoporous structure	SiO_2, Al_2O_3, ZrO_2, CeO_2, Zr-phosphate, etc	Photon/electron devices, catalysts & catalyst supporters, sensing materials, adsorbents, etc.	Pore geometry, pore size
Nanotubes	TiO_2, carbon, etc	Photon/electron devices, catalysts, sensing materials, etc.	Pore size, wall thickness, tube length
Core-shell structure	Iron oxides (especially magnetite), metallic particles, etc	Chemical separation, Photon/electron devices, catalysts, medical treatments, etc.	Particle size, shell thickness and coverage
Nanoparticle & nano-rods	TiO_2, iron oxides, metallic iron, metallic Pd, etc	Catalysts, photon/electron devices, environmental remediation, cosmetics	Particle size, morphology

Nanotechnology is anticipated to be a trillion dollar industry by 2015.

Environmental & Health Concerns of Nanomaterials

NEWS & VIEWS

NANOECOTOXICOLOGY

Nanoparticles at large

Environmental toxicologists, chemists and social scientists have identified three priorities for research into the impact of engineered nanoparticles on the environment.

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LETTERS

Carbon nanotubes introduced into the abdominal cavity of mice show asbestos-like pathogenicity in a pilot study

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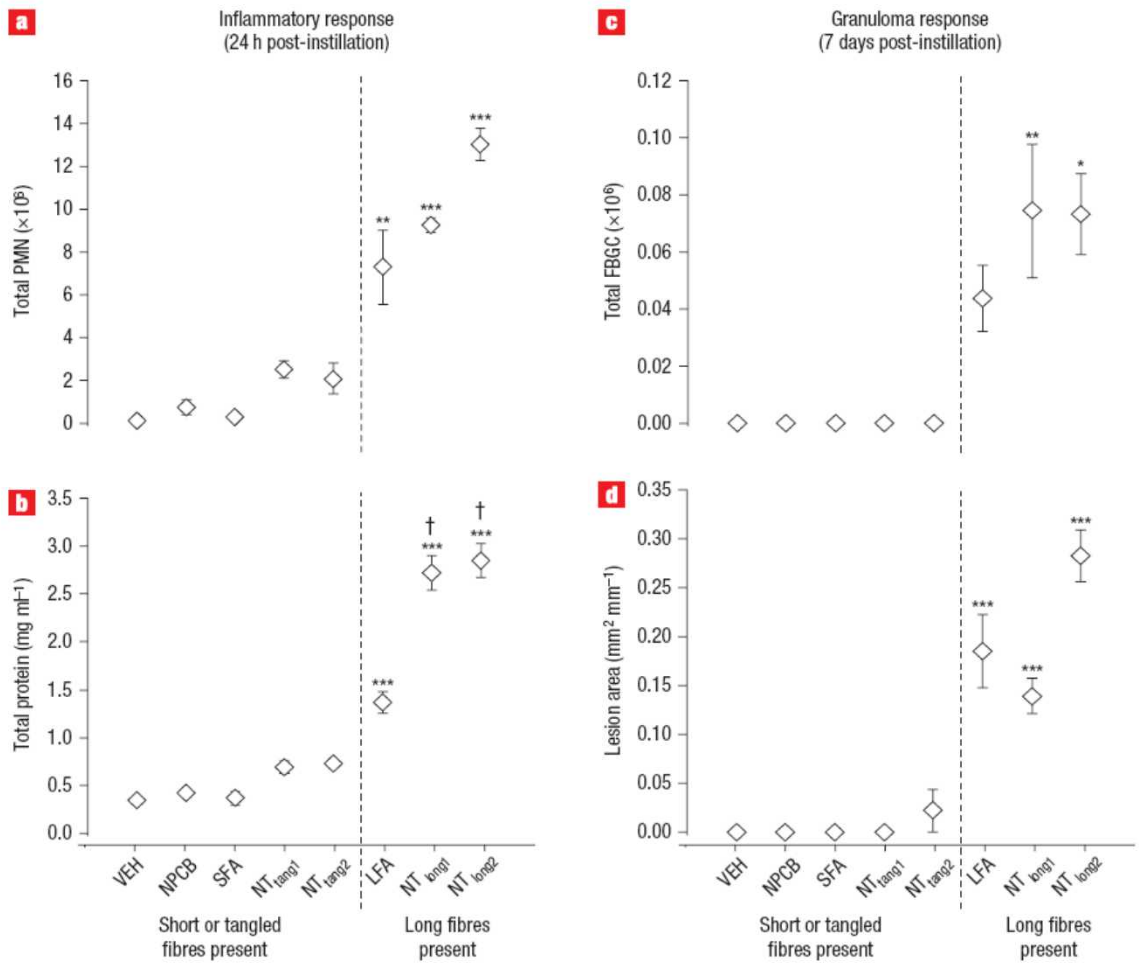
Biological Effect of Carbon Nanotubes



