Evaluation of health risks of technical nanoparticles – the contribution of characterization

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Motivation

Toxicological investigations on nanoparticles (NP) require a comprehensive chemical-physical characterization to gain relevant information about the powder to be analysed.
Furthermore, it is necessary to know the particles' behavior in water and physiological media exactly.

The methods which have to be developed permit a standardized procedure in handling and characterization of powders and suspensions in the context of toxicological experiments.
They form the prerequisite for the interpretation of the results obtained from in vivo and in vitro experiments.

Aims

- Characterization of the powders
- Development of nanoparticle suspensions for the use in toxicological experiments
- Studying the behavior of particles in physiological liquids

Results

Powder characterization

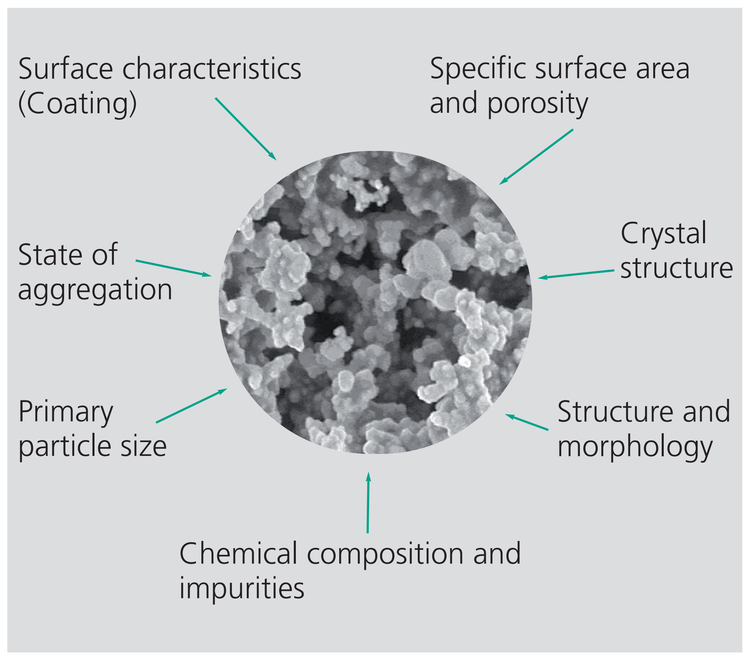


Figure 1
Parameters of the powder characterization.

How are nanoparticles?

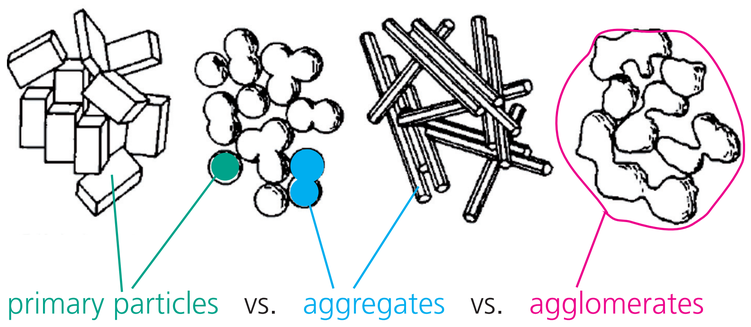


Figure 2
Definition according to DIN 53206.

Preparation and assessment of suspensions

If taken up into organism, nanoparticles come into contact with body's own liquids (lung surfactant, blood) and so suspended NP have to be observed. In vivo and in vitro experiments reconstruct these conditions.
Before studying the NP behavior in physiological media, the preparation and assessment of a electrostatically stable non-physiological NP suspension – in the simplest case by using water – is necessary.

The NP suspension can be stabilized electrostatically at high absolute values of the zeta potential. Hence, a pH adjustment or an addition of a non-toxic dispersant is often needed.

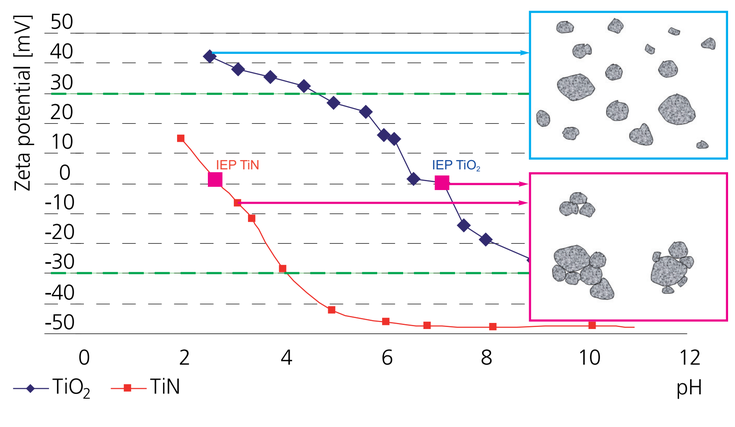


Figure 3
Zeta potential and agglomeration grade of TiO_2 and TiN as a function of pH. TiN shows other surface qualities than TiO_2 although it is oxidized in air and in water.

