ENVIRONMENT/ECOLOGY

Special Topic: Environmental Pollution and Health Risk

Nano products in daily life: to know what we do not know

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Over the past decade, products based on nanotechnology and nanomaterials have created a fast-growing consumer market (http://www.nanotechproject.org/). Over 1827 consumer products have reached the supermarkets and millions of customers. At least about 39 different nanomaterials were found in these products, such as those made from metals (Ag, Ti, Zn, Au), metal oxides (TiO_2, Fe_2O_3, ZnO), carbonaceous (carbon, CNTs, fullerenes, graphene) and silica. The majority of nanotechnology products are usually used in healthcare and fitness, home and garden, automotive, appliances, coatings, electronics, foods and beverages areas. The Future Markets (2012) reported that the worldwide nanomaterial production will be over 340,000 tons by the end of 2016. The production of TiO_2 nanoparticles tops all nanomaterials, followed by ZnO, CNTs and Ag nanoparticles (http://www.marketresearch.com/Future-Markets-Inc-v3760/ Global-Nanomaterials-Production-volumes-revenues-6916724/).

The production, transportation, daily use and disposal of these products have already impacted environment and human health, although these effects are still not well understood quantitatively. This has become a critical issue worldwide. Here, we analyse the life cycles and potential effects of some consumer products based on only four nanomaterials out of 1827 marketed products with the hope that future breakthroughs and research will provide information on key issues in nanosafety research (Figure 1). The selection of that four nanomaterials was based on their wide applications (Ag nanoparticles), their incorporations into a large number of consumer products (TiO_2, ZnO nanoparticles) and their numerous novel properties (CNTs).

Because of their antimicrobial and antibacterial properties, Ag nanoparticles have been heavily used in a wide range of medical supplies and household products, such as food packing and storage utensils, cleaning agents, textiles, water filters, humidifiers and sprays. Ag nanoparticles can be easily released into the environment, from coatings used in outdoor facades, textiles, personal care products or cleaning agents during washing, for example. These Ag nanoparticles contaminate groundwater and are often trapped in sewage sludge. Because of the limited information on their concentrations in the natural environment, modeling studies have predicted their concentrations in sludges to be 1.31–4.44 mg/kg in Europe and 1.29–5.86 mg/kg in the USA [1]. Laboratory studies have shown that Ag nanoparticles can lead to potential toxicity in animal models by affecting organ function [2] and gene expression [3].

Food-grade ZnO and TiO_2 nanoparticles have been widely used in food packing materials to maintain colors, to prevent spoilage, and as a whitener and texture modifier in foods (e.g., ice cream and candy). They are frequently added to cosmetics and sunscreens because of their ultraviolet (UV) protection properties. The use of cosmetics and sunscreens leads to substantial dermal exposure to nanoparticles. The exposure of the skin to 1000 mg of TiO_2 nanoparticles was estimated from only one event of sunscreen use alone [4]. Nanoparticles do not easily penetrate beyond the stratum corneum of the human adult skin model [5], although this is not the case in pigs or hairless mice [6]. TiO_2 nanoparticles have also been added to textiles and are easily released into environmental waters during use and washing cycles. Modeling [1] has estimated the concentrations of ZnO nanoparticles to be 17.1 mg/kg (Europe) and 23.2 mg/kg (USA) in sewage sludges, and the concentrations of TiO_2 nanoparticles to be 136 mg/kg (Europe) and 137 mg/kg (USA). In surface water, the concentrations of ZnO nanoparticles are estimated to be 0.08–1.60 μg/L [7]. The concentration of TiO_2 nanoparticles in the Old Danube Lake in Austria increased from 1.7 μg/L in the winter to 27.1 μg/L in the summer, indicating that sunscreen use might be the season-dependent contaminating source [8]. Cytotoxicity and organ toxicity have been shown for both ZnO and TiO_2 nanoparticles.

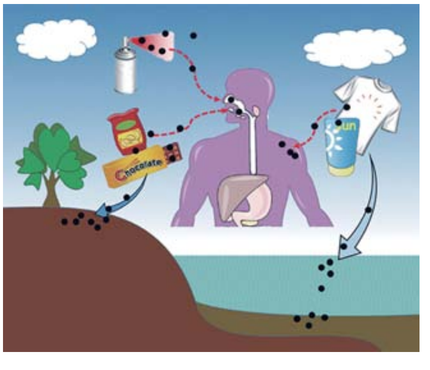

Figure 1. Overview of the fate of nanoparticles and their impacts on the environment and human health during the use of nanotechnology-based consumer products.

Carbon nanotubes (CNTs) have been widely used in industries and in consumer products such as sporting goods, clothing, bikes, touch screens and automobiles owing to their superior strength and excellent electrical and thermal conductivity. CNTs cause male reproductive toxicity [9] and immunotoxicity [10] among other toxicities in human cells and in animals. Modeling estimates the concentrations of CNTs to be 0.09–1.70 mg/kg in sludges and 0.08–1.60 μg/L in surface water [7].

In the natural environment, nanoparticles undergo further transformations: being released as ions, aggregated and agglomerated, surface modified or embedded into natural matrices. The above cases are only a handful of better-known nano contaminants. Our limited understanding of the life cycles of nano contaminants from all 1827 nano consumer products calls for more research in this area. We need to know the detailed fate of these nanomaterials during the life cycles of these products. Quantitative analysis methods and techniques for real-time monitoring of various nanoparticles in the air, water and soils need to be developed. Only with these technical breakthroughs will we eventually realistically evaluate the impacts of environmental nanoparticles on human health and the environment.

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