European Commission

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Nano and the Environment Workshop – Resource Saving Session – 31st March 2006 – Quantum Dot Nano-materials

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* The views expressed in this presentation are personal and may not necessarily reflect those of the European Commission.

Examples Nano-Materials

(Ron Hardman (2006), A Toxicologic Review of Quantum Dots (QDs): Toxicity Depends on Physicochemical & Environmental Factors, Environmental Health Perspectives, 114(2), pp.165-172)

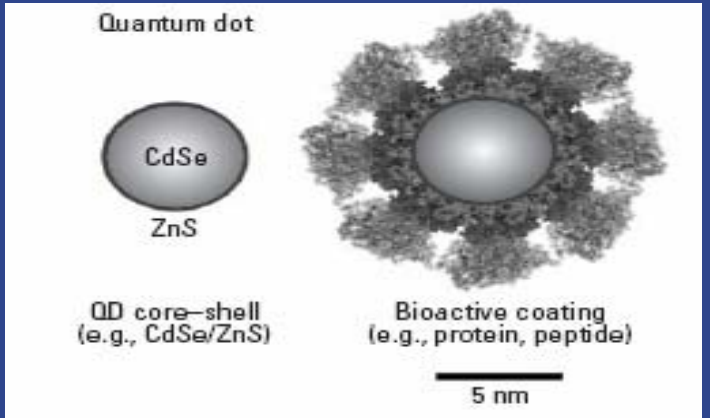

Figure 1. QDs consist of a metalloid core and a cap/shell that shields the core and renders the QD bioavailable. The further addition of biocompatible coatings or functional groups can give the QD a desired bioactivity.

Toxicology Aspects of Quantum Dots (QDs) Type Nano-Materials

(Ron Hardman (2006), A Toxicologic Review of Quantum Dots (QDs): Toxicity Depends on Physicochemical & Environmental Factors, Environmental Health Perspectives, 114(2), pp.165-172)

Table 1. Review articles summary of QD types, exposure concentrations, experimental conditions, and observed toxicity.

QD	Model	Exposure conditions/ administration	QD concentration	Exposure duration	Toxicity	Reference
CdSe/ZnS–SSA	EL-4 cells	1×10^6 cells/well	0.1–0.4 mg/mL	0–24 hr	Cytotoxic: 0.1 mg/mL altered cell growth; most cells nonviable at 0.4 mg/mL	Hoshino et al. 2004a
CdSe/ZnS–SSA	EL-4 cells	200 µL cell suspension injected (iv) into mice	0.1 mg/mL QDs per 5×10^7 cells	2 hr to 7 days	No toxicity in mice *in vivo*	Hoshino et al. 2004a
CdSe/ZnS conjugates: NH_2, OH, OH/COOH, H_2/OH, MUA, COOH	WTK1 cells	5×10^4 cells/mL	1–2 µM	12 hr	2 µM QD–COOH induced DNA damage at 2 hr DNA repair on prolonged incubation (12 hr)	Hoshino et al. 2004b
CdSe/ZnS–MUA	Vero, HeLa, and primary human hepatocytes	100 µL QDs/3×10^4 cells	0–0.4 mg/mL	24 hr	Cytotoxic: 0.2 mg/mL, Vero; 0.1 mg/mL, HeLa; 0.1 mg/mL, hepatocytes;	Shiohara et al. 2004
CdTe	Rat pheochromocytoma cells, murine microglial cells	1×10^5 cells/cm^2	0.01–100 µg/mL	2–24 hr	10 µg/mL cytotoxic	Lovric et al. 2005
CdSe–MAA, TOPO QDs	Primary rat hepatocytes		62.5–1,000 µg/mL	1–8 hr	Cytotoxic: 62.5 µg/mL cytotoxic under oxidative/photolytic conditions No toxicity on addition of ZnS cap	Derfus 2004
QD micelles: CdSe/ZnS QDs in (PEG–PE) and phosphatydilcholine	*Xenopus* blastomeres	5×10^9 QDs/cell (~ 0.23 pmol/cell)	1.5–3 nL of 2.3 µM QDs injected, ~ 2.1×10^9 to 4.2×10^9 injected QDs/cell	Days	5×10^9 QDs/cell: cell abnormalities, altered viability and motility No toxicity at 2×10^9 QDs/cell	Dubertret et al. 2002
CdSe/ZnS amp-QDs, and mPEG QDs	Mice	200-µL tail vein injection	Injections; ~ 180 nM QD, ~ 20 pmol QD/g animal weight	15 min cell incubations, 1–133 days *in vivo*	No signs of localized necrosis at the sites of deposition	Ballou et al. 2004
CdSe/ZnS–DHLA	*Dictyostelium discoideum* and HeLa cells		400–600 nM	45–60 min	No effects on cell growth	Jaiswal et al. 2003
Avidin-conjugated CdSe/ZnS QDs	HeLa cells		0.5–1.0 µM	15 min	No effect on cell growth, development	Jaiswal et al. 2003
CdSe/ZnS–amphiphilic micelle	Mice	Tail vein injection	60 µM QD/g animal weight, 1 µM and 20 nM final QD concentration	Not given	Mice showed no noticeable ill effects after imaging	Larson et al. 2003
CdSe/ZnS–DHLA QDs	Mice, B16F10 cells	5×10^4 B16F10 cells with 10 µL QDs (~ 10 pmol), tail vein (iv) injection	100 µL of B16F10 cells used for tail vein injection, ~ 2×10^5 to 4×10^5 cells injected	4–6 hr cell incubation, mice sacrificed at 1–6 hr	No toxicity observed in cells or mice	Voura et al. 2004
CdSe/ZnS–MUA QDs; QD–SSA complexes	Vero cells	0.4 mg/mL	0.24 mg/mL	2 hr	0.4 mg/mL MUA/SSA–QD complexes did not affect viability of Vero cells	Hanaki et al. 2003
CdSe/ZnS	HeLa cells	1×10^6 cells	10 pmol QDs/1×10^5 cells (~ 10 nM)	10 days (cell culture)	10 nM QD had minimal impact on cell survival	Chen and Gerion 2004

✓ **QDs absorption, distribution, metabolism, excretion, & toxicity depends on various inherent physico-chemical properties & environmental conditions: *size, charge, concentration, outer coating, bioactivity (capping material & functional groups), oxidative, photolytic, exposure duration, & mechanical stability*.**

Toxicology Aspects of Quantum Dots (QDs) Type Nano-Materials <-> Stability Issues

(Ron Hardman (2006), A Toxicologic Review of Quantum Dots (QDs): Toxicity Depends on Physicochemical & Environmental Factors, Environmental Health Perspectives, 114(2), pp.165-172)

Influences of different QDs coatings on stability & toxicity:

- Coating with ***high molecular mass (100 kDa) co-polymer & a grafted 8-carbon alkyl side chain*** demonstrated greater *in vivo* stability than those with simple polymer & amphilphilic lipid coatings.
- ***Silica coating*** can lead to no observable genotoxicity because of the prevention of interaction of Cd, Se, Zn & S with proteins & DNA in nuclei.
- ***Removal of tri-n-octylphosphine oxide (TOPO) type coatings*** is important to reduce cycto-& genotoxicity.