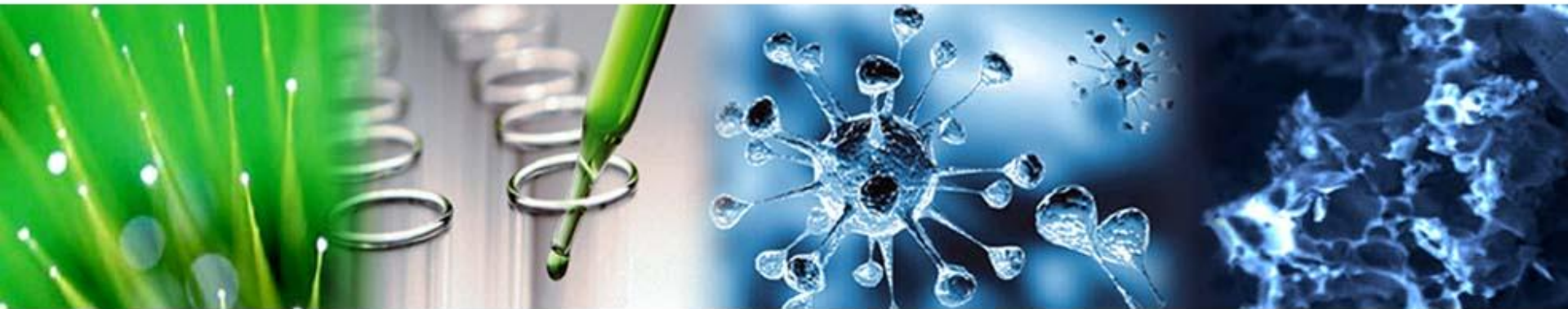




Assessment of nanoparticle release and associated health effect of polymer-silicon composites

Dr Huijun Zhu





Silicon based polymer nanocomposites (NEPHH)

Start Manufacture (occupational exposure via inhalation and skin)



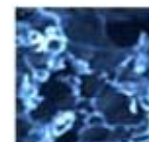
Raw Materials-SiNP
(Aerosil 200, Aerosil 974)

Nanoproducts application (physical processing, end user exposure)



NP release from polymer-nanosilicon composites
- polyamide 6 (PA6) and polypropylene (PP)

Finish End of product life (disposal, recycle, the public exposure)



Very limited data available

- **Workers**

SiNP production-packaging/loading

inhalable ($< 10 \mu\text{m}$) - 3 mg/m^3

respirable ($1-3 \mu\text{m}$)- 1 mg/m^3 (OECD 2004)

- **The public**

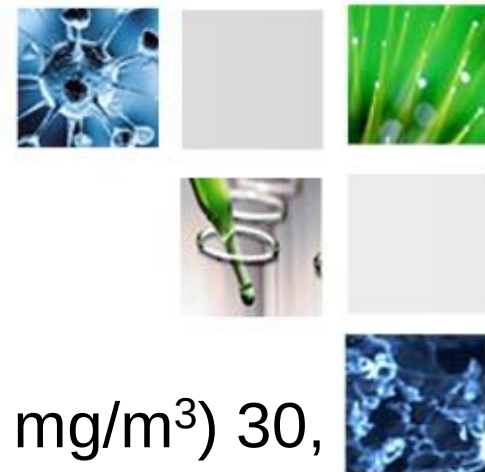
Human daily intake of silica NP via food

1.8 mg/bw ???

Nanocomposite wear/tear

- **Intentional**

Patients



Inhalation

3.7×10^7 N/m³, 1.8×10^8 N/m³ (1.8 or 8.6 mg/m³) 30, 70 nm, 3 days - negative

1.3 mg/m³, 13 weeks – reversible mild lung effect

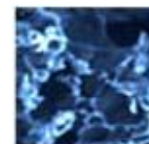
NOEL-1 mg/m³

LOAEL-5.9 mg/m³

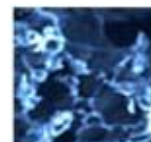
No toxicology evidence for occupational exposure

Skin-irritation

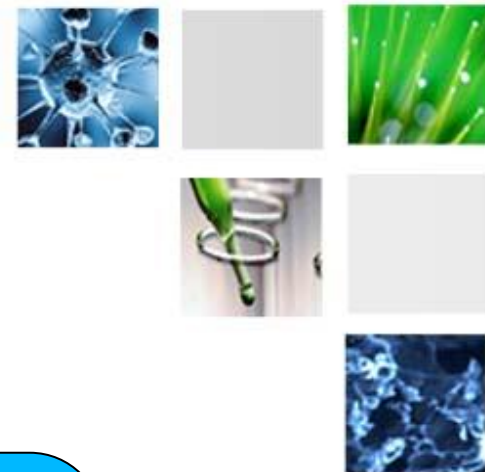
Exposure via other route – toxicity in liver, thrombosis



- Primary NP size/aggregates – characterization
- Surface properties, size , shape - effect relationship
- Uptake & subcellular location-mechanisms
- Cytotoxicity-mode of action (NP-biomolecular interactions)



- Characterization of NP for toxicity study
NP/aggregates size, surface property - toxicity relationship
- Assessment of *in vitro* toxicity of raw SiNP and NP released from silicon-polymer composites
- Mechanisms of toxicity

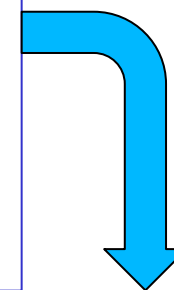


Characterization of NP

- DLS-NP/aggregate size in culture media
- SEM- size, shape, biomolecule adsorption
- Infra red-NP chemistry

