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Migration of nanoparticles from packaging and a sensor for the nanoparticles toxicity

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Application and Communication of Active and Intelligent Packaging
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INTRODUCTION

Nanomaterials - applied worldwide

Safety, implications on human and environmental health and potential risks - under discussion

Opinions - from "completely harmless and safe" to "extremely hazardous".

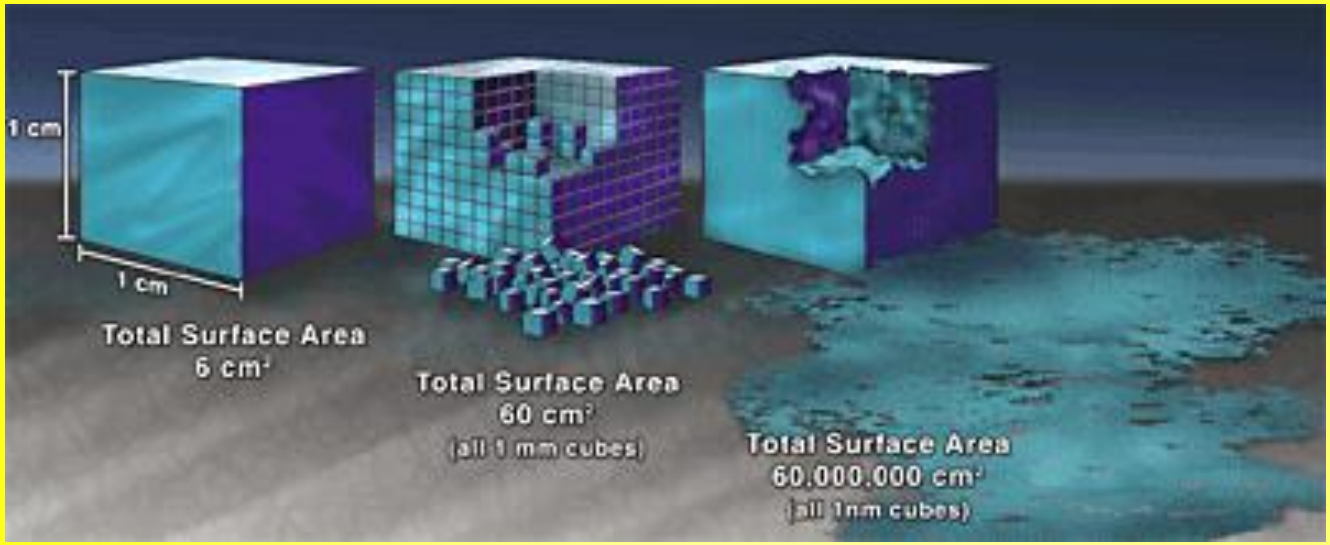
Nanoscale - having one or more dimensions of the order of 100 nm or less

Size of pores in human body - about 200 nm (gut), 70 nm (skin) $\Rightarrow$ additional toxicity of NMs

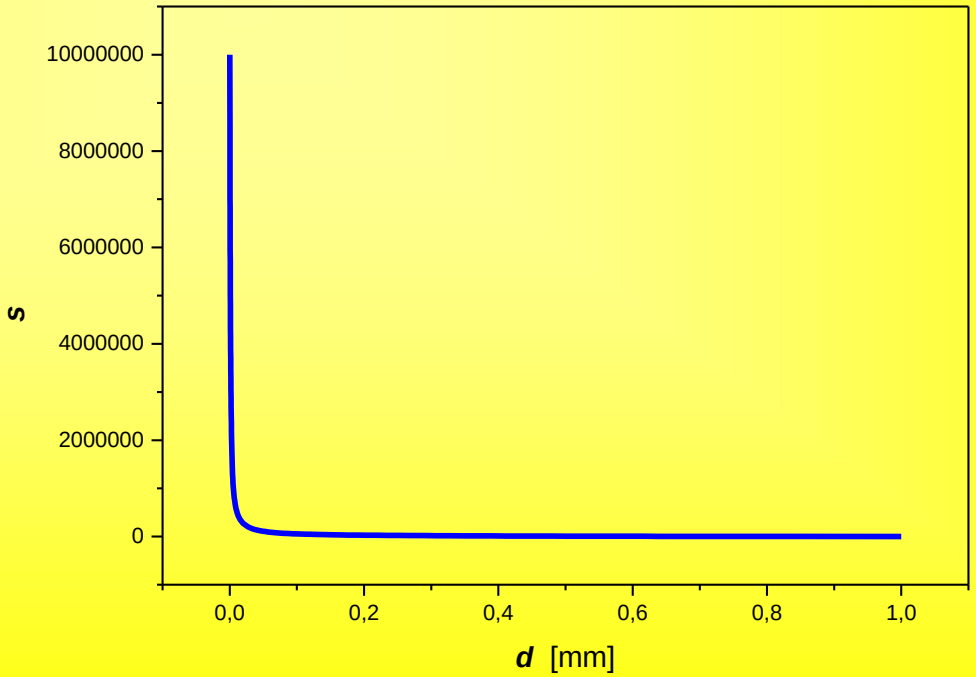
Soluble and biodegradable NMs – toxicity as the bulk counterparts

