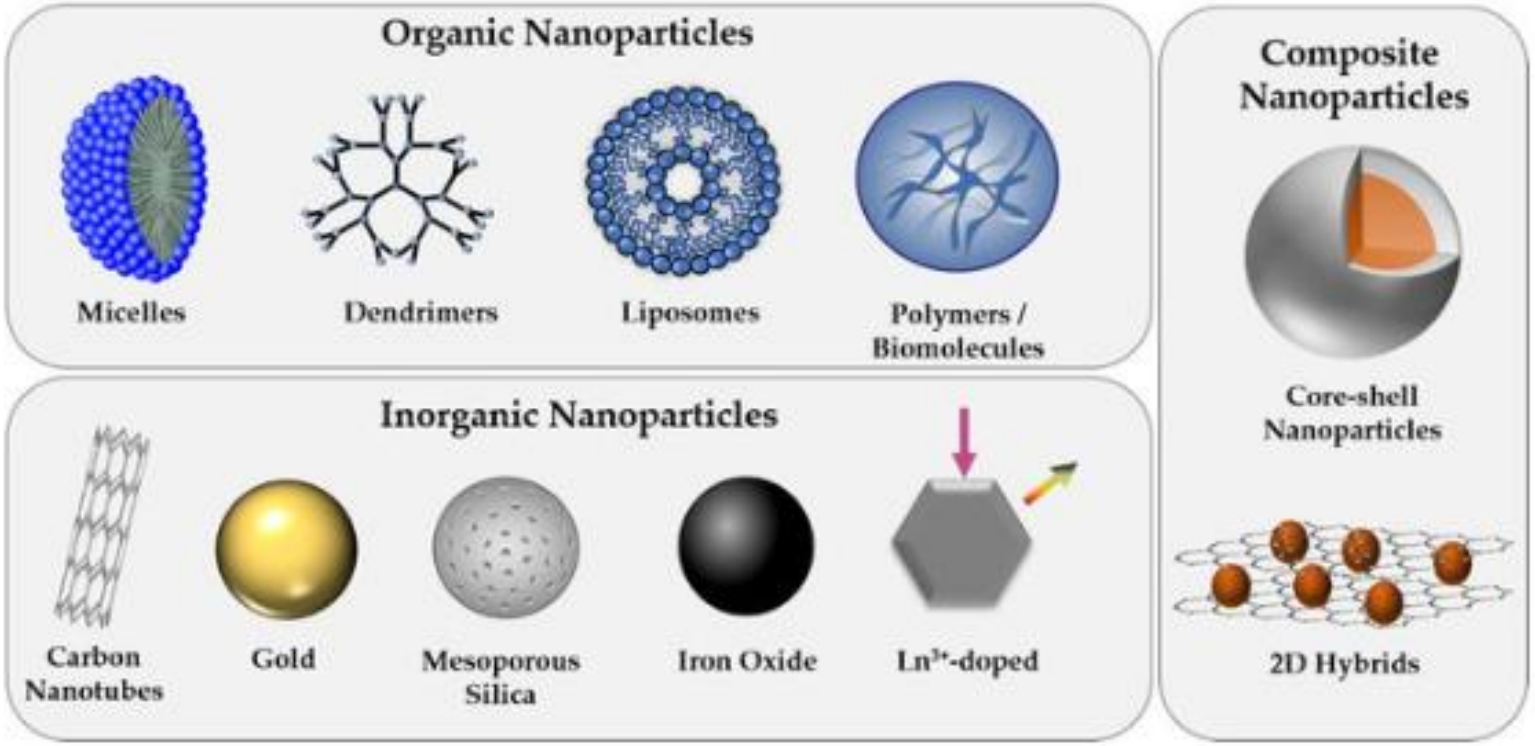
Nanotoxicity: are our allayed fears about toxicity of nanomaterials correct?

