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

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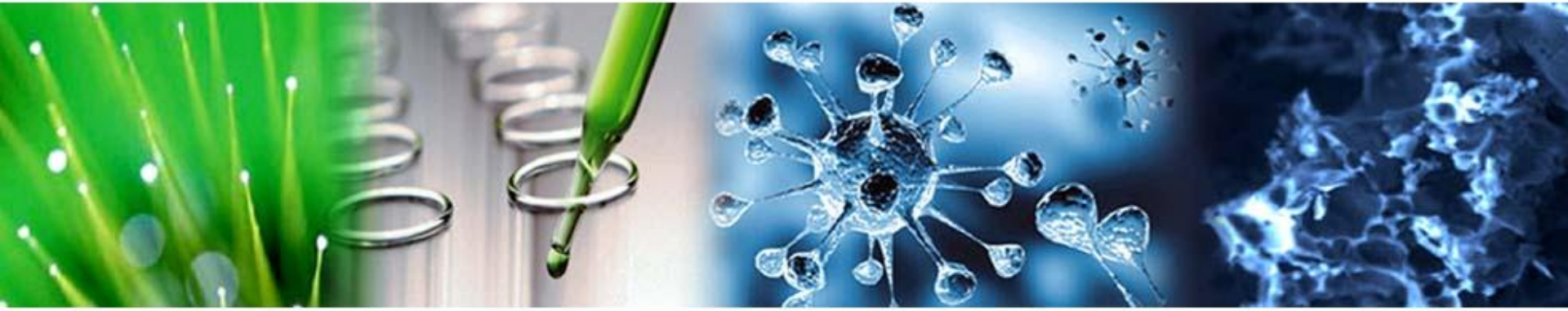


Cranfield UNIVERSITY

228536

SEVENTH FRAMEWORK PROGRAMME

Life cycle assessment of nanoproduct safety




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)

Possible human exposure




Very limited data available

- **Workers**
  SiNP production-packaging/loading

  inhalable (< 10 µm) - 3 mg/m^3
  respirable (1-3 µm)- 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

Toxicity studies




Inhalation

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

1.3 mg/m^3, 13 weeks – reversible mild lung effect
NOEAL-1 mg/m^3
LOAEL-5.9 mg/m^3

No toxicology evidence for occupational exposure

Skin-irritation

Exposure via other route – toxicity in liver, thrombosis

Challenges in toxicity study of NP




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

Objectives




- 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

Methods




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

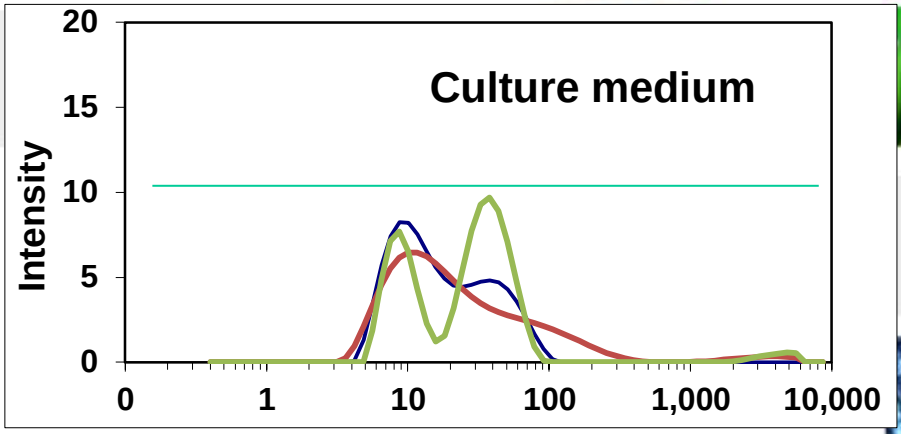
- Metabolism/Cell viability (MTT test)
- Cell membrane damage (LDH assay)
- Intracellular oxygen species (ROS assay)
- IL-8 production