Biopersistent NPs – may accumulate

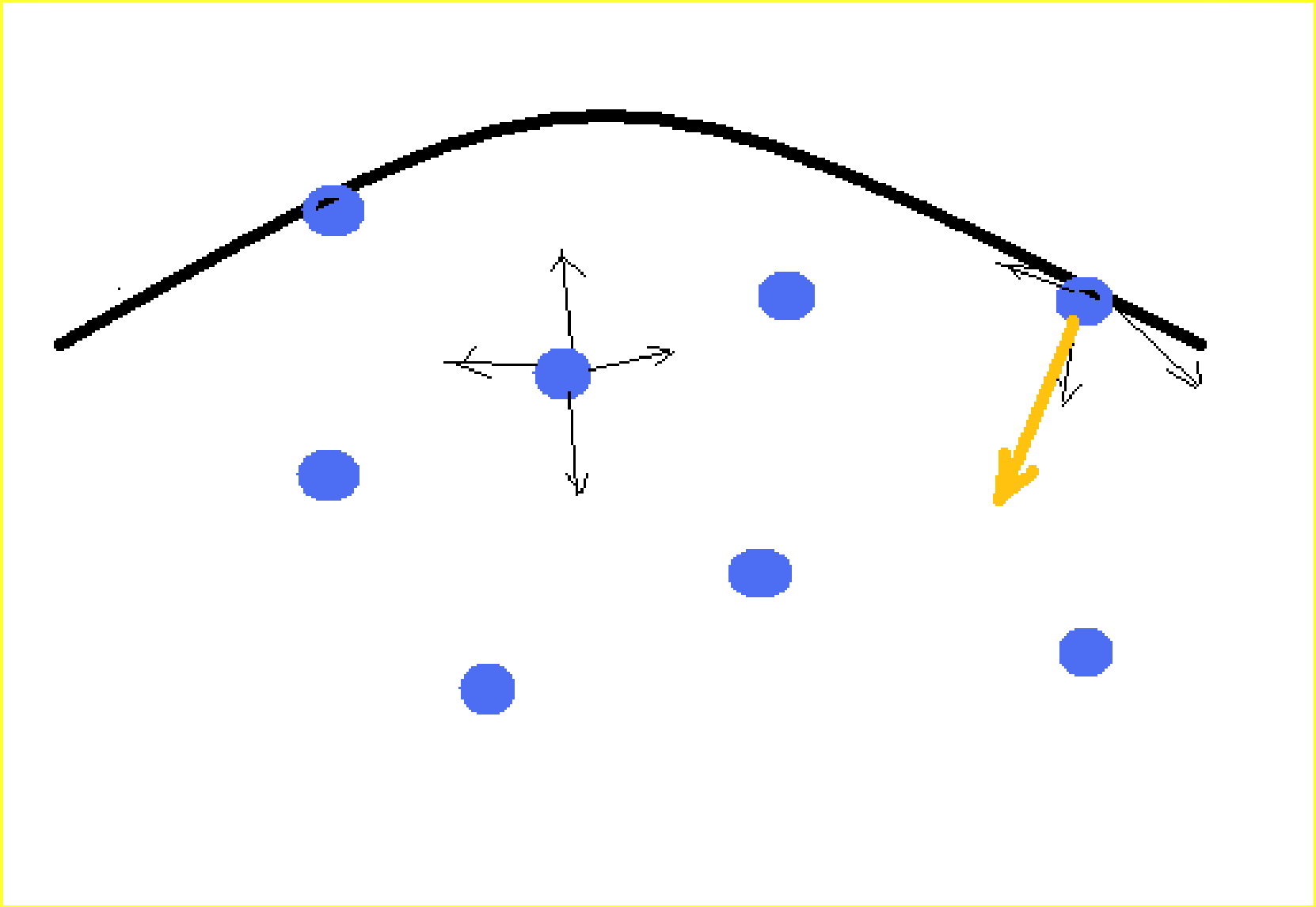
Surface free energy and consequences



$$s = \frac{S}{V} \sim \frac{1}{d}$$



Surface energy



Atoms/molecules on a solid surface miss the nearest neighbours above the surface **- unsatisfied bonds exposed to the surface**.

