

Nanotechnology and Health: How do we safely produce and utilize nanoparticles?

Maja Remškar, Ivan Iskra



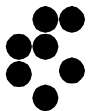
Solid State Physics Department

“Jožef Stefan” Institute

Centres of Excellence:

Polimat, Namaste, NiN

Ljubljana, Slovenia



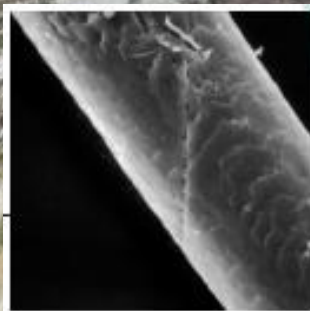
Earth – football ball – C₆₀ molecule



22 cm



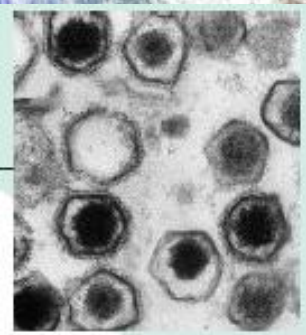
flea - 1mm



hair – 80 μm



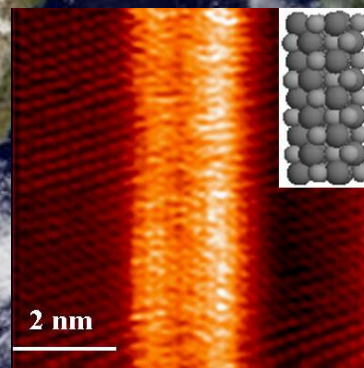
Red blood cell - 7 μm



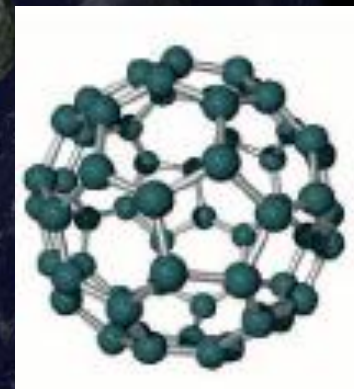
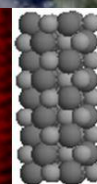
Virus – 150 nm



DNA-diameter 2 nm



Nanotubes
MoS_{2-x}ly
- 0.96 nm



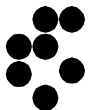
C₆₀ – 0.7 nm

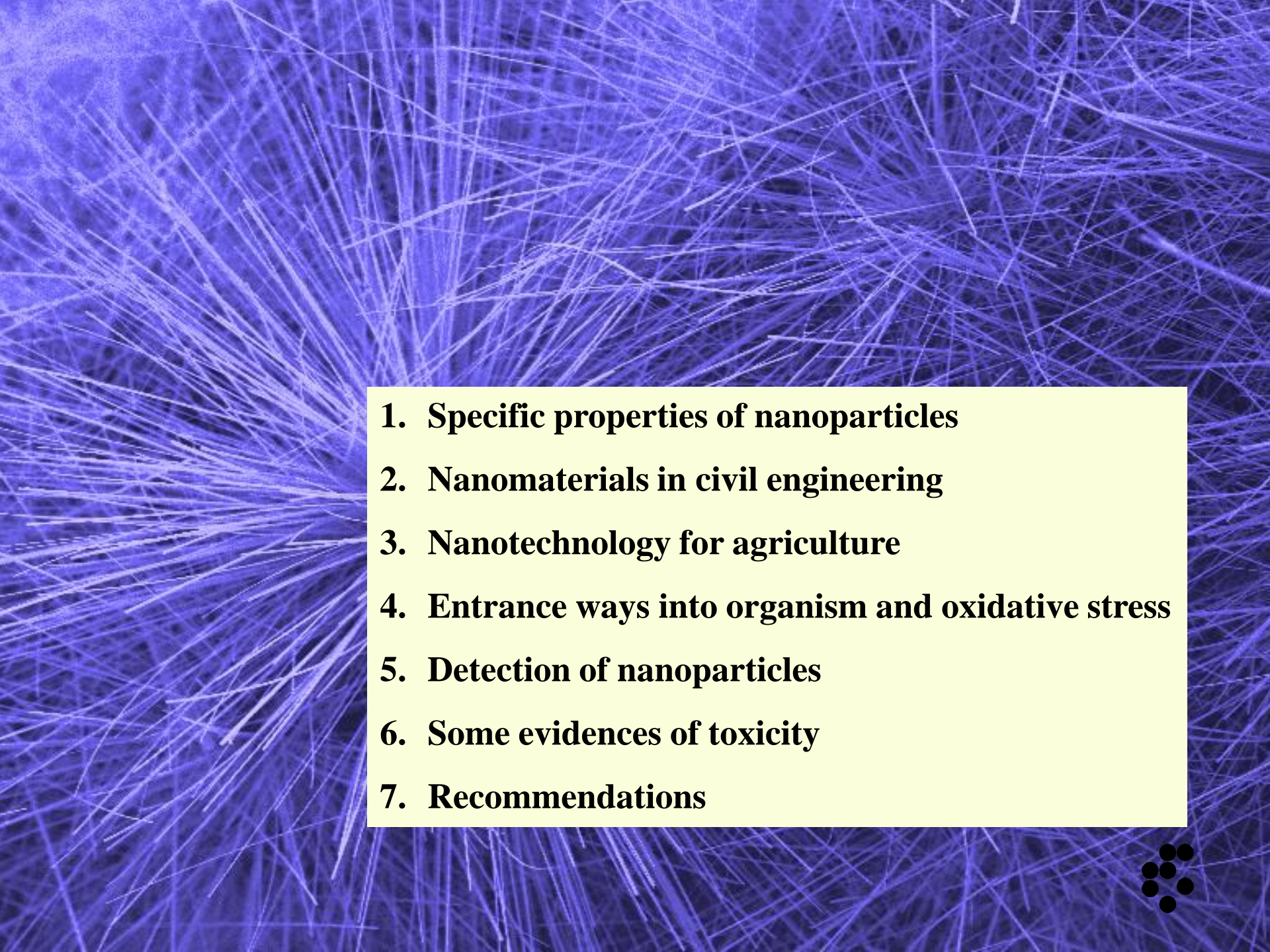
1 nanometre (nm) = 0.0000000001 m

Market assessment for nanotechnologies

	2007	2008	2013
Market for nanotechnologies	11,6 billions \$	12,7 billions \$	27 billions \$
Nanomaterials	87 % 10.8 billions \$	85 % 10.8 billions \$	69 % 18,7 billions \$
Nanomethods and nanotools	12,8 % 1,5 billions \$	15 % 1.9 billions \$	29,6 % 8 billions \$
Nano-devices	0.2 % 23.2 millions \$	0.2 % 26.2 millions \$	1.3 % 366 millions \$

*Nanotechnology: A Realistic Market Assessment
 Research Report # GB-NAN031C
 Publication Date: May 2008
 Principal Analyst: Andrew McWilliams, BCC*



- 
- 1. Specific properties of nanoparticles**
 - 2. Nanomaterials in civil engineering**
 - 3. Nanotechnology for agriculture**
 - 4. Entrance ways into organism and oxidative stress**
 - 5. Detection of nanoparticles**
 - 6. Some evidences of toxicity**
 - 7. Recommendations**



Origin of nanoparticles and where we meet them:

- **engineered:** cosmetics, food, detergents, textile, water protective films
- **natural:** erosion, desert powder, viruses
- **non intentionally produced:**
 - a side product in industrial production (grinding, soldering, milling)
 - combustion of bio-mass
 - emission from diesel engines
 - etc..

Size, and why is important?

70 nm particles cross through alveolar surfaces of the lung

50 nm cross through cells

30 nm through cell nucleus

And **NO** comprehensive data on **< 20 nm** particle movements.



Number of NPs in cm³:

-Office: $1 \cdot 10^4$ - $4 \cdot 10^4$

-Welding: $4 \cdot 10^6$

-Grinding: $2 \cdot 10^5$

-Smoking $>1 \cdot 10^8$
exhalation

Eye: resolution - 0.1 mm

Optical microscope: 300 nm (3000 x)

Transmission electron microscope:
0.12 nm – $1.5 \cdot 10^6$ x

Unvisible

Airborn

NANOPARTICLE

Fast

Reactive

Brownian motion

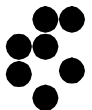
velocity $\propto m^{-1/2} \propto r^{-3/2}$

$m_{\text{Carbon}} (10 \text{ nm}) = 3 \cdot 10^{-22} \text{ kg}$

$v (RT) = 11 \text{ m/s}$

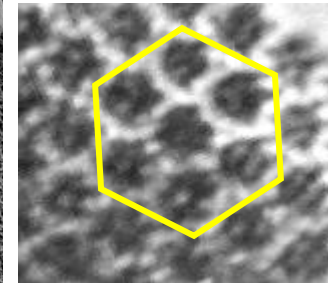
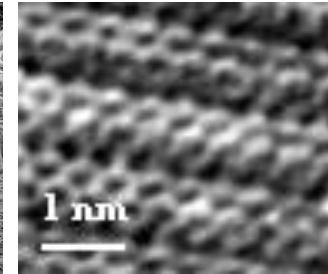
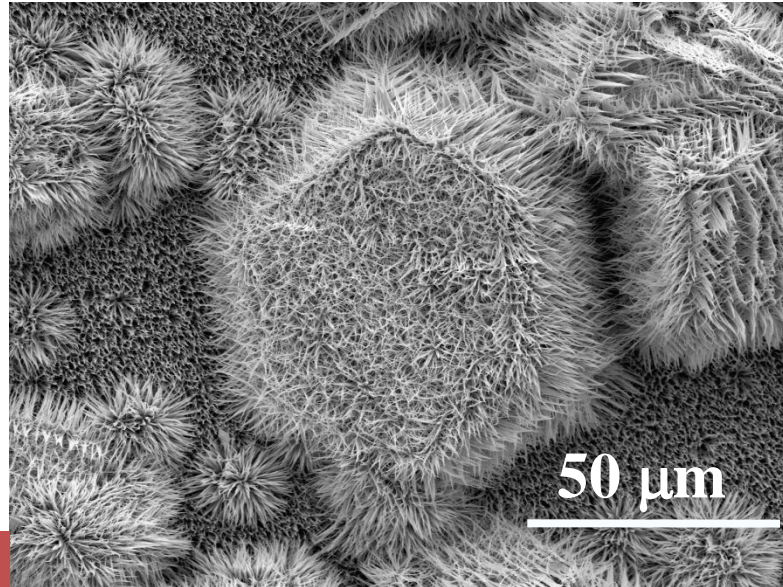
- Large surface area/mass ratio

- Quantum effects



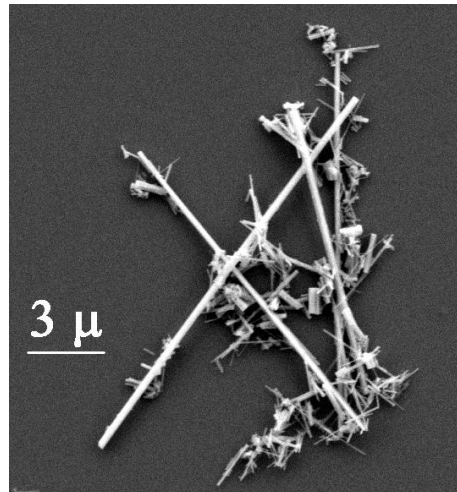
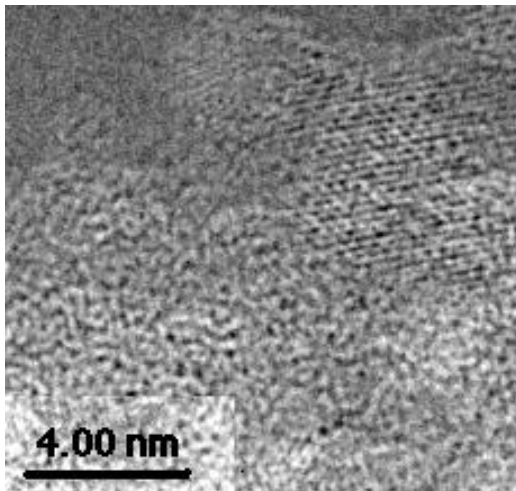
Agglomeration of nanoparticles

- Self-assembly
of $\text{Mo}_x\text{S}_y\text{I}_z$
nanotubes



Agglomeration of
 TiO_2 during the
production process

Agglomeration of WO_x nanowires
during evaporation of solvent



**NO data on agglomeration
and recrystallization in:**

- bio-compatible solvents
- during the transition
through a cell membrane
- inside a cell and its
nucleus

Chemical activity of nanoparticles

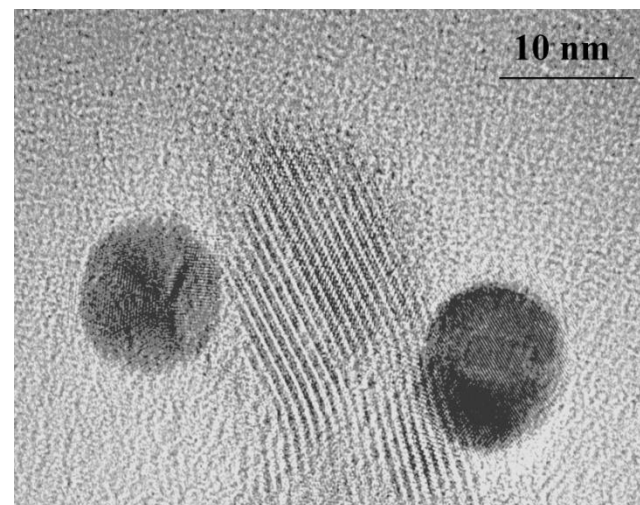
Strongly depends on the ration of surface atoms to volume atoms

Diameter	N_S / N_V atoms
8 nm	7 %
1 nm	58 %

The changes in the coordination number affect the interband transitions in nanoparticles- different electric and optical properties .

Phenomenon of chemical activity of gold

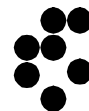
Au particles (diameter less than 10 nm) deposited on metal oxides become surprisingly active (for CO oxidation, propylene epoxidation, etc.)



(A. Haruta, Chemical record 3 (2003) 75)

Use in medicine: detection of biological molecules, as example amino acids, which play different roles in heart disease, rheumatoid arthritis and AIDS.

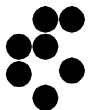
(F.X. Zhang et al., Analyst 127 (2002) 462)



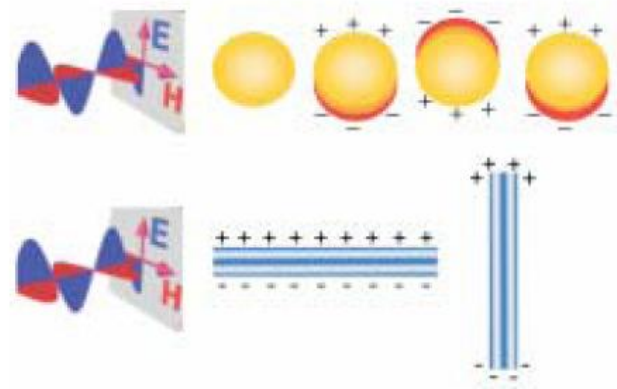
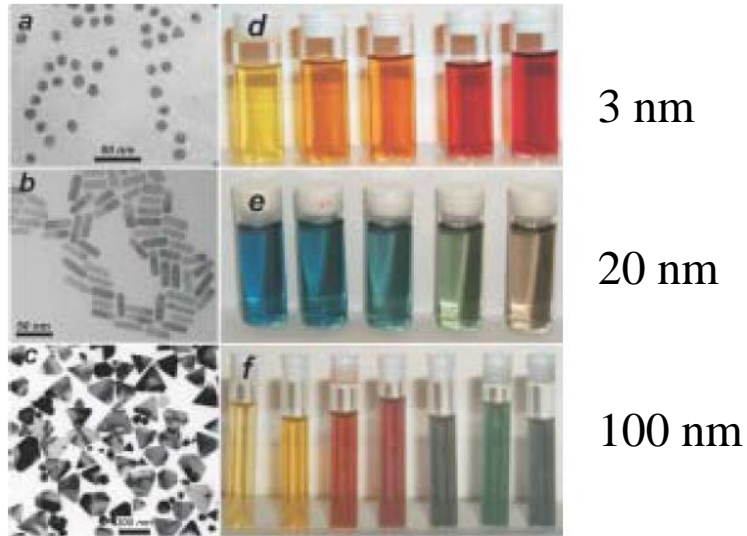
Nanomaterials for civil engineering

Already in use:

- **Concrete is stronger, more durable and more easily placed: nanofibres**
- **Steel is made tougher: Cu, C nanoparticles**
- **Glass is self-cleaning: TiO_2**
- **Paint are made more insulating and water repelling: SiO_2**
- **Energy storage in nanodroplets: polycarbons**
- **Protection agains electro-magnetic pollution: Fe_2O_3 nanoparticles**



Use of Au nanoparticles in paints



Surface plasma resonance
(Au, Ag, Cu, alkali metals)

Intensive colors dependent on size, shape and concentration of nanoparticles.

- **A few % of NPs: intensive and transparent paint**
- **More than 80% of NPs: metallic reflectivity**

Luis M. Liz-Marzán,
MaterialsToday, febr. 2004

Antibacterial activities of nanoparticles Ag, TiO₂, ...

Nanoparticles in paint act as contact fungicides and bactericide.

