Potential risks of nanotechnology to humans and the environment: implications and response mechanisms in Africa

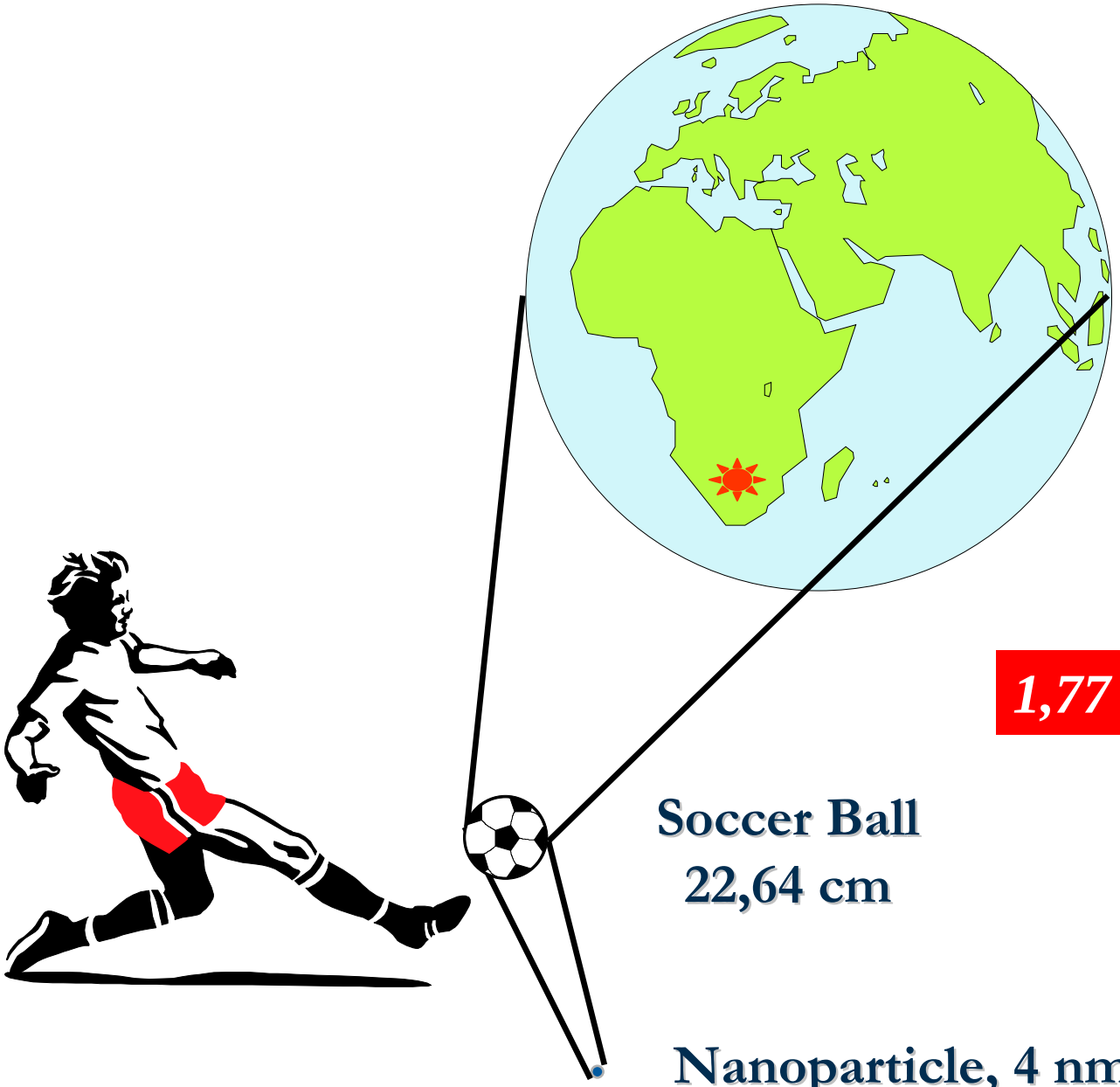
Ndeke Musee, Lucky Sikhwivhilu, Nomakhwezi Nota, Lisa Schaefer