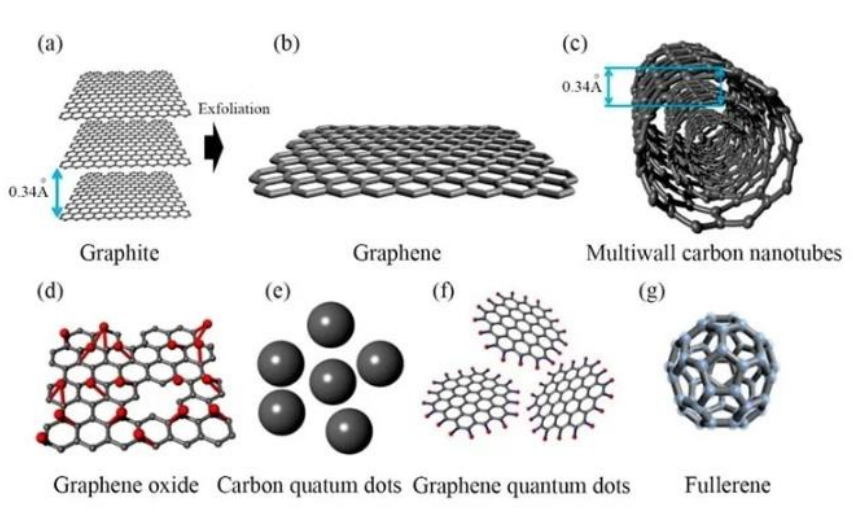
Elias Emeka Elemike(PHD)
Inorganic/Materials Chemistry/Nanotechnology
Sub-Dean, College of Science and the Director Centre for Sustainable Development
Federal University of Petroleum Resources Effurun, Nigeria

elemike.elias@fupre.edu.ng;
+2348035642445

Nanomaterials



Carbon based nanomaterials



Nanoparticle-based Cosmetics: L'oreal

www.superdrug.com

CNT-based Nano Emissive Displays: Motorola

www.optics.org

Structural Nanocomposite Parts: Hummer

www.images.businessweeks.com

Nano-Care fabrics: Nike

www.staticstore.com

Carbon Nanofiber Racquets: Wilson

www.images.businessweeks.com

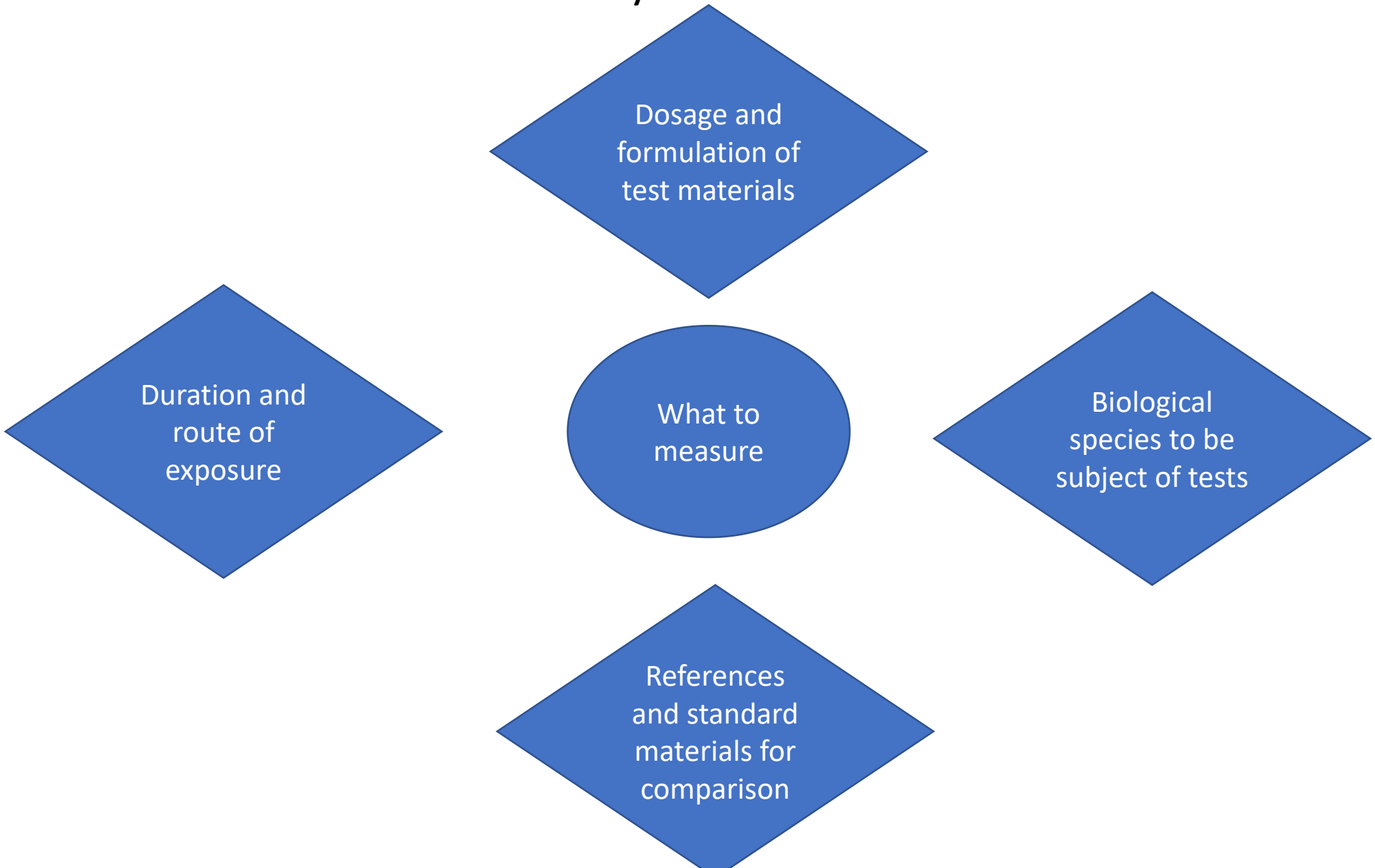
Ag-Nanoparticle Lined Refrigerator : Samsung