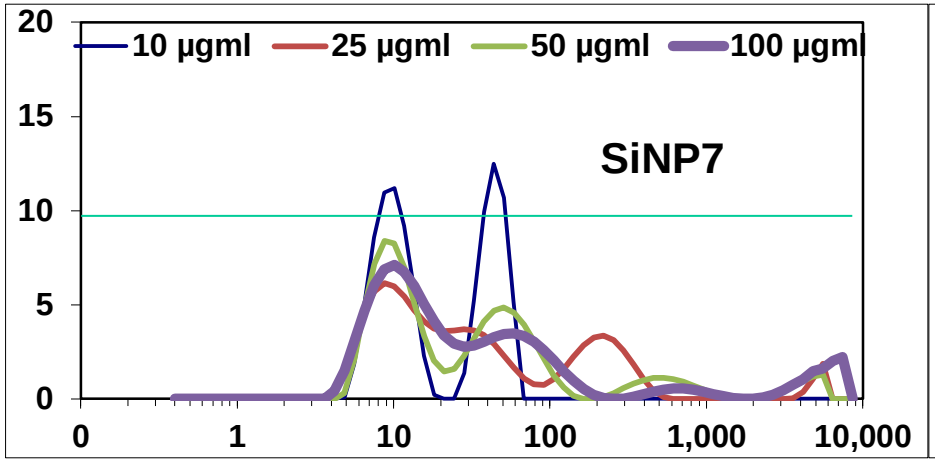
Testing raw silica NP

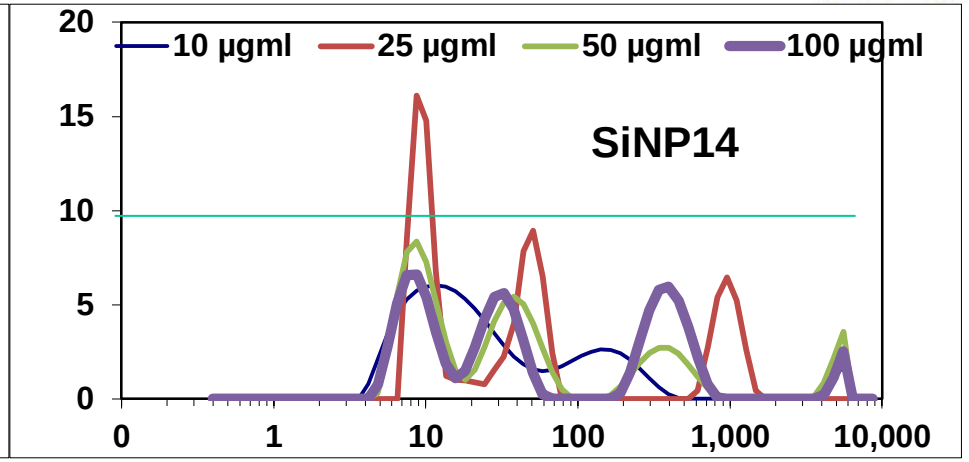


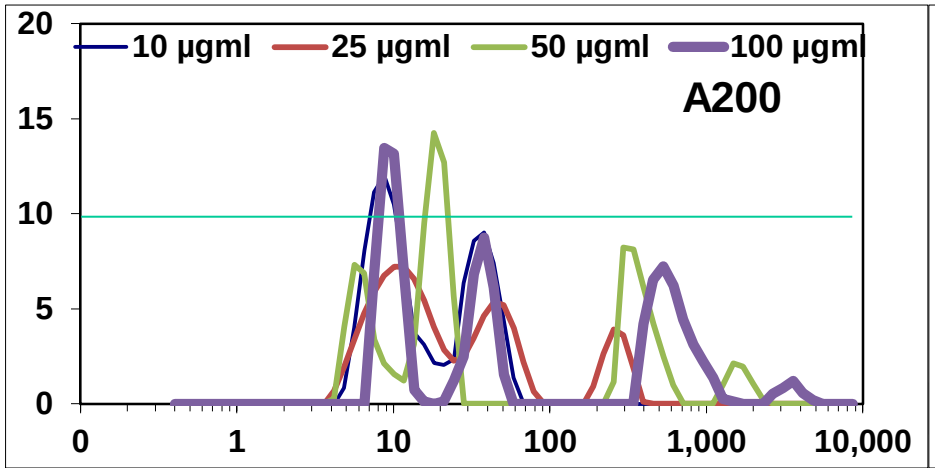

Silica NP	Primary/ aggregates Size (nm)	Behaviour in water
Silica 7, fumed	7/~	Hydrophilic
Aerosil 200, fumed	12/~	hydrophilic
Aerosil 974, fumed	12/~	Hydrophobic