Corresponding author: museen2001@yahoo.com or nmusee@csir.co.za

1st South Africa Nanoscience and Nanotechnology Summer School

Pretoria, South Africa, 22nd NOV– 2nd DEC 2009

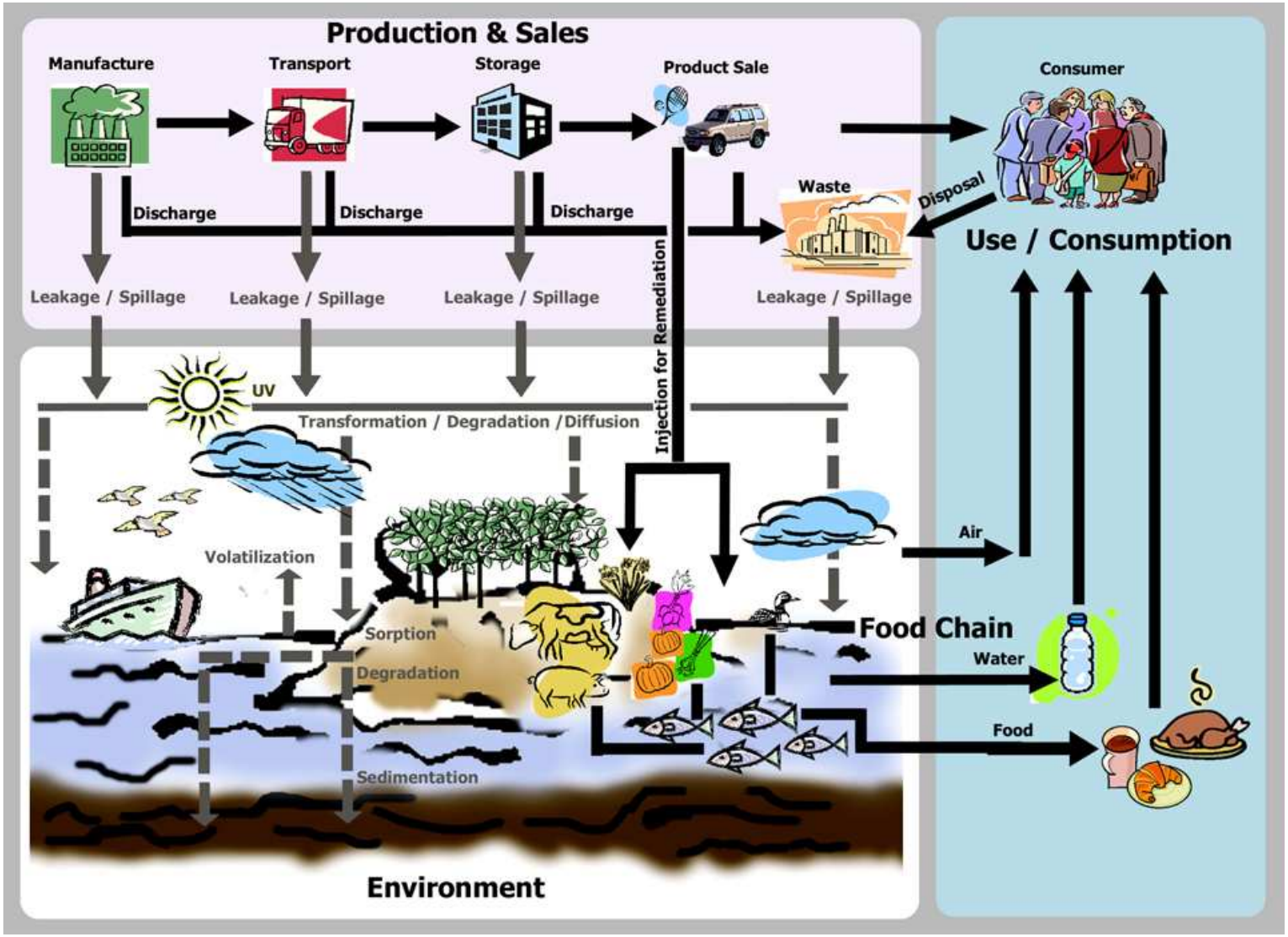
our future through science



N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

CSIR
our future through science

Life cycle and exposure pathways of ENMs

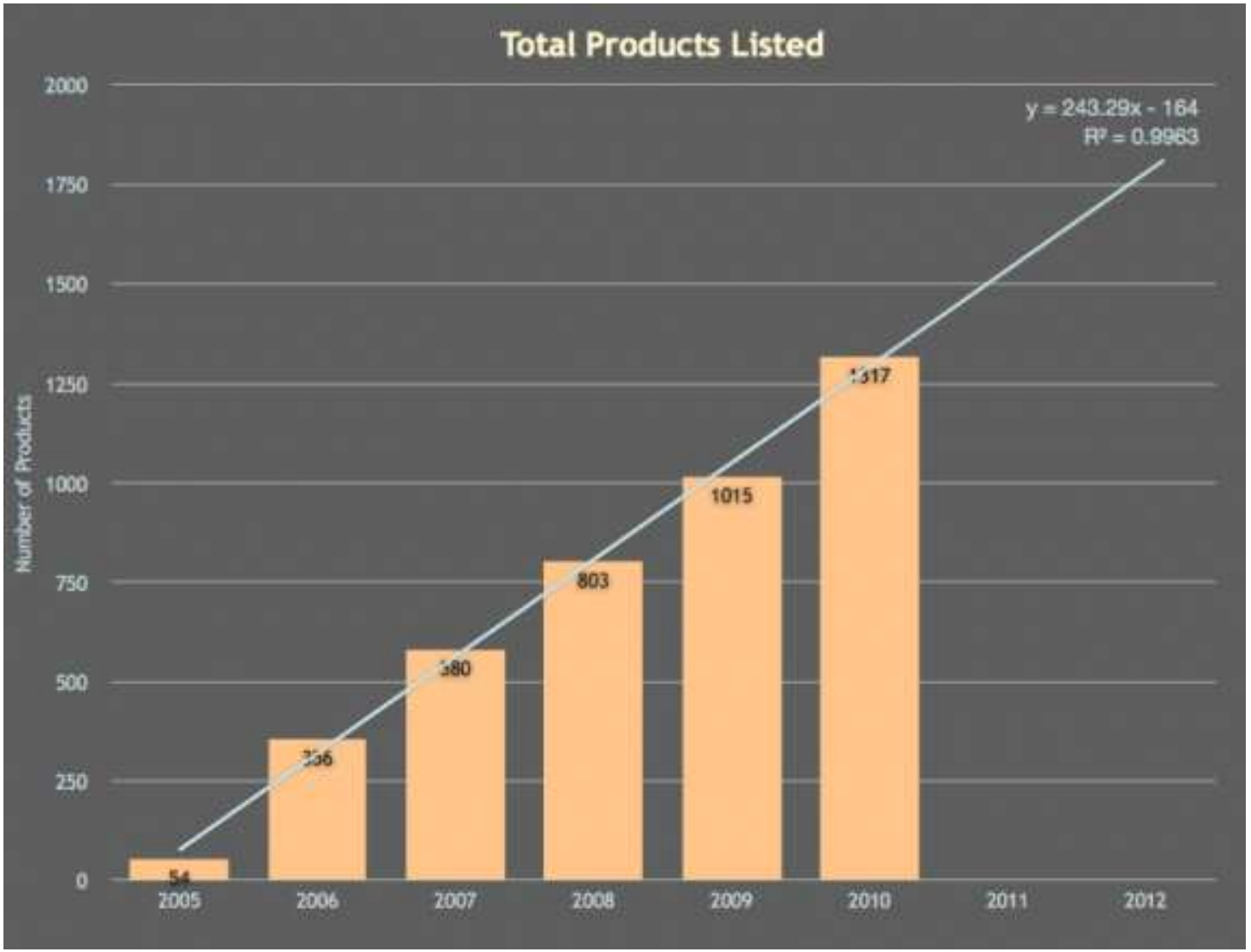


Source: Friedrick s and Schulte, 2007, Science and Technology of Advanced Materials