www.images.businessweeks.com

The same properties that make nanomaterials interesting can also make them harmful

- Enhanced reactivity
- Increased surface to mass ration
- Enhanced permeation
- Relevant quantum effects
- Previously unknown forms of materials

Toxicity of nanomaterials



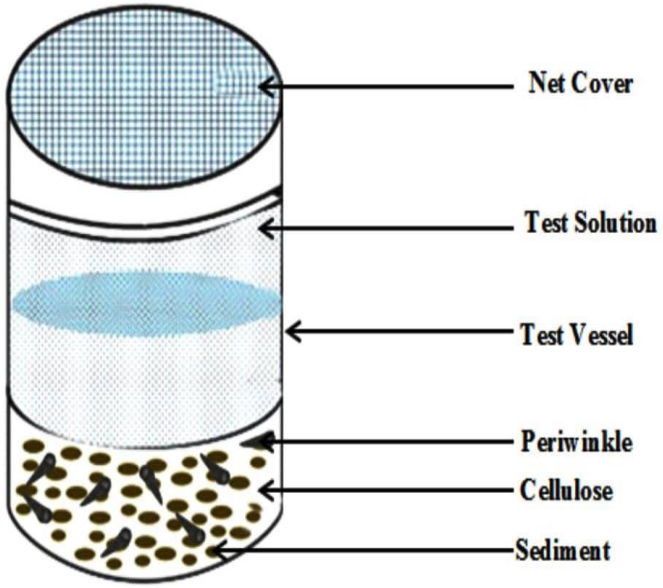
Toxicity tests may be performed employing live (in vivo) organisms, such as microcrustaceans, fishes, rodents, and other animals and/or cell cultures (in vitro).

Several standardized toxicological tests are available to measure the biological response of an organism to a chemical. However, there is no standardization for the evaluation of the toxicity of nanomaterials, which hampers the comparison of results and the consensus about their toxicity. Most of the studies performed so far are adaptations of the standard procedures used for other substances

Toxicological assessment of nanoparticles

The toxicity of nanoparticles depends on their sizes, material concentration, charge, material composition and their stability. The in vitro and in vivo toxicological assessment are carried out with emphasis on the histological changes, biodistribution, pharmacokinetic influence, biochemistry metabolism, and clearance.

Nanotoxicity tests of ZnO synthesized using hibiscus leaf extract



Periwinkles were exposed for 10 days at different concentrations of ZnO NPs and at the termination of the experiment, no mortality was recorded

Healthy periwinkles before and after exposure

Nanomaterial	Mean diameter of the particles (nm)	Test organism	Main results
Ag	13–17 nm	*Lymnaea stagnalis* (Mollusca)	Growth alteration and bioaccumulation
ZnO TiO_2	15–30 nm	*Skeletonema marinoi* (Diatom—Skeletomataceae), *Thalassiosira pseudonana* (Diatom—Thalassiosiraceae), *Dunaliella tertiolecta* (Algae—Dunaliellaceae), *Isochrysis galbana* (Algae—Isochrysidaceae)	Only nanoparticles of ZnO have decreased growth rate of diatom and algae population
Graphene family nanoparticles	—	*Caenorhabditis elegans* (Nematoda)	Decreased reproduction rates