Poland et al., 2008, Nature Nanotechnology

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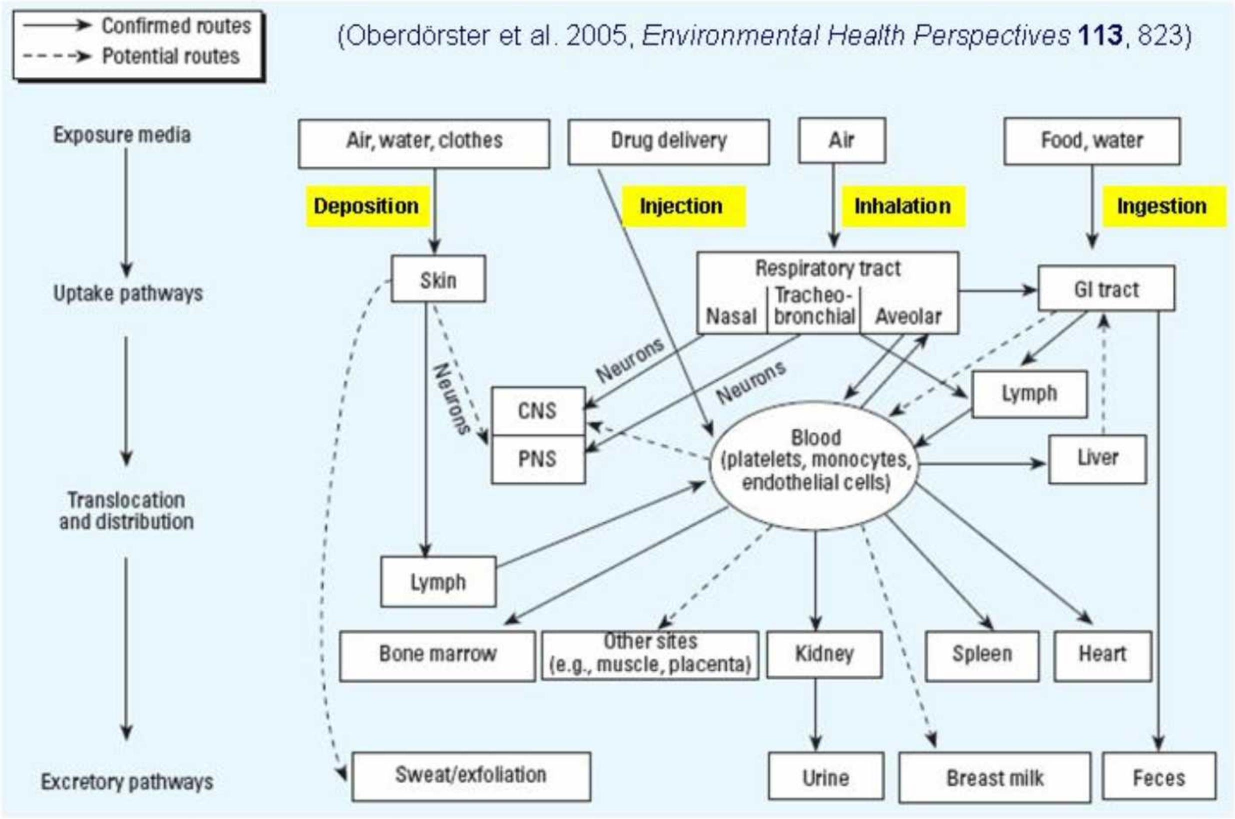
Nanotechnology and Human Health Impact



<u>Acute</u> - Contact with a substance that occurs once or for only a short time (up to 14 days)

<u>Intermediate</u> - Contact with a substance that occurs for more than 14 days and less than a year