N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

CSIR
our future through science

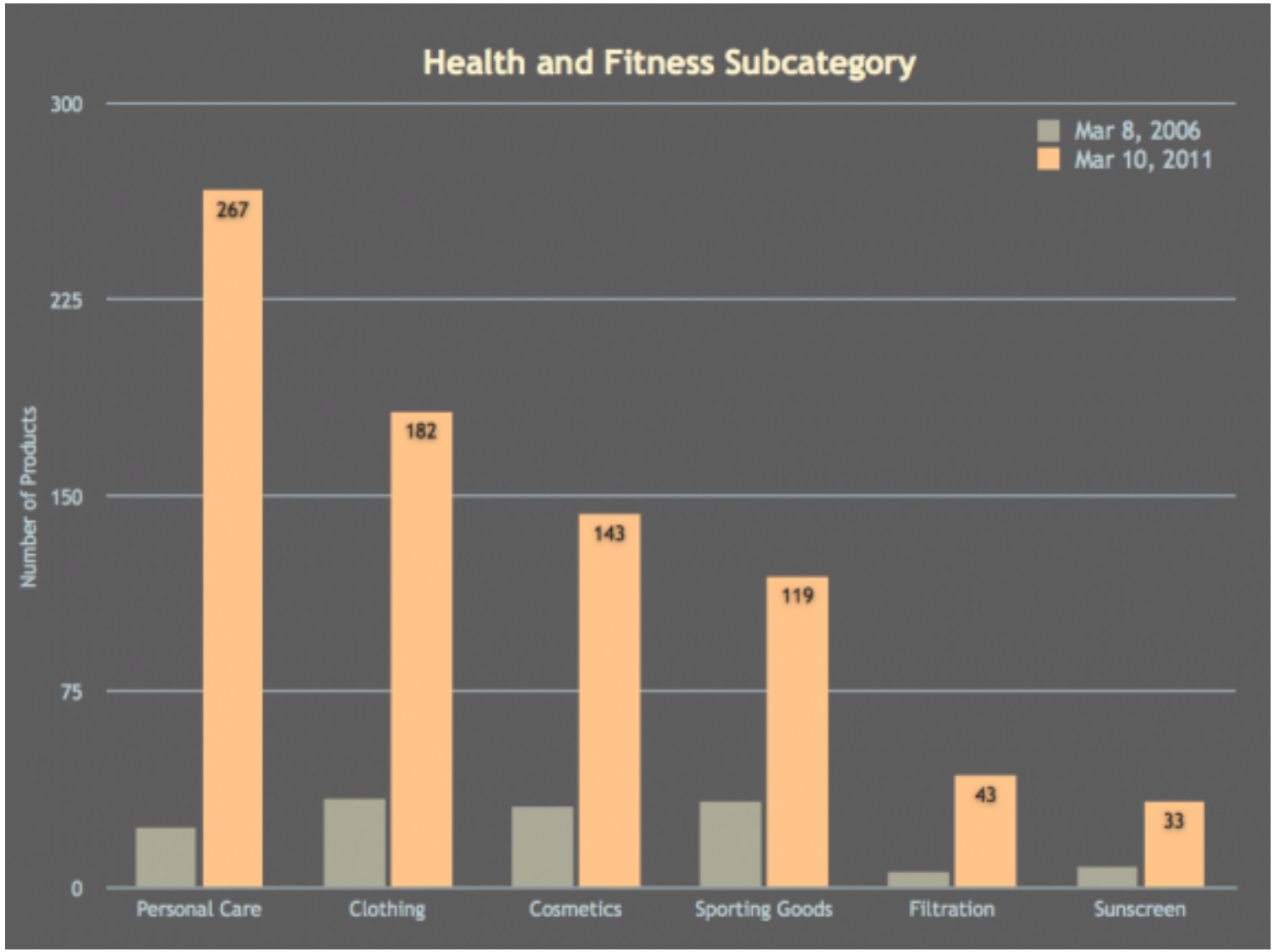
Nanoproducts in Global Markets



N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

CSIR
our future through science

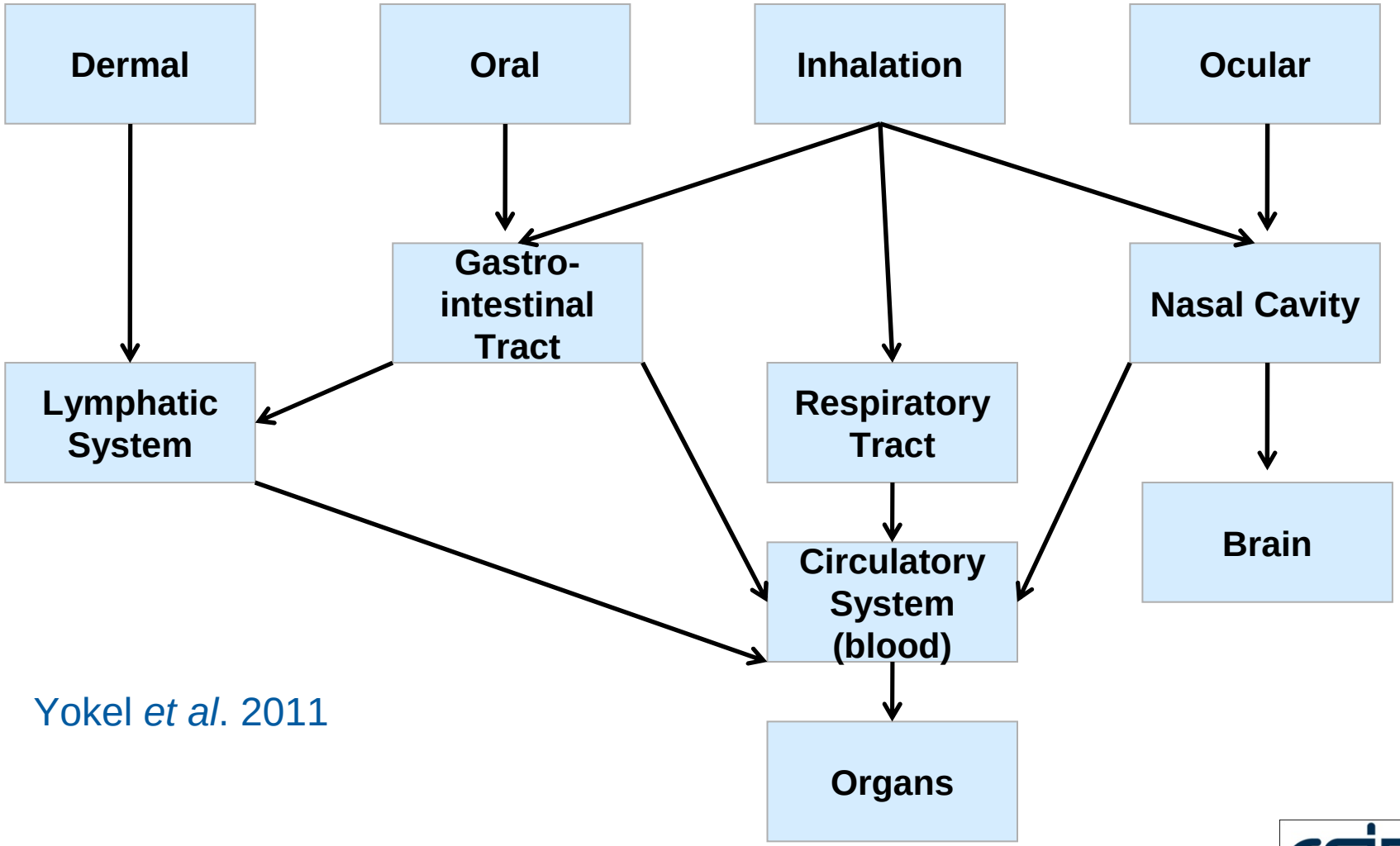
Nanoproducts: Categories



N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

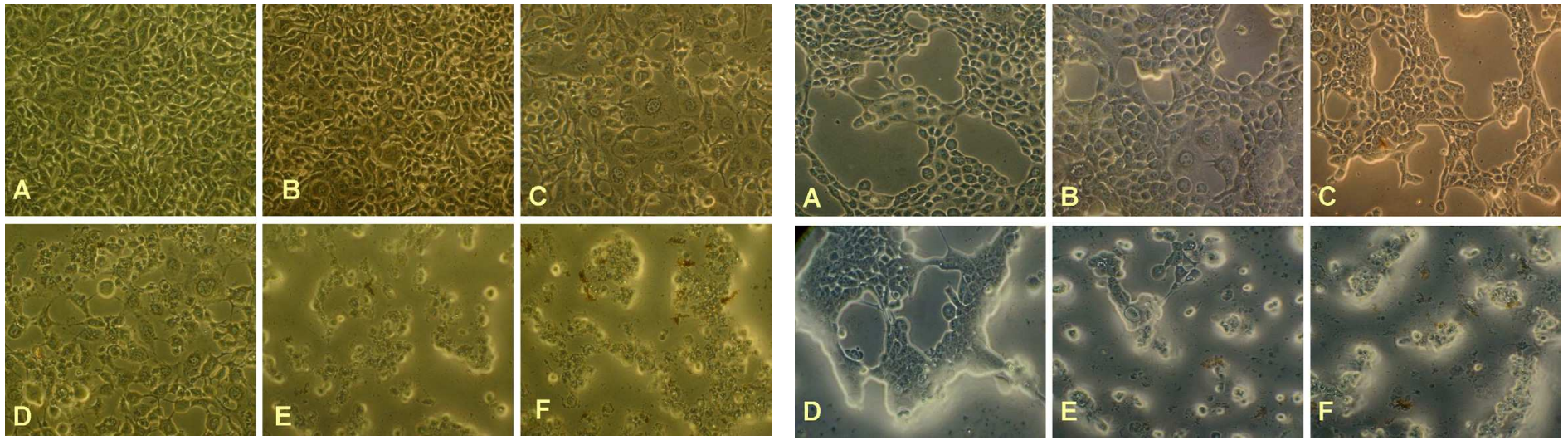
CSIR
our future through science

ENM exposure routes, uptake and potential translocation



Yokel *et al*. 2011

Toxicity of nAg to human fibrosarcoma cells and human skin/carcinoma cells



- **Phase-contrast micrographs of human fibrosarcoma cells (left) and human skin/carcinoma cells (right). (A) unexposed cells; (B–F) 24 h after exposure to 3.12, 6.25, 12.5, 25 & 50 µg/mL nAg respectively (magnification 200×).**

- **At higher concentrations cells became less polyhedral, more fusiform, shrunken and rounded showing concentration dependent toxicity**

Arora et al., T*oxicol. Lett.* 2008, *179*, 93-100.