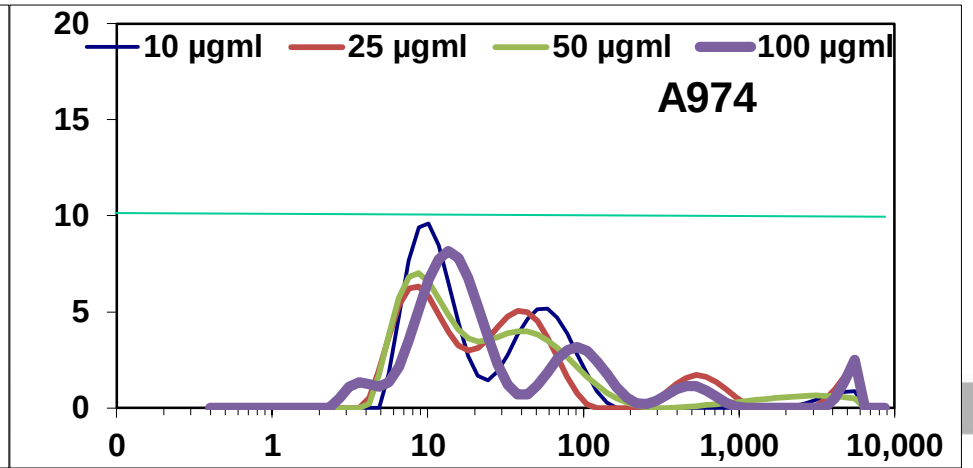
DLS assay of silica NP





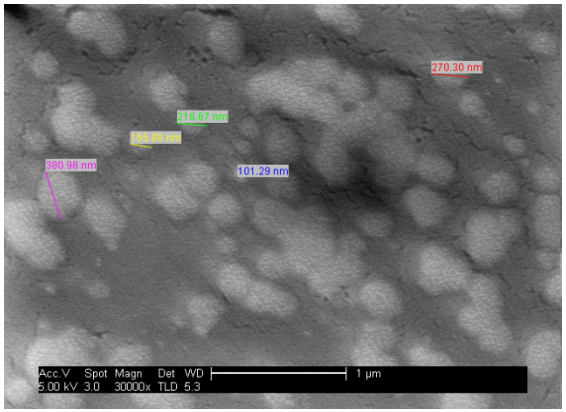




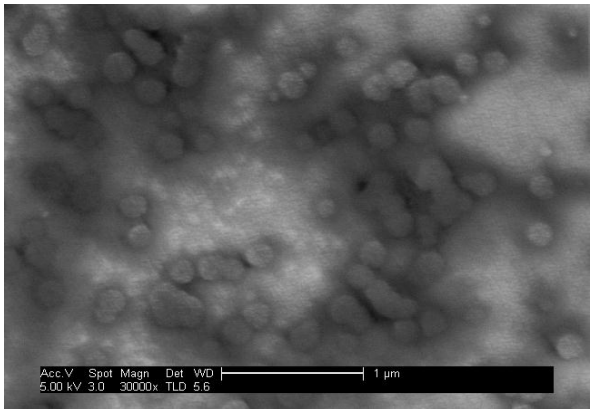


SEM of raw silica NP

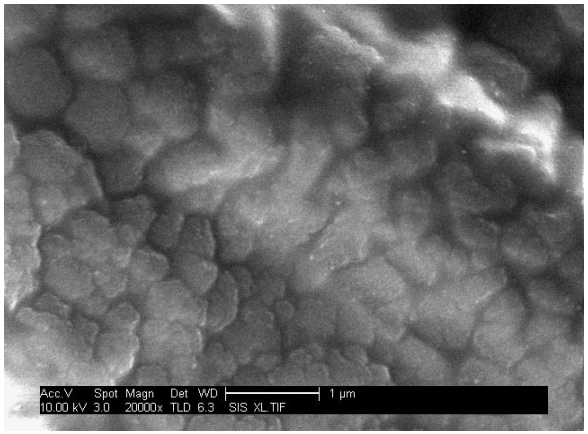
Aerosil 200

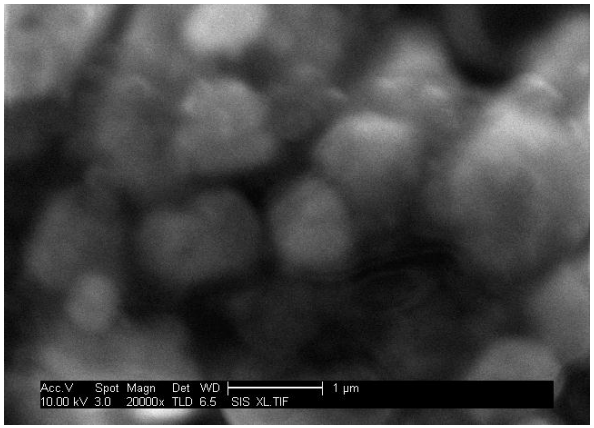


Aerosil 974



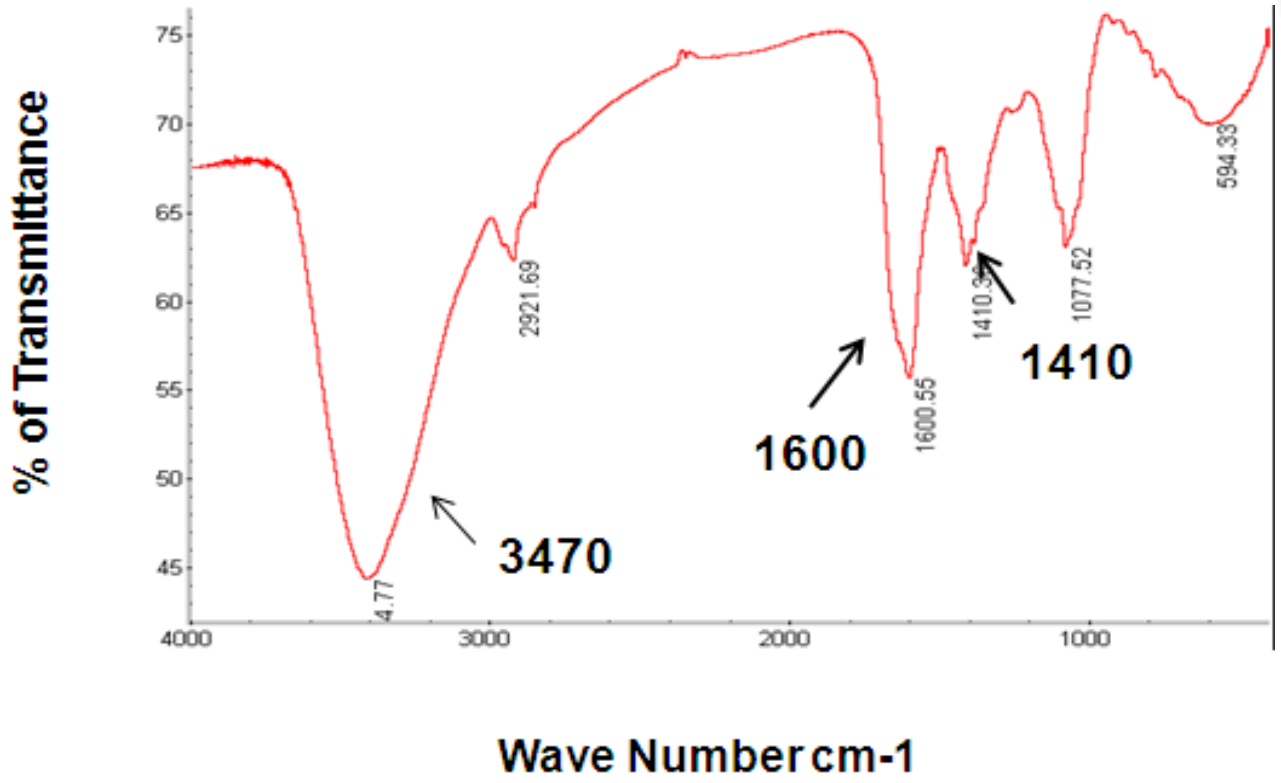
SiNP in culture medium at 10 µg/ml





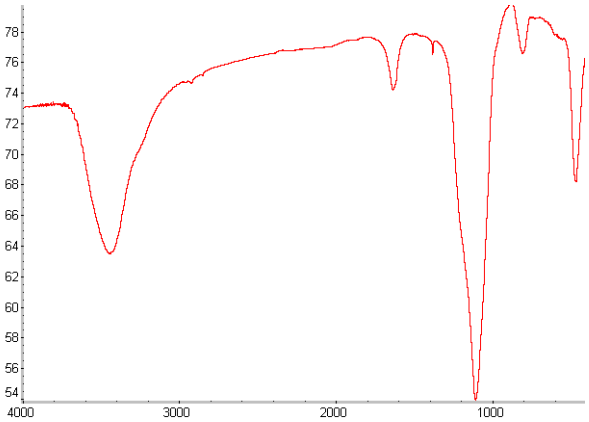
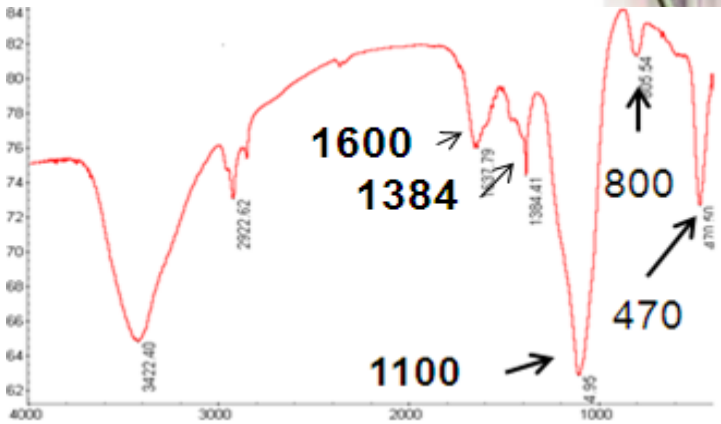
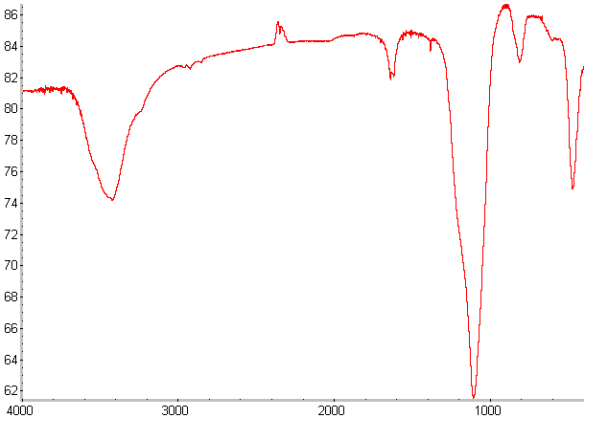
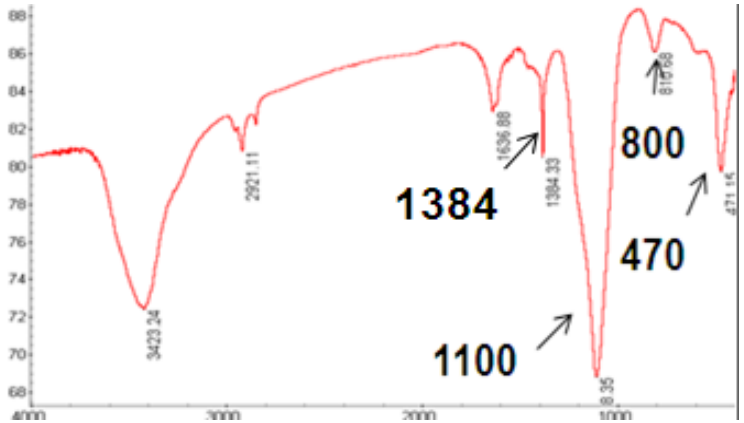
SiNP in culture medium at 100 µg/ml