- stop enzymes, which transfer nutrition into a cell
- destroy structure of protein
- interact with genes
- influence biochemical processes for synthesis a cell membrane

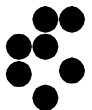
Sufficient quantities: 1 gramme of NPs per 10 kg of paint

Enhanced thermal isolation and durability of a paint

Prevent absorption of water with simultaneous ability for its diffusion and desorption

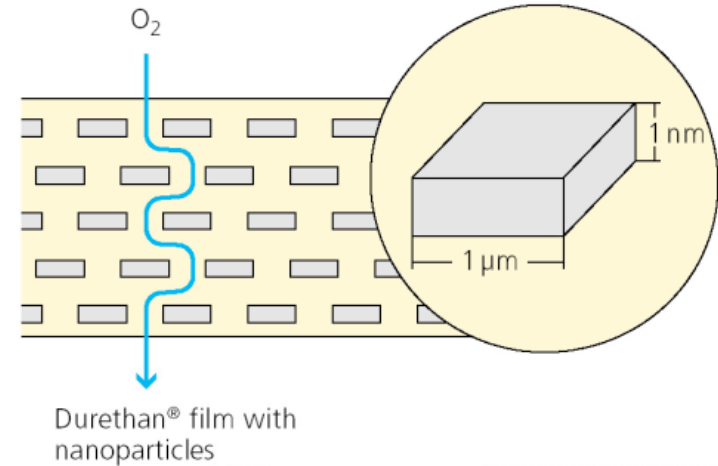
Prevent growth of mold

Particularly, TiO₂ catalyze breakdown organic pollutants, volatile organic compounds and bacterial membranes.



Nanotechnology in agriculture

- Smart and effective packaging materials incorporating silicate nanoplates which keep food fresher and longer than their previous plastics



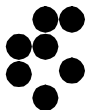
- Enhanced chemical activity of materials used for chemical treatment of growing plants
- encapsulation and controlled release of pesticides and herbicides
- Purification of water and cleaning up contaminated soil (iron NPs catalyse the oxidation and breakdown of organic contaminants such as trichloroethene, carbon tetrachloride, dioxins, and PCBs to simpler carbon compounds which are much less toxic)
- Decoration effects

- sensors which can almost instantly reveal whether a food sample contains toxic compounds or bacteria;
- anti-bacterial surfaces for machines involved in food production;
- thinner, stronger and cheaper wrappings for food;

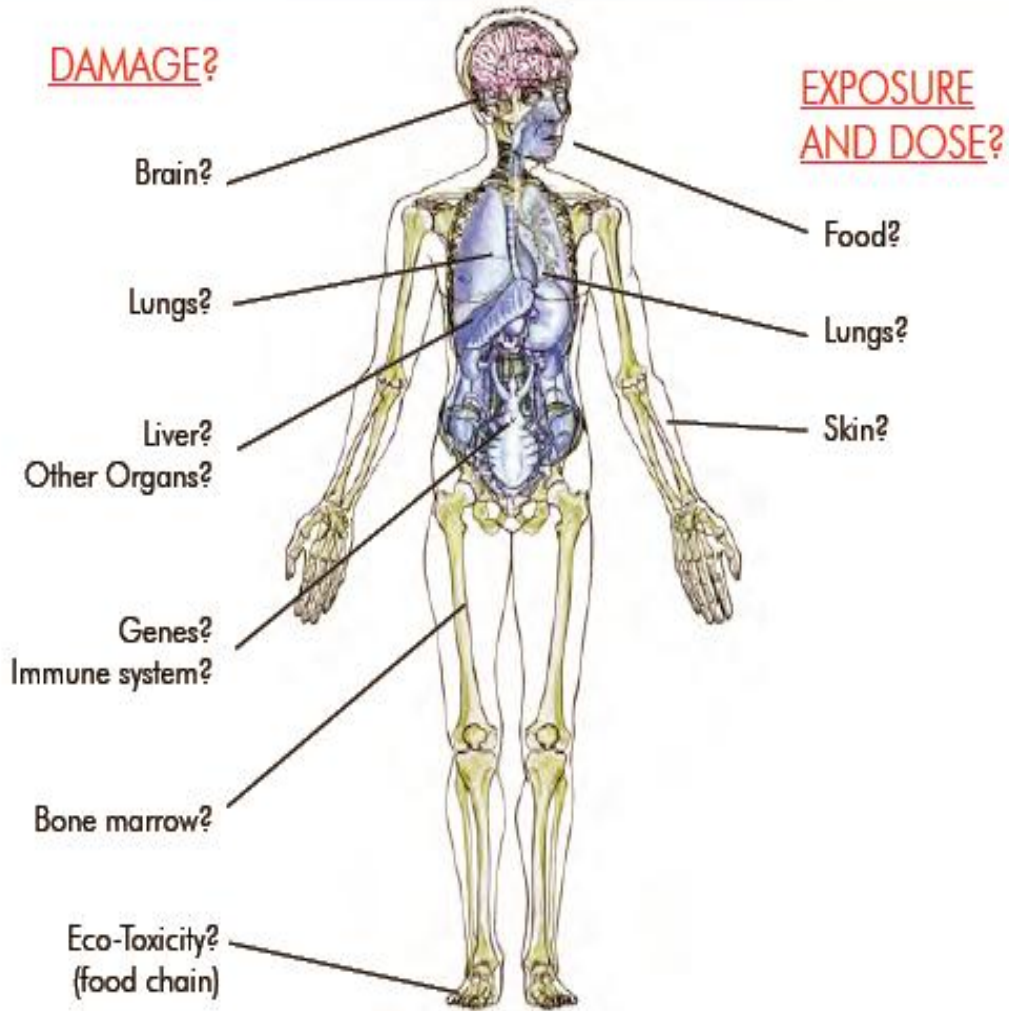
and the creation of food with a healthier nutritional composition

50 nm coiled nanoparticles can be used to deliver nutrients such as vitamins and omega fatty acids more efficiently to cells, without affecting the color or taste of food

and interactive foods which will allow the consumer to choose between different flavors and colors



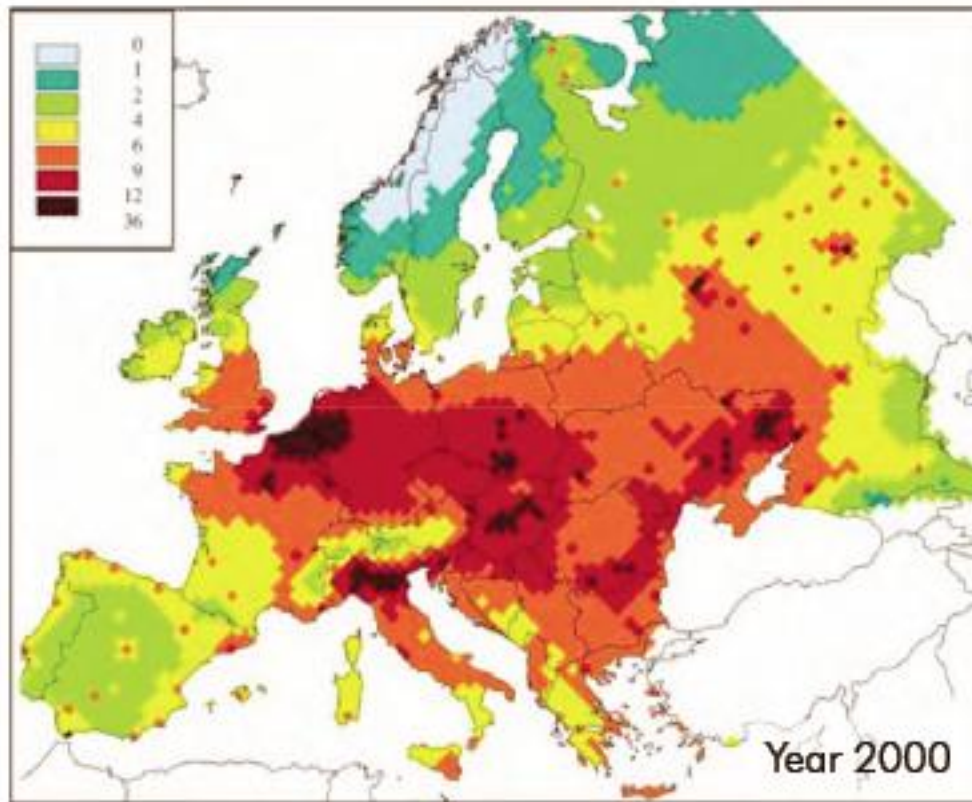
Entrance paths into human body



Based on slide from Geoffrey Hunt, University of Surrey, UK



“Particles increase mortality” **All** particles?



Loss attributable to anthropogenic PM_{2.5} (in months)

Affected:

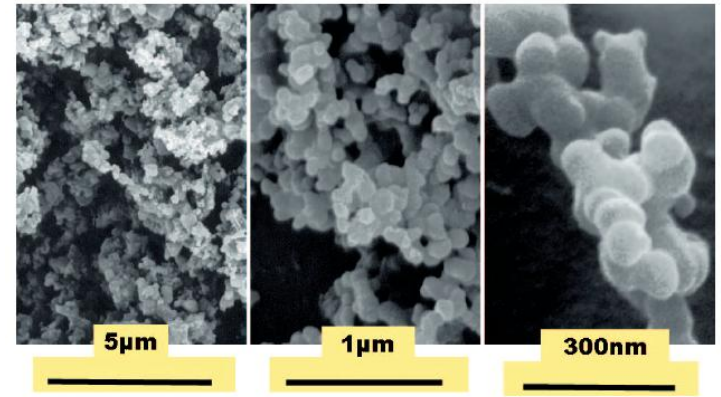
- Brain
- Heart
- Lungs

(ischemic stroke, MI, arrhythmias, lung inflammation)

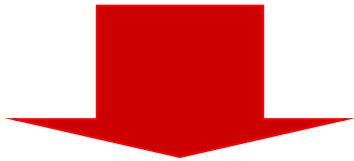
Combustion, or Prometej is the guilty one!

London, december 1952 – 4000 death due to air pollution (a few mg of carbon PM / m³)

Prof. R. Richards, University of Cardiff



Condensation of not completely oxidized carbon in combustion process forms 10 nm large aggregates, which agglomerate to 100 nm large groups, which can stay in atmosphere for a few weeks (volcano eruptions, wildfires, fireplace, bonfires)



generates highly redox active fine particulates

Limitations in coal usage → a few µg/m³

Still a reason for heart and lung disease and increased mortality in urban Europe

Loading in lungs



Mucus, cough, damage due to chemical reactivity



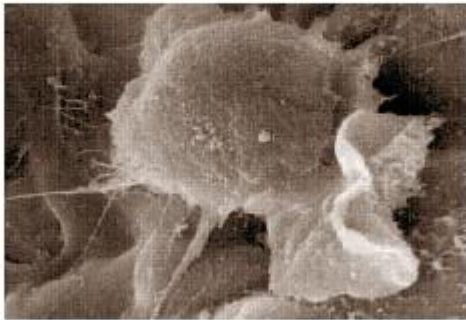
Penetration to blood system

Each additional 10 µg/m³ → 1% increased mortality due to heart disease



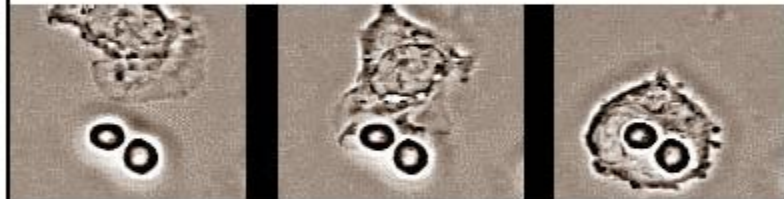
Jonathan Grigg, Senior Lecturer in Paediatric Respiratory Medicine
University of Leicester, UK --- partner in the IMPART project

alveolar macrophage



only live in lower airway

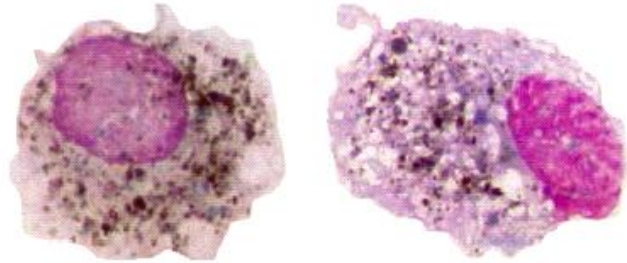
alveolar macrophage removing particles



Carbon loading of alveolar macrophages in adults and children exposed to **biomass smoke** particles (*Science of the Total Environment* 345 (2005) 23)

Jonathan Grigg

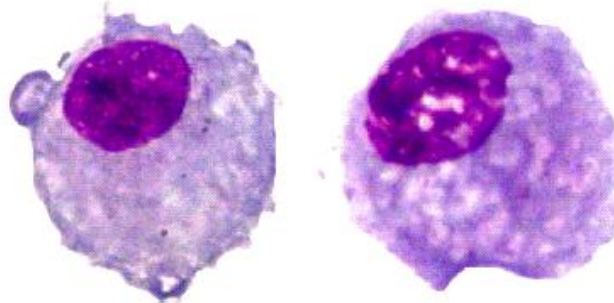
Gondar
adult



Gondar
child

Macrophages
collected in
induced sputum.

UK adult



UK child

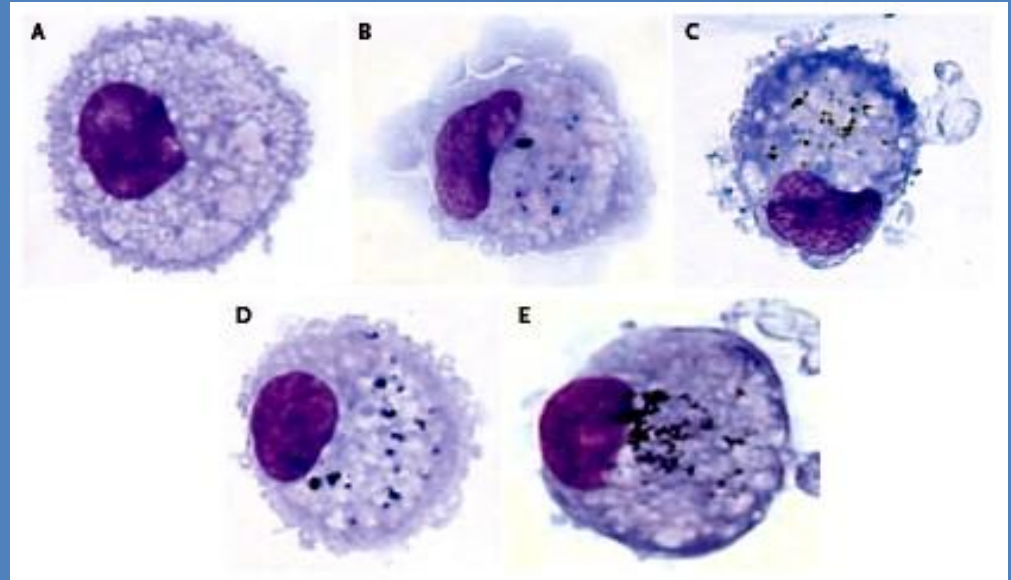
Carbon particles from biomass smoke cause two million deaths per year, a major proportion of these in young children. The total surface area of carbon per alveolar macrophage in Ethiopian women and children is 10 times larger compared with UK ones.



Carbon from **diesel vehicle** exhaust harms healthy kids' lung function

(The New England Journal of medicine, July 6, 2006)

Jonathan Grigg



The half-life of particles in airway macrophages is 3.9 months.

Each increase of $1 \mu\text{m}^2$ of carbon content in alveolar macrophage is associated with a reduction of 17 % in forced expiratory volume in one second.

Compared with gasoline engines, diesel engines emit less CO_2 , but they produce **more NO_x and PM**. The rat studies showed that high levels of both diesel exhaust and carbon black particles cause lung tumors. The mechanisms of carcinogenesis are related to high doses of the NPs themselves and to possible lung overload.



TiO₂ in ZnO₂ nanoparticles – (BASF, Degussa, L'Oreal, Oxonica)

UV protection + transparency

smaller - 200 nm - larger

Chemically
non-active

Photo-activity under UV irradiation, partial absorption.

Use for solar cells, self-cleaned windows, water purification,
Genetic engineering-DNA separation (Aragon nacional laboratory)

Nano TiO₂ is a strong oxidant of organic molecules and causes free radicals, i.e. unstable reactive parts of molecules.

1997, UK, Canada: TiO₂ isolated from sun cream Hydroxil radicals in human cell culture, which can damage DNA → a possible cause of skin cancer (penetration of NPs into skin by rubbing, along hairs' channels and through wounds

R.Dunford, et al., "Chemical oxidation and DNA damage catalysed by inorganic sunscreen ingredients," FEBS Letters, Volume 418, Issues 1-2, 24 November 1997, pp. 87-90.

Influence of TiO₂ on lungs

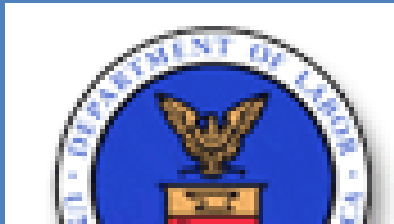
Nano-powder of TiO₂

- americal military investigation – evidences of toxicity of nanoparticles TiO₂.

Recommendation: safe concentration of airborne TiO₂ is 8 x lower for nanoparticles than for microparticles.

Commission on Life Sciences (CLS), Toxicity of Military Smokes and Obscurants, volume 2, National Academies Press, (1999), pp. 68-96.