Cytopathology of MWCNT for lung tumour cells

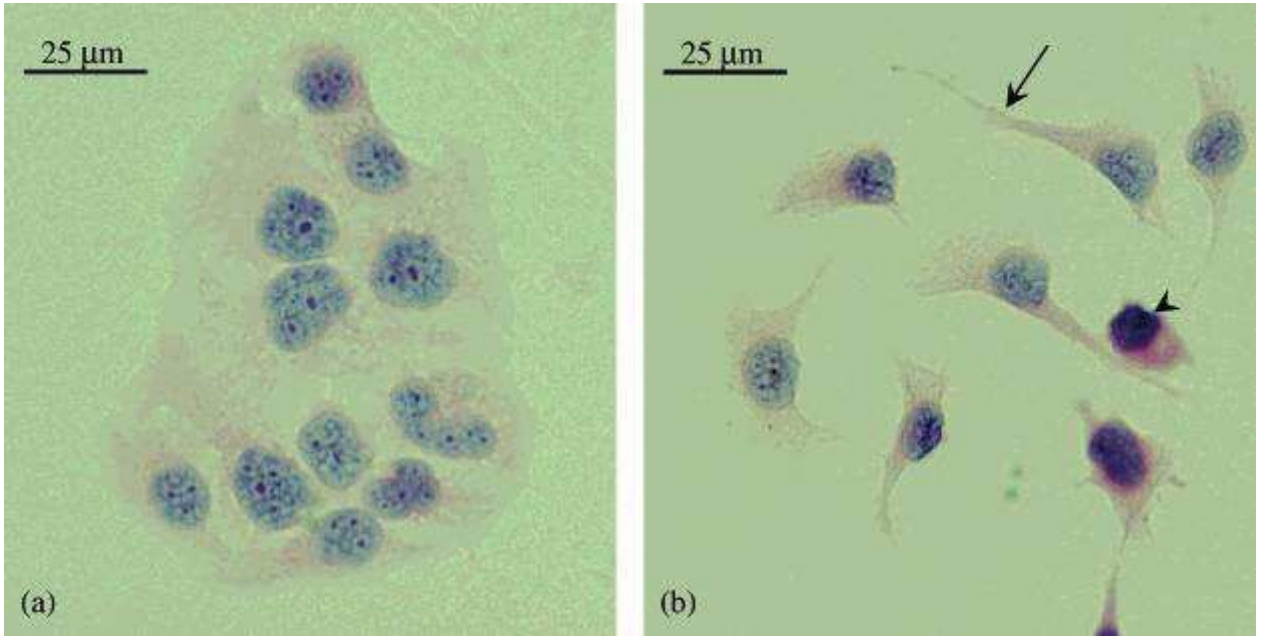


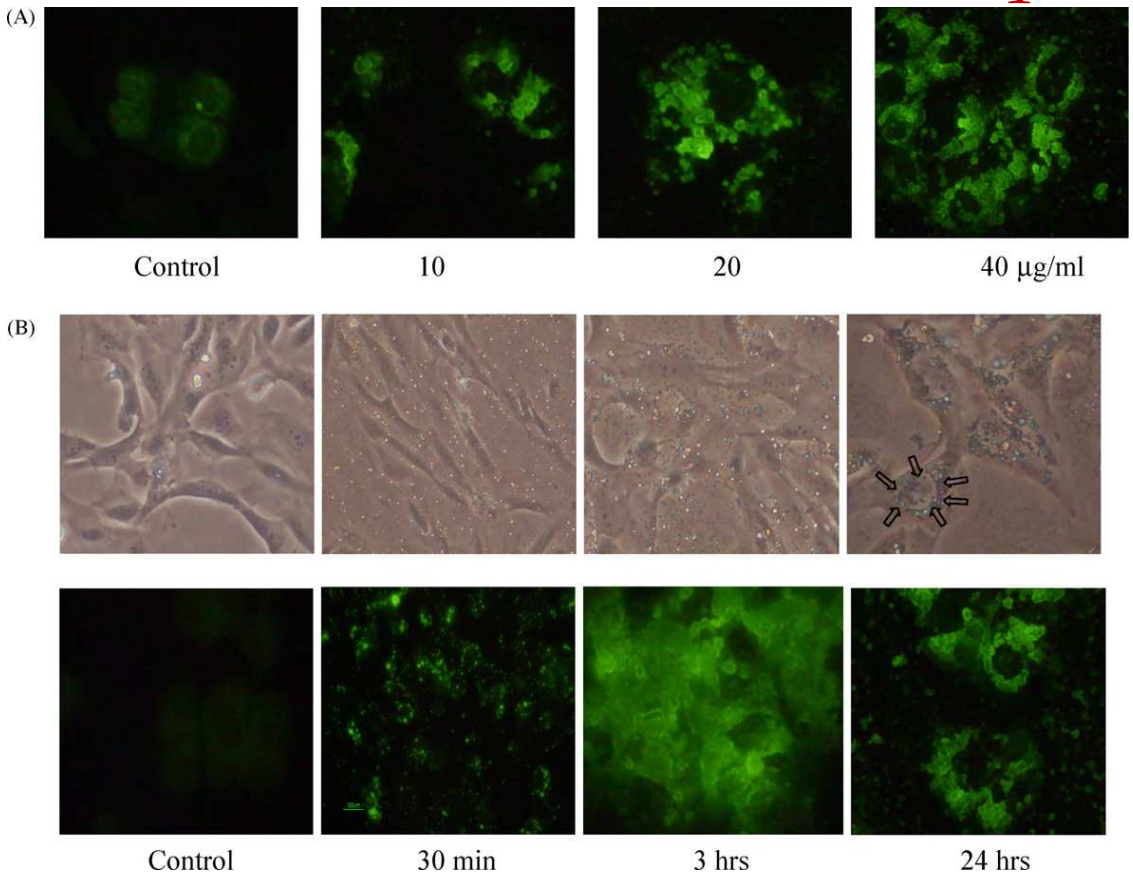
Figure 2. (a) Control of lung tumour cells (stained with hematoxyline-eosine)

- The nuclei appear purple and patchy, the cytoplasm is weekly stained (pink).
- Clusters of cells are characterized by close cell/cell contacts.

(b) Lung tumour cells after 1 day treatment with 0.02 µg/mL with MWCNT.

- Cells have lost their mutual attachments, retracted their cytoplasm (arrows)
- Nuclei are smaller and more condensed (picnotic) shown by the stronger purple staining. *(Magrez et al. 2006)*

ROS generation by titanium dioxide nanoparticles in human bronchial epithelial cells



Cells cultured with nano TiO_2 (10, 20 and 40 µg/ml) showed induction of ROS (fluorescence) in a concentration- and time-dependent manner, compared to the control (A and B).

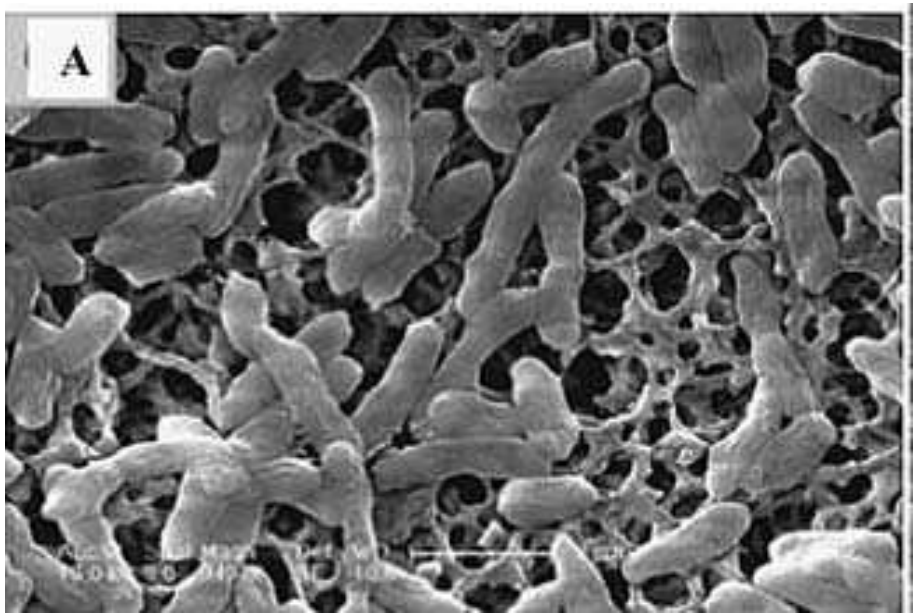
The induction of ROS was correlated with the amount and position of nano TiO_2 which entered the cells (B).

Nano TiO_2 appeared to penetrate the cytoplasm, and were located in the peri-region of the nucleus as aggregated particles.