FTIR-Culture medium



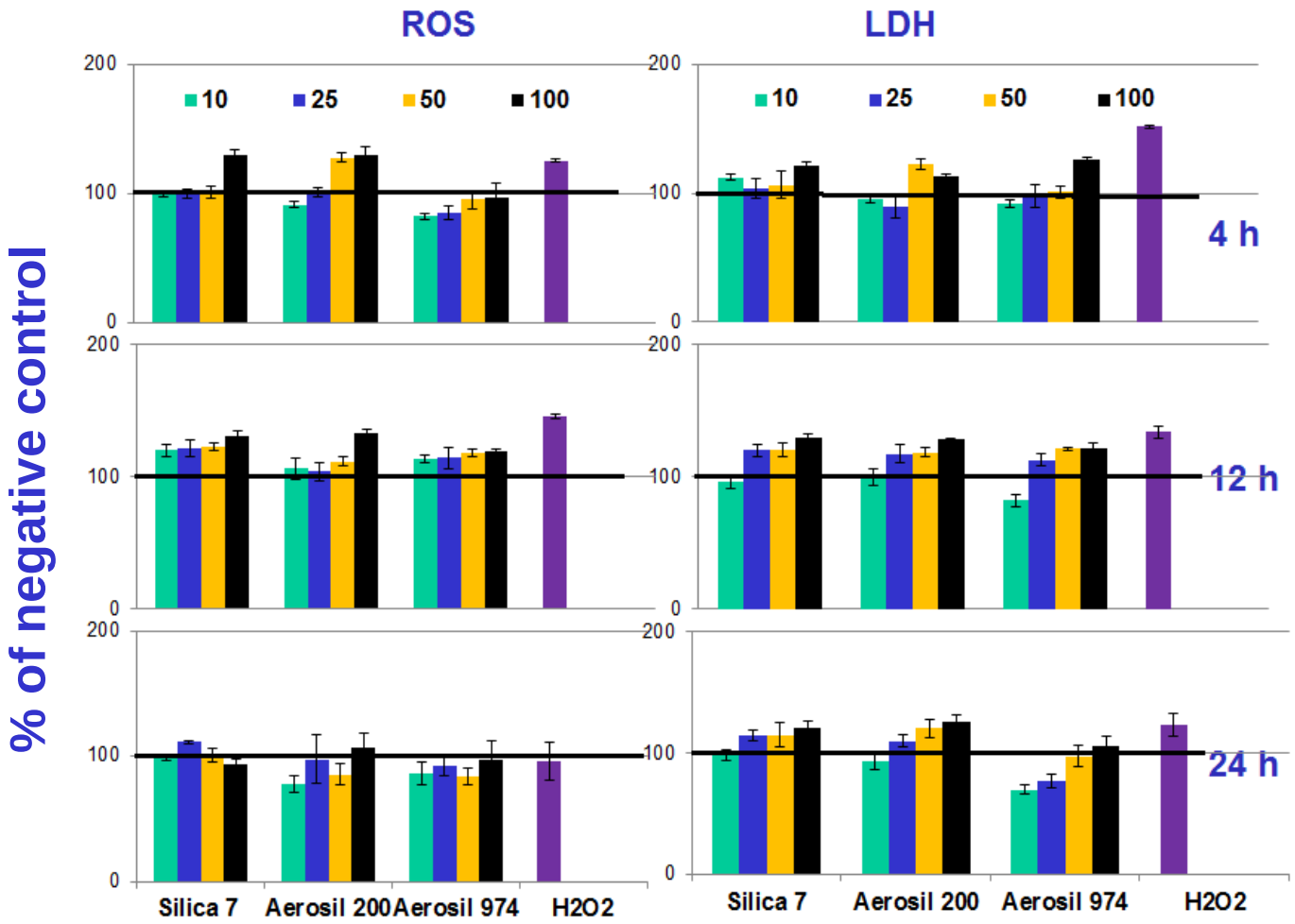
The peaks at 3470 cm-1 corresponds to –OH. The peaks at 1600 cm-1 and 1410 cm-1 correspond to the C=O and C-H bounds respectively.

Chemical composition of SiO2 NP

	In water	In culture medium
A200		
A974		

Wave number cm-1

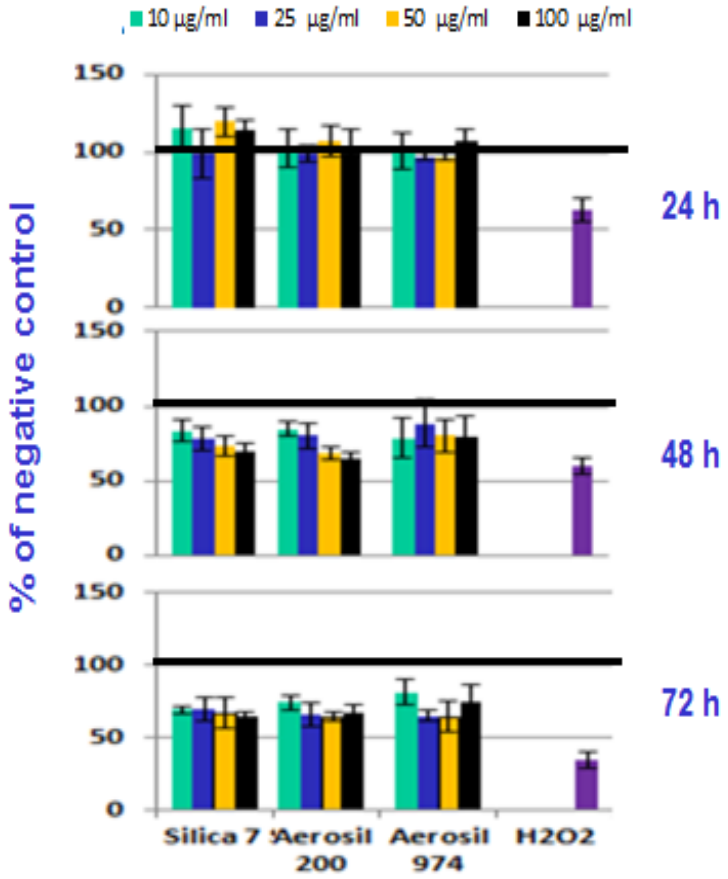
Toxicity study of silica NP in A549 cells



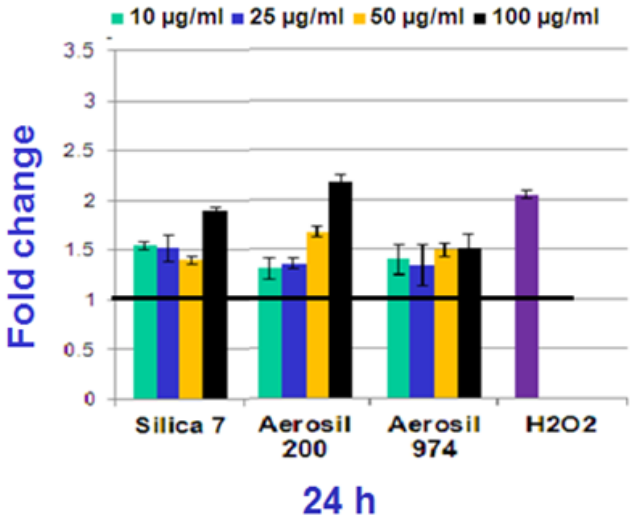
Concentration dependent toxicity of silica NP was evidenced