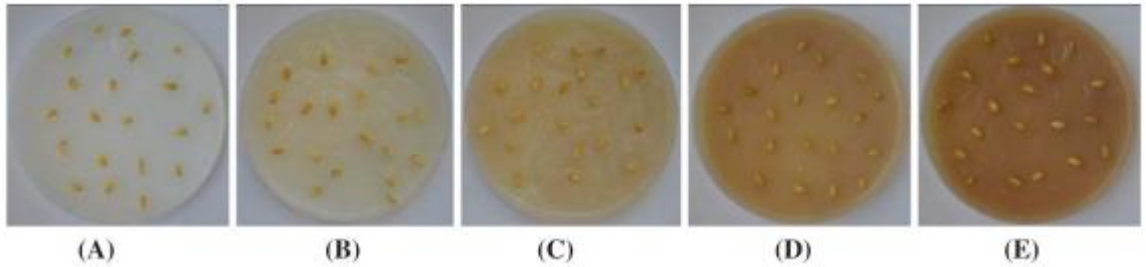
ZnO CuO AgO	ZnO: 20–30 nm CuO: 20–100 nm AgO: 20–70 nm	*Thalassiosira weissflogii* (Diatom—Thalassiosiraceae)	Decreased diatom population growth in similar way to respective dissolved metals. Bioaccumulation of nanoparticles in cell wall and possible transfer through trophic chain
ZnO Al_2O_3 TiO_2	—	*Danio rerio* (Chordata)	Metal oxide nanoparticles induced different toxic effects in zebrafish development according to each metal. ZnO delayed larvae and embryo development and also induced serious ulceration in larvae
TiO_2	~43 nm	*Pimephales promelas* (Chordata)	Fish immunotoxicity and gene expression alteration
TiO_2	~43 nm	*Pimephales promelas* (Chordata)	Fish immunotoxicity and gene expression alteration
TiO_2	5, 10, and 32 nm	*Xenopus laevis* (Chordata)	Significantly affected tadpole growth. The highest concentration caused mortality, suppressed tadpole body length, and delayed animal development

TiO_2	—	*Daphnia similis* (Crustacea)	The highest concentration (100 mg L^{-1}) did not induce toxic effects under experimental conditions. A mixture of TiO_2 forms induced toxic effects by ROS generation when exposed to UVA light
TiO_2 ZnO CuO	TiO_2: 25–70 nm ZnO: 50–70 nm CuO: 30 nm	*Vibrio fischeri* (*Gammaproteobacteria*), *Daphnia magna* (Crustacea), *Thamnocephalus platyurus* (Crustacea)	Suspensions of nano- and bulk TiO_2 were not toxic. A nano-ZnO formulation was very toxic to *V. fischeri*, *D. magna*, and *T. platyurus*. Cu compound also showed toxicity; however, for Daphnia magna were less bioavailable than for bacteria

Metallic nanoparticles of Ag, Cu, Al, Co, Ni and TiO_2	Ag (20–30 nm), Cu (15–45 nm), Al (51 nm), Co (10–20 nm), Ni (5–20 nm), and TiO_2 (30 nm)	*Raphidocelis subcapitata* (Algae—Selenastraceae), *Ceriodaphnia dubia* (Crustacea), *Daphnia pulex* (Crustacea), *Danio rerio* (Chordata)	Nanometals caused acute toxicity in multiple aquatic organisms, but the effect was different according to the metal particle and the species used. Since *R. subcapitata*, *C. dubia*, and *D. pulex* were susceptible to nanometals, trophic chain could be compromised
Ag ZnO TiO_2 CeO_2 Cu	Ag (15 nm) ZnO (34–42 nm) TiO_2 (10–23 nm) CeO_2 (10–33 nm) Cu (76 nm)	*Raphidocelis subcapitata* (Algae—Selenastraceae), *Daphnia magna* (Crustacea), *Danio rerio* (Chordata)	Ag and Cu nanoparticles affected all organisms; ZnO was toxic to algae and daphnids; TiO_2 and CeO_2 were toxic only to algae

Phytotoxicity evaluation of green synthesized nanoparticles on flax seeds

As regards silver nanoparticles, at first, they stimulated the growth of garden cress. Next, the growth was hindered, and later it was stimulated once again. The solution of silver nanoparticles stimulated fax growth at all tested concentrations. Those results demonstrate that silver nanoparticles synthesized biologically using V. officinalis extract are nontoxic. They also suggest that fax germination is somehow resistant to the negative impact of silver nanoparticles. Flax germination was shown to undergo no signifcant changes due to any type of treatment, regardless of concentrations (El-Temsah and Joner, 2012).



	Veronica officinalis extract	Solution of $AgNO_3$	Biosynthesized silver nanoparticles
IC_{50} for *L. flavum* (mg/ml)	3.3927	0.0171	nt
IC_{50} for *L. sativum* (mg/ml)	nt	0.0125	nt