Drilling of testing polymer materials

Monitoring of airborne NP by SMPS+C-SEP



Assessment of multi toxicity endpoints in vitro in A549 cells

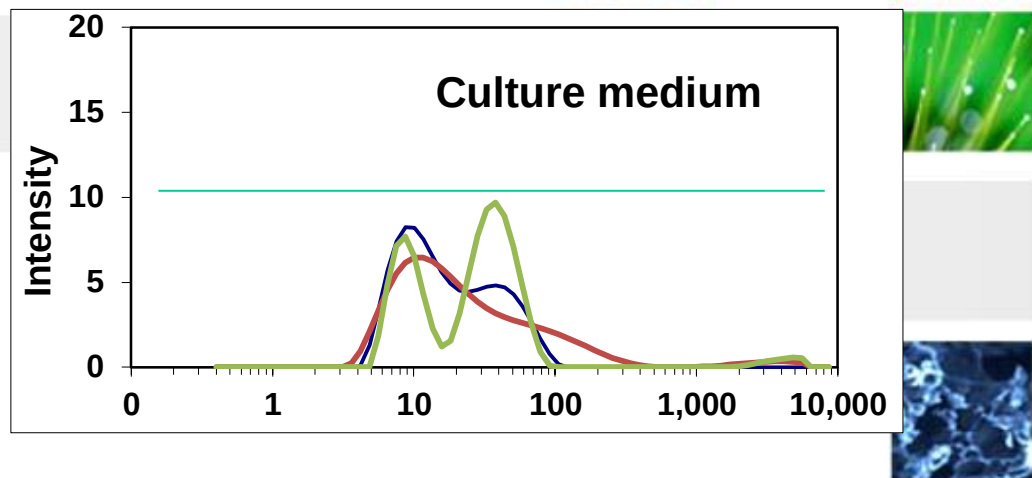
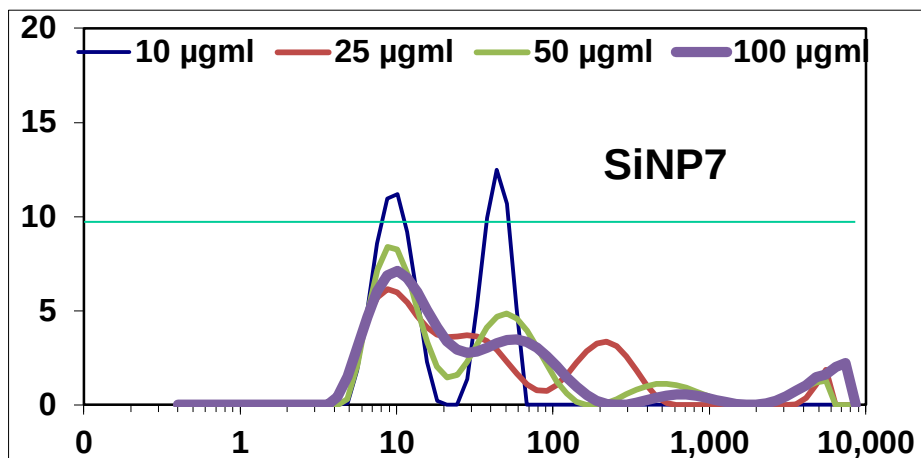
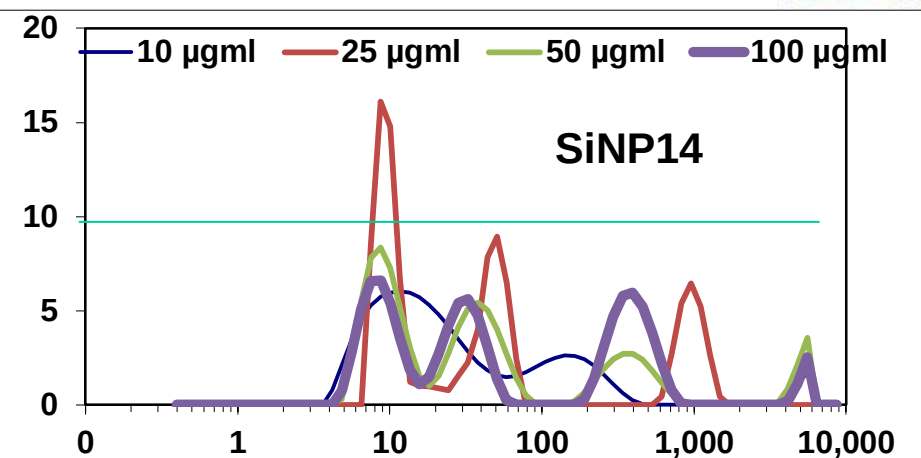
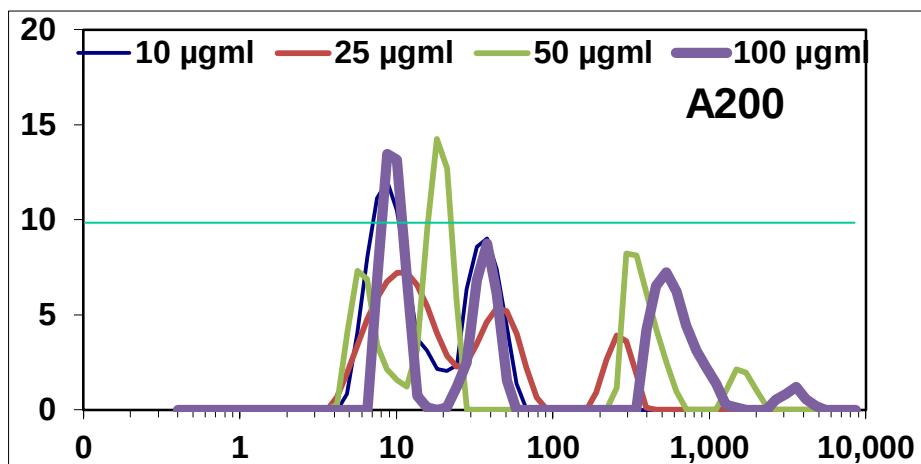
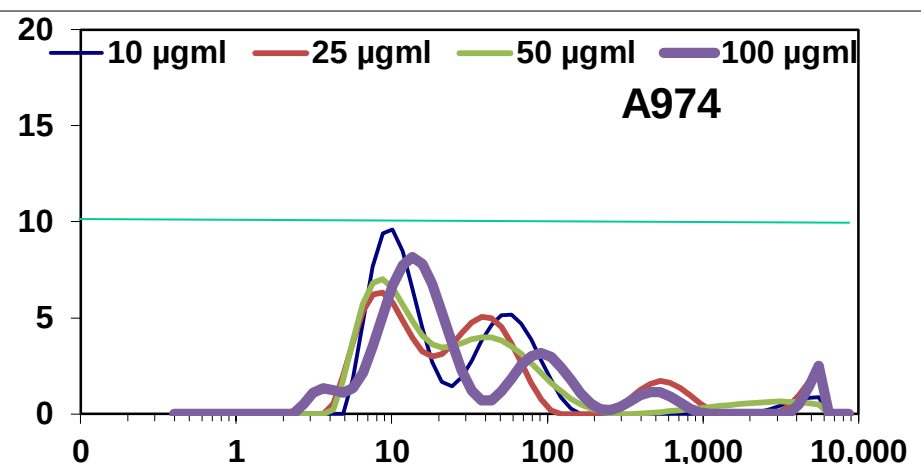
- Metabolism/Cell viability (MTT test)
- Cell membrane damage (LDH assay)
- Intracellular oxygen species (ROS assay)
- IL-8 production



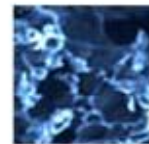
Silica NP	Primary/ aggregates Size (nm)	Behaviour in water
Silica 7, fumed	7/~	Hydrophilic
Aerosil 200, fumed	12/~	hydrophilic
Aerosil 974, fumed	12/~	Hydrophobic



DLS assay of silica NP

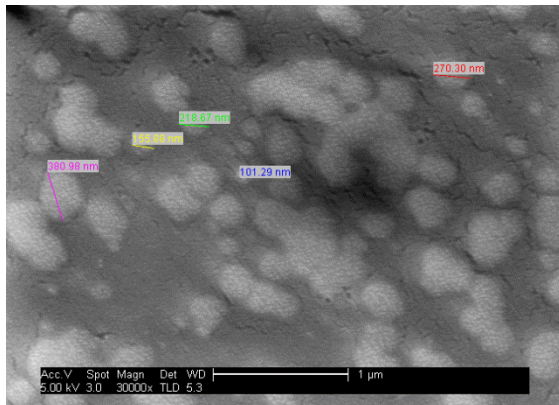
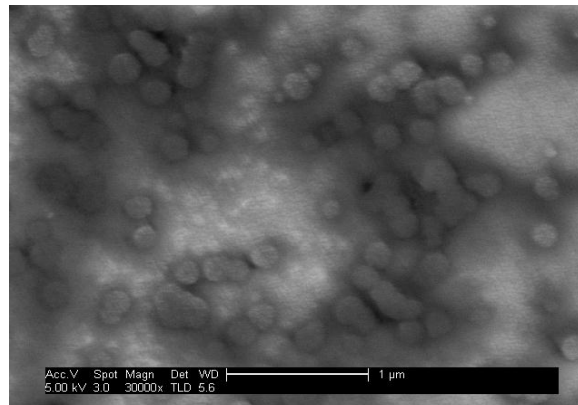


SEM of raw silica NP

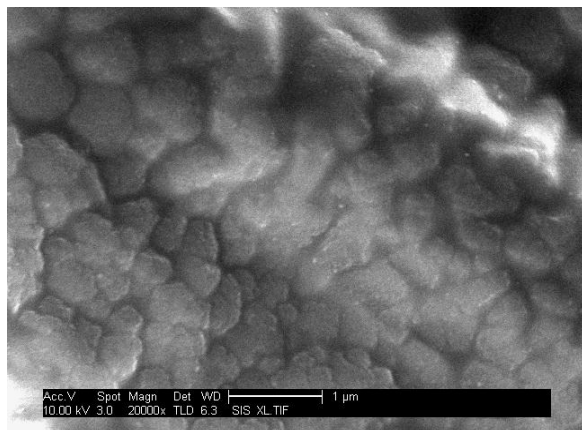
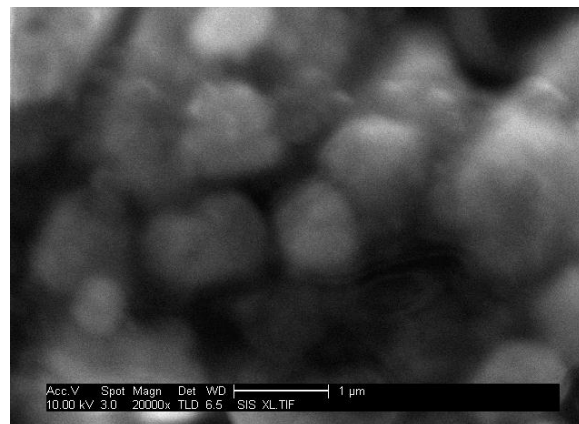