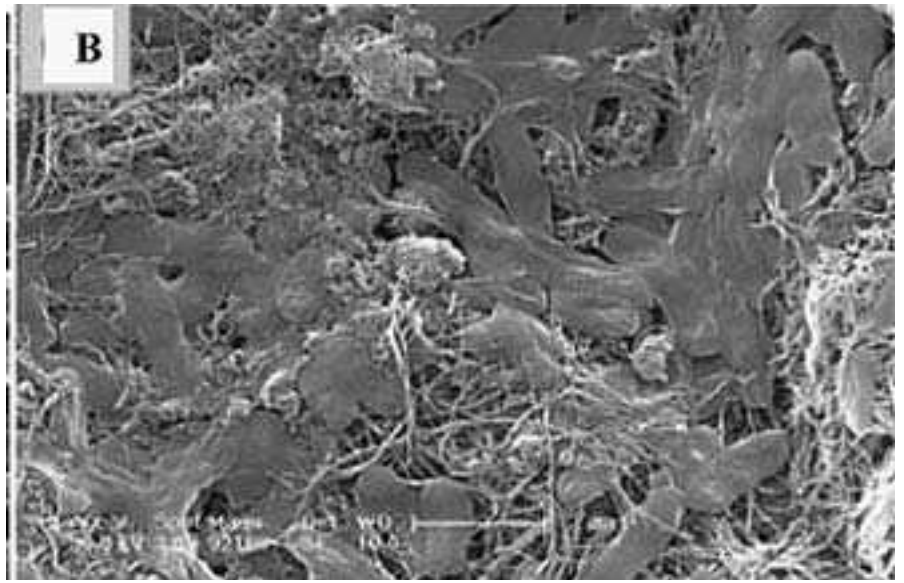
Visualization of ROS generation (using DCF staining)

Park *et al*. 2008

Effect of SWCNT on Eschericia coli



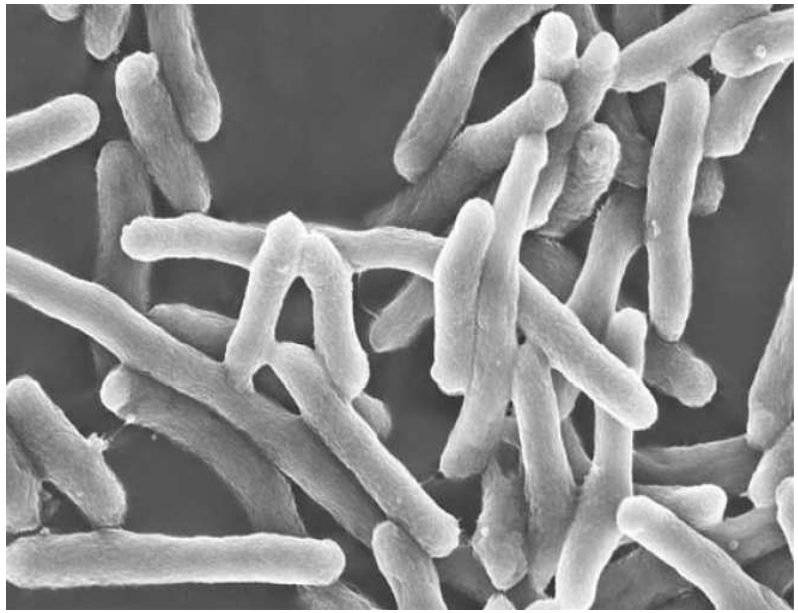
(a) SEM image of *E. Coli* incubated without SWCNTs for 60 min.

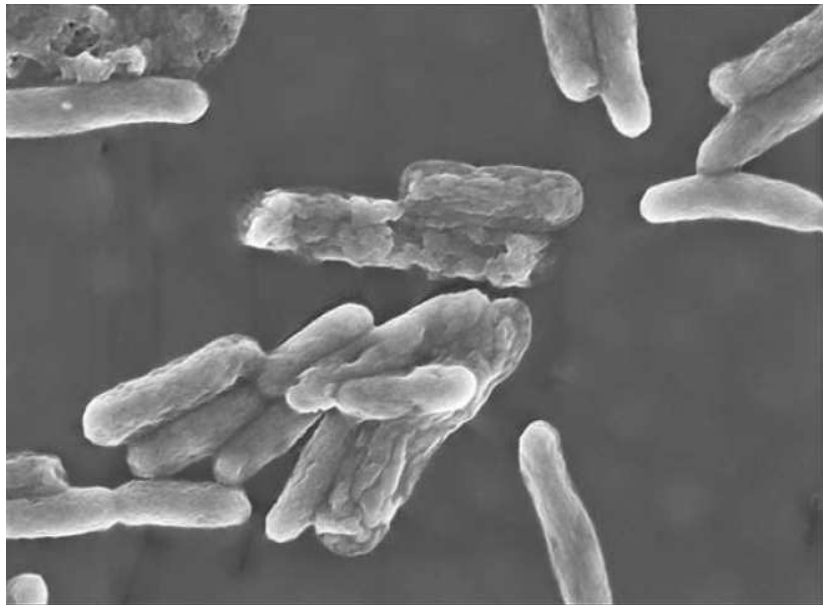


(b) SEM image of *E. Coli* incubated with SWCNTs for 60 min.

[Source: Kang et al. / Langmuir 2007, 23, 8670-8673]

Effect of ZnO nanoparticles on Eschericia coli





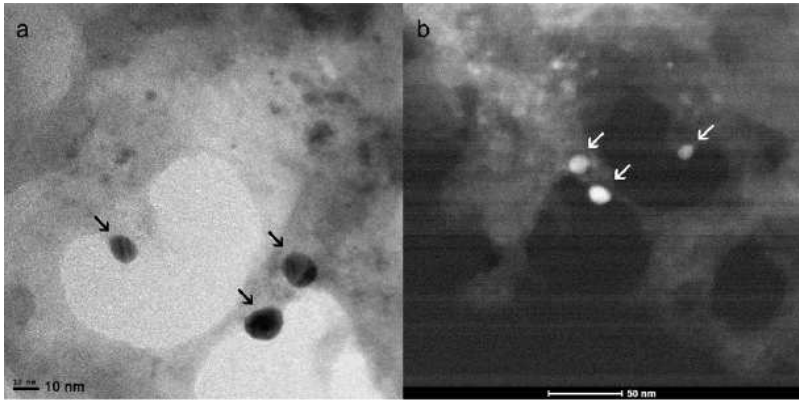
SEM images of *E. coli*:

(1)before antibacterial tests

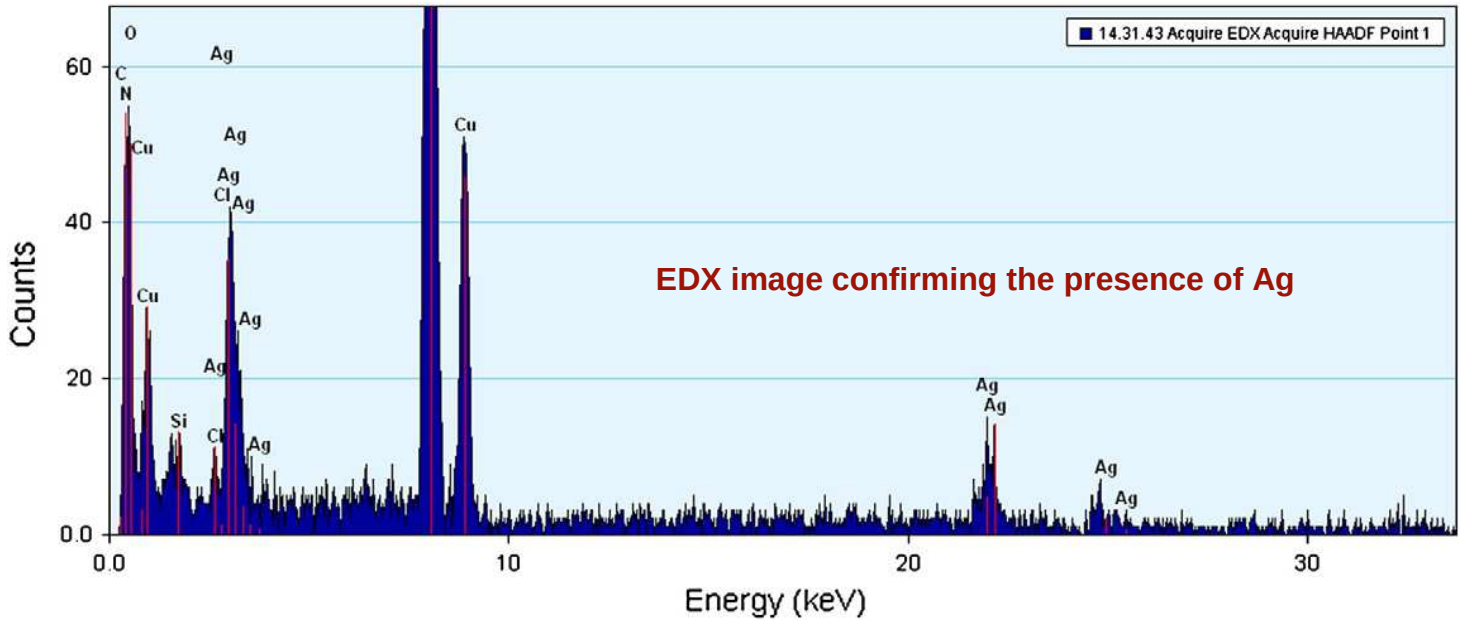
(2) after treatment with 0.2% ZnO nanofluids for 5 h.