Toxicity of silica NP in A549 cells

MTT



IL-8



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

- Silica NP also induced IL-8 production

Conclusions

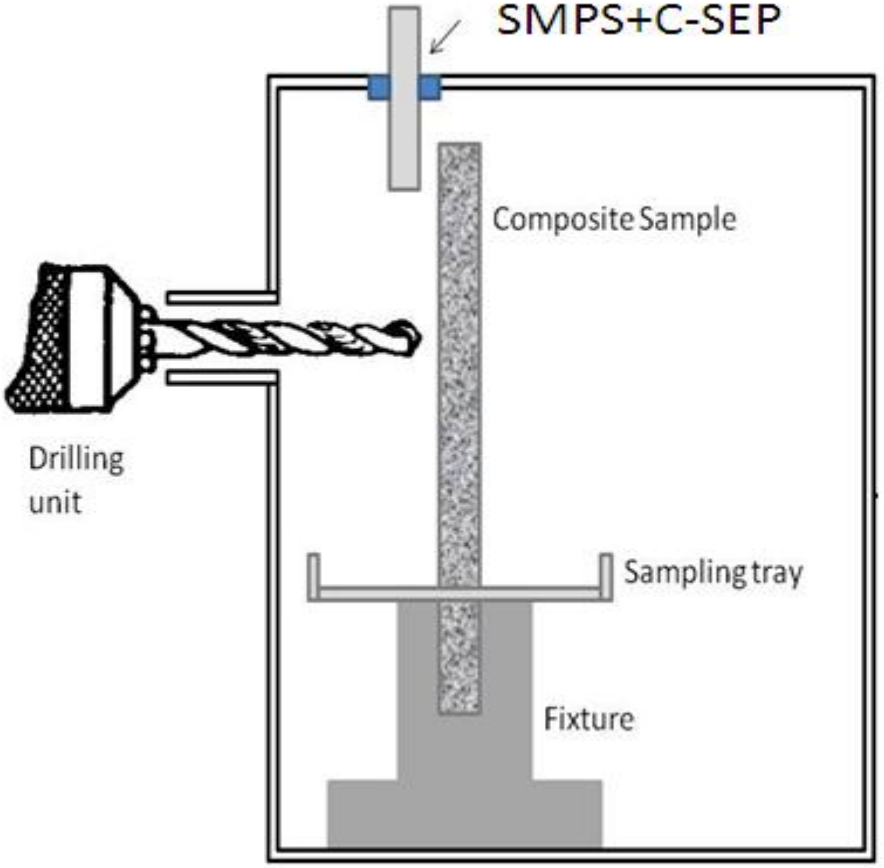
- At 10-100 µg/ml, all the silica NP tested induced time dependent loss of cell viability which was associated with early membrane damage, increase in intracellular ROS level and IL-8 production.

- 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.

Testing composites

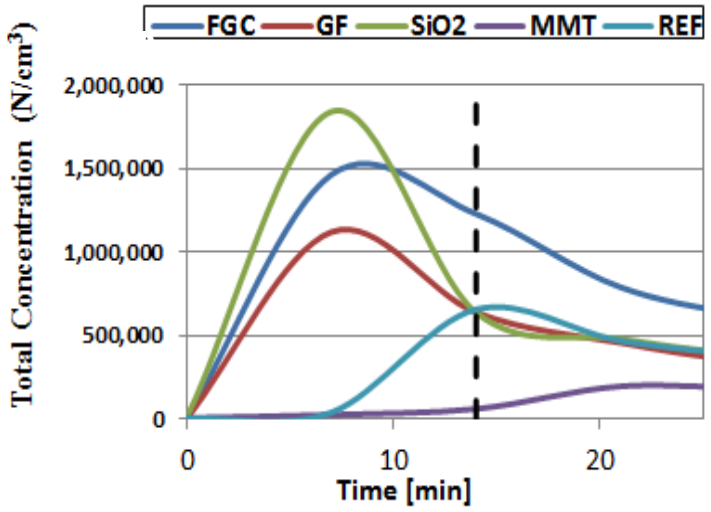
PA6/PP-silicon composites	Filler materials
PA6/PP(REF)	
PA6-MMT	Dellite 43B
PA6-SiO2	AEROSIL® 200
PP-MMT	Dellite 72T
PP-SiO2	AEROSIL® 974
PA6/PP-FGC	Fiber glass crystal
PA6/PP-GF	Glass fibers

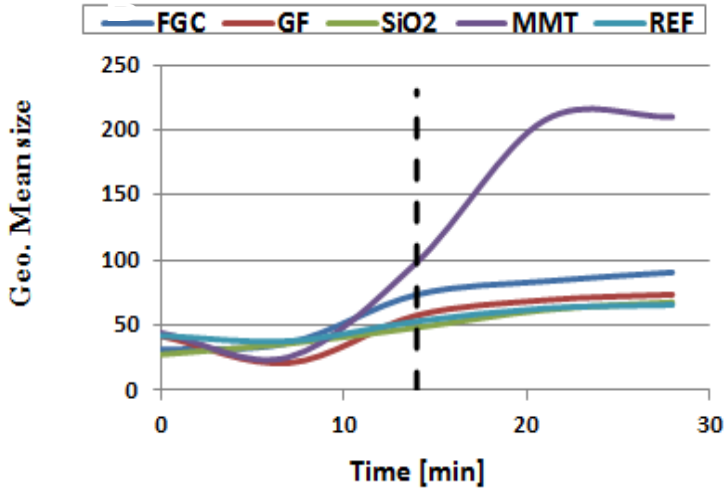
Drilling chamber and airborne NP monitoring



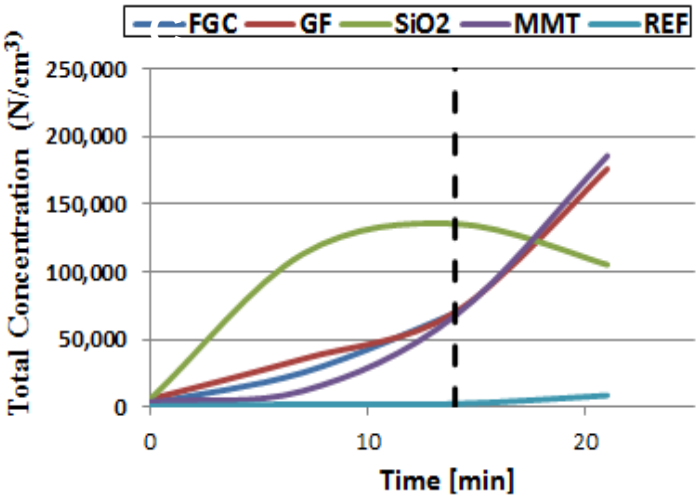
Concentration and size distribution of airborne particles in testing chamber