Aerosil 200

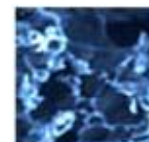
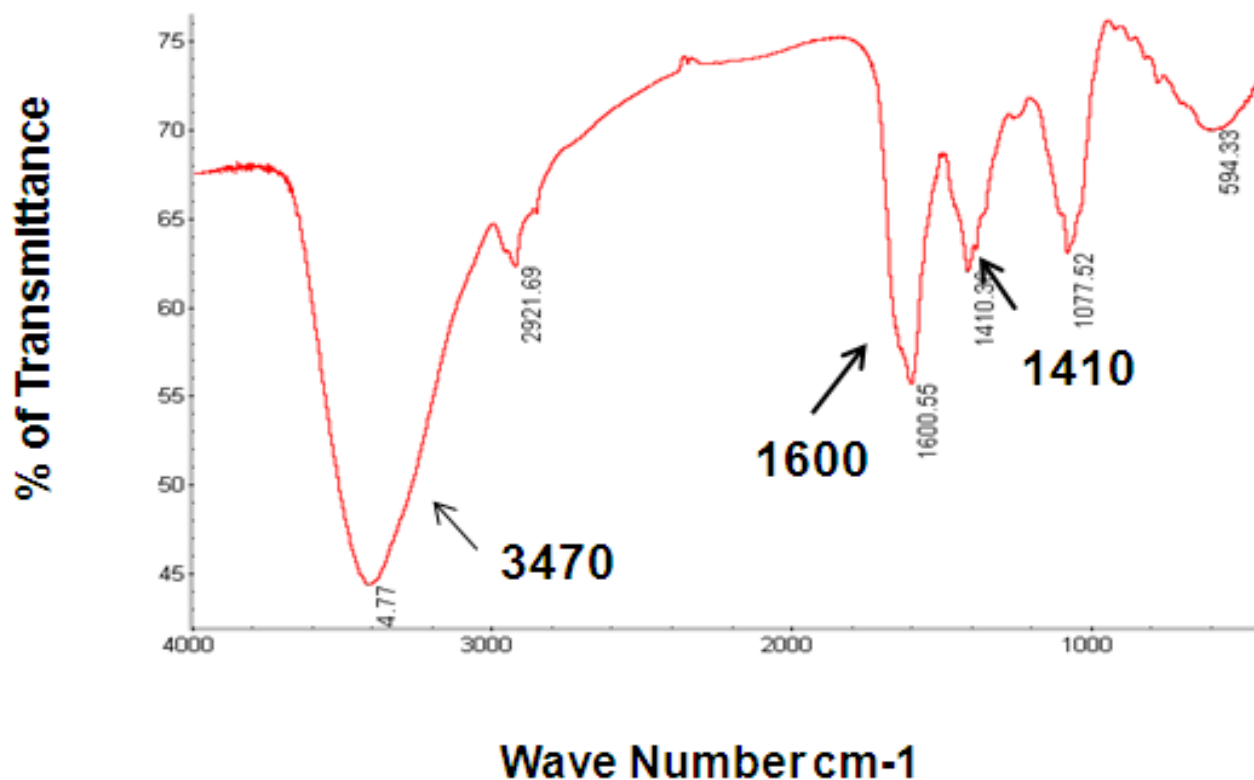
Aerosil 974



SiNP in culture medium at 10 µg/ml



SiNP in culture medium at 100 µg/ml



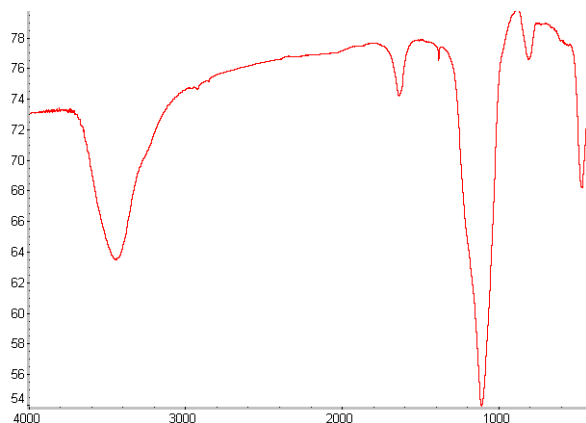
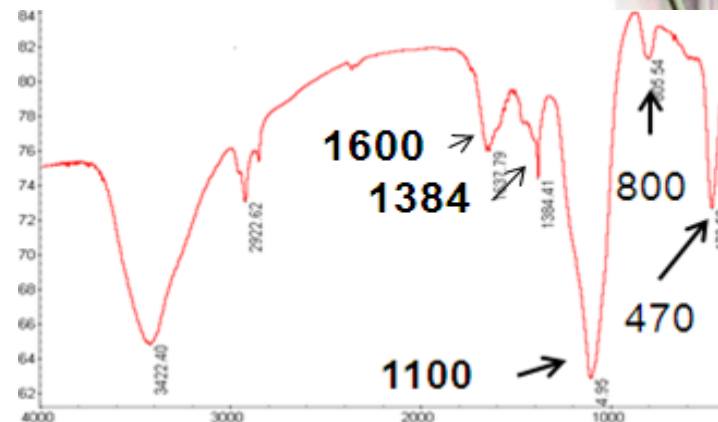
The peaks at 3470 cm⁻¹ corresponds to -OH. The peaks at 1600 cm⁻¹ and 1410 cm⁻¹ correspond to the C=O and C-H bounds respectively.



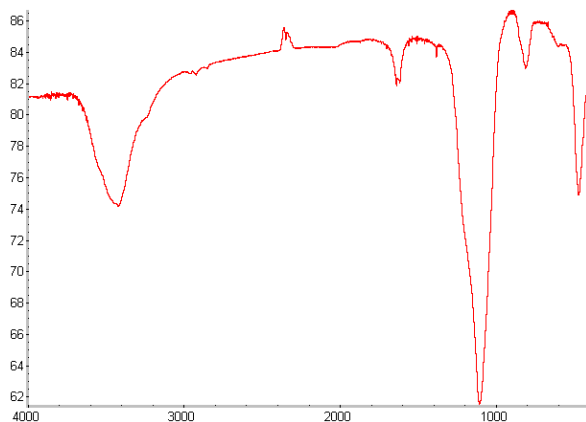
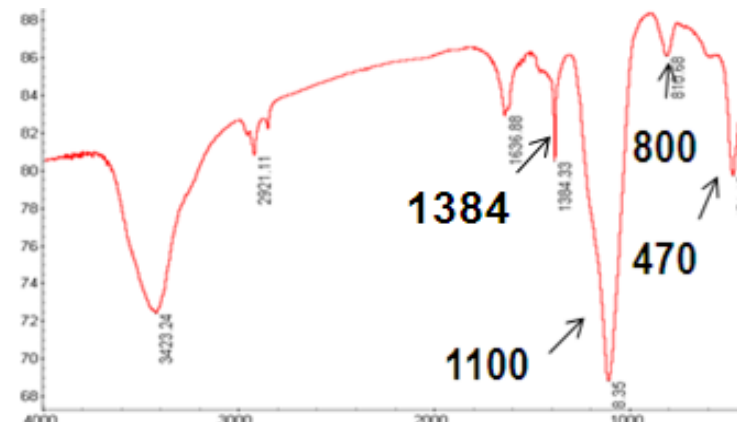
In water