Surface atoms /molecules convey an extra potential energy = **surface free energy**

Due to the huge surface energy, NMs are **thermodynamically unstable** or metastable and exert **high chemical activity**.

Properties of NPs differ from those of the bulk material

NANOPARTICLES IN FOOD

Biopersistent micro- and nanoparticles commonly found in food:

-silicon dioxide (SiO_2, E551),

-magnesium oxide (MgO, E530)

-titanium dioxide anatase (TiO_2, E171).

-The antimicrobial properties of nanosilver are known and such properties have recently been discovered for nano-zinc oxide and magnesium oxide

NANOPARTICLES IN PACKAGING

- filler – Ag, ZnO, TiO_2, etc. – intelligent packaging

- NPs from the matrix – toxicity not tested

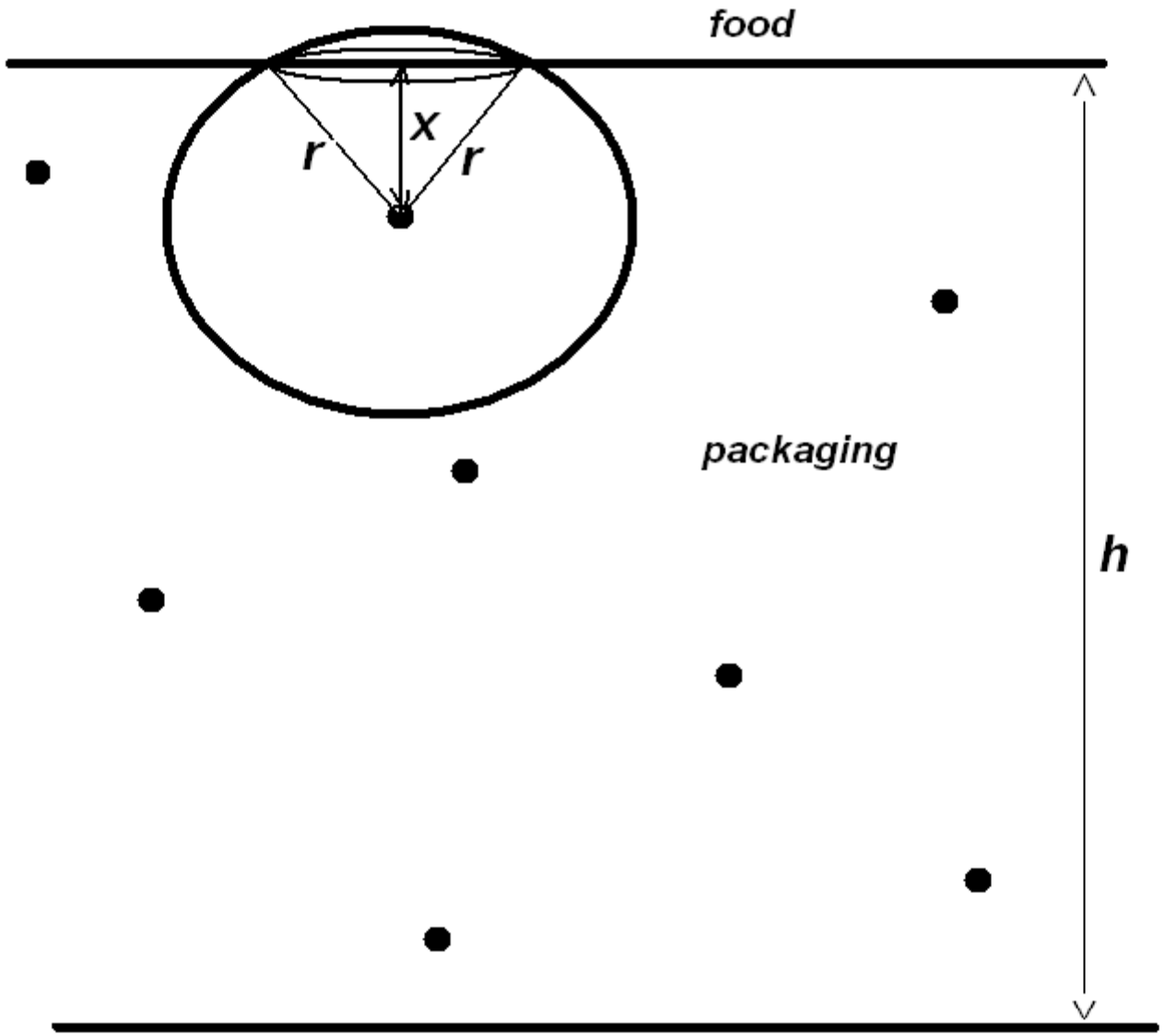
Migration of nanoparticles from packaging to food

