V. Drozdova, PhD in Ped., As. Prof.
K. Zelinskiy, Student
Khmelnytskyi National University

NANOMATERIALS: INTRODUCTION TO NANOSIZE AND NANOTECHNOLOGY

Nanotechnology is an important and promising field that can lead to improved environment and human health and contribute to a better social and economic development. Materials in nanoscale have unique physiochemical properties which allow for completely new technical applications. Enlarged surface area and properties due to quantum physics are among the properties that distinguish the nanoscale. Nano safety has evolved as a discipline to evaluate the adverse health effects from engineered nanomaterials (Engineered nanomaterials). The prevalence of allergic diseases is increasing in the society. An additional issue is the influence of inherited factors on the health responses to Engineered nanomaterials. The aim of this thesis was to investigate the respiratory, inflammatory, and immunological effects following inhalation of Engineered nanomaterials; both sensitive and genetically susceptible individuals were used. Sensitive individuals refer to individuals with pre-existing respiratory diseases, such as allergic asthma, and genetically susceptible individuals refer to individuals prone to autoimmune and allergic diseases.

The nanometer is a unit of length, and designates one-billionth of a meter (10-9). The term “nano” is derived from the Greek word “nanos” which translates to dwarf. To give an idea of how small this unit is, it could be mentioned that a human hair has a width of about 80 000 nm.

The presences of nanosized particles (Nanoparticles) are not a new phenomenon. The origin of Nanoparticles can be divided into:

i) Naturally occurring Nanoparticles, from natural processes such as volcanic eruptions, forest fires, earth eruption, water aerosols etc.
ii) Anthropogenic Nanoparticles, originated from origin like combustion, engine exhaust, industrial processes, indoor cooking, etc.
iii) Engineered nanomaterials.

In this thesis, focus will be on engineered nanomaterials (Engineered nanomaterials)

The recent technology, which allows the production of structures on the atomic scale, is entitled nanotechnology. Materials in nanoscale carry unique physiochemical properties which allow for completely new technology applications compared to the corresponding materials on a larger scale. The two main different nanoscale properties include surface and quantum effects. The surface effect causes large area-to-mass ratio, resulting in potentially enhanced chemical reactivity with the surroundings, while quantum effects may influence e.g. mechanical, optical, electric, and magnetic properties [1-3].

Nanotechnology is a very important and promising field that can lead to improved effects on both the environment and the human health, as well as contribute to a better social and economic development [4,5]. The wide use of Engineered nanomaterials in many different applications demonstrates a broad impact in society and that the Engineered nanomaterials affect many people. Despite these great benefits there is a concern that Engineered nanomaterials could have a negative impact on health and environment, and there is a need for toxicological evaluations of these materials [5]. Since Engineered nanomaterials are of the same magnitude as many intracellular machineries, like proteins, enzymes etc., it is of great importance to sort out if they interact with biological systems [6].

The development of nanotechnology and material science is expanding enormously, but only 5% of the invested resources have been dedicated to research to understand the Engineered nanomaterials effects on environmental and human health and thus increase the awareness regarding nanosafety issues [7]. It is important that the environmental effects and the health effects from these Engineered nanomaterials, if any, are well characterized and known in advance, a large production and consuming of Engineered nanomaterials are available to the common man.

An important part of nanosafety is the physicochemical characterization of the material to be studied. It is preferable to perform the physicochemical characterization of the material in all surrounding matrices: in the dry state, in the buffer- or medium-solution, if used, and finally also in the biological matrices it comes in contact with e.g. lung lining fluid. The physicochemical properties, of the nanomaterials, that are of relevance to determine are: size and surface area, shape, crystal structure, chemical composition, solubility, agglomeration state, surface charge, surface energy, and surface coatings [3, 8].

A mass of small sized particles have increased surface area compared to the same mass of larger sized particles. An increased surface area enhances the possibilities for interaction with the surrounding milieu [8] and because a large percentage of the atoms lies on the surface of nanomaterials, there is increased reactive potential [9]. A consequence of increased surface reactivity in the nanoscale for some material is the enhanced capability to generate reactive oxygen species (reactive oxygen species) within biological systems [5, 8]. Oxidative stress is a result of increased levels of reactive oxygen species, this could be due to surface activity of nanomaterial or intracellular process from phagocytic cells [5]. Normally, reactive oxygen species is a result from vital processes, such as photosynthesis, respiration, and cell signalling, in which superoxide, hydrogen peroxide (hydrogen peroxide), and hydroxyl radicals (hydroxyl radical) are formed. The body has through evolution developed systems to rapidly take care of these reactive species, by means of antioxidants, such as glutathione, vitamin C and E, uric acid, and beta-carotene, and also by means of enzymatic systems, such as superoxide dismutase (superoxide dismutase), catalase, and peroxidases [10, 11]. An excessive production of reactive oxygen species generates an imbalance between oxidants and antioxidants that may harm the biological system due to interaction with vital macromolecules, that might affect the functions of the macromolecules [5].

Nanomaterials can be produced in different shapes and forms, such as particles, wires, sheets, rods, fiber etc. It is well known that the fiber structure of asbestos induce frustrated phagocytosis of macrophages, since they are not able to internalize the long fiber structure. This frustrated phagocytosis further results in the release of oxidants and mediator signals to the surrounding milieu [12]. Occupational exposure to asbestos over a long time is known to induce diseases like pulmonary fibrosis [13]. The structure similarities of asbestos and fiber nanomaterials cause concerns for their possible pathological capabilities in in the long term. Additionally, the crystal structure of the nanomaterials has different properties that e.g. affect the ability of the nanomaterial to be internalized into cells. It has been shown that the two Titanium dioxide crystal structures, anatase and rutile, have different abilities to be internalized into the cells due to the intrinsic physiochemical forces between their agglomerates; anatase forms soft agglomerates that are loosely bonded and consequently can be internalized more easily, whereas rutile forms harder agglomerates that do not internalize to the same extent [14].

The general discussion surrounding nanotechnologies and their impact on health and the environment emphasizes the need for careful study and assessment of risks associated with the use of nanomaterials. While nanotechnologies have great potential to improve quality of life and advance various fields such as medicine, energy, and electronics, it is also important to consider their potential negative consequences.

Research conducted within the scope of this thesis underscores that the effects of nanoparticles on health can be complex and vary depending on various factors, including dosage, material type, mode of exposure, and individual characteristics.

Further research in this direction is crucial for understanding the mechanisms of nanoparticle impact on health and for developing effective strategies to mitigate potential hazards. Additionally, the inclusion of sensitive populations and genetically susceptible individuals in research and the development of safety measures are critically important for ensuring the guaranteed safety of nanomaterials' utilization in industry and scientific investigations.

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