Advanced Powder Technology 21 (2010) 507–512

Contents lists available at ScienceDirect

Advanced Powder Technology

journal homepage: www.elsevier.com/locate/apt

Review Article

Risk assessment of airborne fine particles and nanoparticles

Toshihiko Myojo *, Akira Ogami, Takako Oyabu, Yasuo Morimoto, Masami Hirohashi, Masahiro Murakami, Kenichiro Nishi, Chikara Kadoya, Isamu Tanaka

University of Occupational and Environmental Health, Institute of Industrial Ecological Sciences, Japan

ARTICLE INFO

Article history:
Received 23 March 2010
Received in revised form 18 May 2010
Accepted 19 May 2010

Keywords:
Dust
Fine particle
Nanoparticle
Health effect
Risk assessment
In vivo study

ABSTRACT

Pulmonary health effects of fine particles and nanoparticles are overviewed in this paper, mainly based on the researches conducting in our laboratory. For the hazard assessment, we exposed rats to aerosolized asbestos-substitutes or nanoparticles aerosols (nickel oxide and titanium dioxide), and examined the biological and pathological effects of the particle on lung, a major target organ for the particles, and cytokines which are related to inflammation, fibrosis and carcinogenesis in the lung. It is essential to perform comprehensive evaluation of the toxicity of poorly soluble powder samples using the precise characterization data and exposure methods, such as single instillation or aerosol inhalation.

Contents

1. Introduction

Well-known health effects of particulate matters include pollinosis caused by pollen of several 10 microns and pneumoconiosis caused by dust particles of several microns. In recent years, there has been a lot of interest in the health effects of sub-micron particles such as diesel exhaust particles and nanoparticles of less than 0.1 μm (100 nm). The nanoparticles are not only spontaneously generated particles such as combustion exhaust particles but also derived from manufactured materials with nanoscale structure that are called nanomaterials (or manufactured nanomaterial). These nanomaterials have a potential to be applied to a wide variety of fields including information technology, environmental technology, and biotechnology in the near future, and the production of some nanomaterials is being scaled up from laboratory size to industrial size. However, nanomaterial or nanoparticles may deliver not only expected benefits but also unexpected effects on the environment, health, and society. Even if the final product of nanoparticles is tightly sealed, laboratory researchers and workers who handle the nanoparticles may be exposed to them in the process of material production and distribution; however there still remain many unknown aspects regarding the hazardous effect of nanoparticles and nanoparticle exposure. The present paper introduces mainly the result of our study on the health assessment of fine particles and nanoparticles.

2. Process of risk assessment

The risk assessment of chemical substances considers health effect resulting from direct exposure of people and effects on the environment such as the ecosystem. In this paper we will discuss

* Corresponding author. Address: Iseigaoka 1-1, Yahata-Nishi-ku, Kitakyushu-city, Fukuoka 807-8555, Japan. Tel.: +81 93 691 7459; fax: +81 93 602 1782.
E-mail address: tmyojo@med.uoeh-u.ac.jp (T. Myojo).

0921-8831/$ - see front matter
doi:10.1016/j.apt.2010.05.004

the health effect when workers and researchers are directly exposed to nanoparticles. Fig. 1 shows a general process of risk assessment. The process of risk assessment is as follows: (1) search for hazardous effect and toxicity of chemical substances that will be used in laboratories and factories in order to collect information on physical and chemical characteristics, and if possible, toxicity information, (2) examine if the target material has any hazard (toxicity and risks) and the degree of hazard, (3) examine the possibility that workers would be exposed to the material under practical conditions such as the working environment, (4) evaluate the risk; the risk is equivalent to the product of hazard and exposure, and safety is collectively determined based on the real situation, (5) take measures to reduce the risk (risk management) if production and use of the target material are continued after risk is proven. The priority of risk-reducing measures is as follows: cessation of/or substitution for highly hazardous materials, modification of process, engineered measures by sealing of processes and local exhaust system, managerial measures such as manual preparation and training, and use of protective masks [1].

