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Bioaccumulation and Ecotoxicity of Carbon Nanotubes

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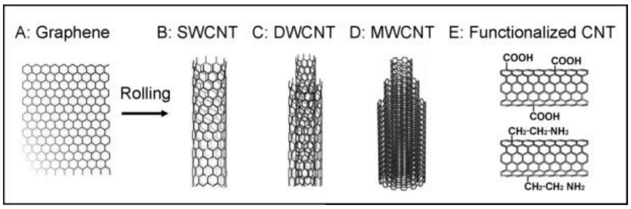
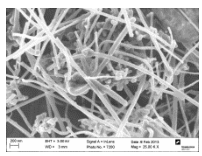


A)



B)

Figure 1.
A) Carbon nanotubes (CNT); Single-walled- (SWCNT); double-walled- (DWCNT); multi-walled- (MWCNT). Surface modification is achieved by adding functional groups to the CNT surface. Presented is carboxylation and amidation.
B) Scanning electron microscope image of pristine MWCNT NM-401 from OECD nanomaterial library.

INTRODUCTION

Carbon nanotubes (CNT) are thin, long hollow fiber-like nanomaterials composed of a single, double or multiple layers of rolled graphen. CNT provide a wide application potential, but pose unique toxicity. Pristine and functionalized CNT reside in water differently, and therefore pose different risks of exposure. Pristine CNT are hydrophobic and aggregate in water. Many CNT are therefore functionalized for better dispersion; or dispersants are used. Natural organic matter can also modify CNT and aid dispersion. The large specific surface area may accommodate pollutant adhesion and thus influence CNT toxicity in itself and/or toxicity of co-pollutants. A literature review has been performed.
(Jackson P *et. al.*, 2013 Chemistry Central Journal *in print*)

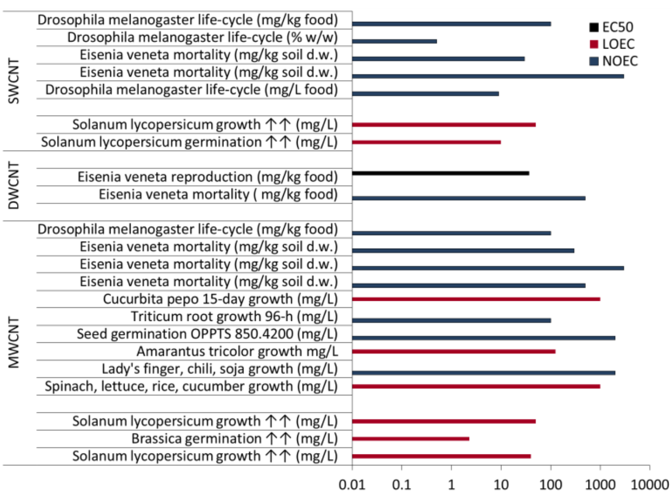


Figure 2.
Dose descriptors for terrestrial toxicity. Lowest EC50, LOEC, NOEC observed.

Table 1 CNT aquatic pelagic toxicity

		Extremely Toxic (<0.1 mg/L)	Very Toxic (0.1-1 mg/L)	Toxic (1–10 mg/L)	Harmful (10–100 mg/L)	Not Toxic (>100 mg/L)
SWCNT	invertebrates	X	X	X		
	vertebrates		X			X
DWCNT	invertebrates		X	X	X	
	vertebrates			X		X
MWCNT	invertebrates		X	X	X	
	vertebrates				X	X

The CNT aquatic toxicity classified according to the European Union Commission Guideline 93/67/EEC, introduced for nanoparticle toxicity by Blaze *et al*., Ecotoxicity of selected nano-materials to aquatic organisms. Environ Toxicol 2008, 23(5):591-598.

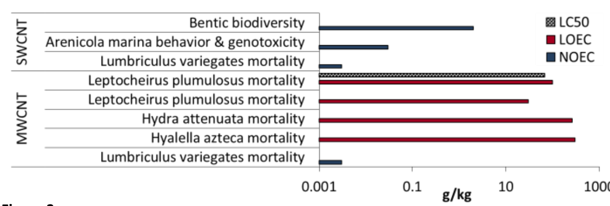


Figure 3.
Dose descriptors for aquatic benthic toxicity. Lowest LC50, LOEC, NOEC observed.

Conclusion

For the hazard assessment of ecotoxicological effects of CNT, the exposure scenario and exposure route have to be derived from the CNT usage. The surface modifications and dispersion method are important factors affecting toxicity. The reported effect concentrations are above current environmental concentrations. However, more robust data are needed for future estimates. Future studies with benchmark materials are required to clarify uncertainties about exposure/effect relationships. The exposure characterization is an essential part of result reporting.

RESULTS AND DISCUSSION

CNT do not cross biological barriers readily. When ingested, CNT are subsequently excreted. When internalized, only a minimal fraction translocates into other body compartments. Thus, bioaccumulation is limited; however organisms containing CNT or organisms with CNTs adhering to the outer surface may be a source of CNT in the food chain, potentially leading to biomagnification.

CNT toxicity depends on exposure, model organism, CNT type and dispersion state. Aquatic organisms are more affected than terrestrial organisms. Invertebrates are more sensitive than vertebrates, with SWCNT being more toxic than MWCNT. The CNT fiber shape, length, length/diameter ratio and dispersion affect toxicity. Direct mechanical effects are observed in plants, bacteria, and fish, were the CNT pierce and damage cells. Indirect mechanical effects are observed in algae, crustaceans and insects, where an interaction with the outer body surface occurs, leading to interference with growth and movement.