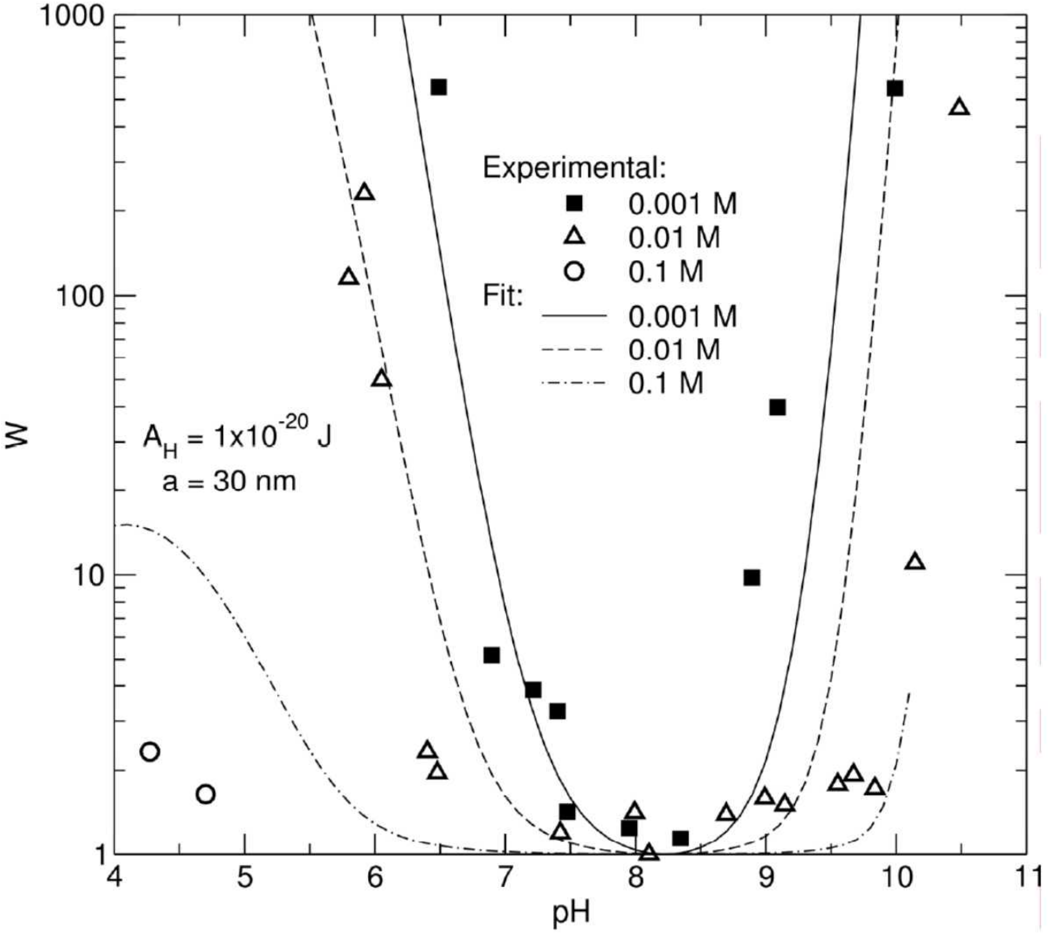
<u>Chronic</u> - Contact with a substance that occurs over a long time (more than 1 year)