In culture medium

A200

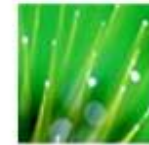
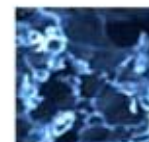
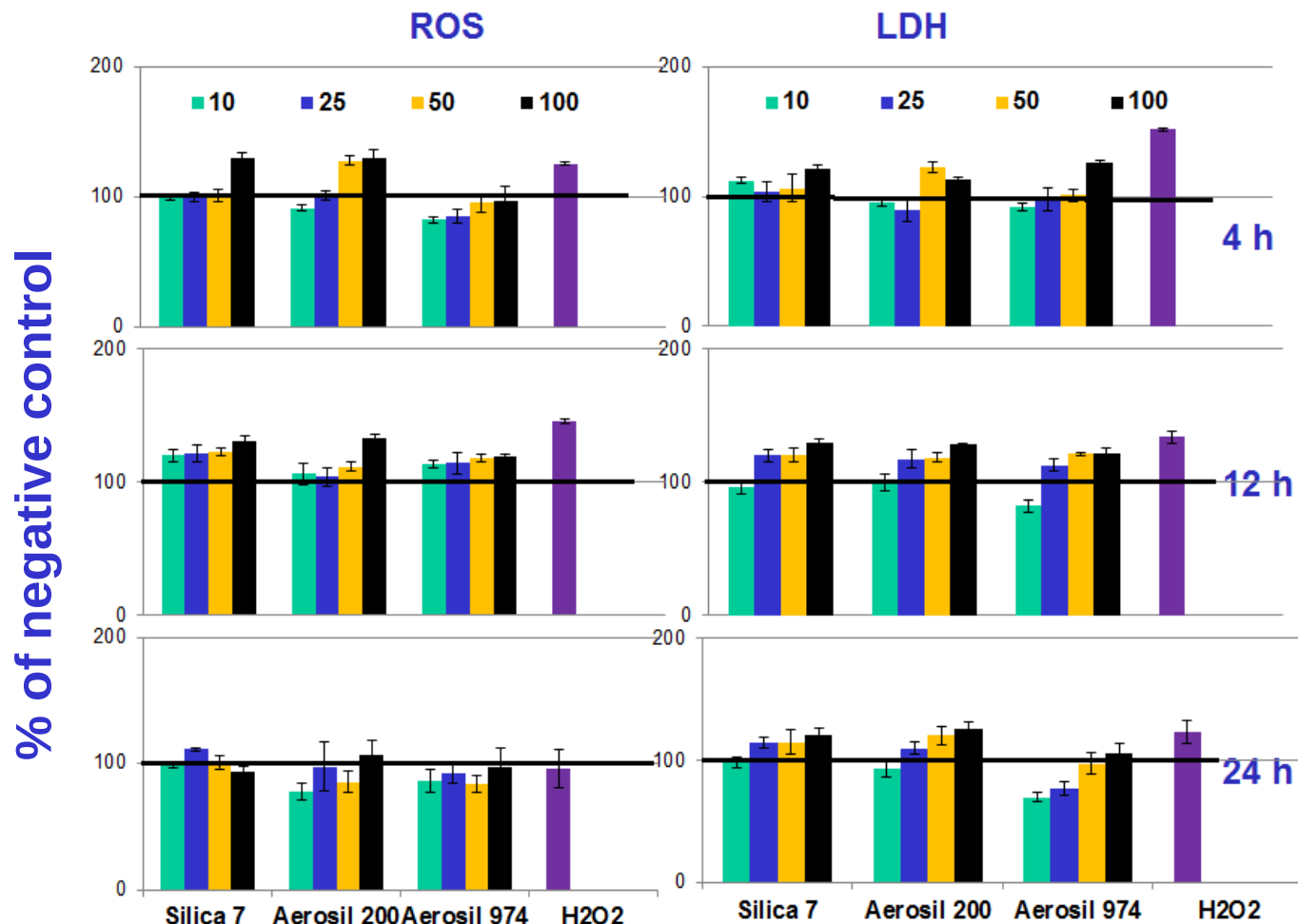


A974

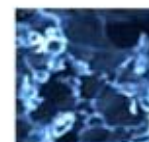


Wave number cm⁻¹

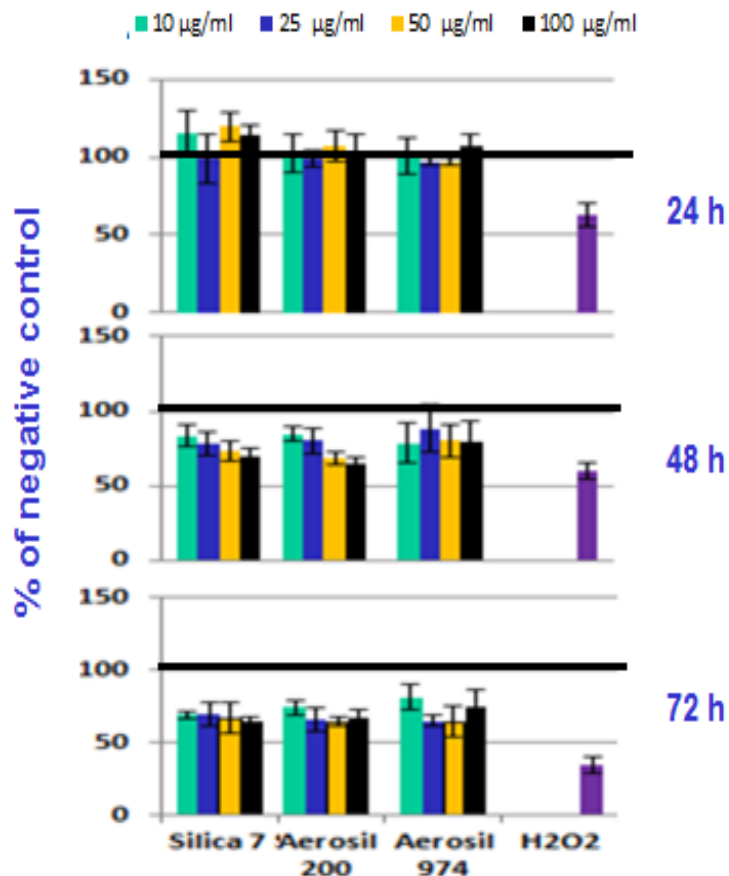
Toxicity study of silica NP in A549 cells



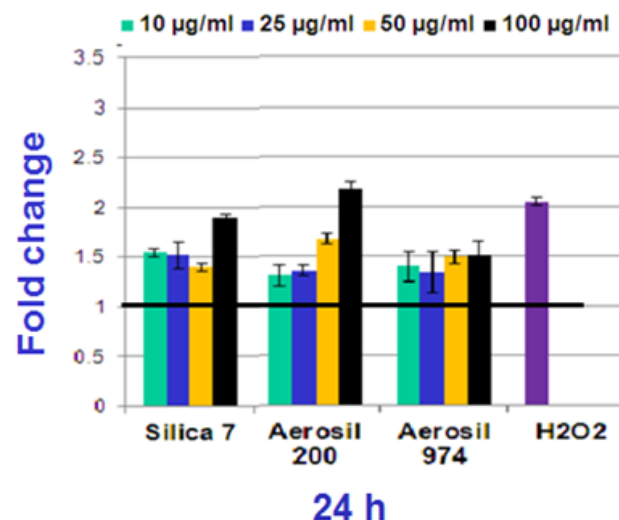
Concentration dependent toxicity of silica NP was evidenced



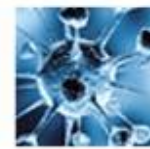
MTT



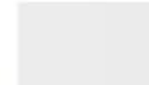
IL-8



- Silica NP induced time dependent loss of cell viability at 10-100 µg/ml
- Silica NP also induced IL-8 production