[Source: Zhang et al. /Journal of Nanoparticle Research (2007) 9:479–489]

Evidence of ENMs in actual environmental systems

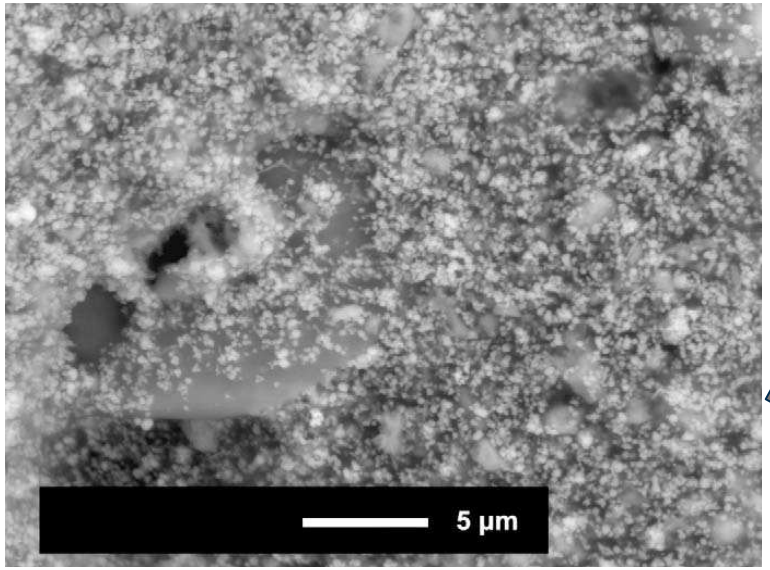


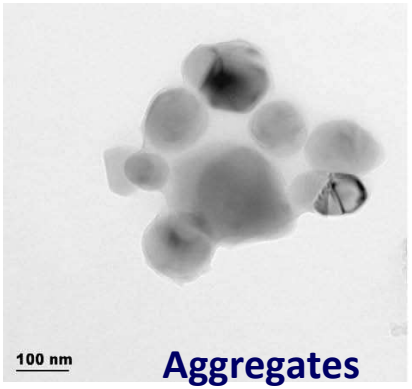
Average nAg size in the effluent was about 10 nm measured with TEM and STEM (St dev=3.2 nm, range 5–18 nm; n=26). The particles were spherical or irregular. TEM (a) and high angle annular dark field (HAADF) images (b) of the nanoparticles (black and white arrows) in the washing machine effluent.

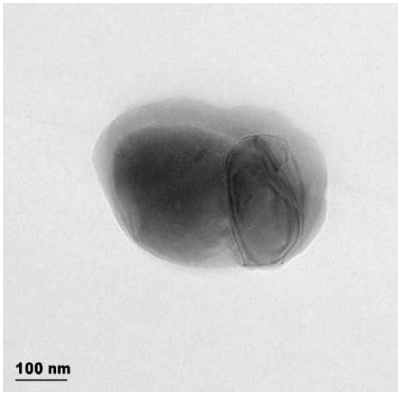


Farkas. et al. Environ. Int. (2011).

CSIR
our future through science

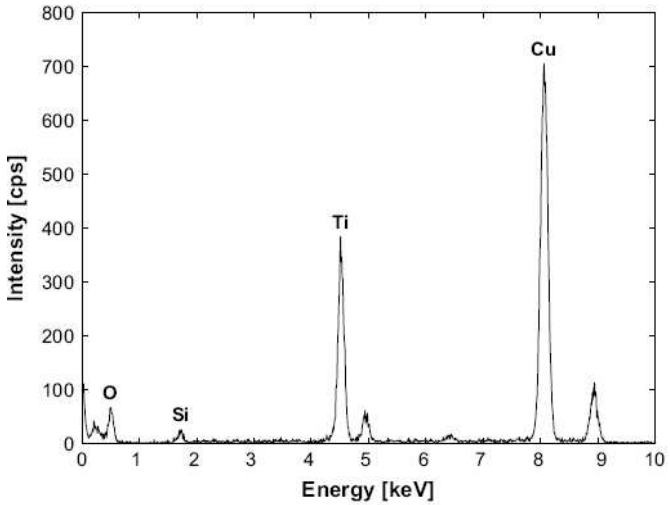






TEM bright field image of $nTiO_2$ from the runoff of the new facade

SEM-BSE image of the aged façade (white spots represent $nTiO_2$ particles.

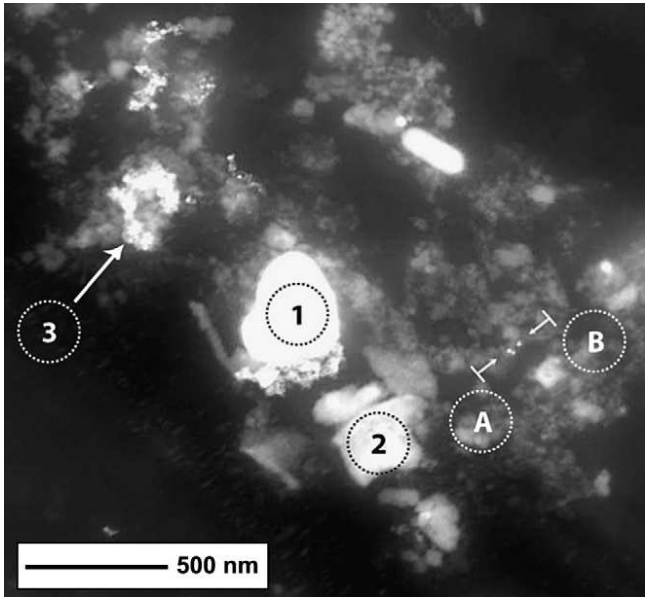


TEM-EDX of TiO_2 particles detected in the runoff of the aged facade.

Synthetic $nTiO_2$ within a size range of a few tens to a few hundreds of nm in diameter were successfully detected and identified in the environment using a combination of analytical electron microscopy (TEM-EDX) and bulk chemical (ICP-MS) methods.