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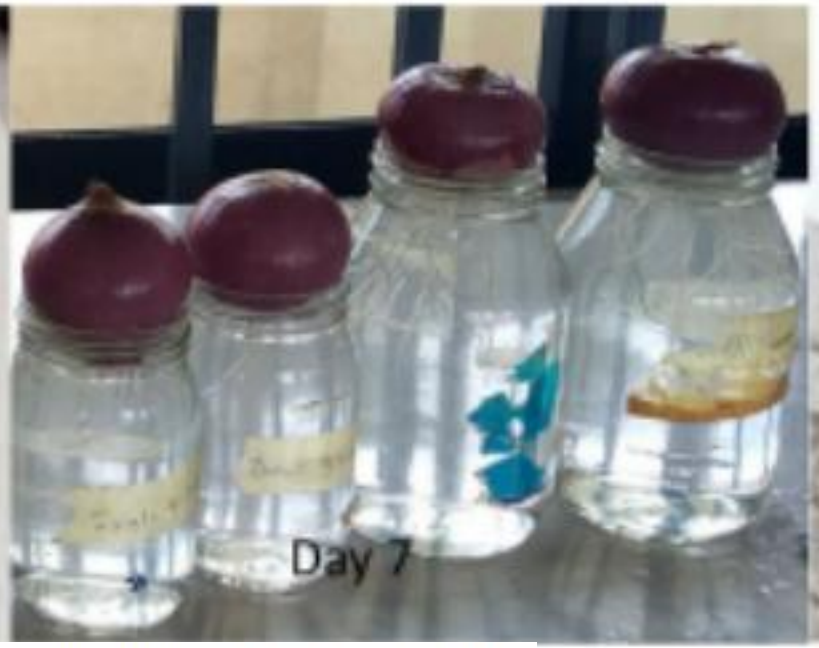
Toxicity Assessment of Cellulose-Ag-ZnO Nanocomposites Using Onions Bulb Plant



	Mean Length (cm)					Mean	SD	SE	SGR	Mean length	% Growth Rate
	1	2	3	4	5						
Conc., mg/L											
0	6.00	5.50	6.50	5.30	5.00	5.66	0.50	0.29	0.059	5.66	100
3.125	5.70	5.90	5.40	4.60	5.30	5.38	0.25	0.15	0.056	5.38	95
6.25	4.10	4.30	4.00	4.00	3.70	4.02	0.15	0.09	0.042	4.02	71
12.5	3.80	3.90	4.00	3.50	2.90	3.62	0.10	0.06	0.038	3.62	64
25	3.10	2.50	2.30	2.80	2.00	2.54	0.42	0.24	0.027	2.54	45
50	2.00	2.50	2.80	2.20	2.10	2.32	0.40	0.23	0.024	2.32	41

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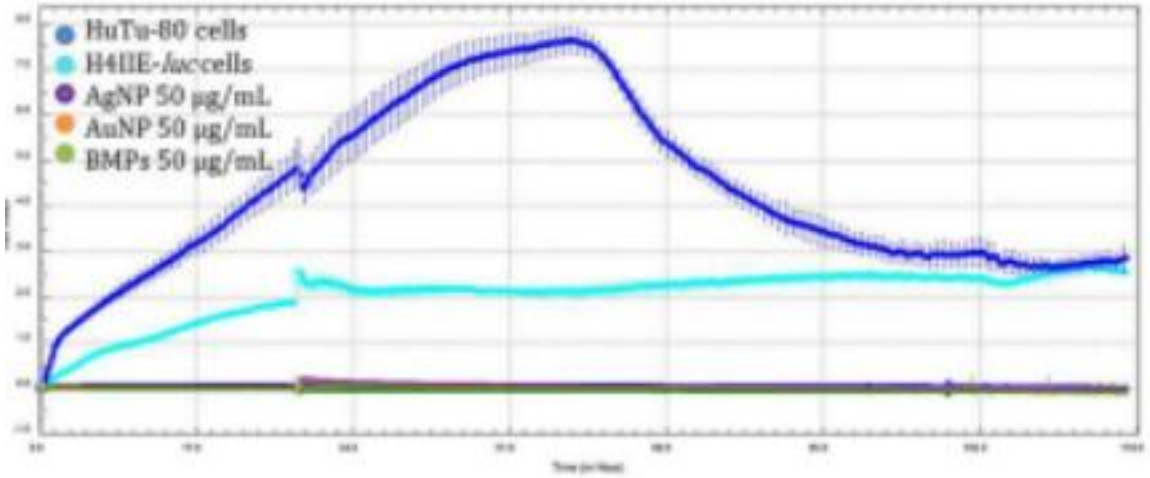
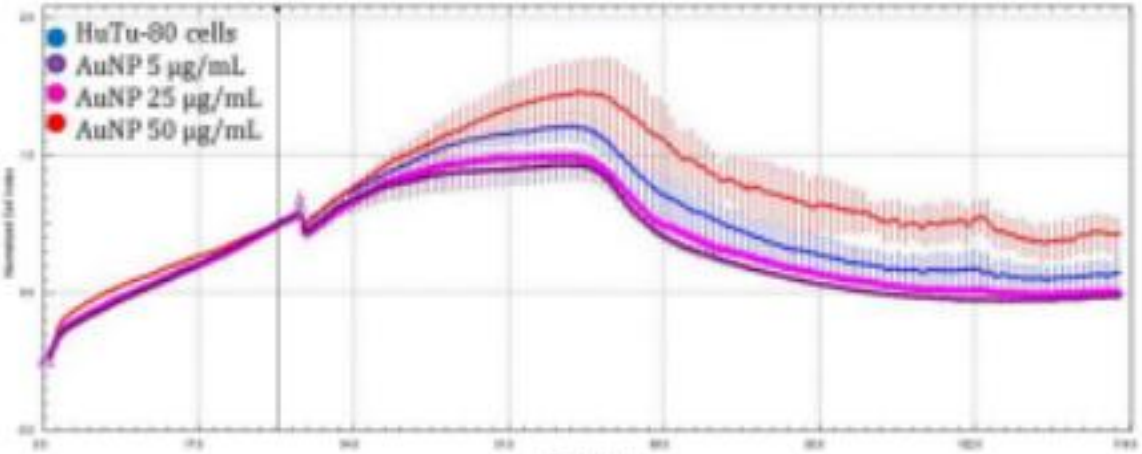
Cytotoxicity of Ag, Au and Ag-Au bimetallic nanoparticles prepared using golden rod (Solidago canadensis) plant extract