EXPOSURE LIMITS



OSHA

Occupational Safety and
Health Administration

10 mg/m³

The National Institute for Occupational Safety and Health (NIOSH)
<http://www.osha.gov/SLTC/healthguidelines/titaniumdioxide/recognition.html>



NIOSH recommends
exposure limits of

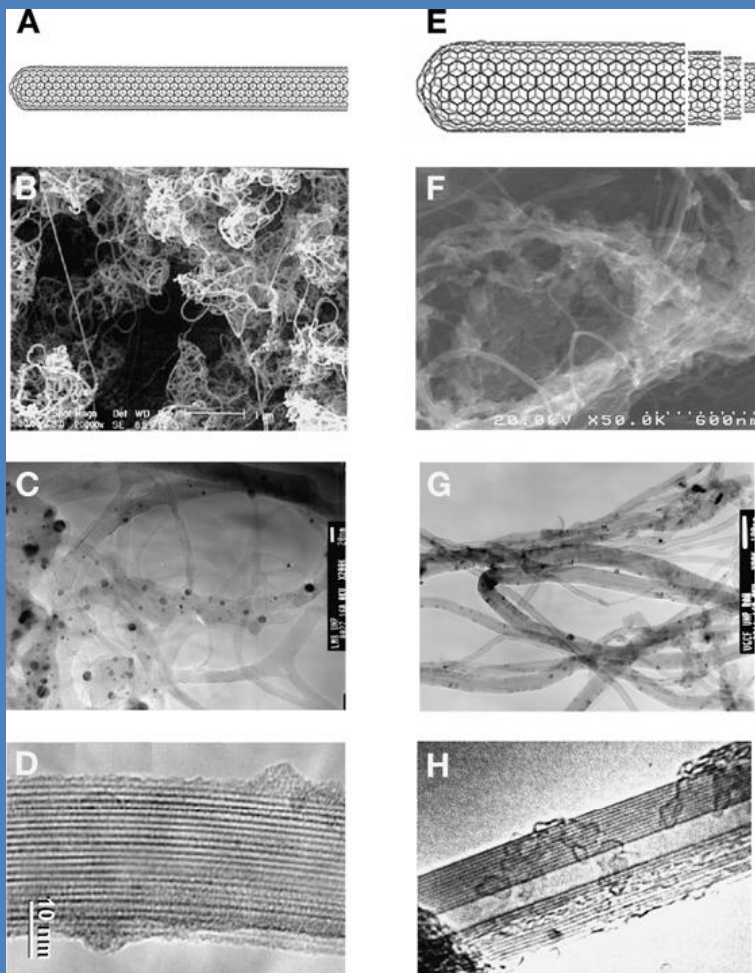
1.5 mg/m³ for fine TiO₂

0.1 mg/m³ for ultrafine
TiO₂



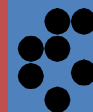
Carbon nanotubes

Critical Reviews in Toxicology, 36, 189–217, 2006



Single walled and multiwalled CNTs caused histopathological changes in **rodent** lungs, **including granuloma formation**-compact collection of mononuclear phagocytes (macrophages or epithelioid cells) **and fibrosis**; both were found to **release toxic cytokines** (proteins and peptides similar to hormones and neurotransmitters and are used to allow one cell to communicate with another) and **biomarkers of inflammation, oxidative stress, and cytotoxicity** (Muller et al., *Toxicol. Appl. Pharmacol.* **207**(3),221 (2005). In addition, single walled NTs produce **cardiac toxicity** (Li, et al., *The Toxicologist—Supplement to Toxicological Sciences*, **90**(1),213, (2006).

Therefore, if airborne fine CNT particles are present in the workplace, strategies to minimize human exposures must be implemented!



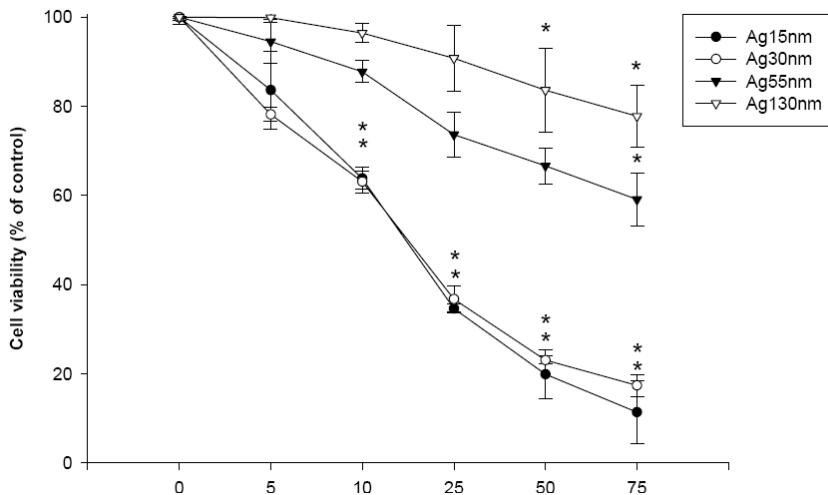
Toxic nano silver

Medicine: NANO-Silver for treatment of burns and chronic damages of skin

Products on market: antibacterial coatings, dyes, creams, lotions, textile

Strong toxicity of silver on a wide spectrum of microorganisms (Sondi, I., (2004). *Silver nanoparticles as antimicrobial agent: A case study on E. coli as a model for Gram-negative bacteria.*

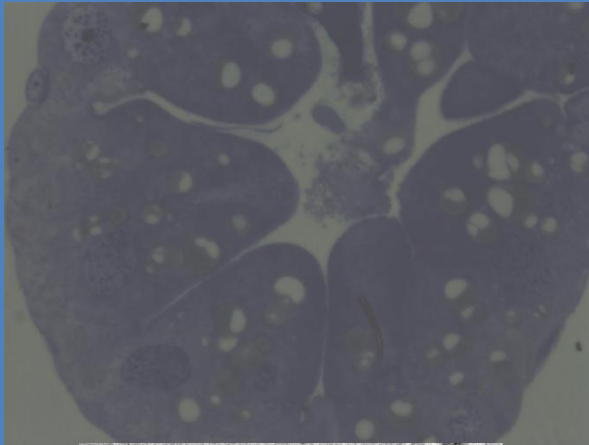
J. Colloid Interface Sci 275, 177-182, 2004)



Toxicity of 15 nm Ag is comparable with 1 μ m CdO

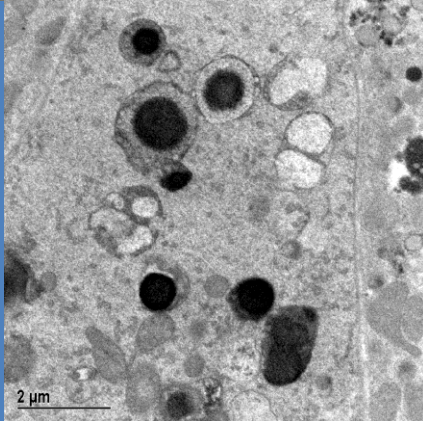
Catalaya Carlson, Wright State Univ., Ohio, 2006

Therefore, the silver nanoparticles **can not be totally regarded as biocompatible**. It was because the oxidation of Ag^0 to Ag^+ ions occur at the surfaces of the nanoparticles and Ag ion might bring out severe cytotoxicity. It was reported that the toxicity of Ag ions affected **basic metabolic cellular functions common to all specialized mammalian cells** [J.C. Grunlan, *Biomacromolecules* 6 (2005) 1149].

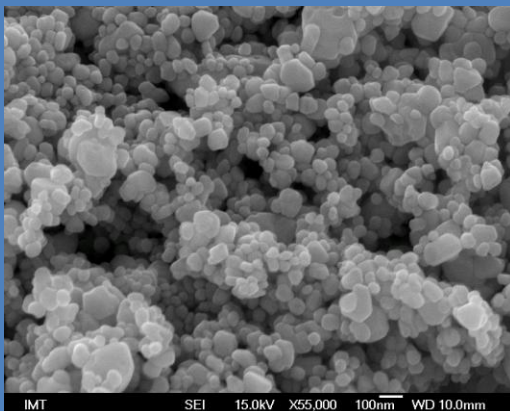


Terrestrial isopods were fed for two weeks with nano-Ag dosed food.

Light micrograph of cross section of digestive gland tube, consisting of dome-shaped B cells and wedge-shaped or cylindrical S cells (S)



TEM micrograph of S cell with B-type metal granules. This is a spot where the TEM analyses were performed.

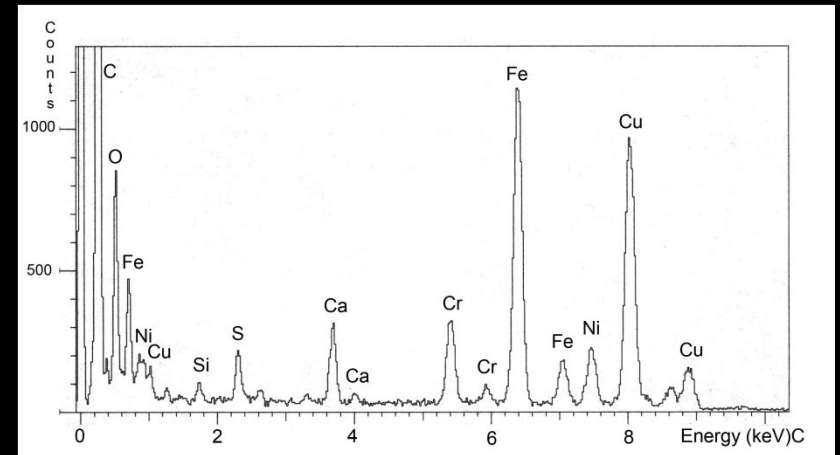
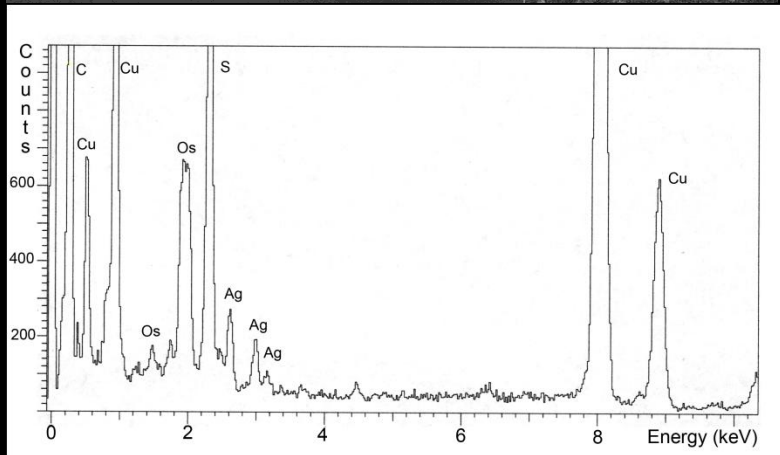
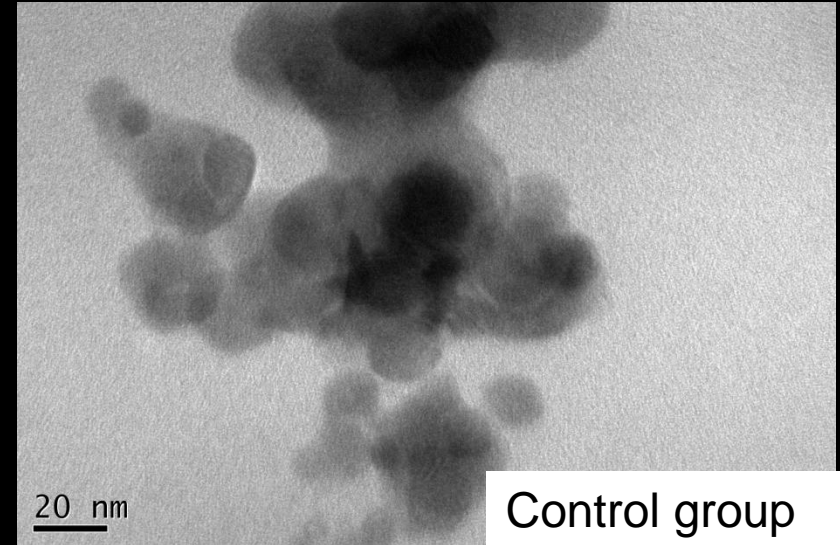
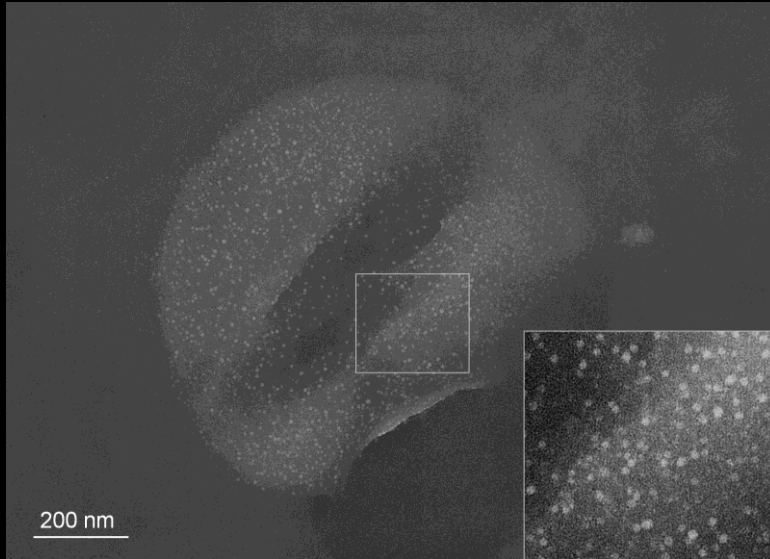


Nano Ag- 50 nm

*D. Drobne, Z. Pipan;
Faculty of Biology,
Univ.Ljubljana*

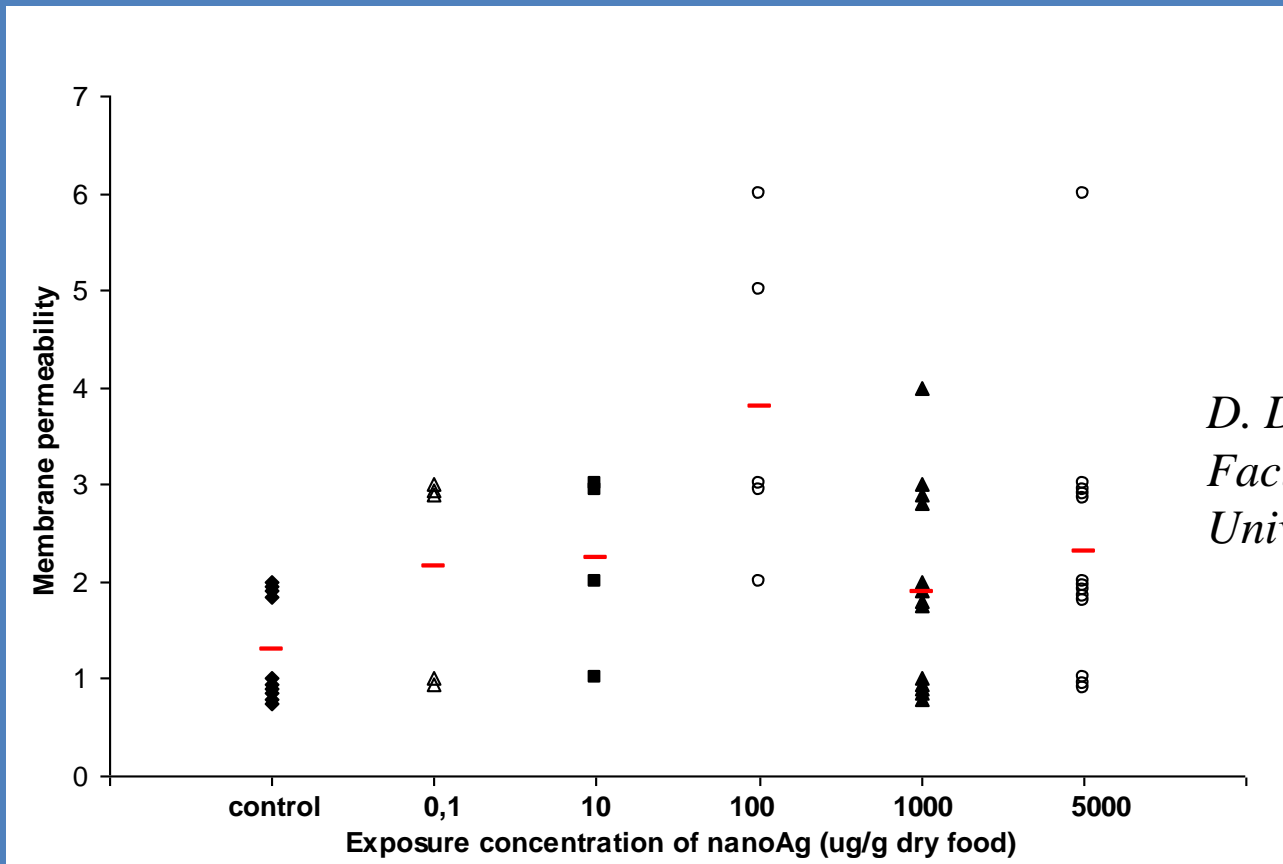


Animals fed with nano-Ag



Concentrations of nano-Ag: 100 $\mu\text{g/g}$, 1000 $\mu\text{g/g}$ and 5000 $\mu\text{g/g}$ dry food

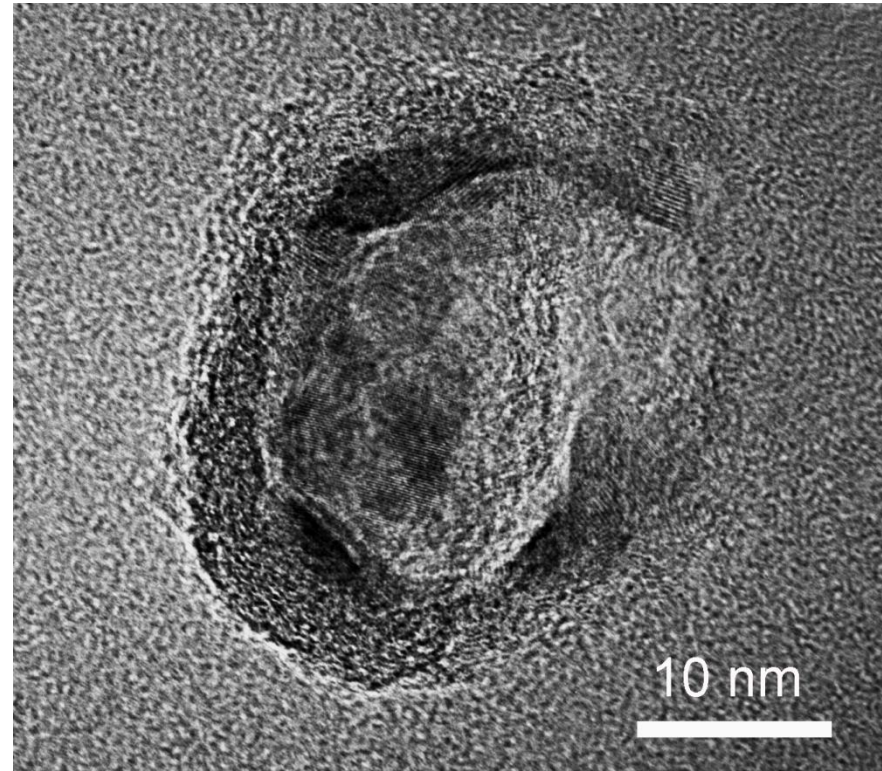
In all groups of nano-Ag feed animals, a portion of animals had **affected membrane of digestive gland cells**.