3. Exposure to nanoparticles via respiratory organs

When the biological effect of nanoparticles is discussed, the invasion route of nanoparticles into the body is in question. There are several invasion routes: oral invasion via food that may have an effect on the digestive system, transdermal invasion via skin, and invasion via respiratory tract by breathing which is most important for workers handling nanoparticles because of the exposure frequency. The inhaled air goes through the nose, mouth, throat, and bronchi to reach the alveoli that exchange oxygen and carbon dioxide. Particles inhaled with this air deposit on the nasal cavity, tracheal tube/bronchi, and alveoli, depending on their size under the deposition mechanisms such as inertial impaction, gravitational sedimentation and diffusion. The bronchi are covered with the bronchial epithelium cells having cilia and remove deposited particles by ciliary movement. The alveoli, which consist of flat Type I alveolar epithelium cells, Type II alveolar epithelium cells that release surfactant, and capillary vessels that carry out gas exchange, are the major tissue that develops lesion such as pneumoconiosis and lung cancer. Whether fine particles reach the alveoli or not, it is important to consider the biological effect of particles. It is thought that, in particular, insoluble fine particles are retained in the alveoli region after deposition and their persistent inflammatory stimulation leads to a change of fibrous proliferation in the alveoli, resulting in pneumoconiosis.

Quantitative estimation of the pulmonary particle deposition needs human lung morphology models, respiratory physiology based models of the entire lung airway system, and aerosol deposition models based on many experimental findings. The model by

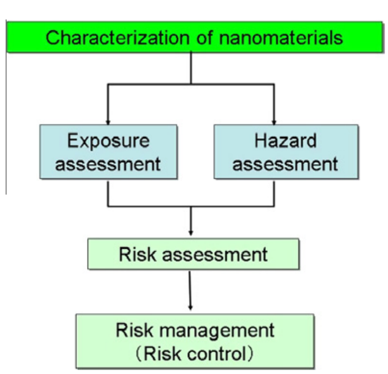

Fig. 1. Risk assessment of nanoparticles.

the International Commission on Radiological Protection, which is widely used in the nuclear field [2] and consists of the morphology model, deposition model, and clearance model, is an applicable model to conventional aerosols. This model can assess the deposited amount of aerosol in each of the compartments of the respiratory organs. Fig. 2 shows the deposition in each compartment based on the reference [2] described above when an adult breathes through the nose at a respiration rate of 1.2 m^3/h. This figure indicates that particles deposit on different regions depends on their size. There is a different tendency in particle deposition: most of micro-particles deposit on the upper respiratory tract, while nanoparticles larger than 10 nm deposit mostly in the alveoli and those smaller than 10 nm deposit in the nasal cavity.

4. Exposure limit of nanoparticles in work environment

In Japan, the permissible concentration and Administrative Control Level (ACL) are used to control hazardous materials in the air including particle matters in the working environment. The permissible concentration, which is recommended every year by the Japan Association of Industrial Health, is defined as a concentration at which nearly all of the workers will not suffer from health hazards if an average exposure level is below this concentration when the workers are exposed to hazardous material for 8 h/day, 40 h/week with physiologically not-hard work intensity [3]. The permissible concentration is defined for three types of respirable dusts with 50% separation size of 5 μm: Class 1 dusts $\leqslant$0.5 mg/m^3, Class 2 dusts $\leqslant$1 mg/m^3, and Class 3 dusts $\leqslant$2 mg/m^3. Class 1 dusts include talc, alumina, bentonite, kaolinite, activated carbon, and graphite. Besides, the permissible concentration of respirable crystalline silica is more strictly specified as $\leqslant$0.03 mg/m^3. A standard similar to the permissible concentration is threshold limit values (TLV) by the American Conference of Governmental Industrial Hygienists (ACGIH-TLV), etc.

The ACL is an index that is used to evaluate the quality of work environment based on the measurement of airborne hazardous materials in order to improve the work environment, and is an administrative concentration in consideration of exposure limit, technical feasibility, etc. In accordance with the article 65 of the Industrial Safety and Health Law, concentration of hazardous materials in work environment shall be measured by the working environment measurement standards and the working environment evaluation standards [4] in certain work areas such as an indoor work area for hazardous operation. The purpose of working environment measurement is to understand the emission of the target materials in the environment and to encourage setting about improving the working environment if necessary; this is not a direct assessment of exposure.

In accordance with article 65-2 of the Industrial Safety and Health Law, the record of measurement results is obligately stored for the operation, with mandatory working environment measurement defined in the article 21-1 of the Enforcement Order of the Industrial Safety and Health Act Cabinet Order. For particulate matter, working environment assessment is prescribed for the works and workplaces defined in articles 25, 26, 26-2, and 26-3 of the Ordinance on Prevention of Hazards Due to Dust Ministry of Labour Ordinance. This has already been explained in a previous article [5]. The ACL of dusts, besides respirable crystalline silica, used for working environment assessment is 3 mg/m^3 [4] and covers respirable particles as with the case of the permissible concentration.

Now, studies are being conducted on hazards of fine particles and nanoparticles, however, different limits are rarely set for different sizes of the same material. Under this situation, it is notable that the National Institute for Occupational Safety and Health, USA