Stability of Colloid Suspension

$$V_T = V_A + V_R$$

$$V_R = 2\pi e d_p \varsigma^2 e^{-\kappa h}$$

$$W = 2\int_0^\infty \frac{\exp(V_T / kT)}{a(h/a+2)^2} dh$$

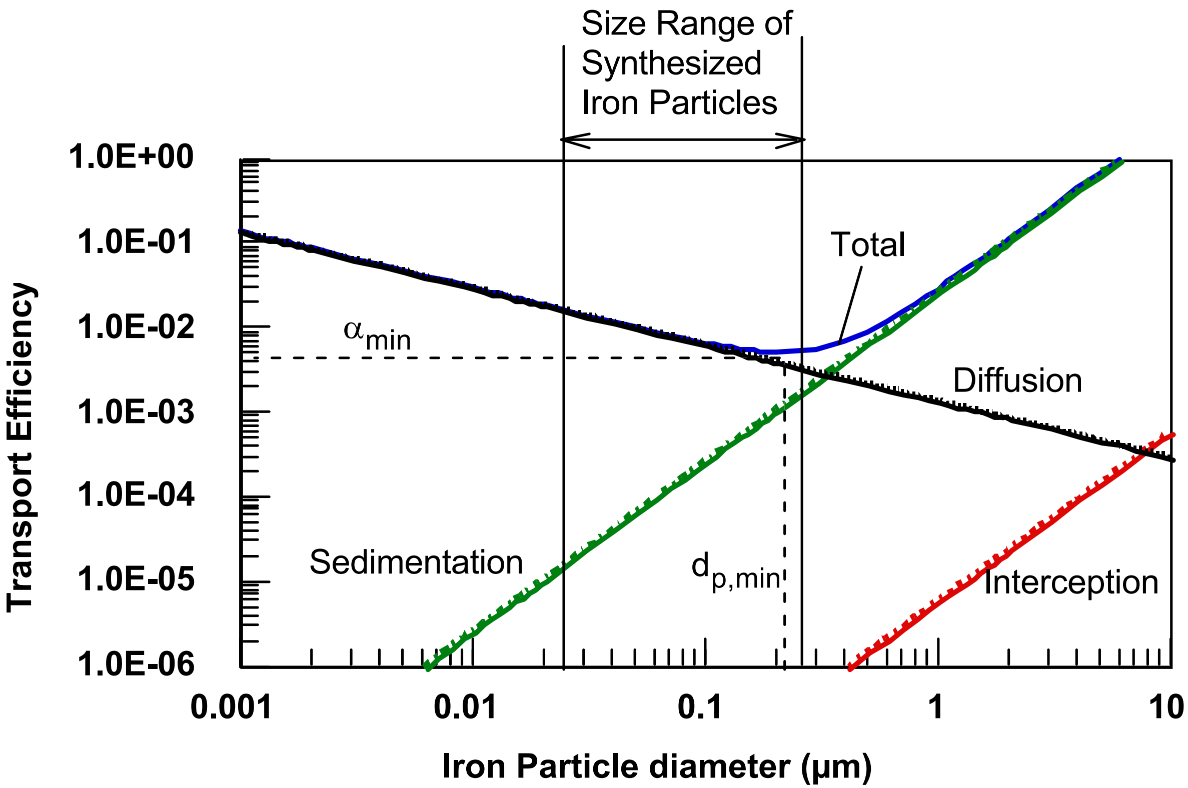


SNL, 2007

Colloid Transport & Filtration

$$\frac{dN}{dL} = -\frac{3}{2}\alpha\eta\frac{(1-\varepsilon)}{d_c}N$$

$$\alpha = f(pK_a, pH, \sigma \ldots)$$



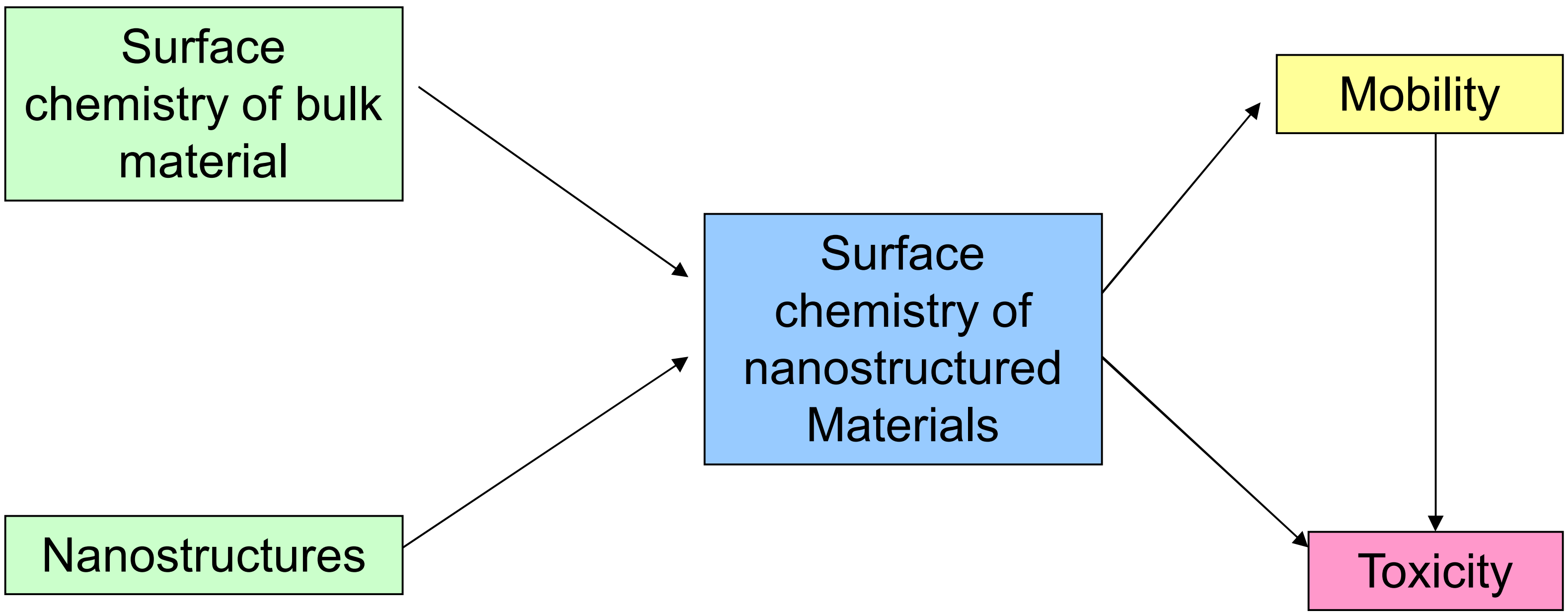
Zhang, per. Comm.