*D. Drobne, Z. Pipan;
Faculty of Biology,
Univ.Ljubljana*

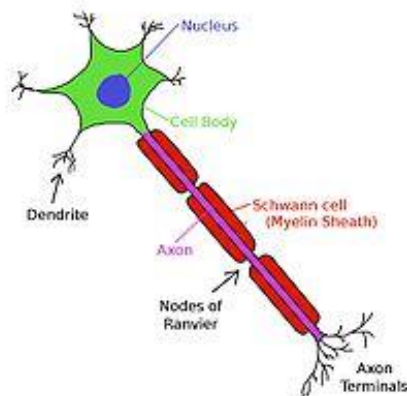


6 μg Ag/l



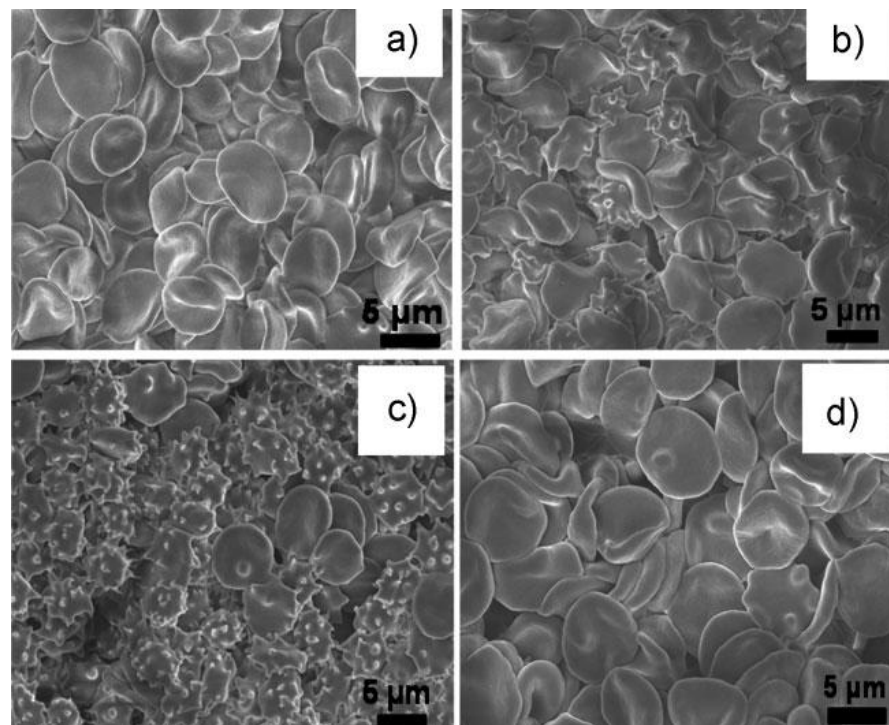
1. <http://www.bolha.com/oglas383879643/koloidno-srebro-v-nano-obliki-nano-silver-500ml>
2. <http://sites.google.com/site/faderoproject/>
3. <http://med.over.net/forum5/read.php?177,4364003>
4. <http://med.over.net/forum5/read.php?268,5660739>. (*****)
5. <http://med.over.net/forum5/read.php?13,4866500>
6. <http://www.bolha.com/oglas383717202/koloidno-srebro-edini-poznani-100-naravni-antibiotik-ki-pomaga-zdraviti-vec-kot-650-bolezni->

Ag⁺ acts directly as a developmental neurotoxicant. At high concentrations, **Ag⁺ inhibits cell replication and enhances cell death**, leading to a loss of cells, as well as retarding neurite formation.



Food storage material silver nanoparticles interfere with DNA replication fidelity and bind with DNA,
W. Yang et al., Nanotechnology 20 (2009) 085102

Erythrocytes exhibit significant lysis, haemagglutination, membrane damage, detrimental morphological variation, and cytoskeletal distortions following exposure to Ag NPs at a concentration of 100 μg/mL.

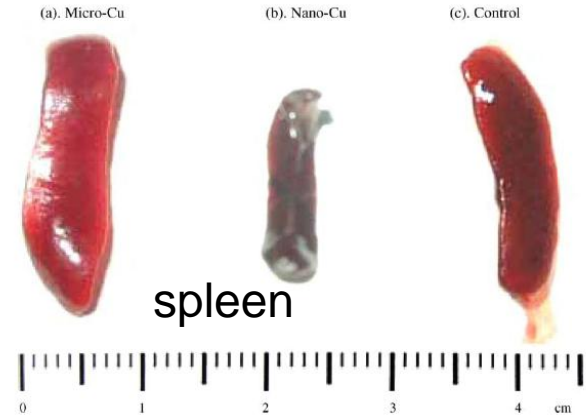
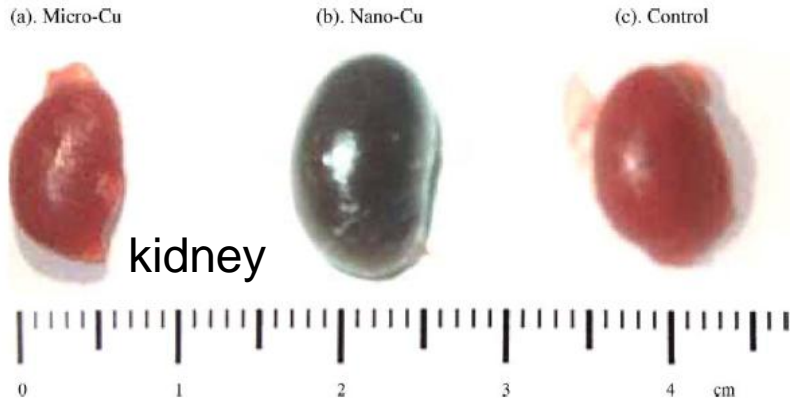


- a) Control
- b) Ag – 5.8 nm
- c) Ag-PVA – 10.9 nm
- d) Au-PVA – 28.3 nm

PVA- polyvinyl alcohol

*PV Asharani et al.,
Adv. Funct. Mater.
2010, 20, 1233*

Toxic nano-copper (23.5 nm): damage of kidney, liver, and spleen (Z. Chen et al., Nanotoxicology Letters, 2005)



Step

3

od 1-5

Male mice suffered more serious damages at equal doses of nano-Cu than female animals.

Micro- 17.6 μm

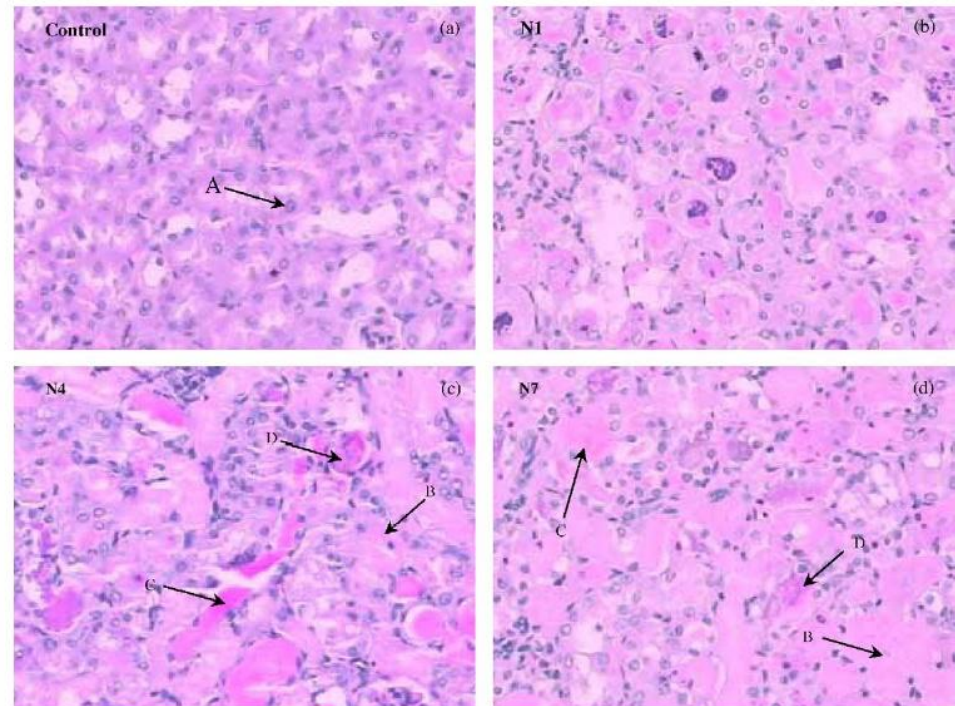
Damage changes in liver:

A: without nano Cu

B: 108 mg/kg

C: 341 mg/kg

D: 1080 mg/kg



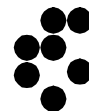
Koloidni baker



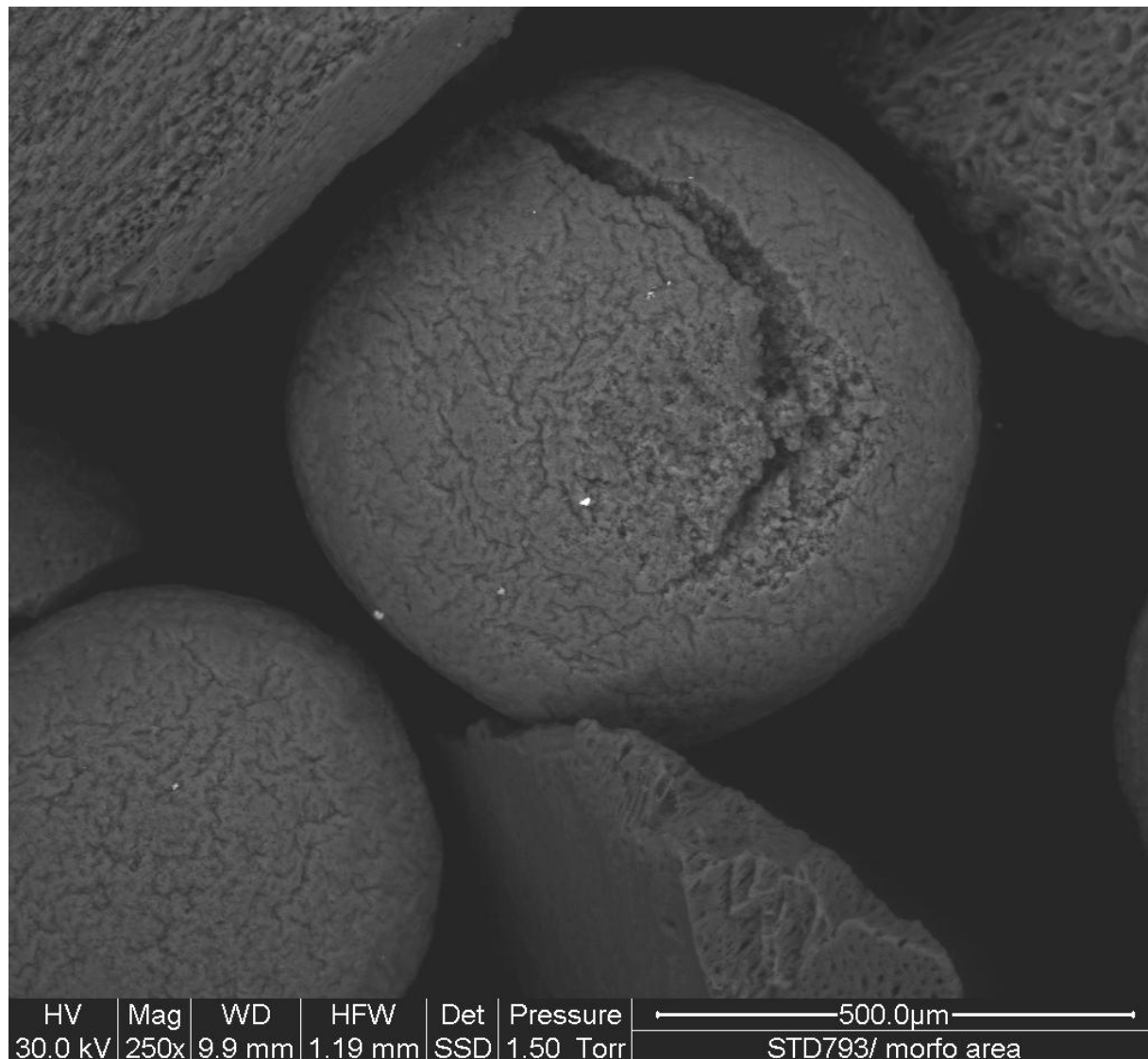
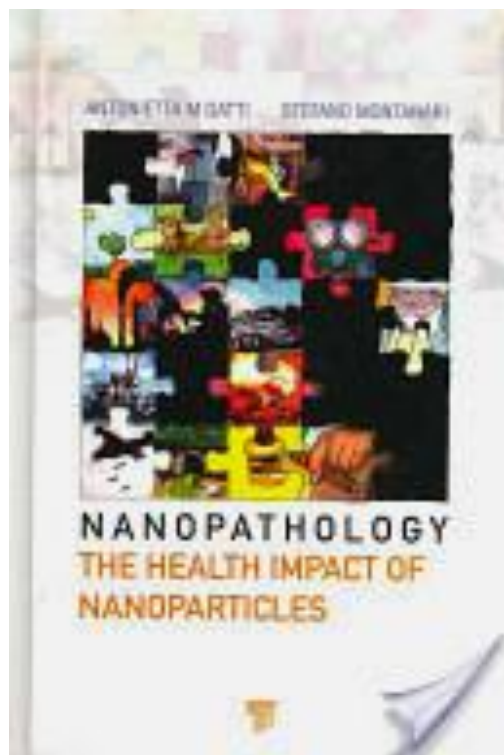
<http://sites.google.com/site/aderoproject/>

Koloidni baker je uporabljen proti sivenju las, opeklinam, artritisu, parazitom, ter virusnim in bakterijskim infekcijah, zdravi arthritisa, osteoarthritis, revmatično vročino, revmatoidni arthritisa, išjas, Wilsonovo bolezen... Pomaga stabilizirati in uravnati pretok krvi po telesu. Sodeluje kadar je potreben večji pretok krvi v telesu. Čisti kri, žile, žilam vrača njihovo elastičnost. Sodeluje pri tvorbi kolagena v kožnem tkivu. Posebej je primeren za ljudi, ki imajo **premalo energije, so razdraženi, nevrotični, brez volje, pasivnost, ne sprejemanje sebe**; ti se počutijo mnogo bolje ali pa sploh ni več teh dejavnikov. Uravnava delovanje možganov, **uravnovesi levo-desno polovico možganov**. Poskrbi za povečanje prevodnosti nevrološkega sistema, da živčni impulzi hitreje potujejo. Uravnava tudi delovanje **spolnih organov, poveča slo**.