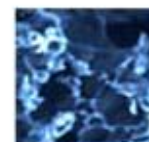
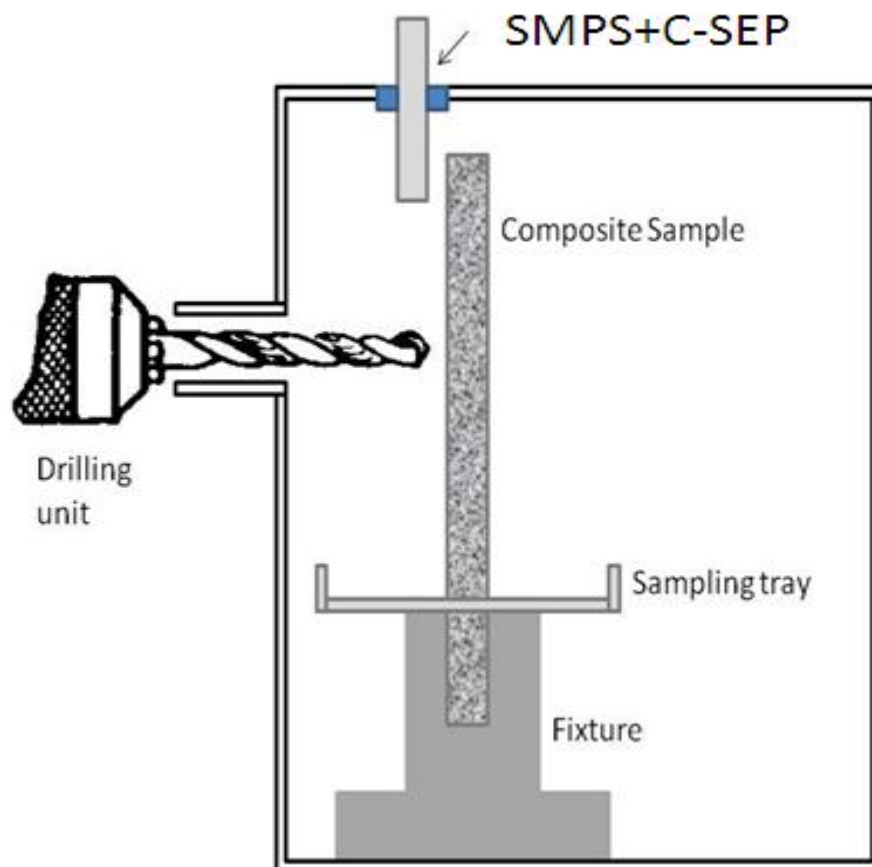


- At 10-100 $\mu\text{g/ml}$, all the silica NP tested induced time dependent loss of cell viability which was associated with early membrane damage, increase in intracellular ROS level and IL-8 production.
- The lack of concentration dependent effect of silica NP on cell viability suggests that the toxicity could be induced by silica NP via different mechanisms at different concentrations.



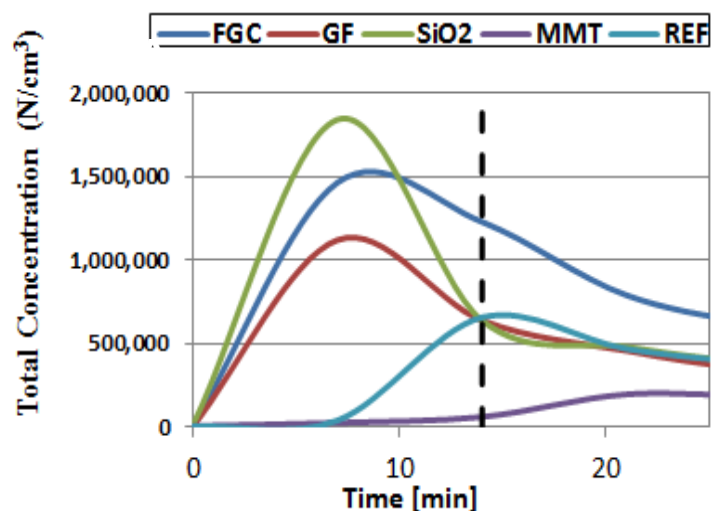
PA6/PP-silicon composites	Filler materials
PA6/PP(REF)	
PA6-MMT	Dellite 43B
PA6-SiO ₂	AEROSIL® 200
PP-MMT	Dellite 72T
PP-SiO ₂	AEROSIL® 974
PA6/PP-FGC	Fiber glass crystal
PA6/PP-GF	Glass fibers

Drilling chamber and airborne NP monitoring

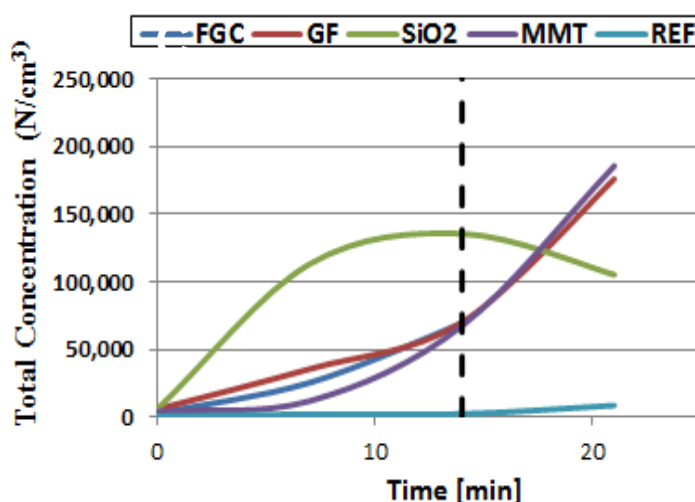
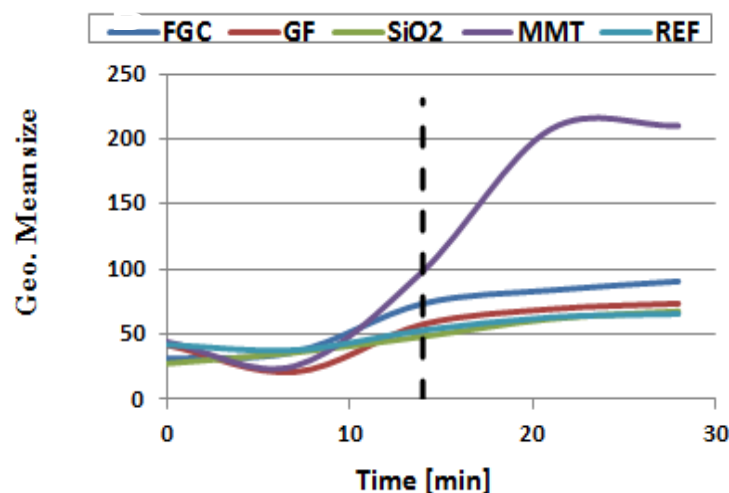
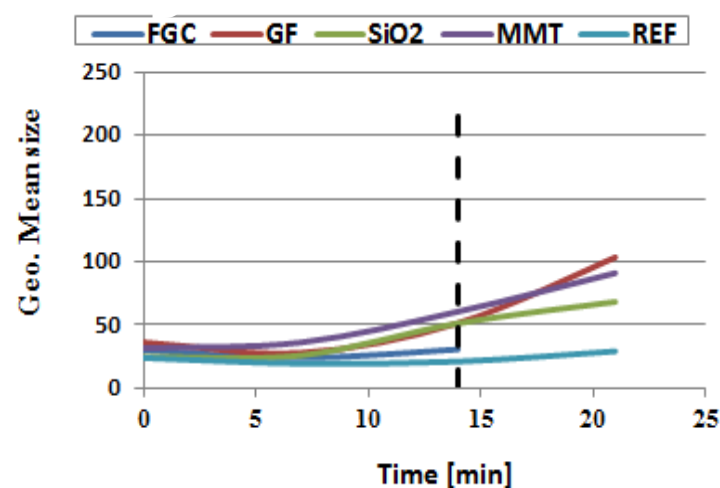


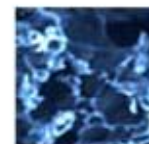
Concentration and size distribution of airborne particles in testing chamber