$$\eta = \eta_D + \eta_I + \eta_G = 0.9\left(\frac{kT}{\mu d_p d_c v}\right)^{\frac{2}{3}} + 1.5\left(\frac{d_p}{d_c}\right)^2 + \frac{(\rho_p - \rho)g d_p^2}{18\mu v}$$

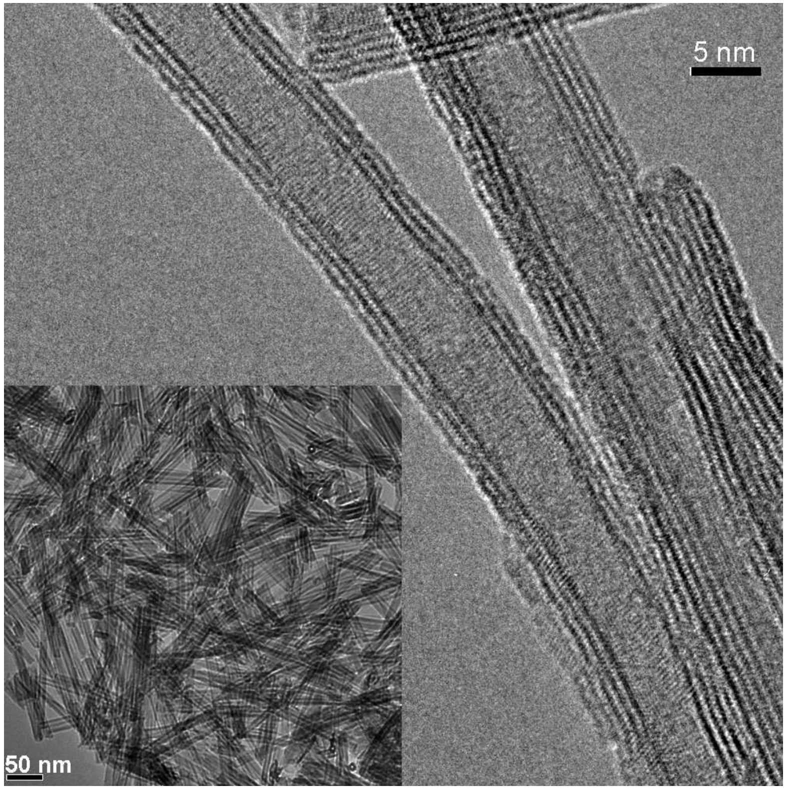
Technical Gaps for Evaluating the Impacts of Nanomaterials

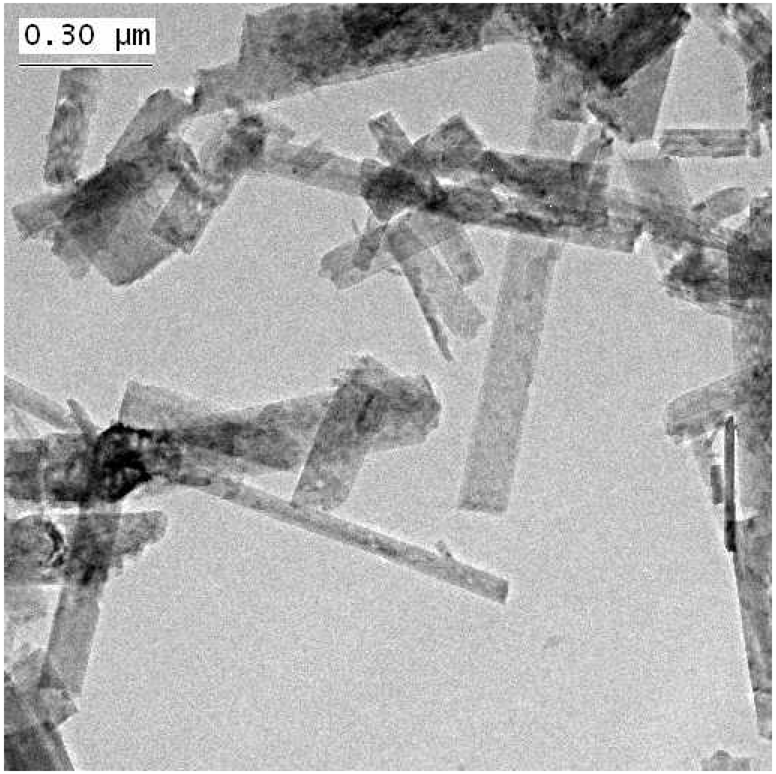
- The key factors controlling the mobility of nanomaterials are the chemical properties of particle surfaces including the point of zero charge (PZC), acidity constant, and sorption capability.
- These properties are also important for mechanistic understanding of the uptake, persistence, and biological toxicity of nanoparticles inside living cells.
- Given the number of new nanomaterials daily emerging, to determine their surface chemical properties individually is a formidable task, if not impossible.