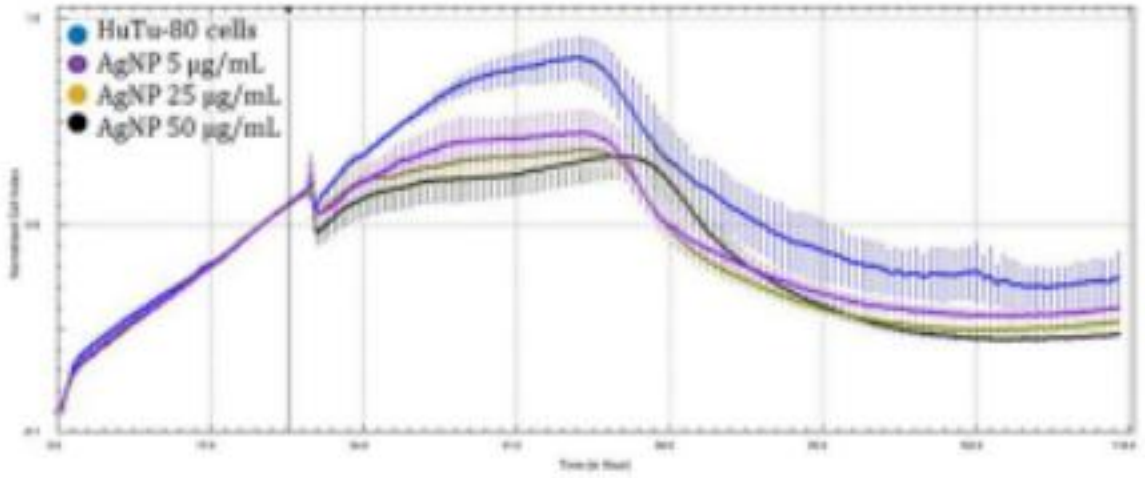
Behaviour of NPs in biological media or determination of their toxic potency depend on material constitution or arrangement. Shapes of nanoparticles are important in determining toxicity. For instance, triangular-shaped silver nanomaterials exhibit greater toxic potency relative to spherical NP. Surface area, large ratio of surface atoms to bulk atoms results in greater reactivity and toxic potencies



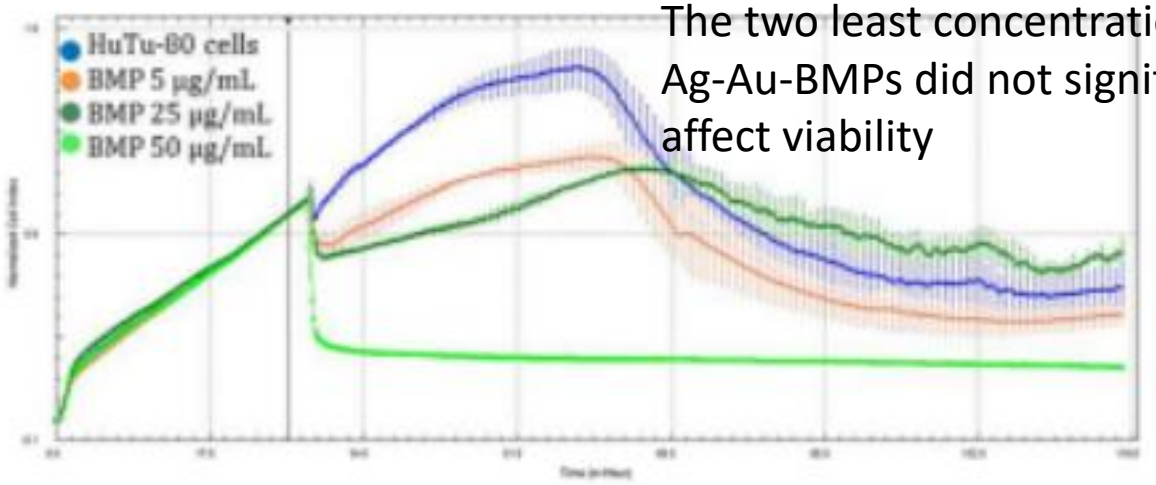
Comparison of pre normalized CI values between H4IIE-luc cells (cyan) and HuTu-80 cells (blue) control cells and blank wells containing only NPs indicating no particle interference