Stokes-Einstein relation: $$D = \frac{k_B T}{6\pi\eta a}$$

The average distance, *r*, travelled by particles: $$r = 2\left(\frac{Dt}{\pi}\right)^{1/2} = \left(\frac{2k_B Tt}{3\pi^2 \eta a}\right)^{1/2}$$

Williams-Landel-Ferry equation for polymer melts: $$\eta(T) = \eta(T_g)\exp\left[-\frac{C_1(T - T_g)}{C_2 + T - T_g}\right]$$

The ability of NPs to migrate from the packaging to food, i.e. the migratability (*m*): $$m = \frac{n}{Sc_0} = \frac{1}{4}\left(\frac{2k_B Tt}{3\pi^2 \eta a}\right)^{1/2} = \left(\frac{k_B Tt}{24\pi^2 \eta a}\right)^{1/2}$$

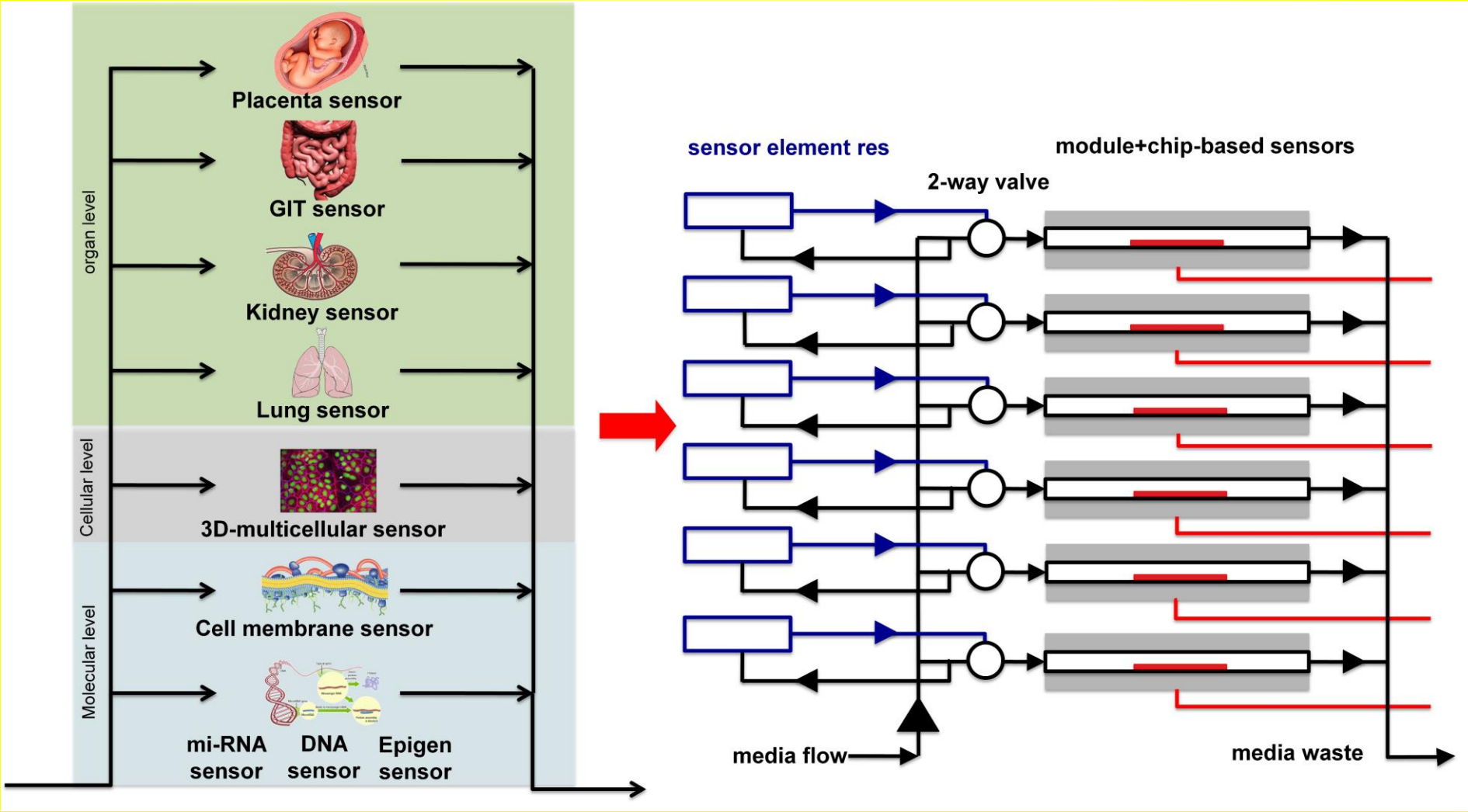

food
x
r
r
packaging
h

Polymer	***m*** [m] 25 ° C 1 month	***m*** [m] 25 ° C 1 year	***m*** [m] 4 ° C 1 month	***m*** [m] 4 ° C 1 year	***m*** [m] –18 ° C 1 month	***m*** [m] –18 ° C 1 year
LDPE	3.7×10^{-7}	1.3×10^{-6}	2.5×10^{-7}	8.9×10^{-7}	1.9×10^{-7}	6.7×10^{-7}
HDPE	2.6×10^{-7}	9.2×10^{-7}	1.5×10^{-7}	5.3×10^{-7}	6.9×10^{-8}	2.4×10^{-7}
PP	1.5×10^{-7}	5.2×10^{-7}	5.1×10^{-8}	1.8×10^{-7}	8.0×10^{-9}	2.8×10^{-8}
PET	$< 3.0 \times 10^{-9}$	$< 1.0 \times 10^{-8}$	$< 2.9 \times 10^{-9}$	$< 1.0 \times 10^{-8}$	$< 2.8 \times 10^{-9}$	$< 9.7 \times 10^{-9}$
PS	$< 2.1 \times 10^{-9}$	$< 7.4 \times 10^{-9}$	$< 2.0 \times 10^{-9}$	$< 7.1 \times 10^{-9}$	$< 2.0 \times 10^{-9}$	$< 6.8 \times 10^{-9}$

Migration of NPs from packaging to food will be detected mainly in the case of:

- very small NPs with the radius in the order of 1 nm
- from the polymer matrices that have a relatively low dynamic viscosity,
- from the polymer matrices that do not interact with the NPs.
- These conditions could be met for nanocomposites of silver with polyolefines (LDPE, HDPE, PP).