Kaegi et al. Environ. Poll. 156 (2008) 233–239

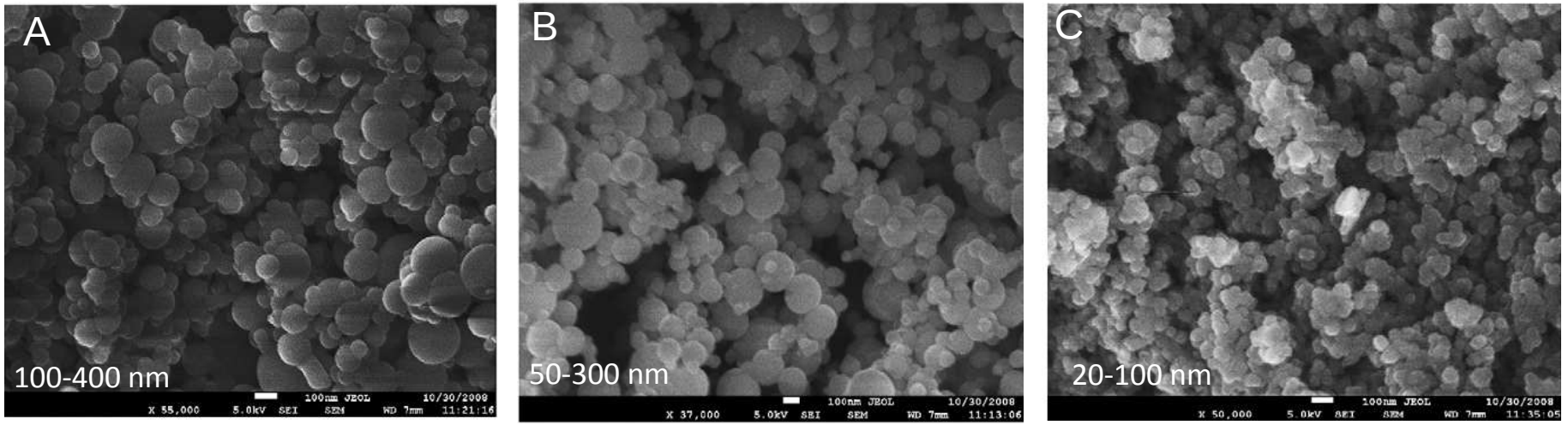
Model house with panels with the Ag-NP paint



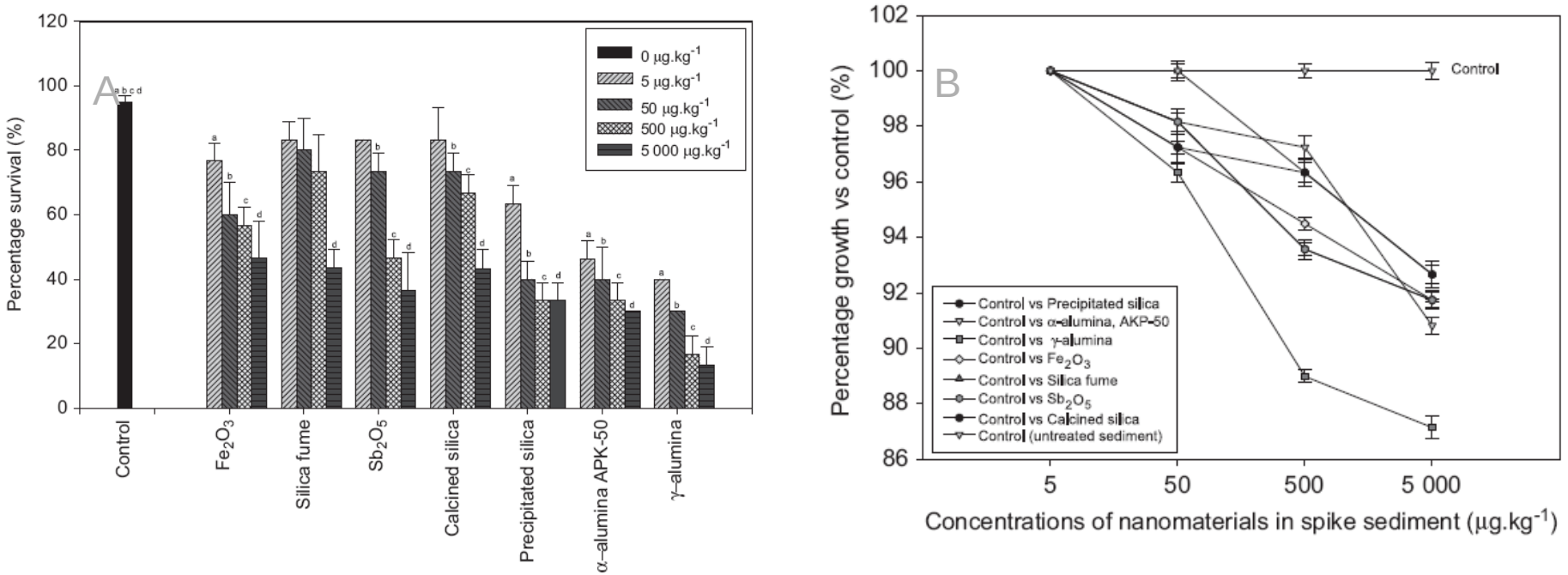
TEM image (HAADF-STEM) of the Ag-NP

- Findings provide first direct evidence for the release of Ag-NP from a typical outdoor application to the aquatic environment.
- About 30% of the Ag-NP initially contained in the paint were lost within one year of exposure
- Ag-NP were attached to an organic binder from the paint and released mostly as composite colloids.
- Microscopic findings clearly showed the difficulties encountered in detecting or monitoring ENMs in the environment

Kaegi et al. Environmental Pollution 158 (2010) 2900 – 2905



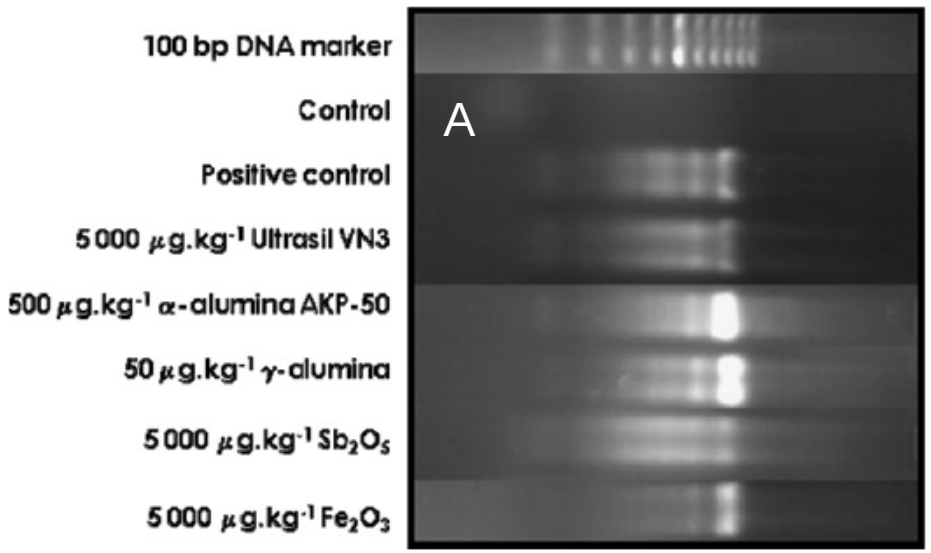
SEM images of: A: Silica fume, B: Calcined silica fume, and C: precipitated silica fume