Growth curves of HuTu-80 cells exposed to three concentrations of Au-NPs for 100h (Blue: Control; Purple: 5 µg/mL; Pink: 25µg/mL; Red: 50 µg/mL). Te line indicates addition of the nanomaterials as well as normalization time point

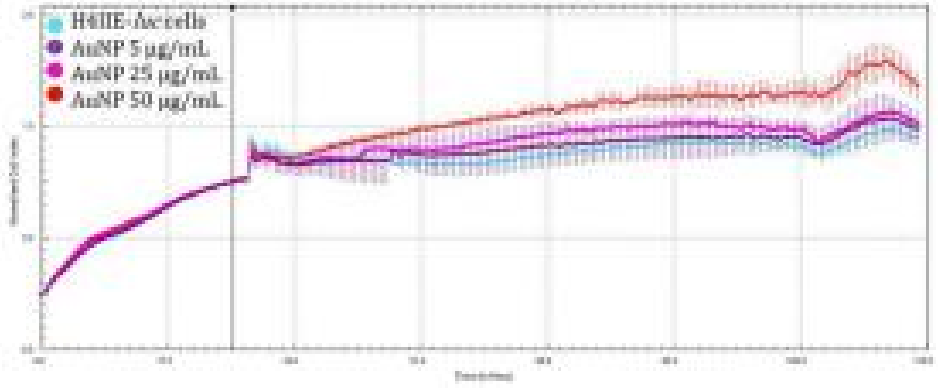


Growth curves of HuTu-80 cells exposed to Ag-NPs for 100h (Blue: Control; Purple: 5 µg/mL; Yellow: 25µg/mL; Black: 50µg/mL).