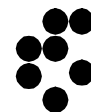
Informacije in naročila: (00 386) 040 999 998, Boris



BRITA : water filter device

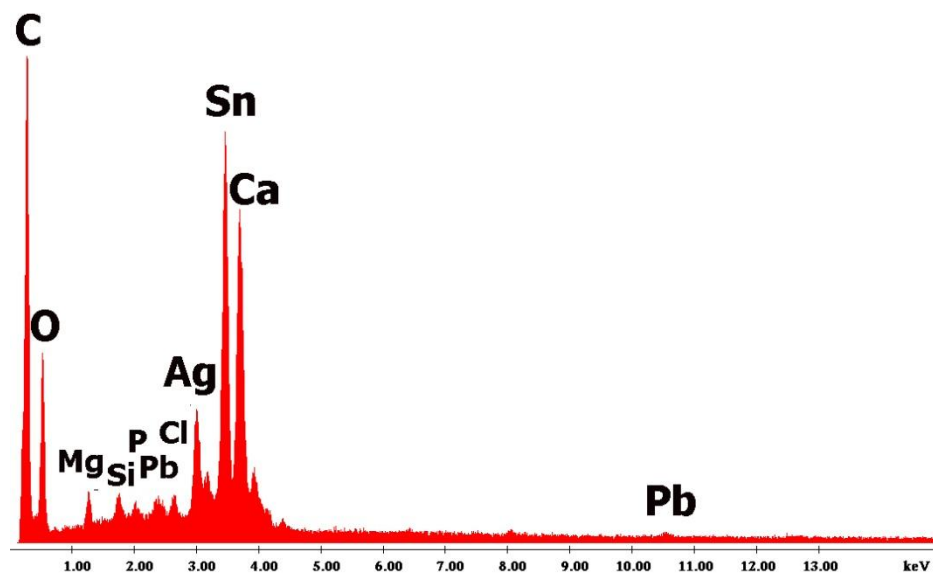
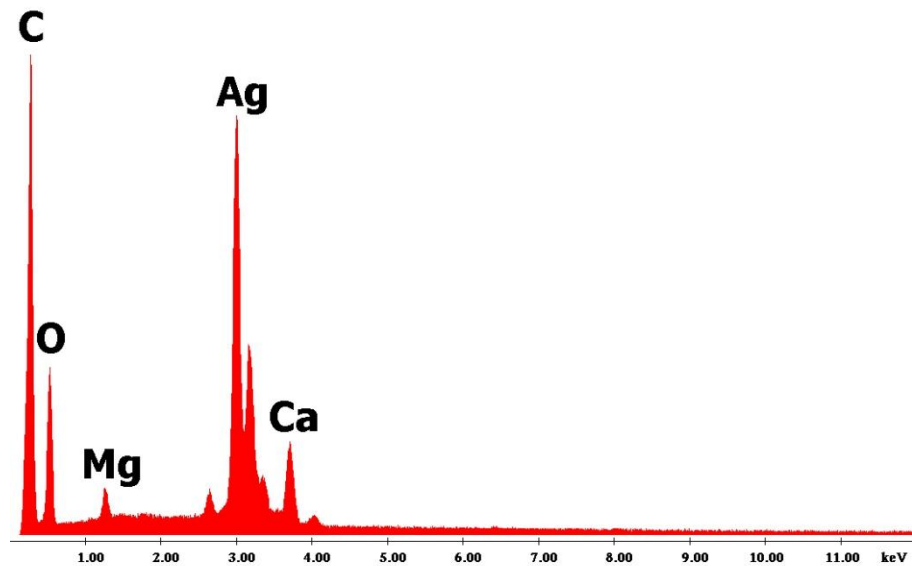
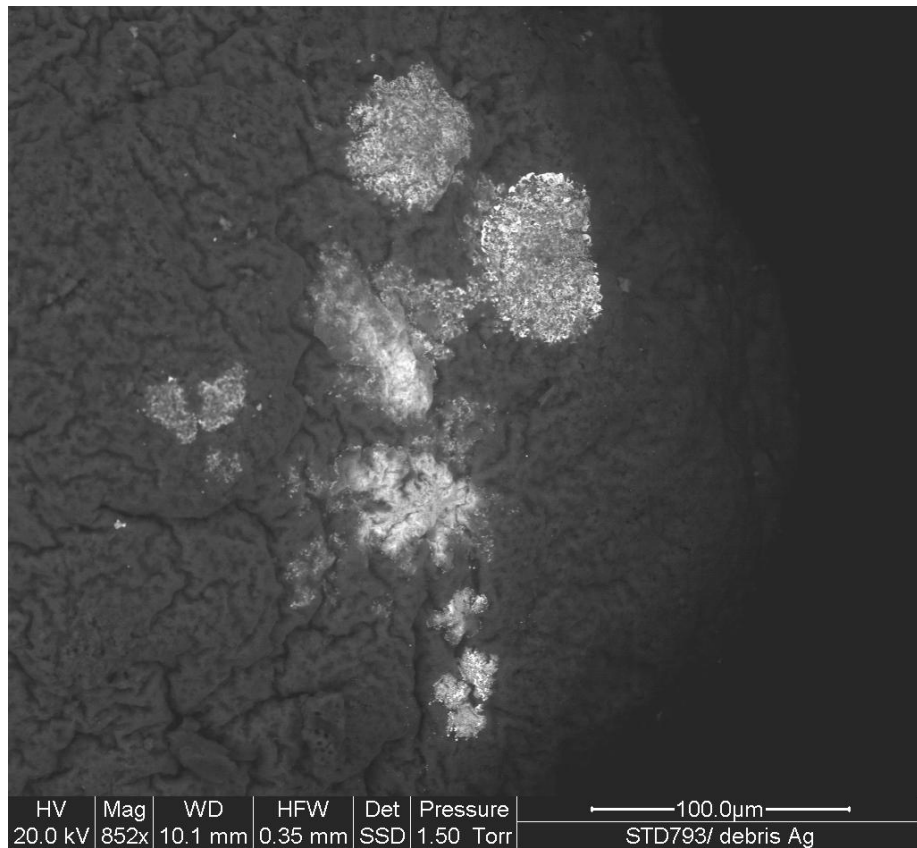


Antonietta Gatti, University of Modena



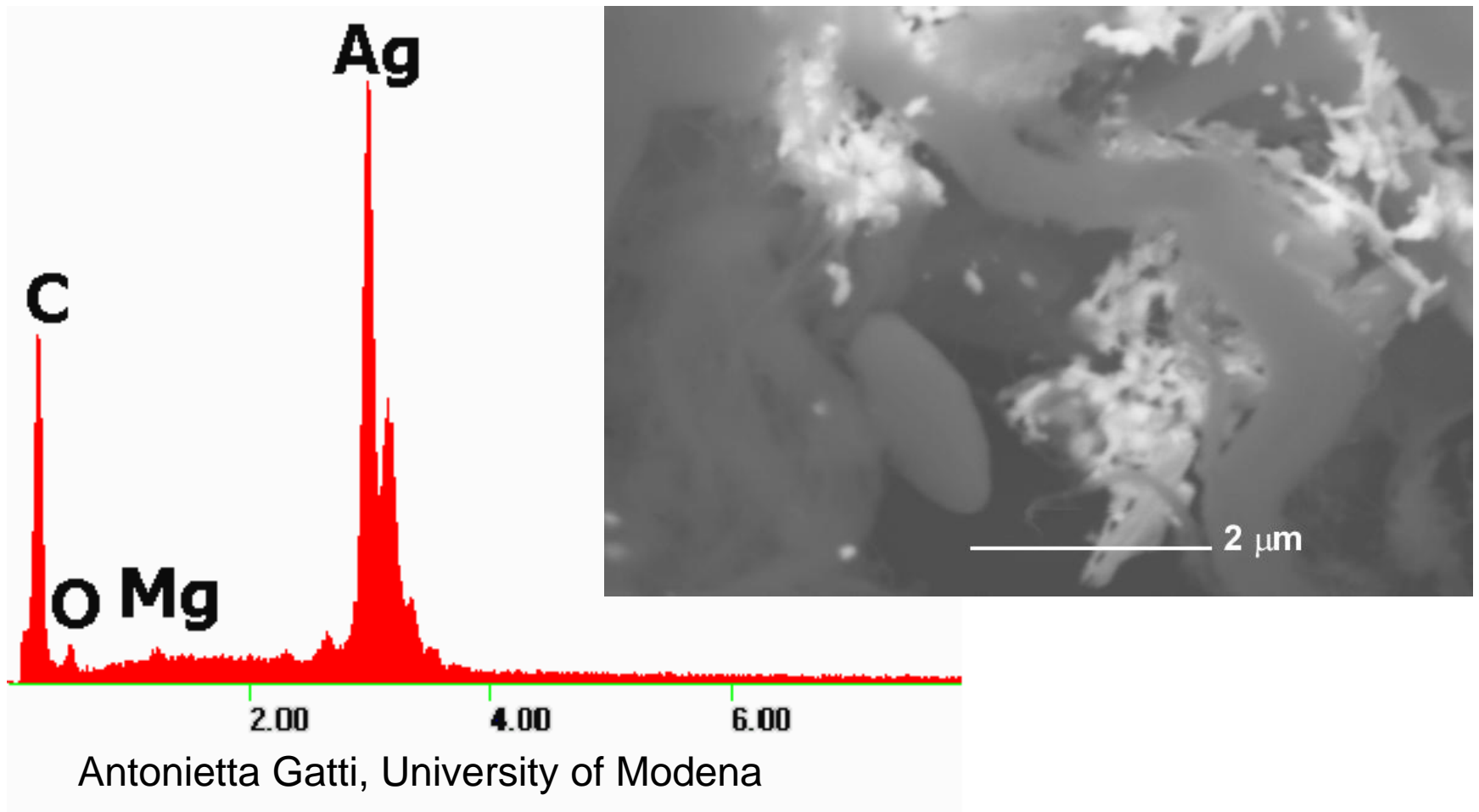
BRITA

water filter system

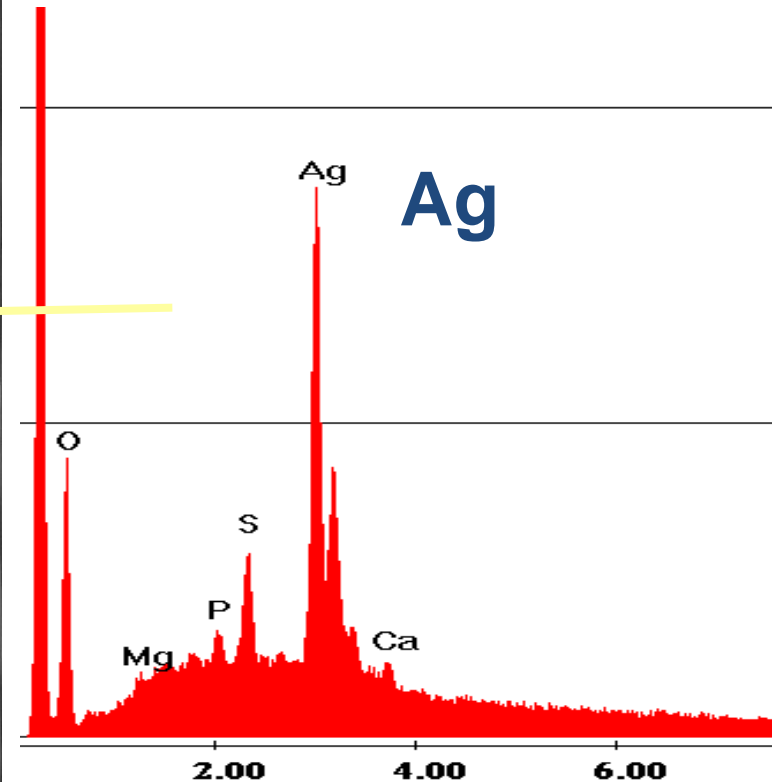
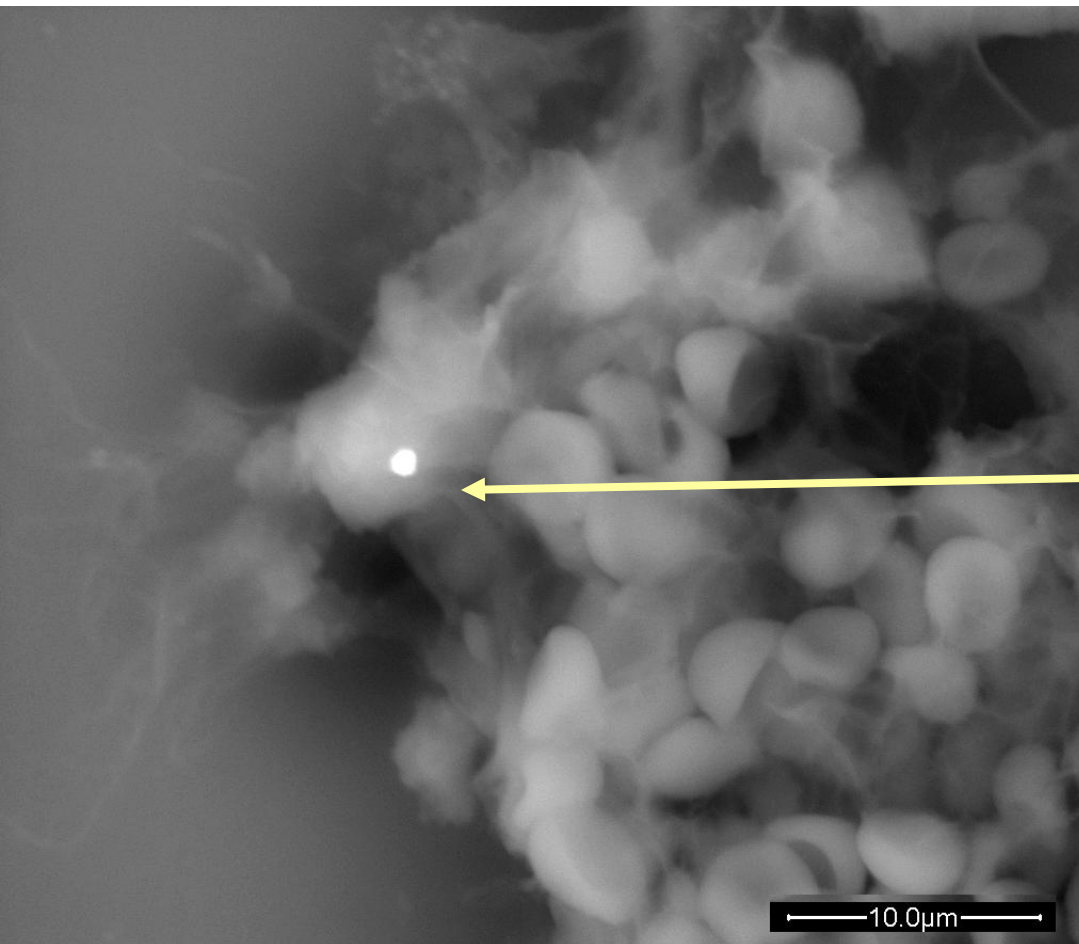


Antonietta Gatti, University of Modena

Colon cancer with clusters of Silver nanoparticles



Blood clot in vivo

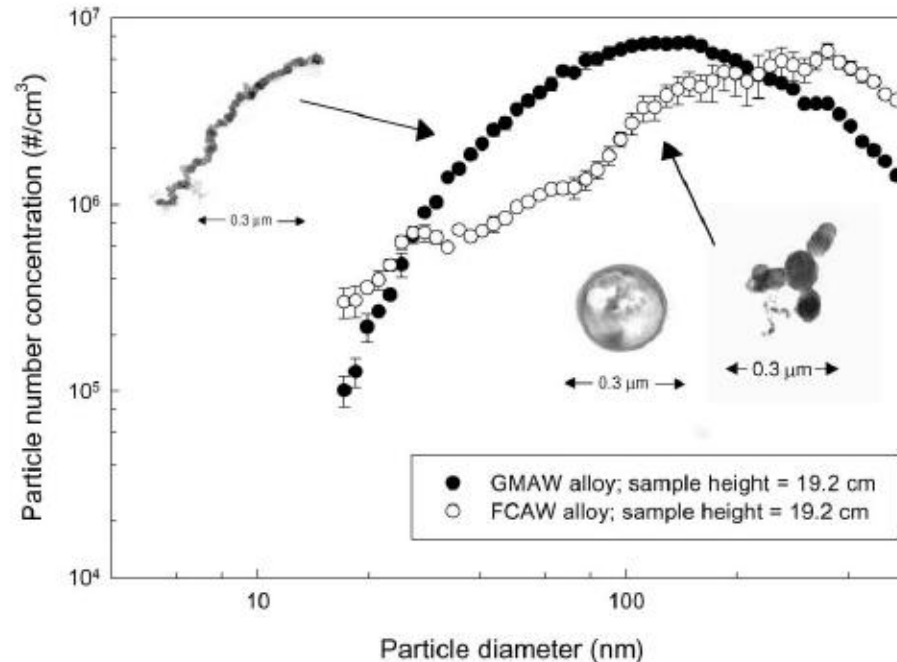


Workplace exposure

Large concentrations of nanoparticles may be present in occupational environments, which deserve particular attention from the standpoint of exposure.



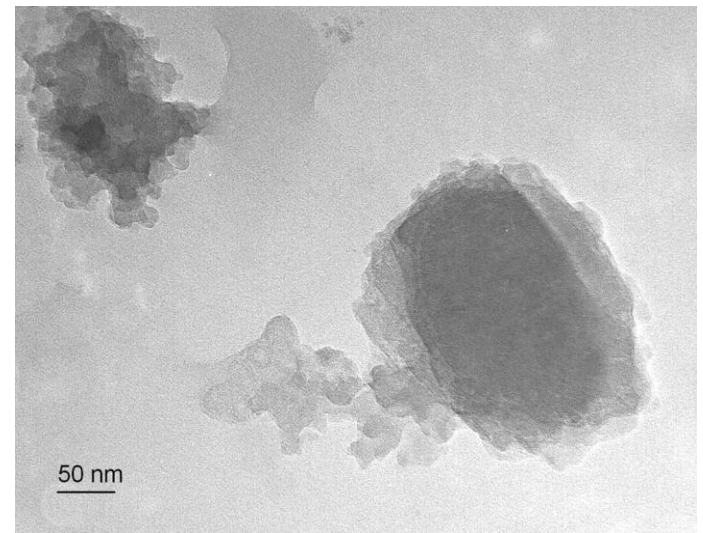
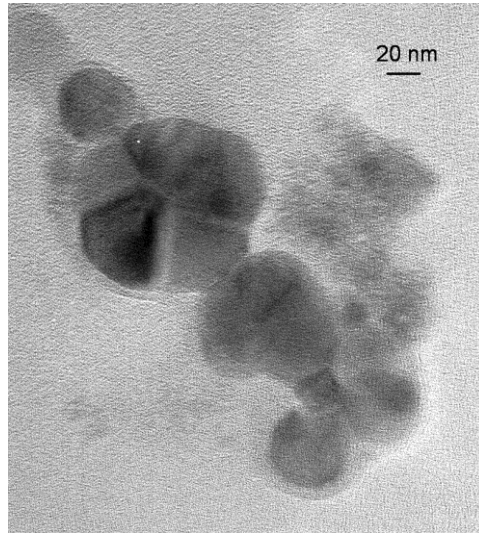
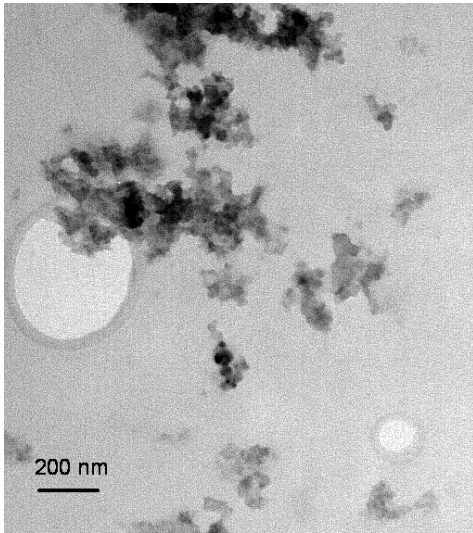
A.T. Zimmer, P. Biswas / Aerosol Science 32 (2001) 993–1008



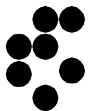
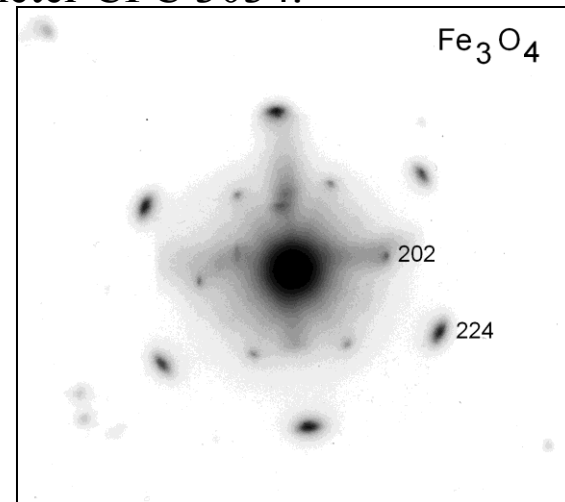
Limited data and guidelines are available for handling nanoparticles in occupational settings as well as research laboratories.