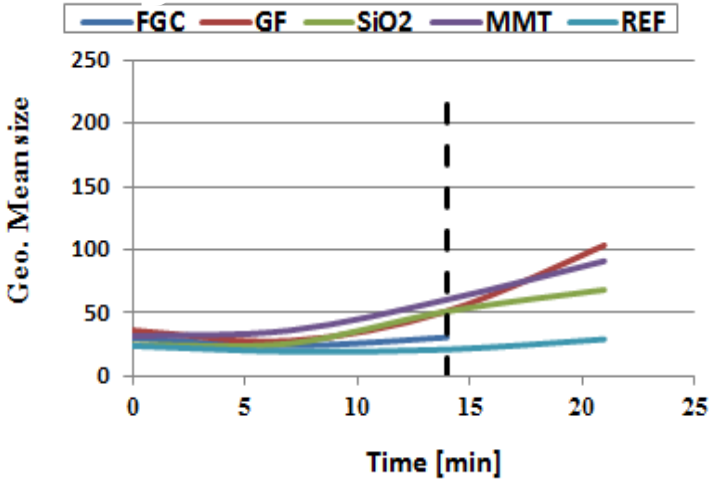
PA6-composite





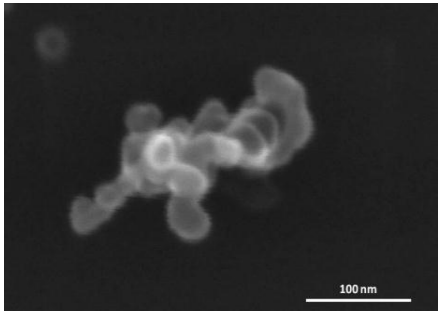
PP-composites



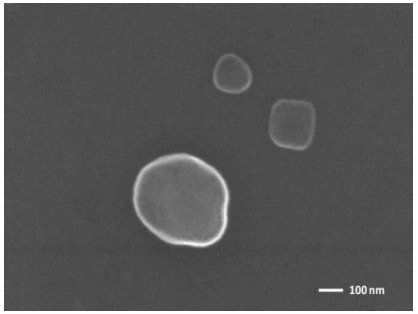


Airborne NP generated from PA6 polymeric materials

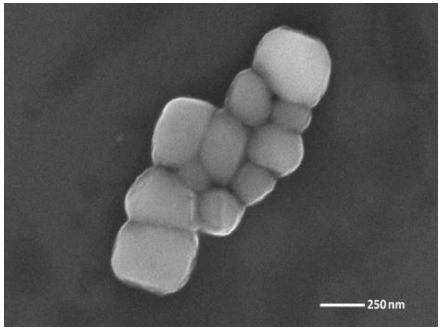
PA6-SiO2



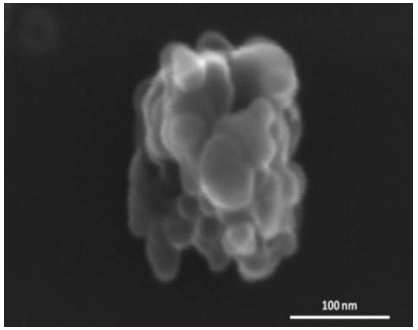
PA6-MMT



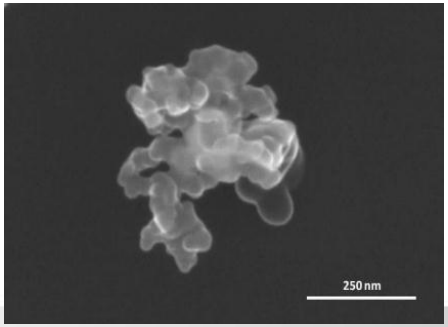
PA6-GF



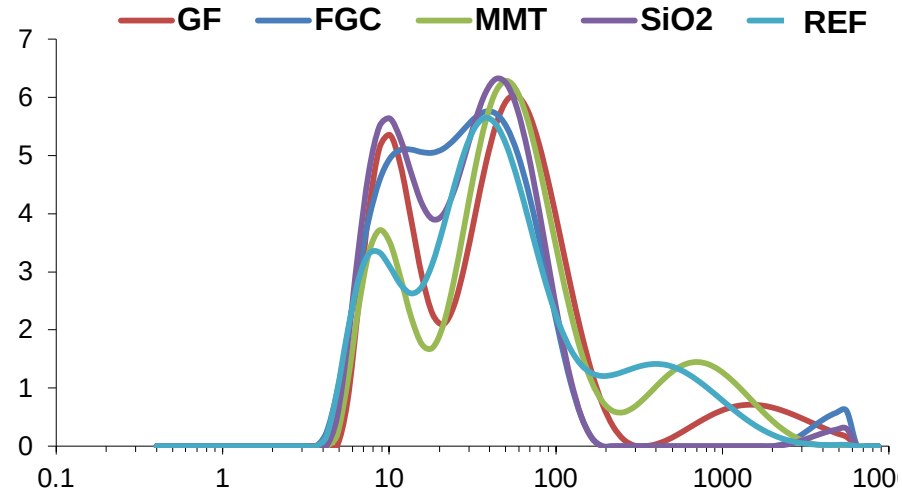
PA6-FGC



