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Carbon nanotubes added to the SIN List as a nanomaterial of Very High Concern

To the Editor — On 14 November 2019 at a public event in Brussels, Belgium, carbon nanotubes (CNTs) became the first nanomaterial to be added to the SIN ('Substitute It Now') List by the Swedish non-profit organization, ChemSec (https://chemsec.org/sin-list/). In attendance were representatives from companies, non-governmental organizations, the European Parliament, the European Commission and the United Nations Environment Programme (UNEP). The event marks the end of a one year collaborative project between ChemSec and the Department of Environmental Engineering at the Technical University of Denmark where we aimed to identify potential nanomaterials of very high concern.

The SIN List is a comprehensive database of chemicals that ChemSec believe should be restricted or banned in the EU, but have not been because of the slow functioning of the European Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) regulation. As REACH implementation has so far been slow, companies, public procurers, financial investors and others have turned to the SIN List for guidance on which chemicals to stay away from. Historically, updates of the SIN List with new categories of chemicals have raised much attention both in the political arena as well as in the corporate world. For instance, the addition of endocrine disruptive chemicals (EDCs) was recognized by UNEP as one of the most robust and scientific lists of EDCs[1]. In 2016, the SIN List was included in the Dow Jones Sustainability Index by RobecoSAM[2]. It is also included in various ecolabels[3], certification requirements[4] and procurement schemes, especially in the Nordic countries[5]. Many companies, including H&M[6], Akzo Nobel[7] and Scandic[8] have stated that they look closely at the SIN List when prioritizing chemicals for phase-out.

SIN List criteria

The criteria used by ChemSec for including a given substance on the SIN List are the criteria for Substances of Very High Concern (SVHC) described in REACH. The first category of substances is substances that can cause cancer, alter DNA or damage reproductive systems. The second category are harmful substances that do not easily break down and accumulate in the food chain. The third category are substances that give rise to equivalent levels of concern in terms of potential health and environmental damage, for example EDCs. It is important to note that the SVHC criteria only focus on hazardous properties and do not consider potential exposure, which might vary greatly depending on how the substance is used. Furthermore, it is possible to receive REACH authorization for specific and crucial uses of a SVHC substance, but the vast, uncontrolled use of the substance everywhere is no longer possible.

Carcinogenicity of CNTs

In 2014, the International Agency for Research on Cancer (IARC) classified a certain group of multiwalled carbon nanotubes (MWCNTs) known as MWCNT-7 as "possibly carcinogenic to humans" (Group 2B) based on rodent studies that showed that MWCNT-7 caused peritoneal mesotheliomas in male and female rats after injection of CNTs into the peritoneum (intraperitoneal injection) and the scrotum (intrascrotal injection) and that inhalation promoted bronchioloalveolar adenoma and carcinoma in male mice[9]. IARC found limited evidence for the two other types of MWCNTs with dimensions similar to MWCNT-7, and inadequate evidence for single-walled carbon nanotubes (SWCNTs). Nevertheless, according to IARC, the results of studies of genotoxicity in vivo and in vitro were positive for both SWCNTs and MWCNTs. Similarly, lung inflammation, granuloma formation and fibrosis were observed in rats and mice exposed by inhalation, intratracheal instillation or pharyngeal aspiration to SWCNTs, double-walled CNTs or MWCNTs. With reference to IARC monographs, "Carbon Nanotube Single-walled (>55%) below 2nm(diam.), 5-15micro m (length)" (EC no. 608-533-6) is listed as a 'suspected carcinogen' in ECHA's REACH Annex III inventory of substances likely to meet the criteria for category 1A or 1B carcinogenicity, mutagenicity or reproductive toxicity[10,11]. Since the IARC's review, other studies have been published that support the conclusion that CNTs are carcinogenic[12,13].

Reproductive toxicity of CNTs

The dozens of studies that exist on the reproductive toxicity of CNTs vary in applied designs, extent of CNT characterization and reported information on the number and sex of animals, administration schedule and identification of toxicological endpoints[14,15].

Furthermore, reported effects vary depending on the route of administration. No adverse effects were observed on foetal development in rats or on female reproduction and offspring growth in mice after oral administration of MWCNTs to dams[15]. However, after intratracheal instillation of MWNCTs, a delay in the delivery of the first litter was observed in female mice prior to mating[16]. Pristine and functionalized SWCNTs have been found to be embryolethal and teratogenic in mice when administered via intravenous injection or oral gavage[17,18]. Placental transfer of SWCNTs has also been observed and so has a high percentage of early miscarriages and foetal malformations in female mice exposed to oxidized SWCNTs[15,19].

Intratracheal instillation (introduction of a substance directly into the trachea) could seem to be the most relevant route of administration as it is widely used to test the respiratory toxicity of a substance as an alternative to inhalation in animal testing[20]. Intravenous administration has relevance for medical applications and supplies information on the potential effects once CNTs have entered the maternal blood.

Persistency of CNTs

Besides being carcinogenic and a reproductive toxicant, CNTs are generally considered as some of the strongest materials known to man. Under unrealistic environmental test conditions, for example in the presence of horseradish peroxidase and mixed bacteria culture at 39 °C, some degradation of carboxylated SWCNTs and ^{14}C labelled MWCNTs has been observed[21,22]. However, CNTs are resistant to biotic degradation. The half-life of carbon nanotubes in the environment is more than 60 days in water and 180 days in sediment and soil, which are the criteria used to designate a very persistent substance under REACH[23].

Carbon nanotubes as SVHCs

In conclusion, we believe that there is strong evidence that CNTs — irrespective of type and surface-modifications — meet the criteria for cancer due to their ability to induce long-lasting pulmonary inflammation. We furthermore conclude that CNTs fulfil the criteria for reproductive toxicity as pristine and functionalized MWCNTs and SWCNTs have been observed to cause a range of reproductive and developmental toxicological effects. Also, they meet the criteria for persistency. The decision to include the entire group of CNTs was taken, as all evidence points towards most types of CNTs having similar or related hazardous properties. To exclude specific forms of CNTs from the SIN List might provide the unwanted incentive to substitute well-studied forms with less studied forms.

Beyond carbon nanotubes

CNTs are unique and create new opportunities in a wide range of potential applications, including batteries and accumulators; electronics, sensors, optics; polymer composites, chemical process intermediates; rubber products and fine chemical manufacture[24,25]. The promises of CNTs to solve problems and provide unique services have been and are still many. However, the introduction to the SIN List sends a very clear message to avoid CNTs in new products, and urges the exploration of using other ways or alternative nanostructures that can provide similar functionalities with less risk. ❐

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