Structure-Function Relationships



Synthesis of TiO_2 Nanotubes and nanorods





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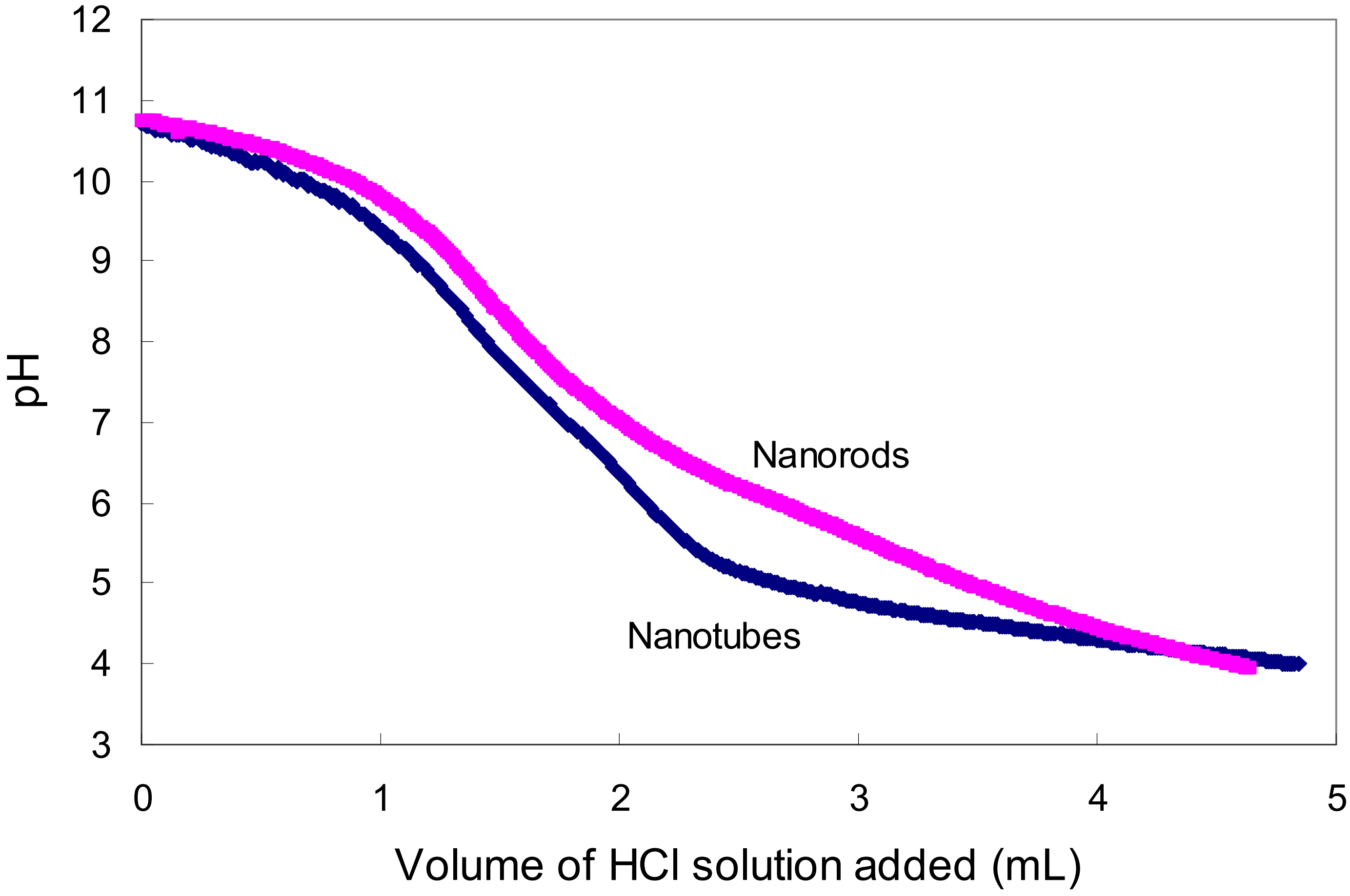
Titration Results