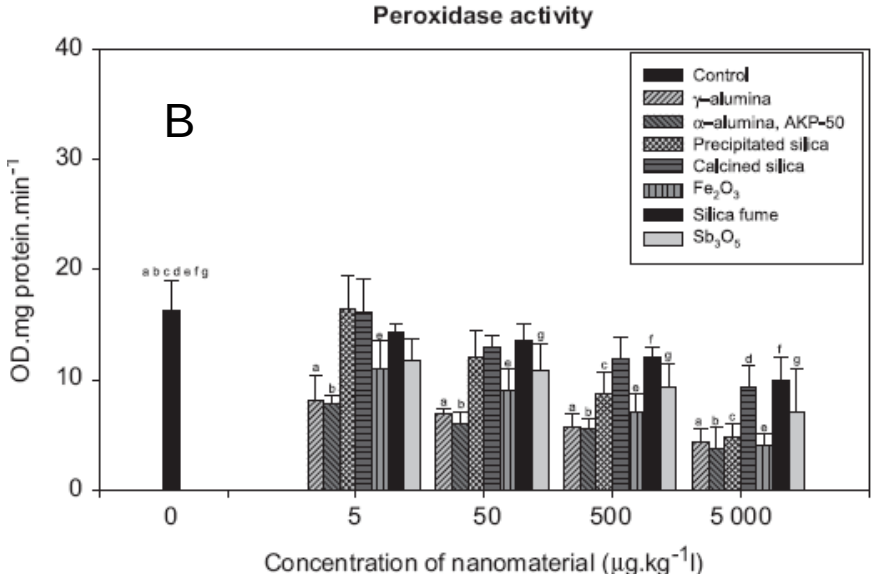


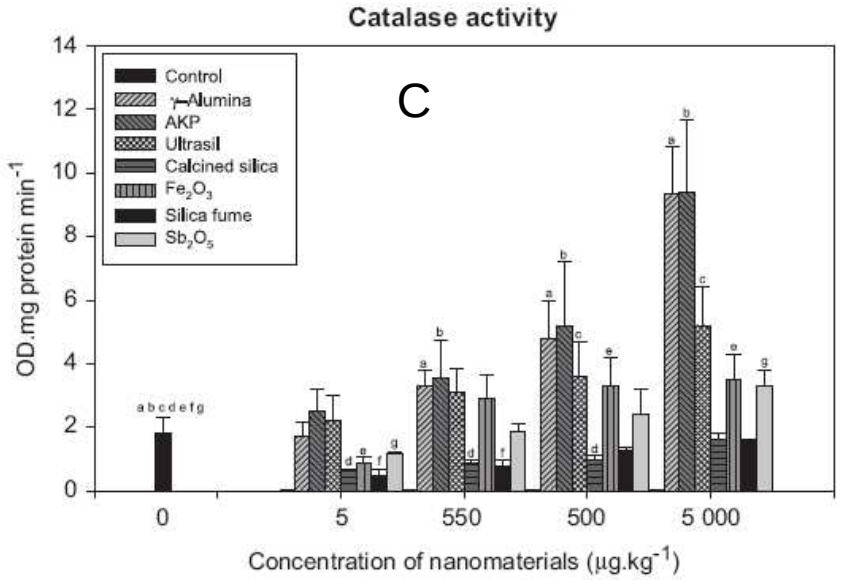
Effects of ENMs on percentage survival (A) and growth inhibition percentage (B) of *C. tentans*

N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

CSIR
our future through science





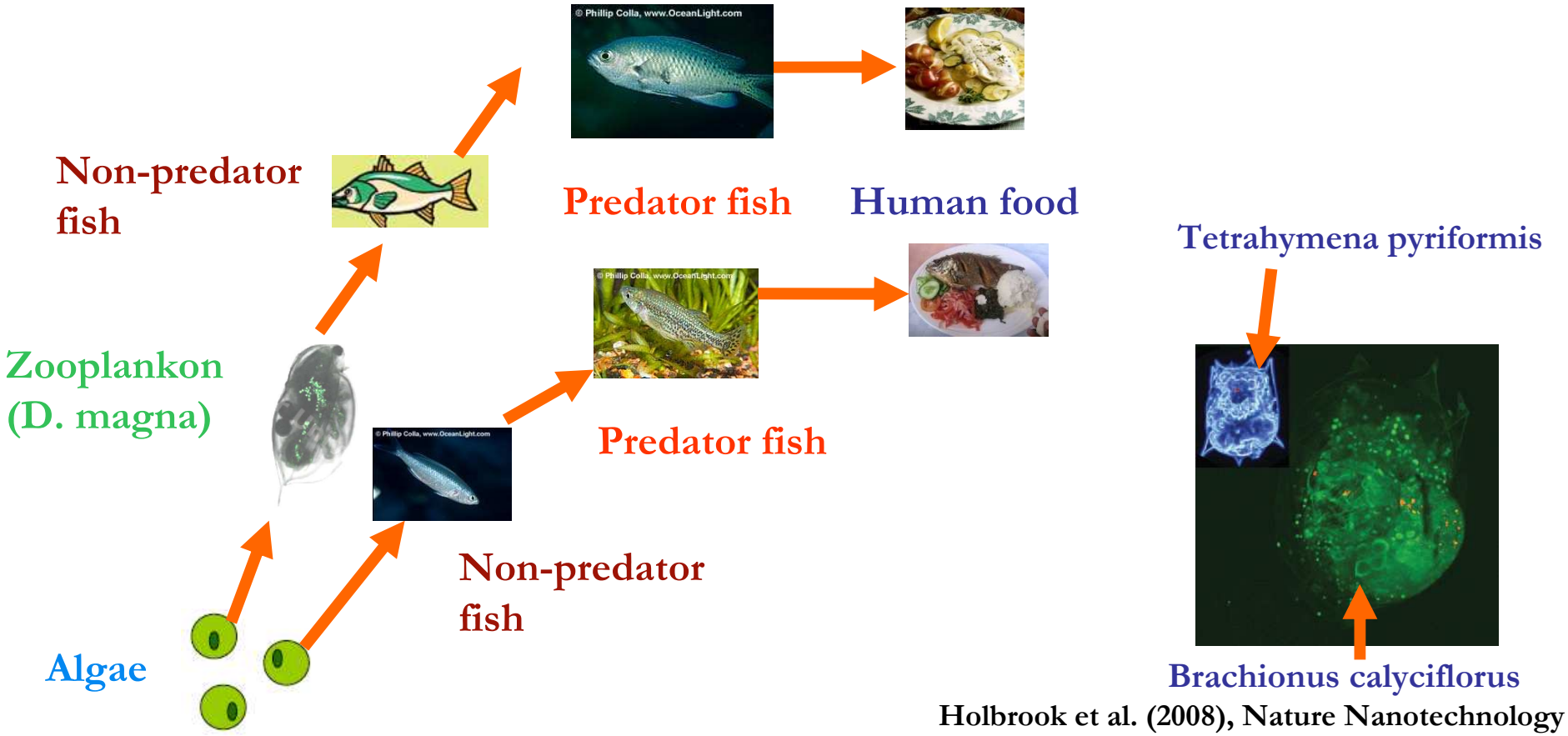


Results of DNA laddering (A) , peroxidate activity (B), and catalase activity (C)

N Musee et al ANSTI COVISET Conference, Johannesburg, South Africa, 22-25 Nov 2011

CSIR our future through science

Potential Risk Transfer Across Trophic Level Effects



Holbrook et al. (2008), Nature Nanotechnology

First direct evidence of ENMs undergoing trophic transfer in a food web. Trophic transfer by means of ingestion of ciliate Tetrahymena pyriformis by rotifer Brachionus calyciflorus

CSIR our future through science

Challenges of Nanotechnology to Africa

- **Nanowastes management - increasing products/ manufacturing**
- **Limited human capacity (absence of**
- **Poor or lack of legislative framework**
- **Vulnerable populations**

Where From Here?

- **Hansen et al., (2007) stated: "until now, no one has been able to pinpoint which properties determine or influence the inherent hazards of nanoparticles"**

- **Powers et al., (2006) stated: "Key parameters affecting biological activity of nanoparticles are largely unknown at this point; characterisation of test material must be comprehensive and broad in scope. A study conducted with material that has not been characterised with respect to a property later found to be critical for toxicity will ultimately be of little value"**

Why Risk Assessment Now for Engineered Nanomaterials Materials (ENMs)?

Three fold reasons:

- Dramatically increasing quantities of ENMs into the environment, and exposure to workers and consumers
- Rapidly growing risk concerns on the applications and safety of ENMs by the media, environmental protection agencies and governments, and public in general
- And, **to protect humans and the environment from unintended consequences of nanotechnology-based products and materials**

Response Mechanisms

- Strategic research collaborations (country, continent, and internationally)
- Development of skilled human capacity (postgraduates research, short courses to government officials, industry, etc
- Positive science impact lobby groups to African governments, industry
- Development of multidisciplinary research and teaching programmes
- Outreach programmes (risk assessment communication ...)

Expected outcomes

- **New breed of scientists, government officials, industry players ... Evidenced by protected environment (health ecosystems) and the humans from adverse effects of emerging technologies such as nanotechnology!!**

Acknowledgements

- **DST**
- **CSIR**
- **Colleagues**
- **ANSTI**