PA6-composite

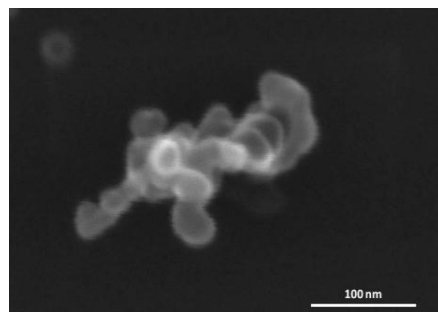


PP-composites

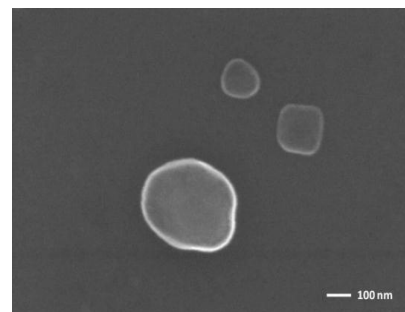




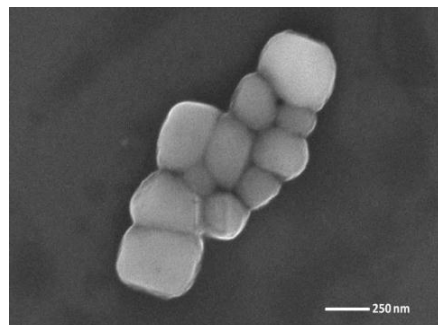
PA6-SiO₂



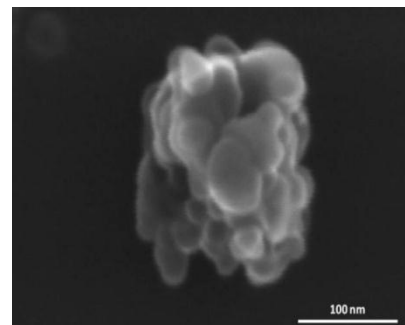
PA6-MMT



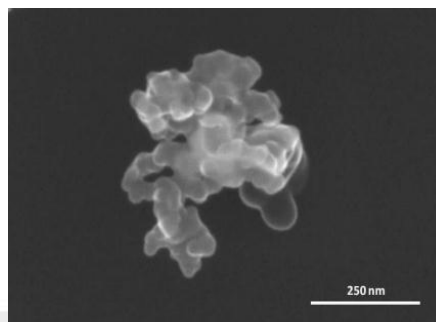
PA6-GF

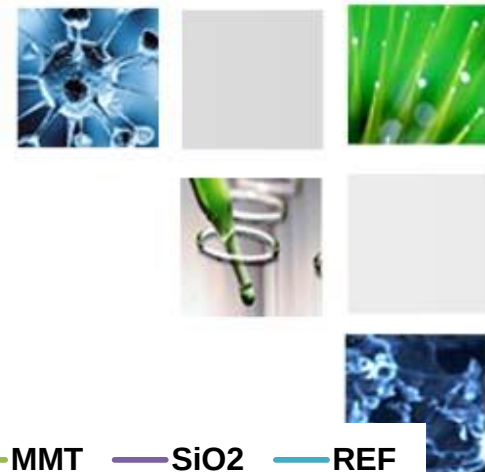
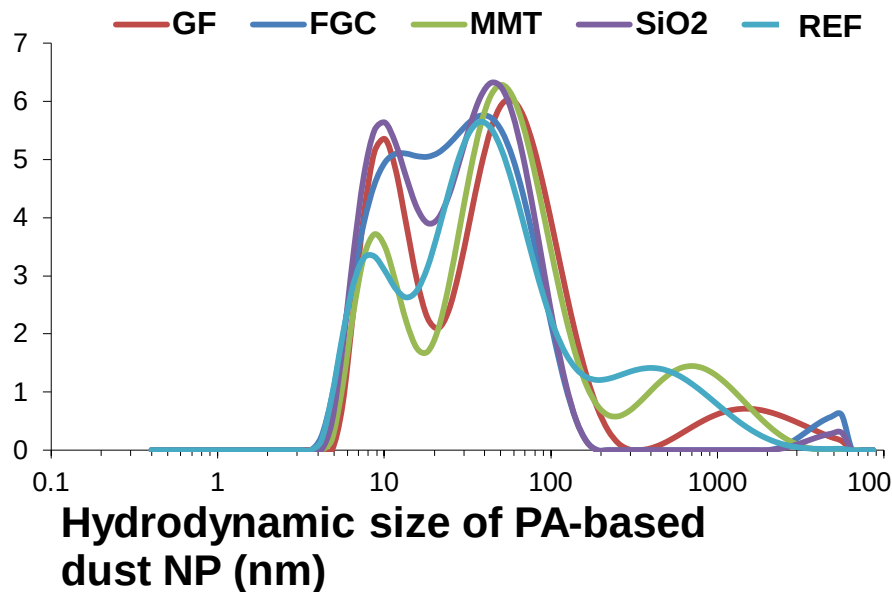
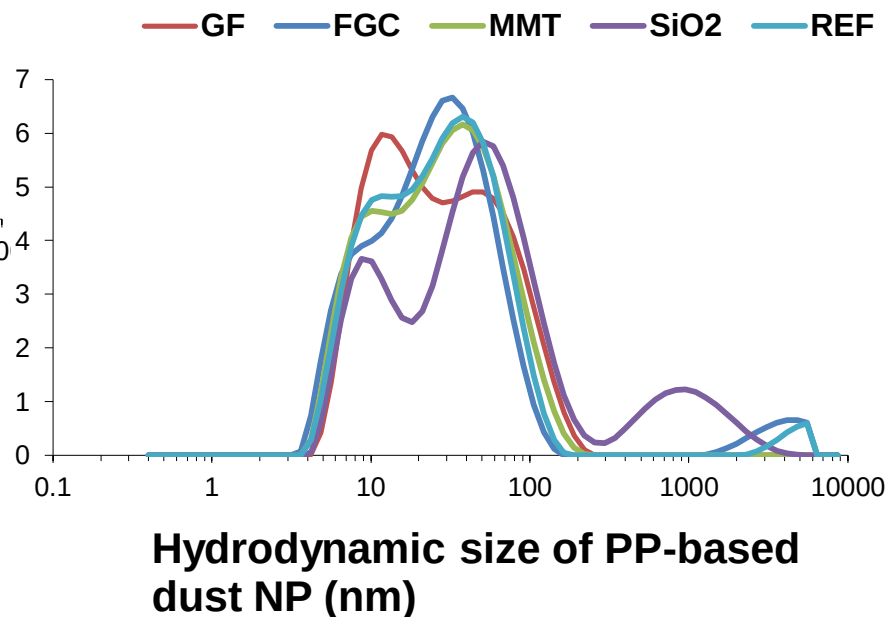


PA6-FGC



PA6-REF



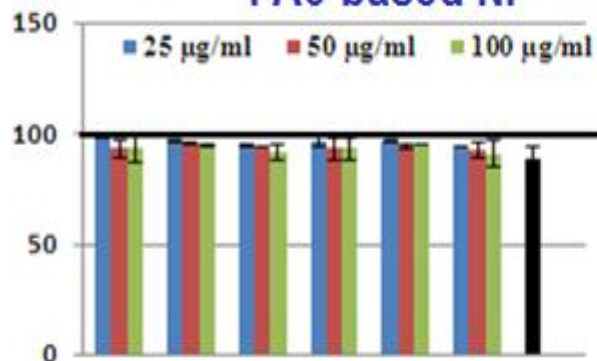
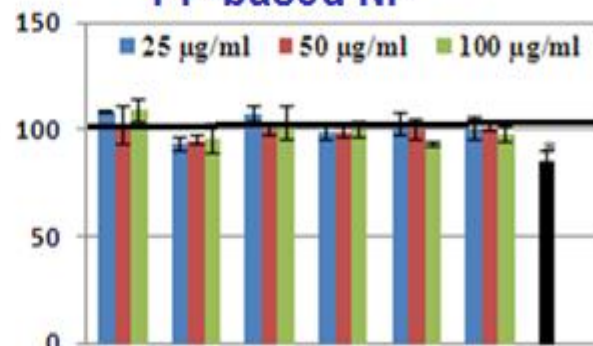


The dust NP were diluted in cell culture medium (DMEM) at 100 µg/ml. All the dust samples contain NP with average hydrodynamic size less than 100 nm.