- For bigger NPs that are bound in polymer matrices with relatively high dynamic viscosity, the migration will not be detectable.
- This corresponds to nanosilver composites with PET and PS, and surface-modified montmorillonite embedded in various polymer matrices.

Sensor platform for the NPs toxicity: Project H2020 HISENTS



Toxicity – depends on the concentration of NPs and contact time

Physiologically **B**ased **P**harmaco**K**inetic model

PBPK model – a multicompartment model:

Description of :

Adsorption
Distribution
Metabolism
Excretion

of chemical substances in an organism via a series of differential kinetic equations

Parameters for the model – from the sensor platform - ***Human on a chip***

Conclusions

1. Nanomaterials – may enter unusual sites in the body

2. Biopersistent nanomaterials may accumulate

3. Packaging – sources of NPs: filler, matrix

4. Toxicity of nanomaterials – not fully clear in many cases

5. **Sensor platform for NPs toxicity** – measuring the response of cells and modelling the response of mammals – ***human on a chip***

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Some publications:

1. Šimon P. & Joner E., *Journal of Food and Nutrition Research* **47** (2008) 51-59: Conceivable interactions of biopersistent nanoparticles with food matrix and living systems following from their physicochemical properties.
2. Šimon P., Chaudhry Q. & Bakoš D., *Journal of Food and Nutrition Research* 47 (2008) 105-113: Migration of engineered nanoparticles from polymer packaging to food – a physicochemical view.


Thank you for
your attention!
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