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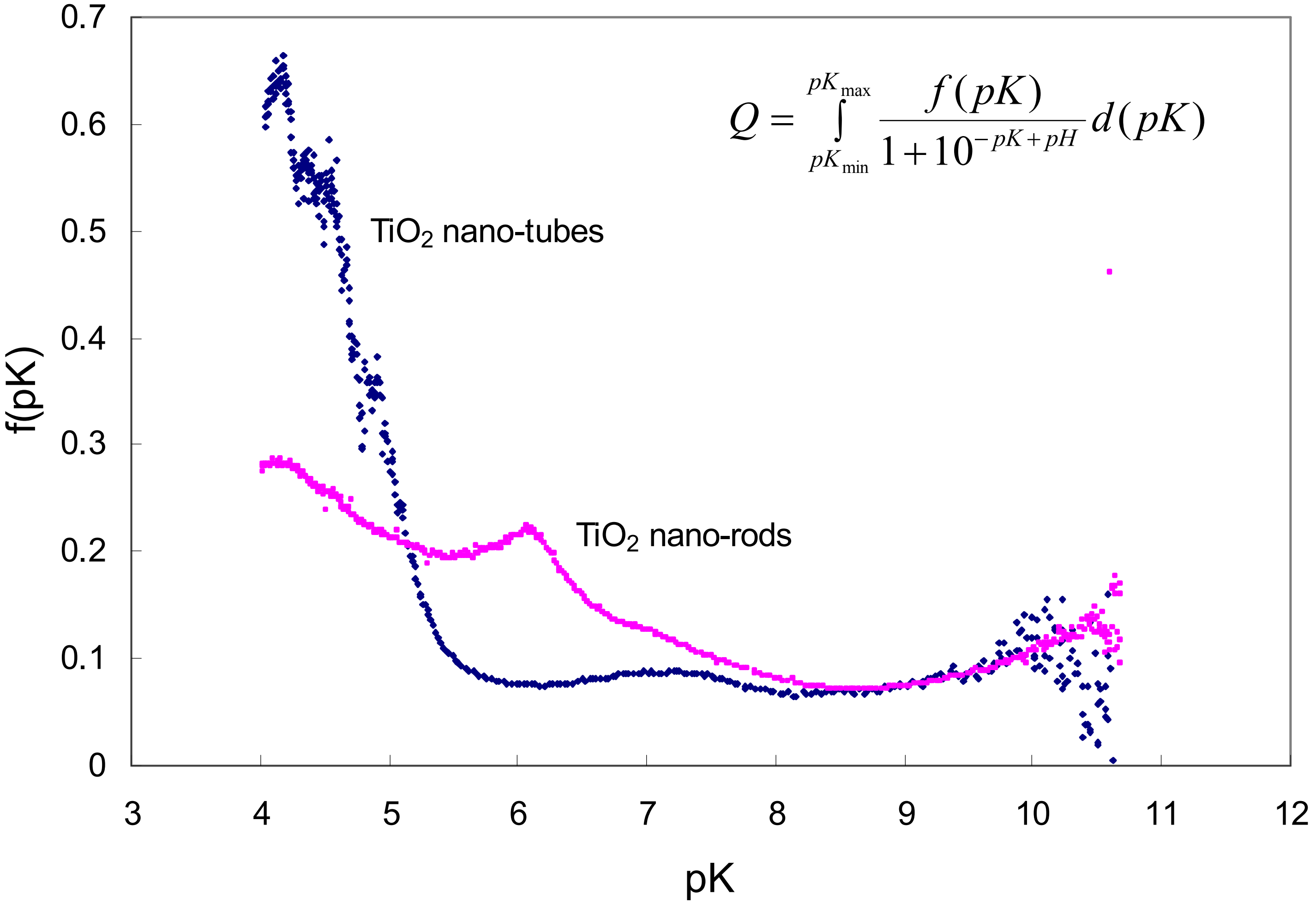
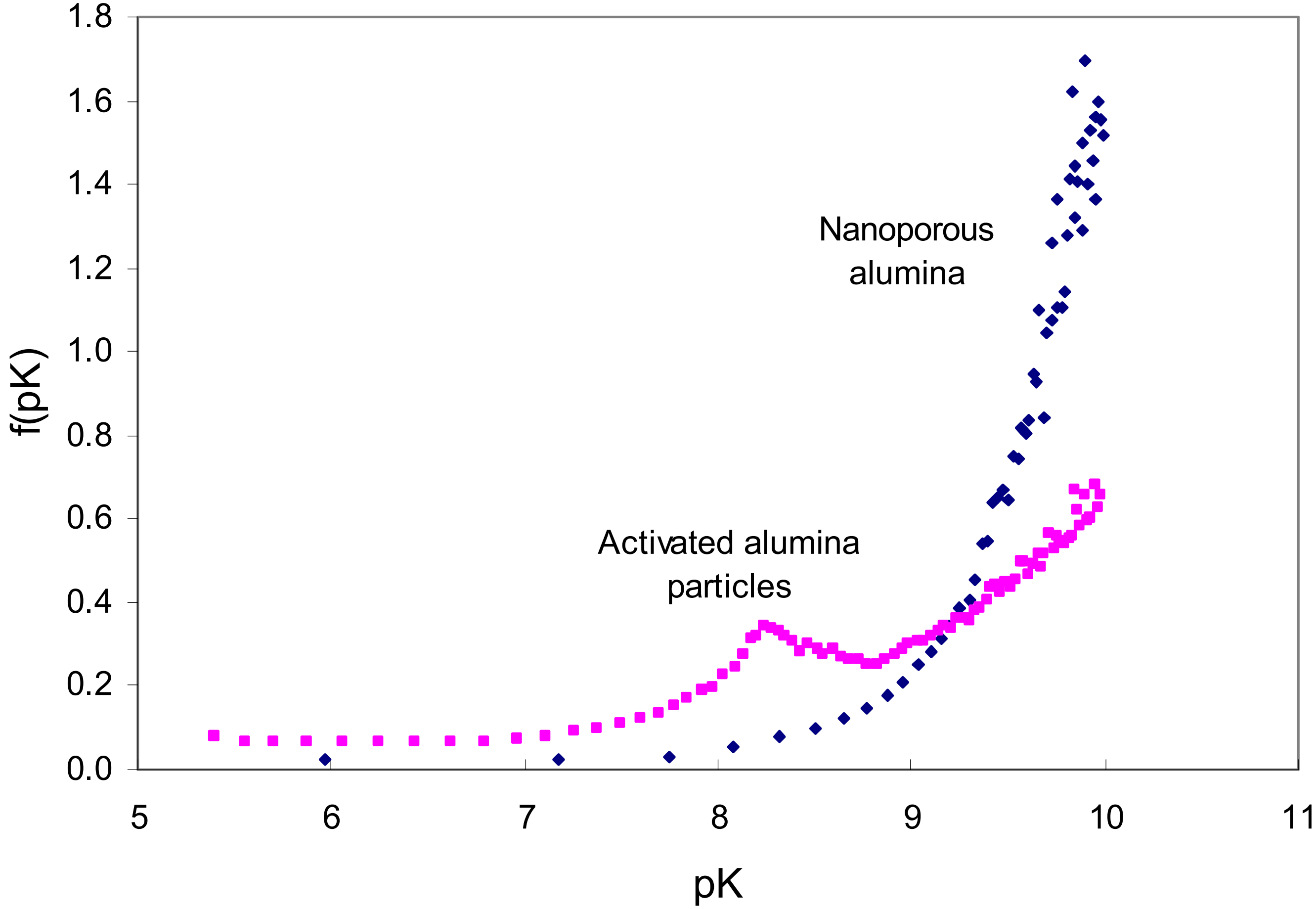
Distribution of Acidity Constant



Distribution of Acidity Constant



Concluding Remarks

- Like natural colloids, nanomaterials released into aquatic environments will experience a sequence of transformations including coagulation, settling, and filtration, which will ultimately control the bioavailability of these materials.

- The key factors controlling the mobility of these materials are chemical properties of particle surfaces including the point of zero charge (PZC), acidity constant, and sorption capability.

- It is possible to predict these properties based on the underlying nanostructures.