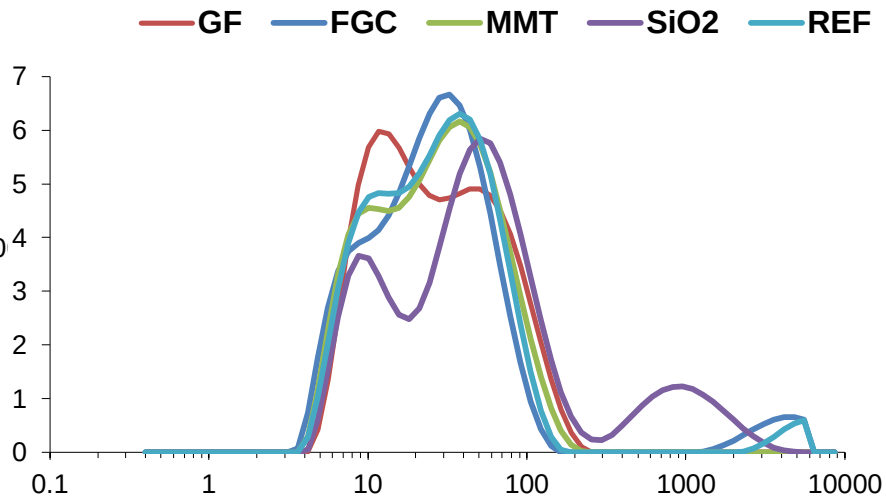
PA6-REF



DLS profiles of NP from PA and PP-composites in cell culture medium

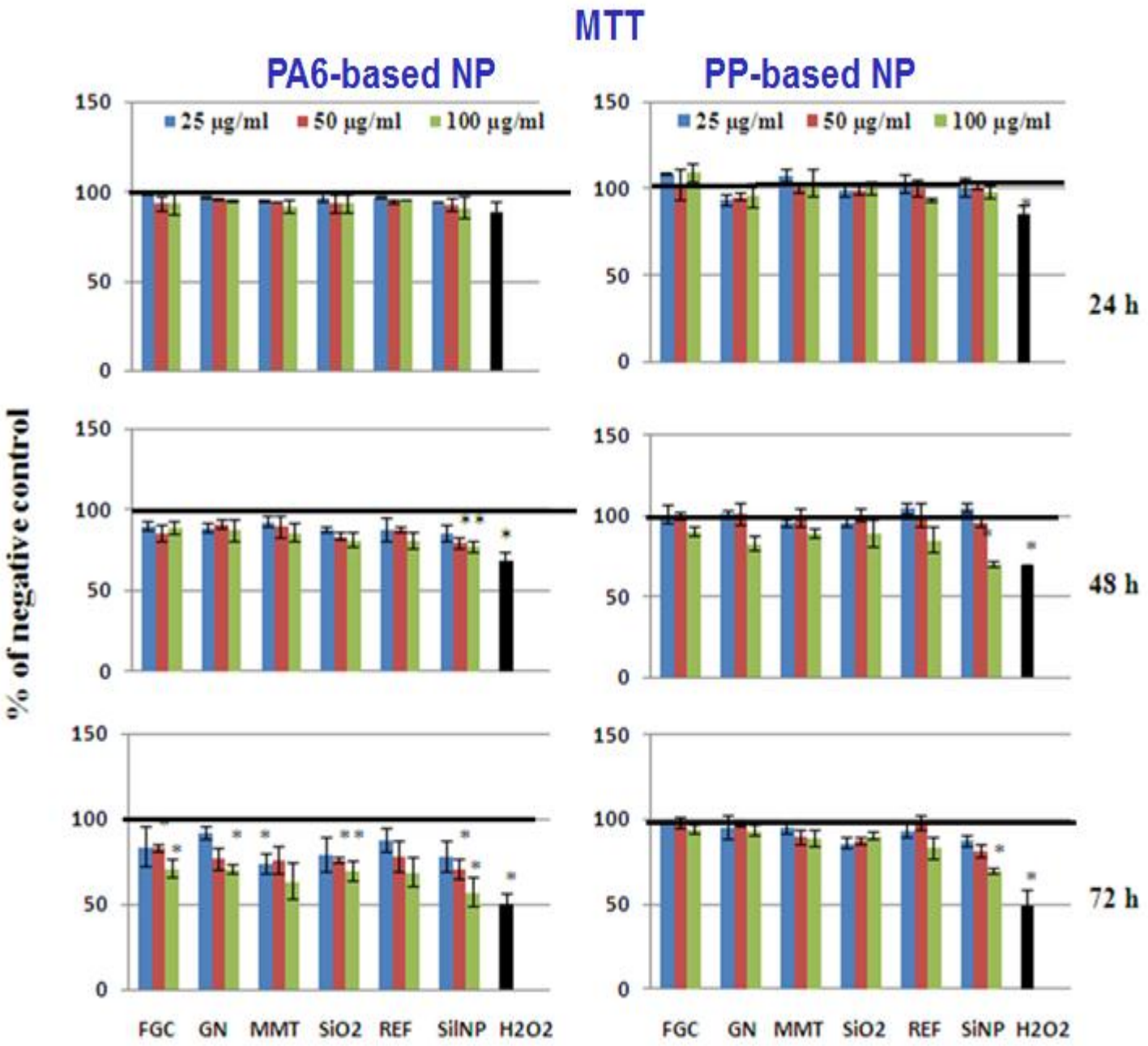


Hydrodynamic size of PA-based dust NP (nm)



Hydrodynamic size of PP-based dust NP (nm)

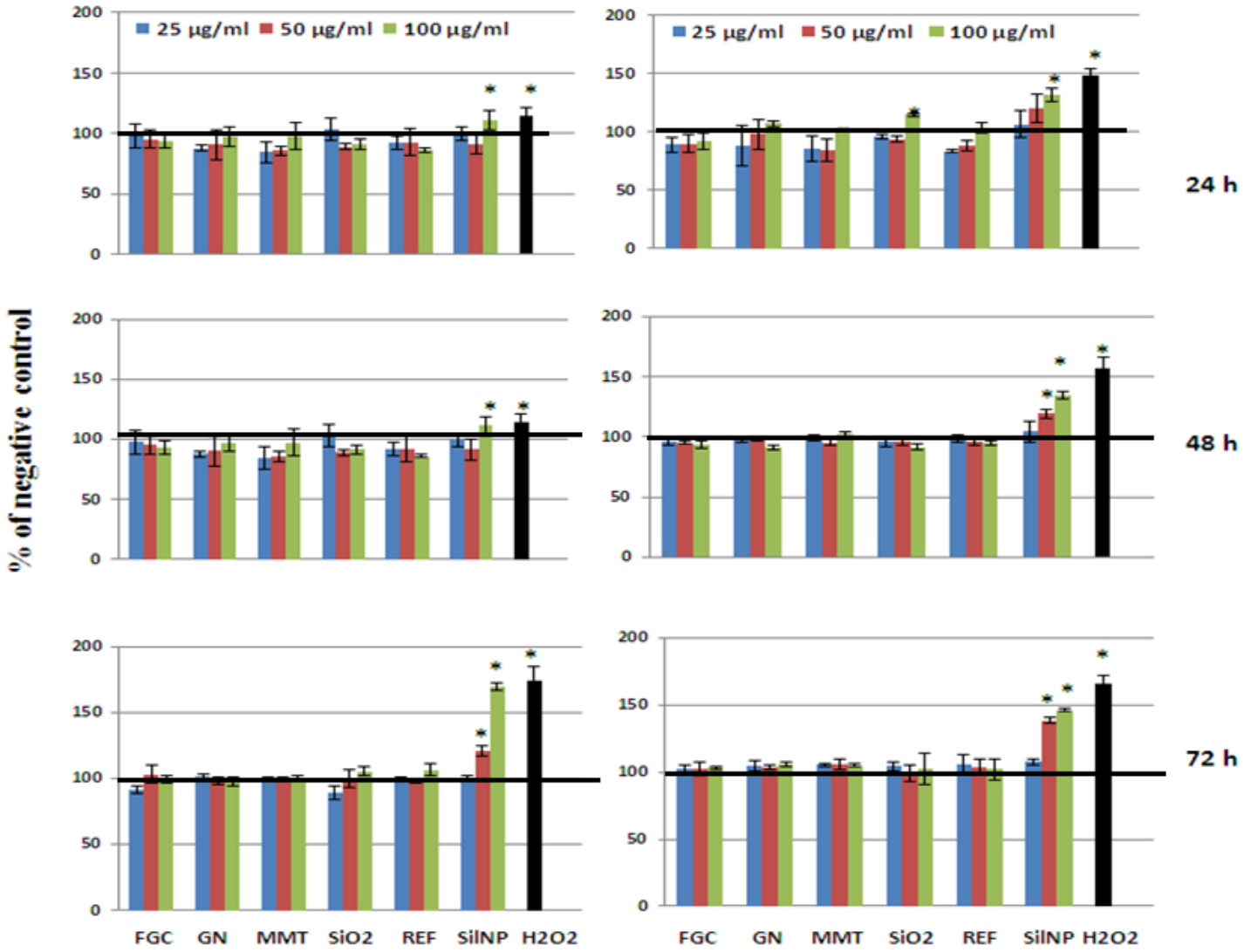
The dust NP were diluted in cell culture medium (DMEM) at 100 µg/ml. All the dust samples contain NP with average hydrodynamic size less than100 nm.