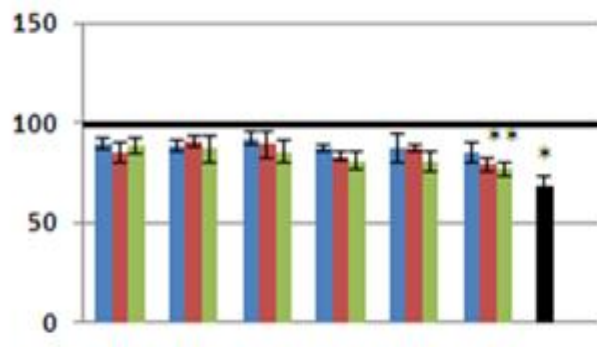
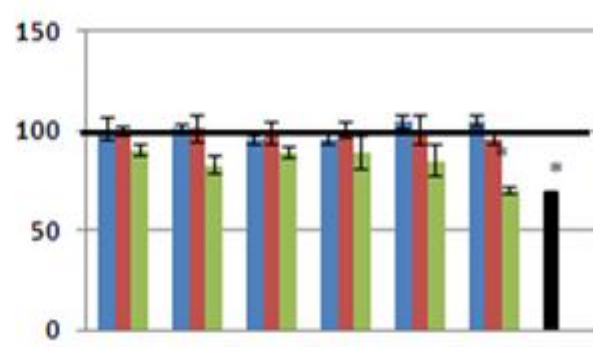
PA6-based NP

PP-based NP

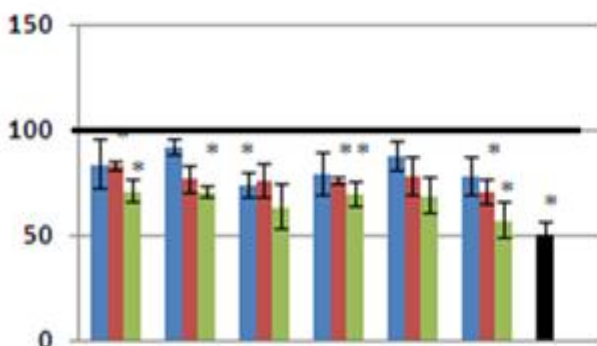
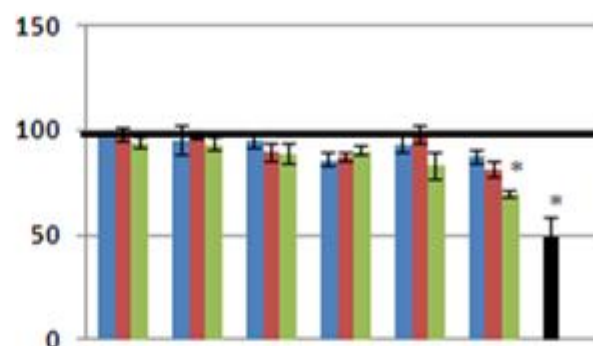
% of negative control



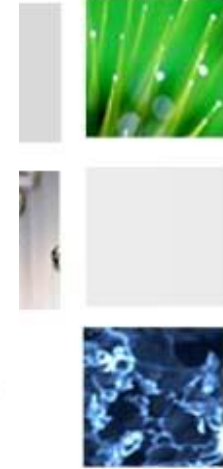
24 h

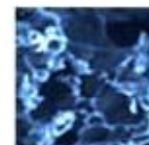
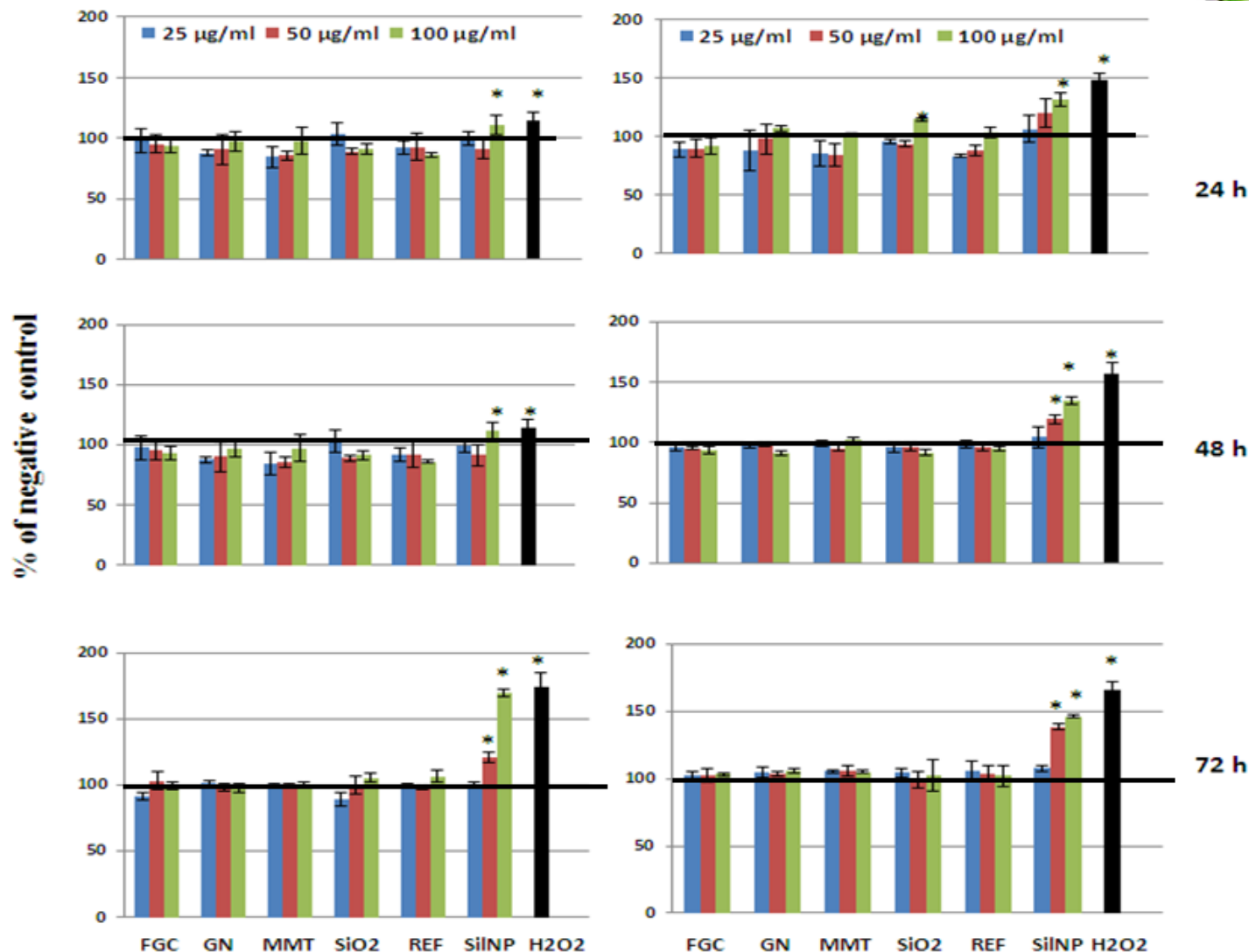