For example, guidelines for the selection of respiratory protection for specific types of nanoparticles are lacking.

Transmission electron micrographs

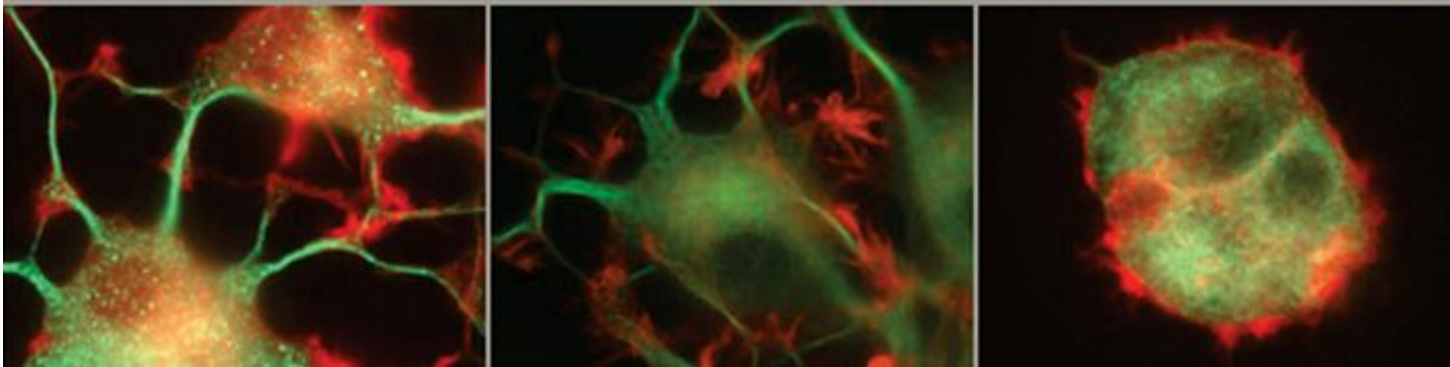
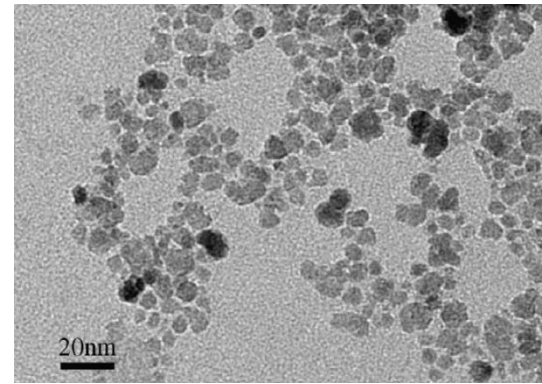


Average size of NPs is 40 - 80 nm, in accordance with background data measured with Scanning Mobility Particle Sizer™ Spectrometer CPC 3034.



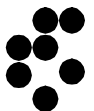


Nanotoxicity of iron oxide nanoparticle internalization in growing neurons,
TR Pisanic, Biomaterials 28 (2007) 2572



Intracellular delivery of even moderate levels of iron oxide (Fe_2O_3) nanoparticles affect cell function. Exposure to increasing concentrations of anionic MNPs, from 0.15 to 15mM of iron, results in a dose-dependent diminishing viability and capacity of PC12 cells (isolated from adreanl gland tumor) to extend neurites in response to their putative biological cue, i.e. nerve growth factor.

Fe_3O_4 **Enhancement of neurite outgrowth in PC12 cells by iron oxide nanoparticles, JA Kim, et al., Biomaterials 32 (2011) 2871.**



Detection of nanoparticles

TSI model, cost > 50.000 Eur

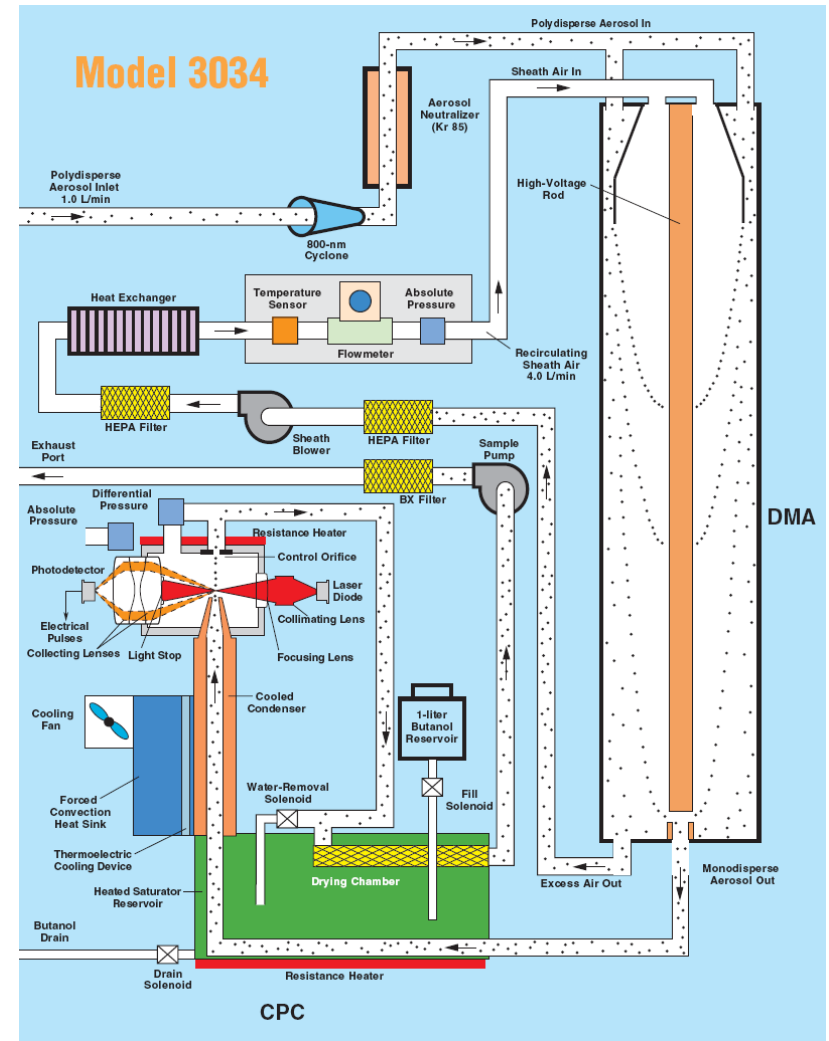


n-butyl alcohol

Particle Size Range:

10 to 487nm

Concentrations: up to $2,4 \cdot 10^6$ NPs / cm³



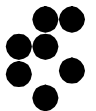
Differential mobility analyzer

Condensation particle chamber





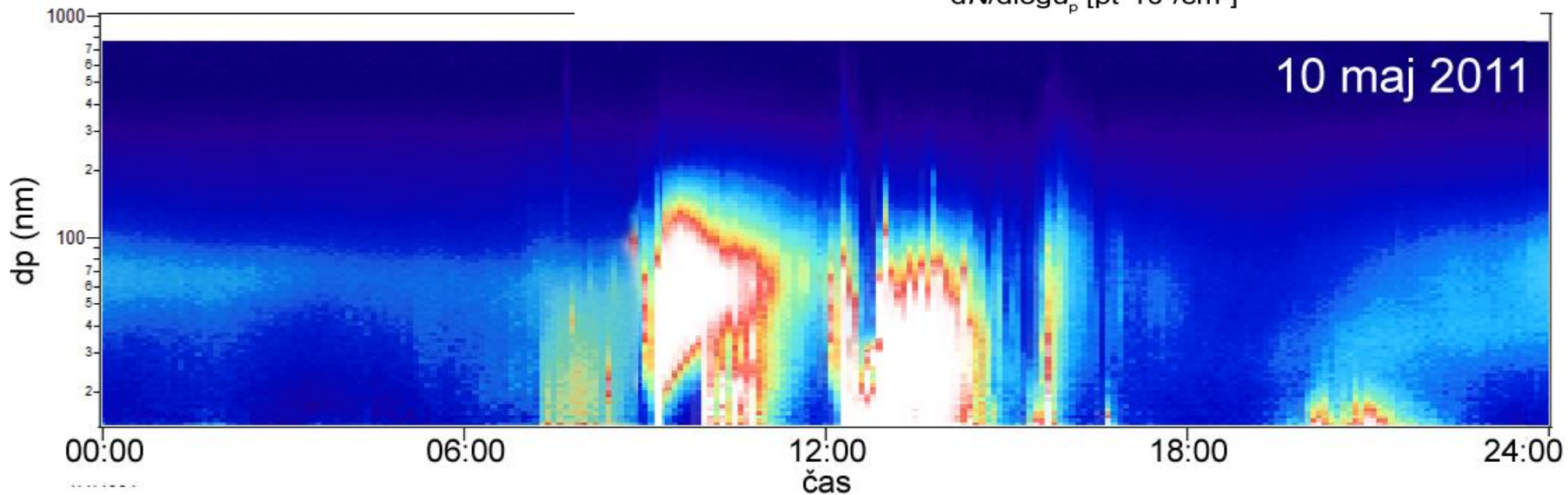
Ivan Iskra



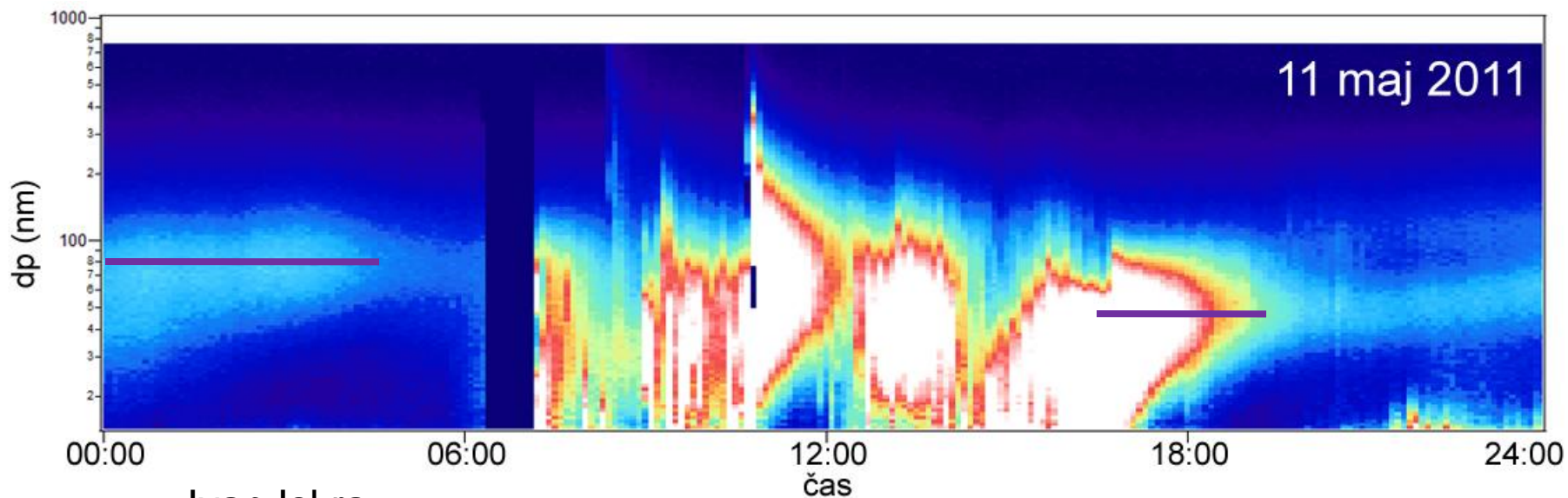
Tuesday



$dN/d\log d_p$ [pt*10³/cm³]



Wednesday



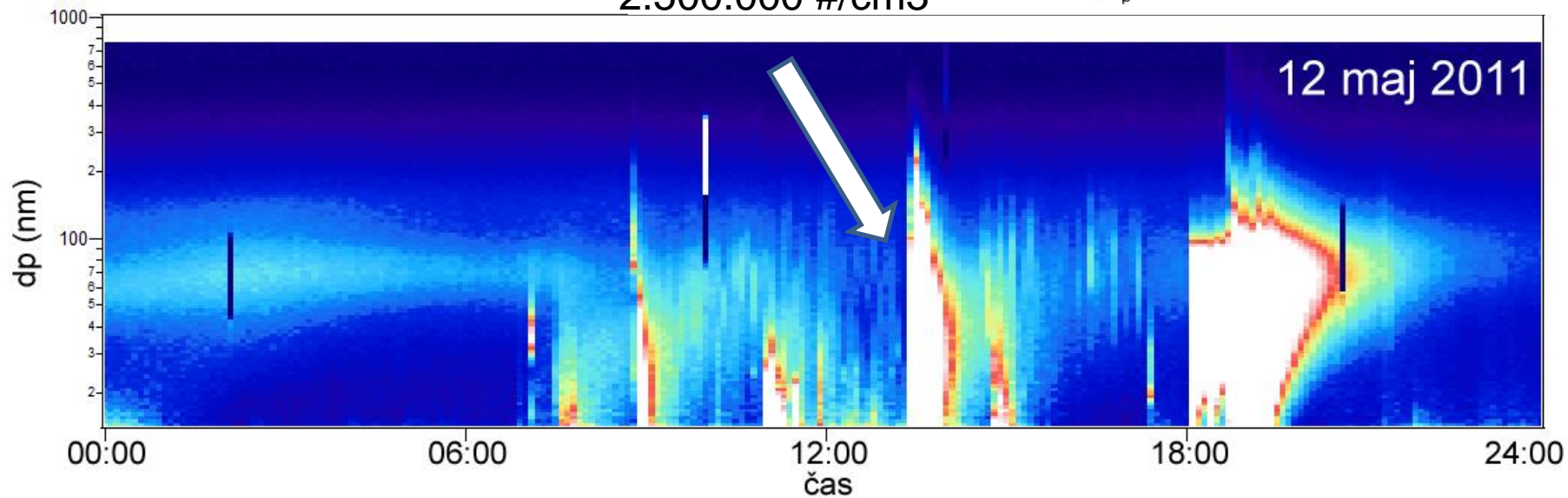
Ivan Iskra



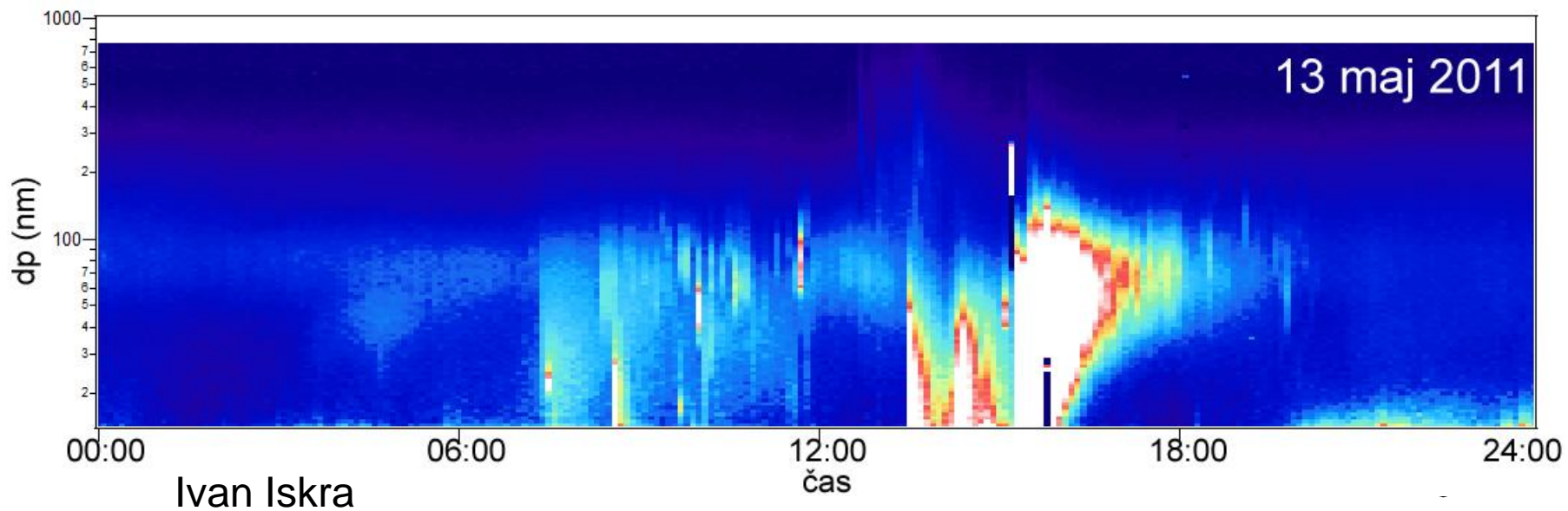
Thursday

2.500.000 #/cm³

$dN/d\log d_p$ [pt*10³/cm³]