Under these circumstances agglomerates can be destroyed via ultrasonication without inducing a reagglomeration. However, the primary particles are present in the form of aggregates. A breakage into isolated particles is usually not possible.

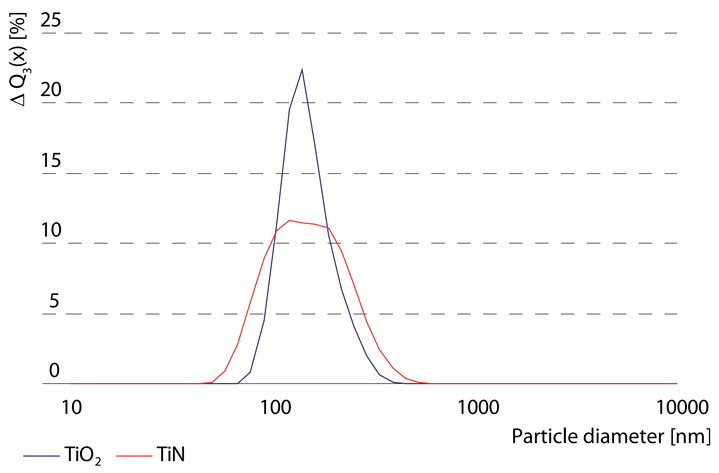
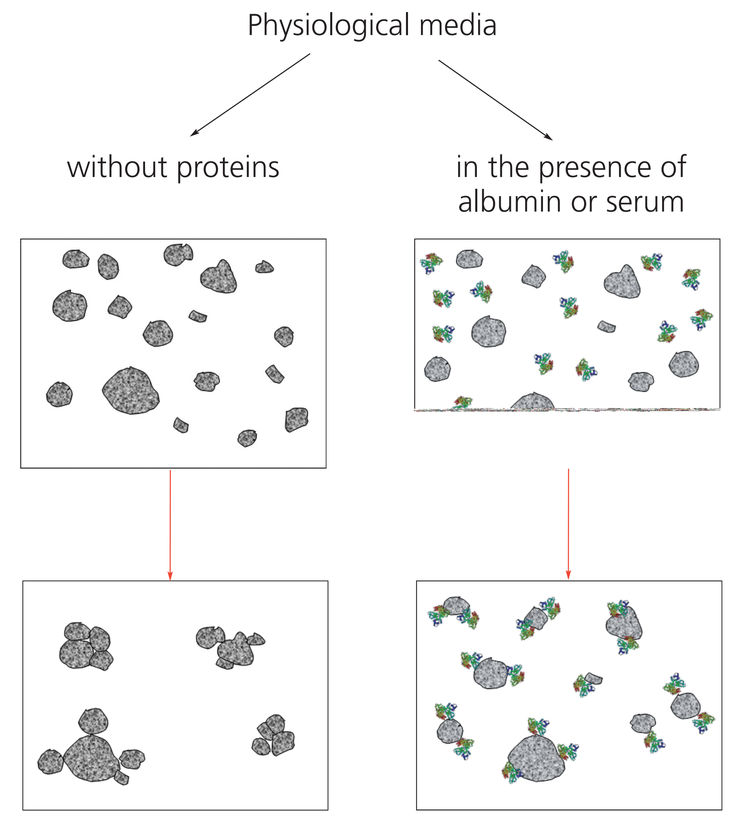


Figure 4
Size distribution of a NP suspension after ultrasonication measured by means of dynamic light scattering (DLS).

The suspensions produced that way are stable over several weeks. Thus, an increased reproducibility is given in toxicological examinations.

Behavior in physiological media

The stable well-defined initial NP suspension is added to the appropriate physiological media. The chemical-physical and also toxicological behavior of the particles in these media can be analysed now.



Agglomeration of particles due to weak electrostatic repulsion forces

Reason:
Electrochemical double layer around the NP is reduced in physiological solutions

Stabilization and effective hindrance of an agglomeration through albumin and serum, respectively

Reason:
Adsorption of albumin on the NP surface and transfer of the protein's abilities to the covered particle

The adsorption of albumin and resulting nanoparticle stabilization change the identification of the particles within the organism. Thus, cellular uptake and toxicological mechanism can be altered.

Conclusion

Chemical-physical characterization
- Powder assessment as basis for all further examinations
- Preparation of stable, deagglomerated nanoparticle suspensions based on the analysis of zeta potential and particle size
- Description of the behavior in physiological media, especially of agglomeration and influence of proteins

The method was tested and verified for example on Al_2O_3, AlOOH, TiO_2, TiN and WC particles.
Due to the standardized method, the approach is adaptable to many particle systems. Handling with NP in toxicological experiments will be simplified and more reproducible.
As a consequence, a better correlation between chemical-physical data and toxicological results is possible.

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