48 h



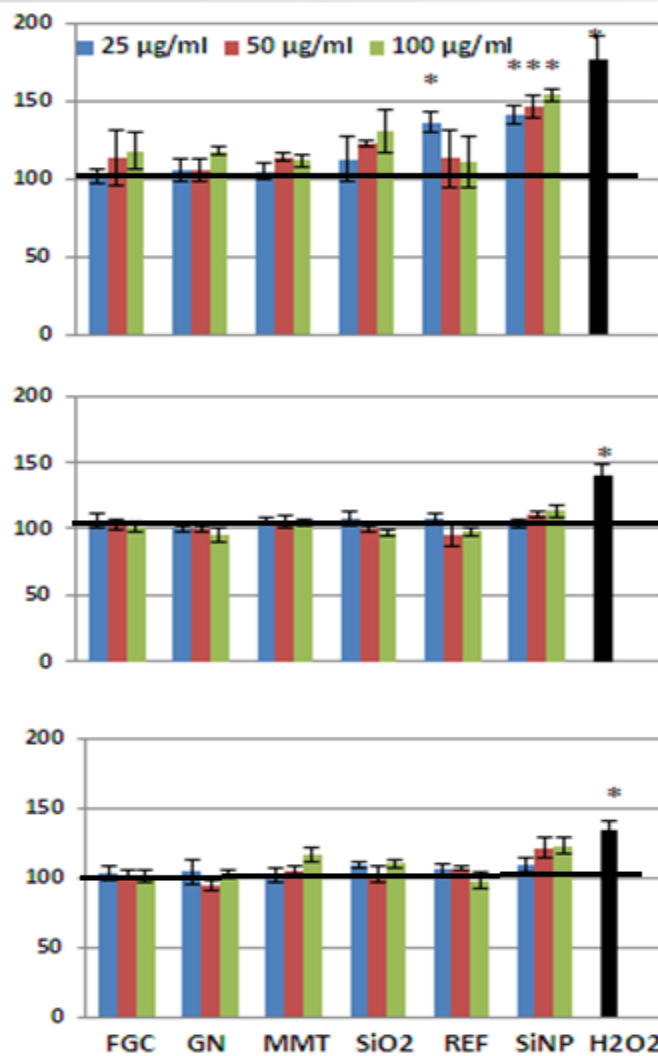
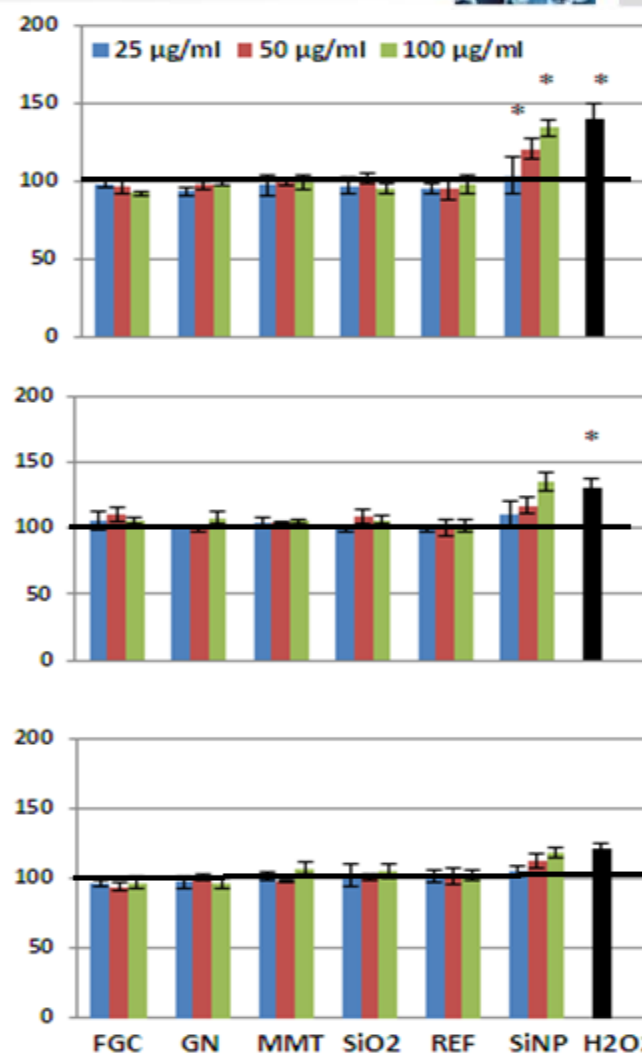
72 h







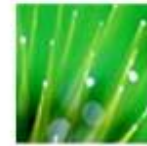
% of negative control



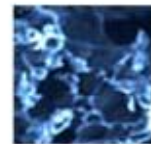
12 h

24 h

48 h



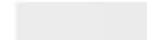
- The addition of silicon filler materials has no negative effect in term of toxicity of the NP released from the respective polymer composites as compared with neat polymer products as tested in the given model
- At 25-100 $\mu\text{g/ml}$, PA6-based NP exhibit higher toxic potency than PP-based NP as determined by MTT assay, regardless of with or without reinforcement agents, which could be due to difference in the material property of the polymers.



Further study of the effect of novel filler materials on NP release from final polymer products and the effect of released NP on environment and human health will inform design of safe materials and minimization of negative impact.

Further work on the toxicity mechanisms of silica nanomaterial in more in vitro systems

- Cellular uptake-toxicity related?
- Subcellular location-
- Molecular pathways-receptor mediated?



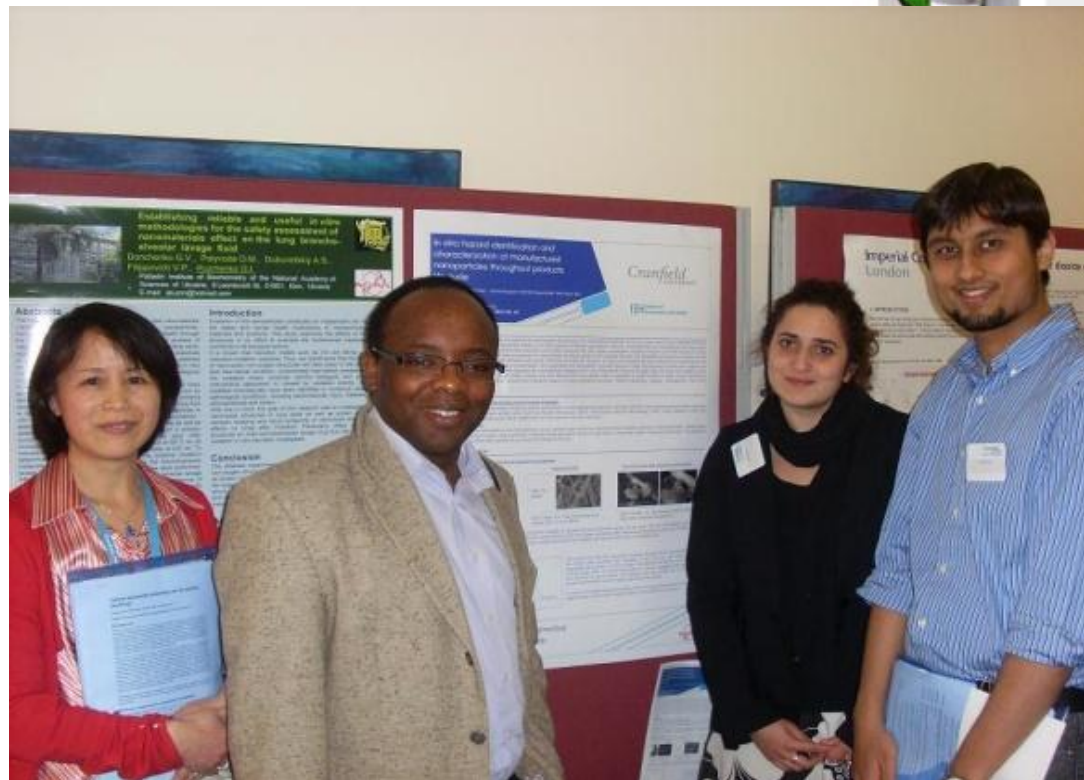
Adeel Irfan

Sophia Sachse

James Njuguna

**Krzysztof
Pielichowski
(Poland)**

**Olga Kazmina
(Russia)**



Thank you for your attention



DSPACE

<https://dspace.org/>

Assessment of nanoparticle release and associated health effect of polymer-silicon composites

Zhu, Huijun; Irfan, Adeel; Sachse, Sophia; Njuguna, James

2014-04-15

<http://dx.doi.org/10.1088/1757-899X/40/1/012015>

Huijun Zhu, Adeel Irfan, Sophia Sachse and James Njuguna. Assessment of nanoparticle release and associated health effect of polymer-silicon composites. NanoStruc 2012 : Proceedings of the International Conference on Structural Nano Composites, 2-4 July, 2012, Cranfield, UK