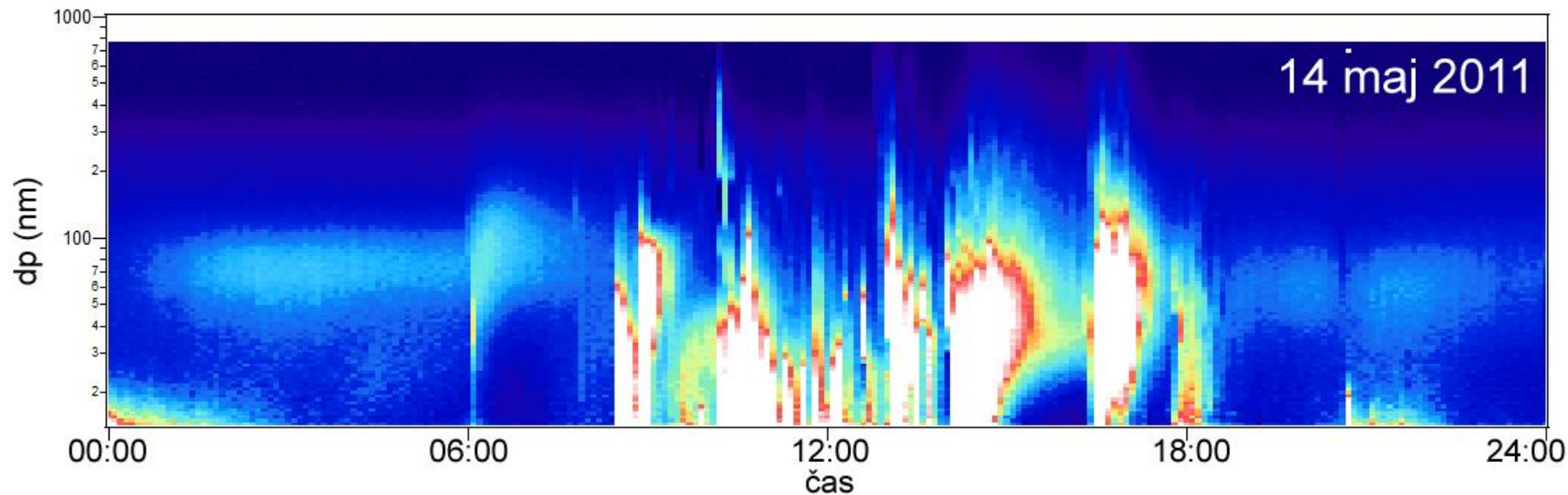
Friday



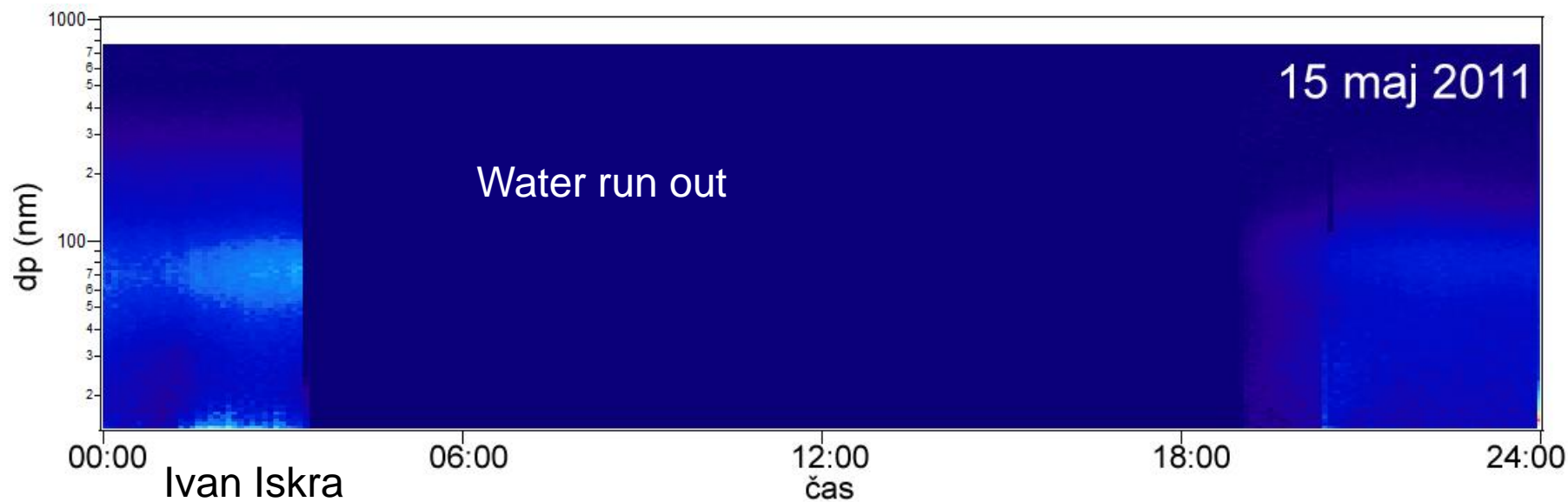


Saturday

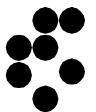
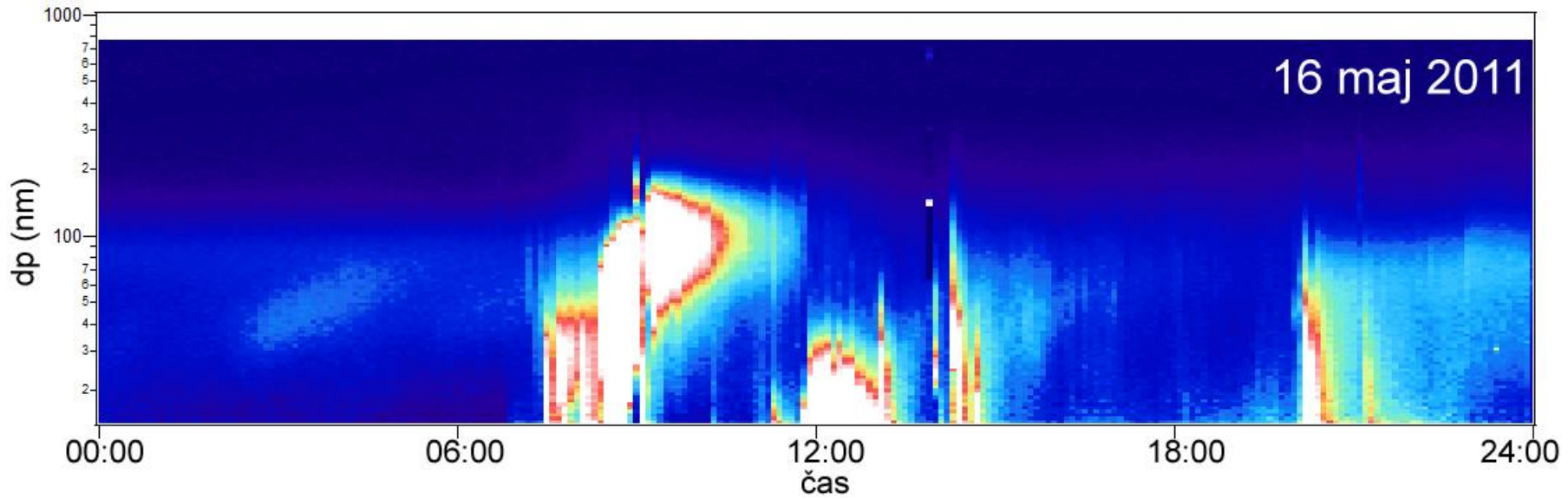
$dN/d\log d_p$ [$\text{pt} \cdot 10^3/\text{cm}^3$]



Sunday



Monday



Safety recommendations

Cleaning work areas at the end of each work day using HEPA vacuum pickup and wet wiping methods.

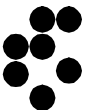
Preventing the storage and consumption of food or beverages in workplaces where nanomaterials are handled.

Providing hand-washing facilities and encouraging workers to use them before eating, smoking, or leaving the worksite.

Providing facilities for showering and changing clothes with the aim to prevent the contamination of other areas

The transfer of powdered material from primary containers to processing equipment has to be undertaken in a fume cabinet.

The HEPA filter half-masks or full-masks (using P3 filters), and silicon rubber (surgical) gloves (double pairs) have to be used, when transferring material from containers to processing equipment.

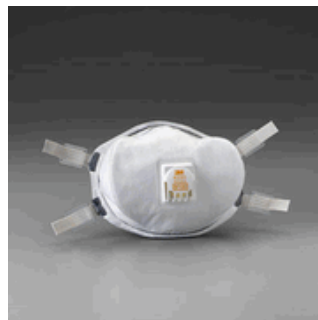


Recommended personal protection: gloves, glasses, masks with HEPA filters



Production of carbon nanotubes,
CEA, Francija

www.maskspnmore.com



HEPA- High Efficiency Particulate Air Filter stops nanoparticles bigger than 300 nm or 100 nm. Air flow 85 l/min

Market names: NIOSH (HEPA)

National Institute for Occupational Safety and Health

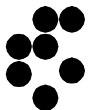
EU standard EN 149

P100: stops 99.97% NPs
(above 300 nm)

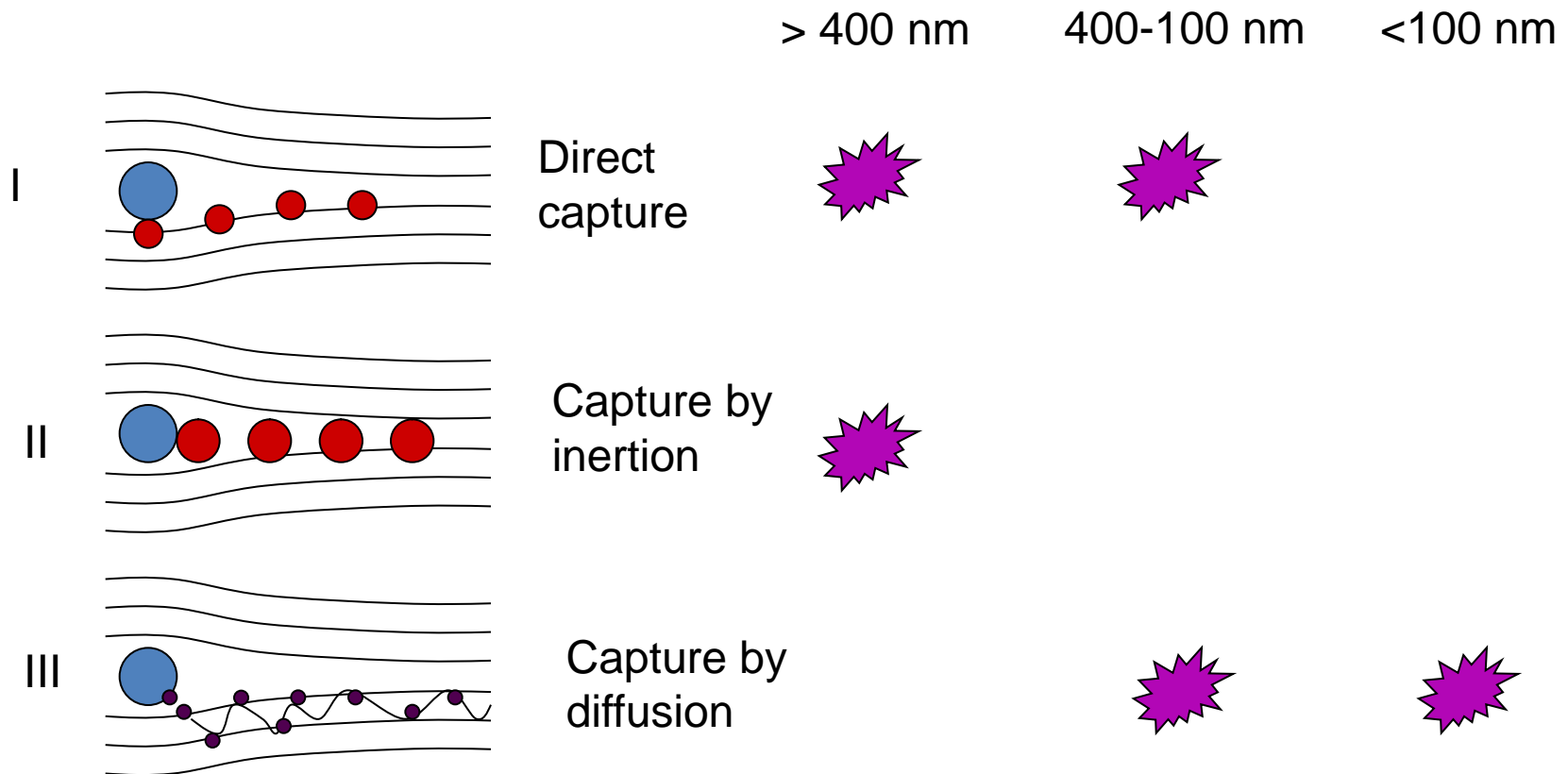
P95: stops 95% NPs
(above 300 nm)



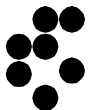
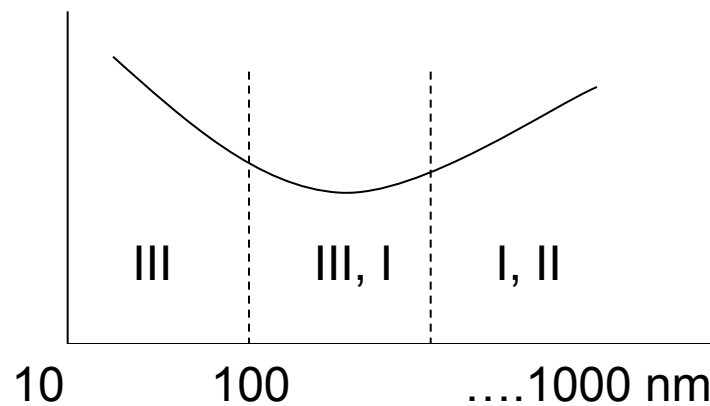
www.security.globalsources.com



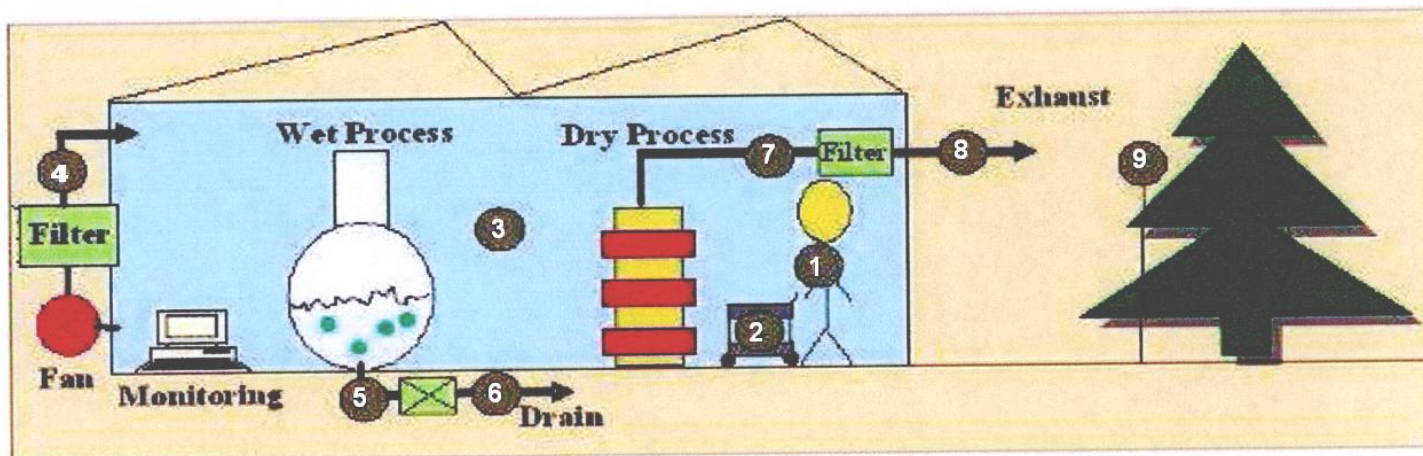
Basic principles of filtration



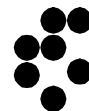
300 nm – filters window



Monitoring at workplace (Nanosafe 2)



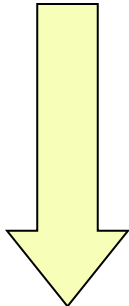
1. **Personal sampling:** Exposure integration or alarm for personal use. Daily to monthly analysis.
2. **Mobile device:** New operations, maintenance. Response time: 5 min.
3. **Work places:** Monitoring tool for data collection and alarm. Response time: 5-30 min.
4. **Efficiency of collective protective equipments.** Qualification after new filter installation.
- 5-6: **Drain:** Environmental protection in the liquid drain.
- 7-8: **Extraction:** Environmental protection in the air.
- 9: **External:** 2 different needs:
 - Monthly survey of the impact of the factory on the environment (routine and accidental situations)
 - Real time determination of the fluctuation of the external background noise in order to correct inside measurements



Safe production and use of NPs

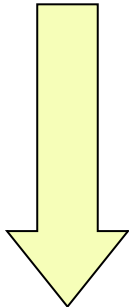
PRODUCTION PLANT

Control, Packing, Storage



TRANSPORT

Imbedding into the final product



Sale, Storage,
USE

Recycling, Waste deponage

Monitoring strategy:

-number and size
distribution of NPs in air
and water

Safety declaration:

-Use of personal
protection (masks, gloves,
cloth, shose)

-Clear declaration of NPs
as ingredients in the final
products

Monitoring strategy:

- number and size
distribution of NPs in air and
water



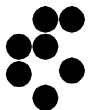


Guidance on Risk Assessment Concerning Potential Risk Arising from Applications of Nanoscience and Nanotechnologies to Food and Feed

EFSA Scientific Network

Member State Activities: conferences and events, **research projects**, **products on the market**, useful links to national nanotechnology sources

EFSA-information point: Blaza.Nahtigal@gov.si (Ministry of Agriculture, Forestry and Food)



Recomendations for regulations and legislation at governmental and European level

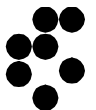
- to registr all producers of mass quantities of engineered nanoparticles synthesizing for the market
- to establish a national network on Safe production and use of nanoparticles
- to demand the toxicological and genotoxic studies of NPs used in products based on size distribution and not on mass or volume concentration
- to prepare and to bring to functioning the safety declaration for engineered and non-intentionally produced NPs
- to organize and financially support the size-distribution measurements of NPs at work place and in environment
- to evaluate the ecological consequences of emission of diesel and biomass NPs
- to prepare the monitoring strategies at the production plants (personal sampling is preferred to ensure an accurate representation of the worker's exposure).