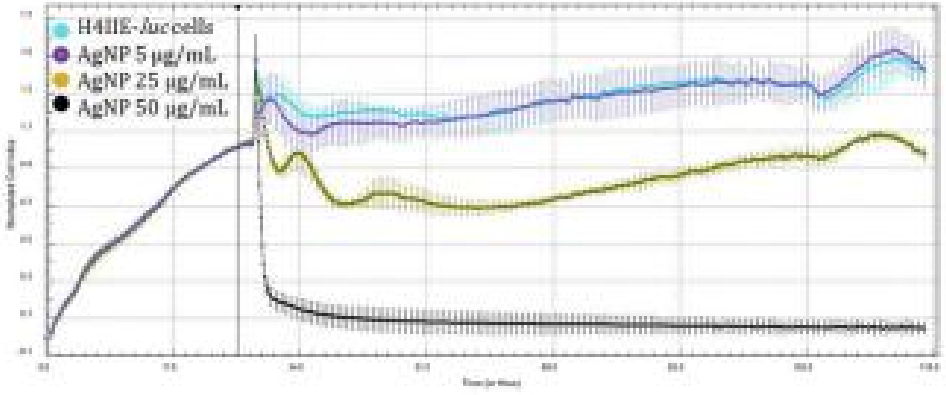


The two least concentrations o
Ag-Au-BMPs did not significan
affect viability

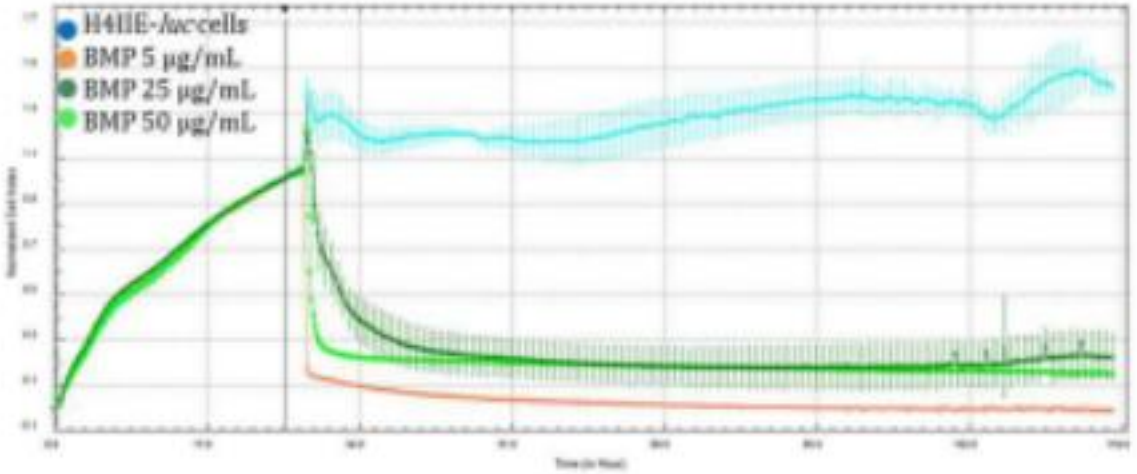
Growth curves of HuTu-80 cells exposed to Ag-Au-BMPs for 100h (Blue: Control; Orange: 5 µg/mL; Dark green: 25 µg/mL Green: 50 µg/mL).



Growth of H4IIE-luc cells s in the presence of three concentrations of Au-NPs for 100h (Cyan: Control; Purple: 5 µg/mL; Pink: 25µg/mL; Red: 50µg/mL).



. Growth curves of H4IIE-luc cells exposed to three concentrations of Ag-NPs for 100h (Cyan: Control; Purple: 5 µg/mL; Yellow: 25 µg/mL; Black: 50µg/mL).



BNPs exhibited the greatest toxic potency to these two types of cells

Growth curves of H4IIE-luc cells exposed to three concentrations of Ag-Au-BMPs for 100h (Cyan: Control; Orange: 5 µg/mL; Dark green: 25 µg/mL; Green: 50 µg/mL).

H4IIE-luc cells exhibited statistically significant diferences in cells exposed to the two greatest concentrations (25 and 50µg/mL) of all three types of NPs. Au-NPs significantly stimulated growth of cells while both Ag-NPs and Ag-Au-BMPs caused signifcant decreases in viability of cells. The least concentration (5 µg/mL) of Ag-NPs and Au-NPs caused non-signifcant stimulation of growth of cells, while Ag-Au-BMPs caused a signifcant decrease in cell viability of H4IIE-luc cells

Conclusion

Contact with materials in the nanoscale may result in penetration of various kinds of cells, which is a very important potential consequence. Nanoparticles exercise a direct impact on algae, plants and fungi by entering into redox reactions with organic particles, which disturbs the processes of photosynthesis and respiration. Cellulose cell walls of algae and higher plants, as well as chitin walls of fungi, have small pores with the diameter of 5–20 nm, and nanoparticles may induce creation of larger pores. After penetrating cell wall, nanoparticles encounter the cytoplasmic membrane. The membrane becomes convex, encloses nanoparticles in bubbles and pulls them in the cell. The majority of the reported phytotoxicity studies used nanoparticles synthesized by means of chemical methods.

Not all biologically synthesized nanomaterials are necessarily safe.

Example: AuNPs synthesized from golden rod extract exhibited lesser toxic potency than NPs synthesized without plant leaf extracts.

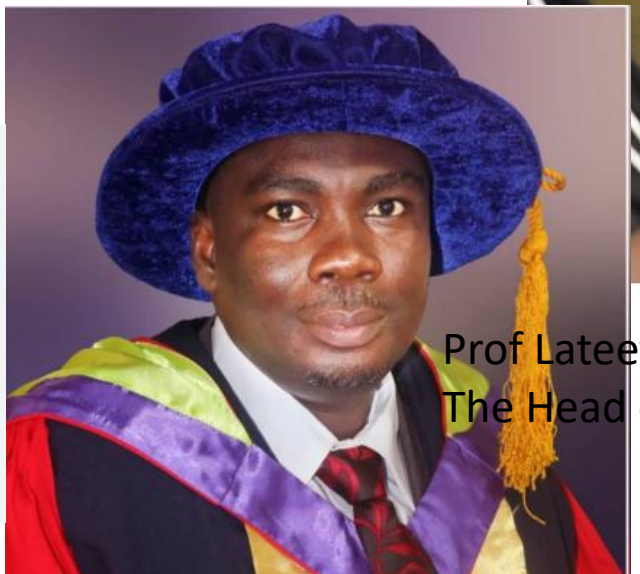
Acknowledgements

Prof Enock Dare

The young shall grow

Nanoschool NWU 2016

Thank you



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The Head of Lautech Nanogroup

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