LDH

PA6-based NP

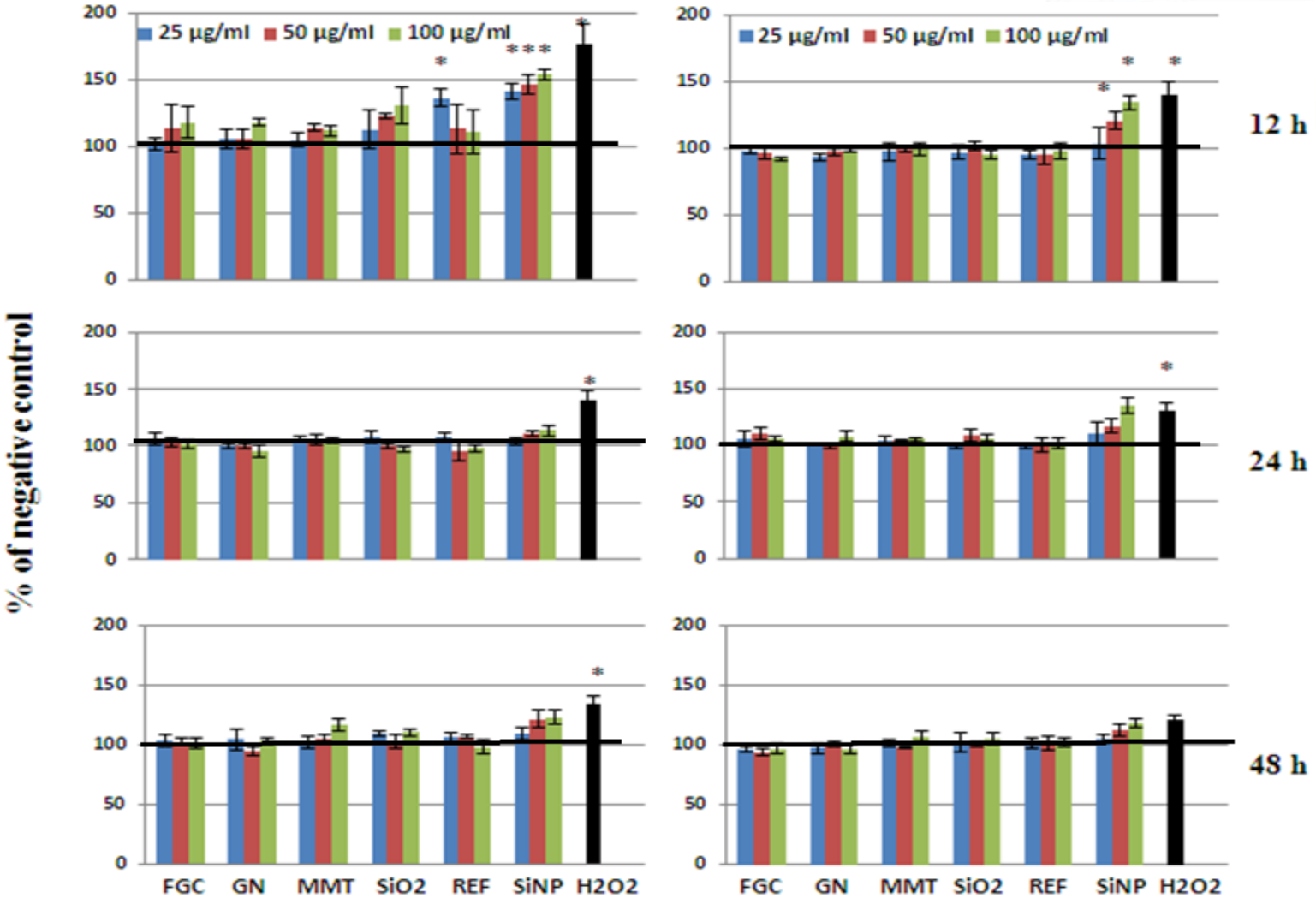
PP-based NP



ROS

PA6-based NP

PP-based NP



Conclusion




- 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 µg/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.

Outlook




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?

Acknowledgement

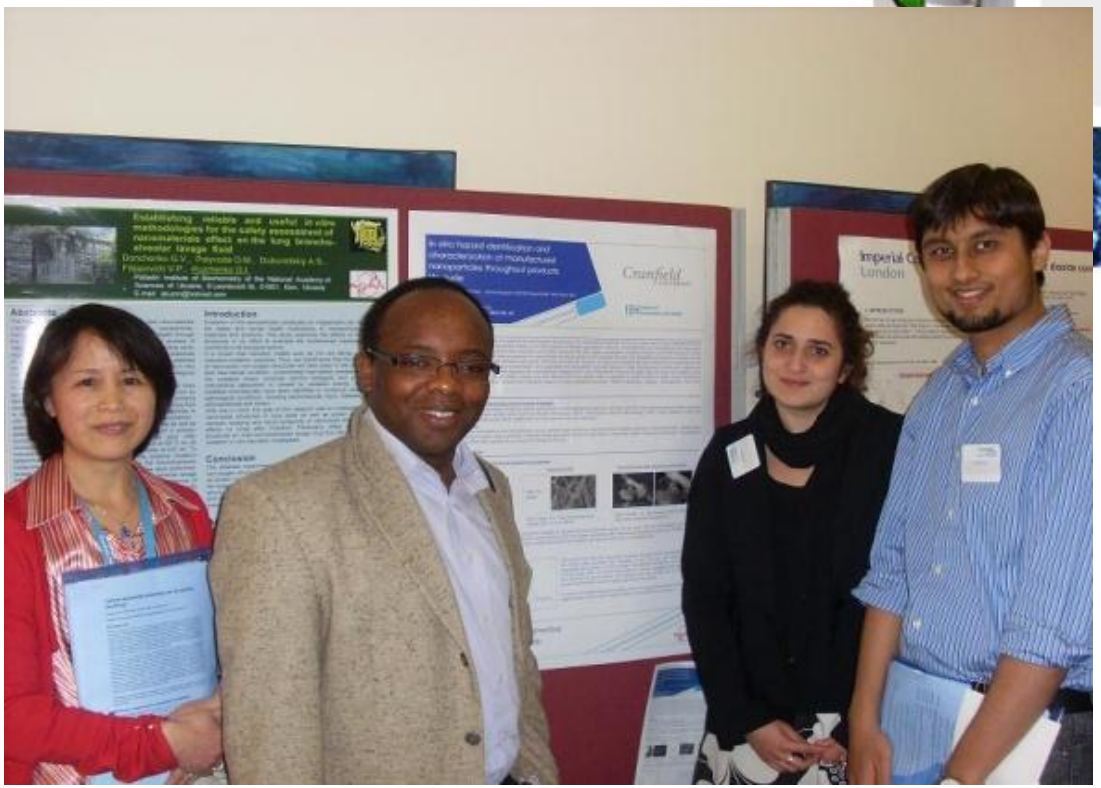
Adeel Irfan

Sophia Sachse

James Njuguna

Krzysztof Pielichowski (Poland)

Olga Kazmina (Russia)



Thank you for your attention