1. There is no regulation in field of safe production and use of nanomaterials and no special recommendations for safe work
2. Most of activities run at Ministry for Health, National Chemical Office – leaflet, booklet, international conference. At Institute for Public Health and Ministry for Agriculture, Food and Forestry the activities just started; at Ministry for Labour the first information are collecting.
3. In last few year three commercial detector for nanoparticles in air were purchased from research money (2- Jozef Stefan Institute, 1- National Institute for Chemistry)
4. Public laboratory or institution with expertizes in nanosafety and with adequate instrumentation for analysis is urgently needed.

Nanosafety in Slovenia

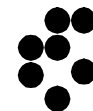
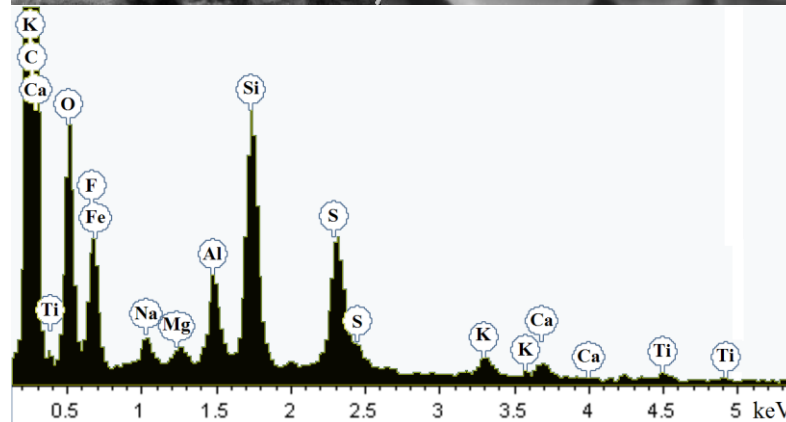
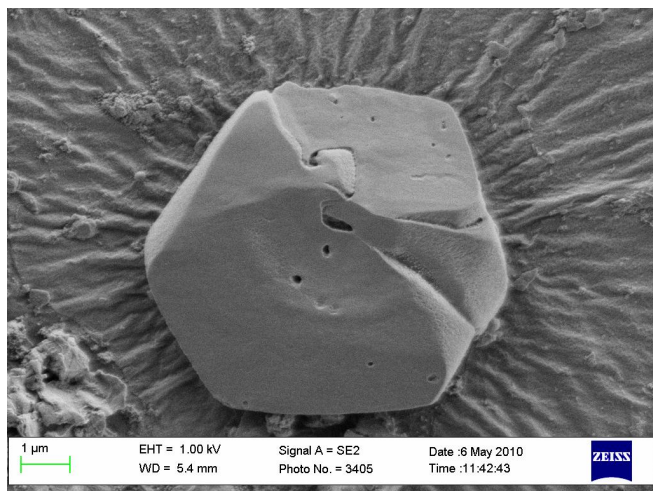
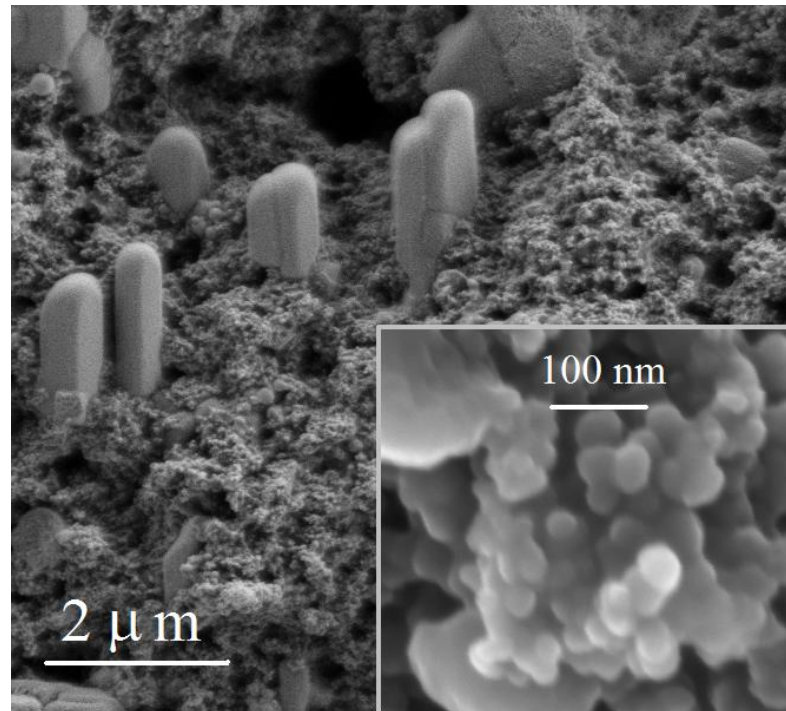


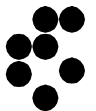
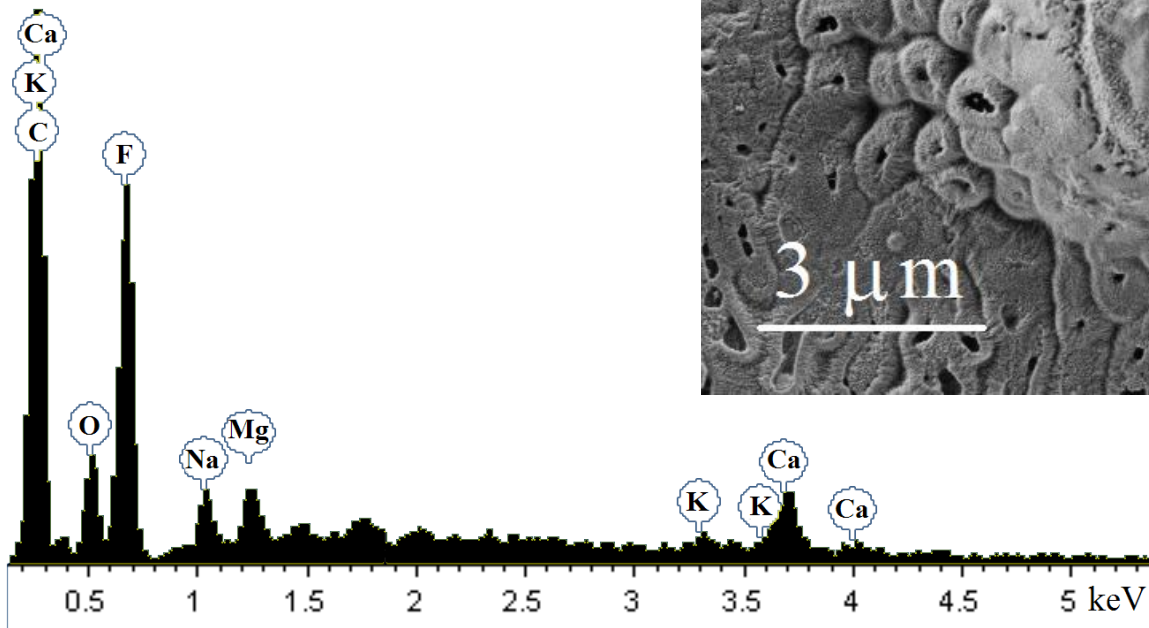
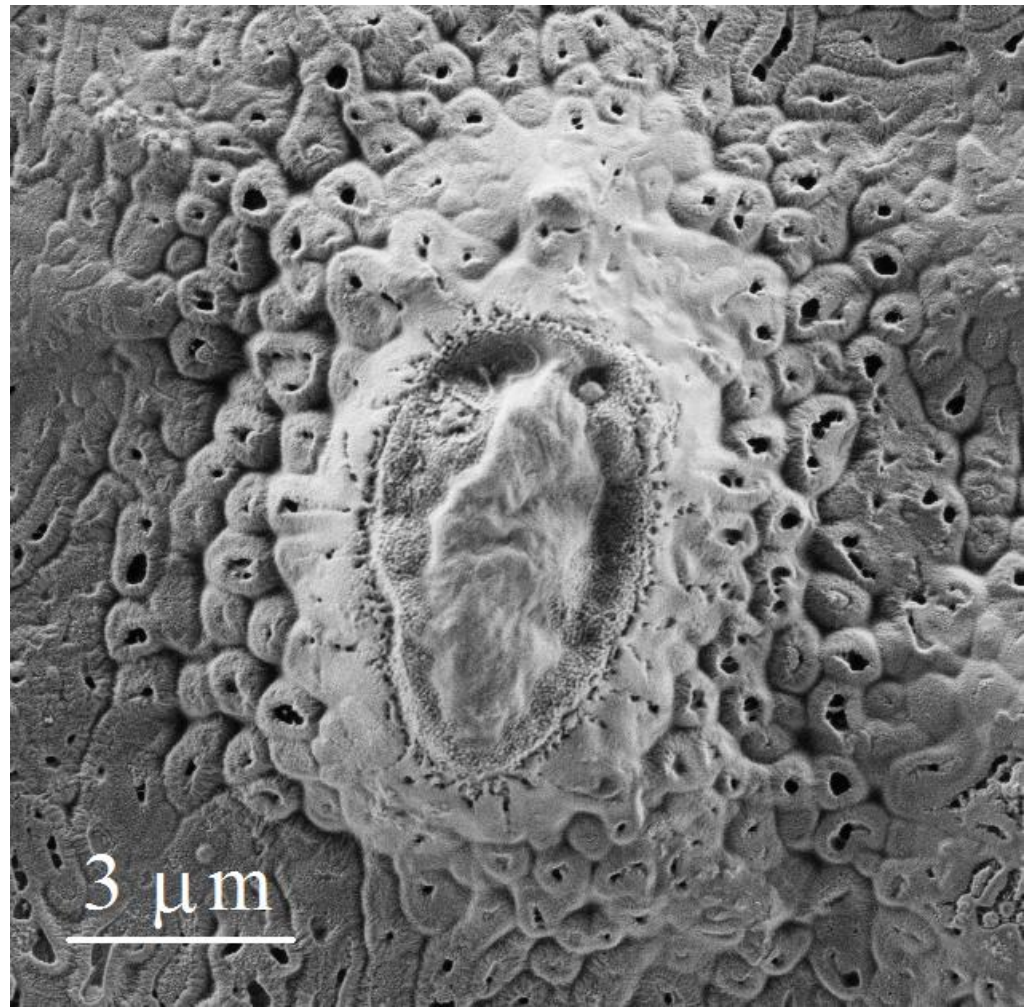
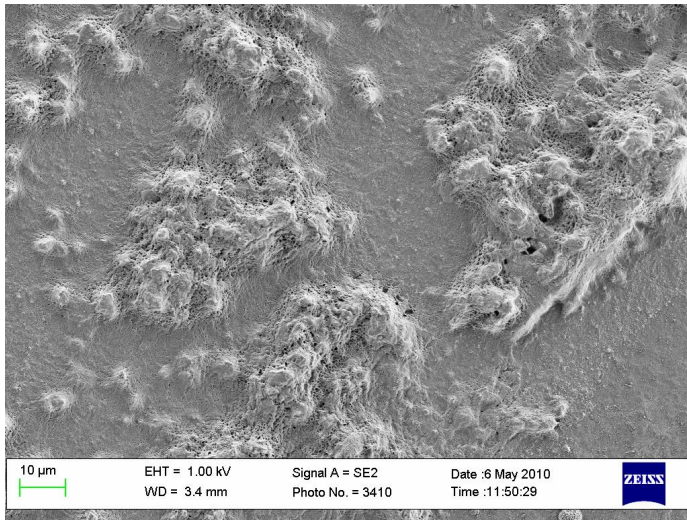
www.pyrouniverse.com/chem.htm

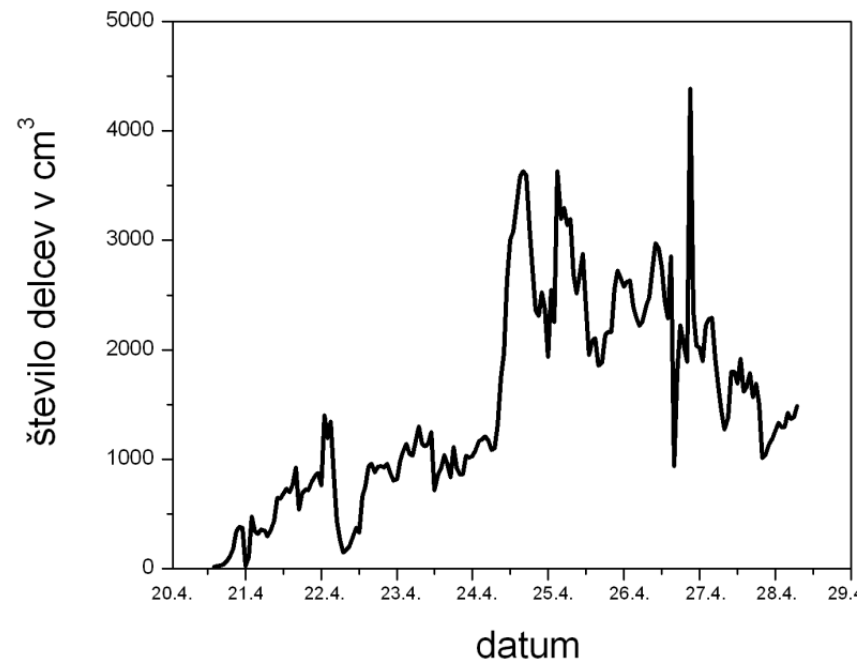
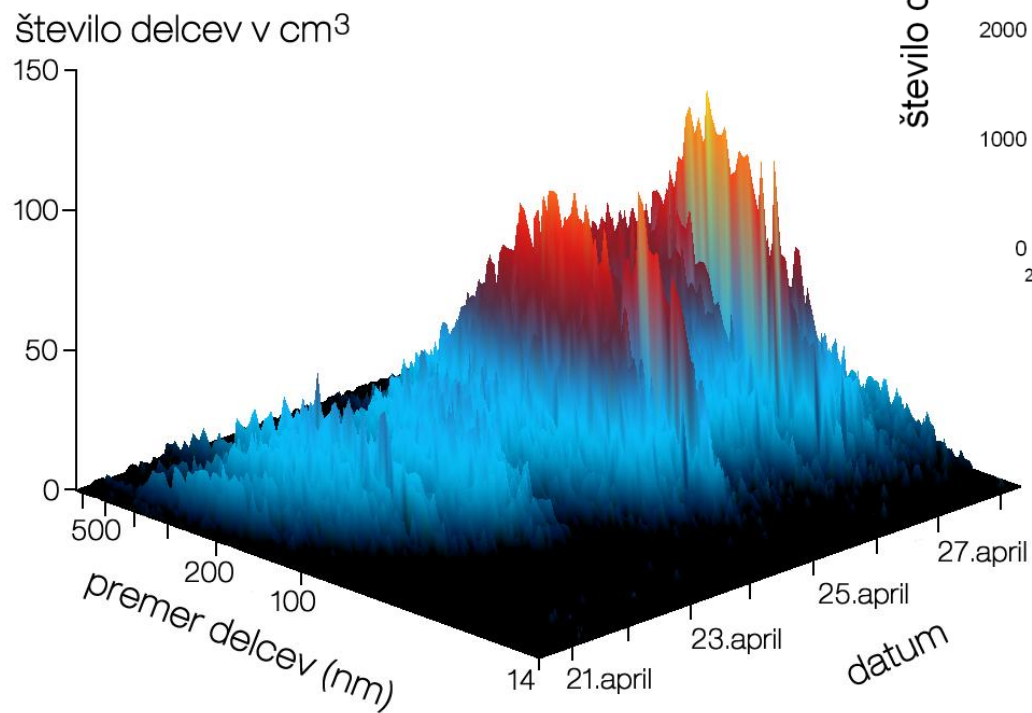




Eyjafjallajökull







Collaboration with
National Institute for
Chemistry (I.Grgic) and
Company Aerosol Ltd.

