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SHORT COMMUNICATION

PHYSIOLOGICAL TESTING OF CARBON NANOTUBES: ARE THEY ASBESTOS-LIKE?

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ABSTRACT

To determine whether carbon nanotubes can induce any significant health hazards we applied methods routinely used in the patho-physiological testing of asbestos-induced disease to show that the soot with a high content of CNTs does not induce any abnormalities of pulmonary function or measurable inflammation in guinea pigs treated with carbon nanotubes.

Many applications of carbon nanotubes (CNTs) have been envisaged, some with practical uses such as cathode ray tube lighting elements[1,2]. Recently, Kim et al. demonstrated[3] the first 9-inch, carbon nanotube-based color field emission display which represents a turning point for nanotubes in the context of large area full color applications.

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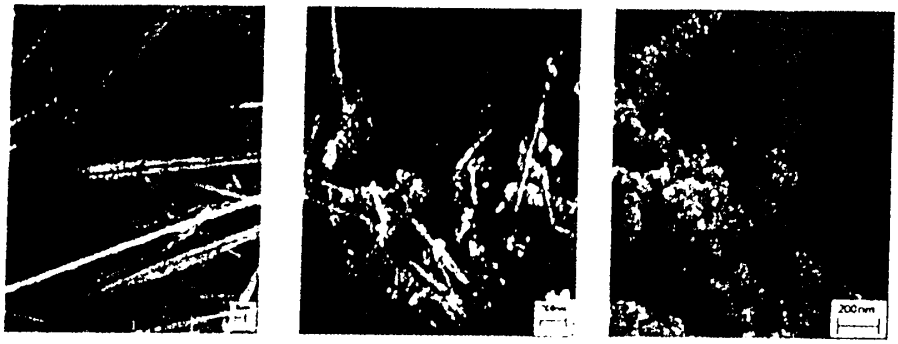

a b c

Figure 1. SEM micrographs showing the morphology of: a) highly fibrous material (standard asbestos). b) soot with a high CNTs content (produced under a He pressure 650 mbar). c) reference soot with a zero content of CNTs (pressure 1 mbar).

Due to their similar aspect ratio, CNTs physically resemble asbestos fibers which, by reacting with cellular components can produce damaging byproducts, and are hazardous to humans.[4] As a matter of fact, CNTs produced in 300 kg quantities daily by HYPERION Ltd., are considered to be potentially "highly toxic compounds"[5]. Thus, with the continual increase in their scope of research, the assessment of potential health hazards of the CNTs is biologically important.

In this study, which we believe is the first account of research on the specific bioactivity of those carbon nanostructures, we show that the soot with a high content of carbon nanotubes, produced routinely by arc sublimation of graphite, does not induce any abnormalities of pulmonary function or measurable inflammation in guinea pigs treated with CNTs. To determine whether CNTs can induce any significant health hazards we applied methods routinely used in the pathophysiological testing of asbestos-induced disease[6].

We used CNTs containing soot, synthesized from a catalyst-doped (Co/Ni) graphite anode by the arc discharge sublimation method under a helium atmosphere[7], using our automated dc arc system[8]. It is well established that iron-group metals are efficient catalysts for the growth of multi-walled (MWCNTs) and single-walled carbon nanotubes (SWCNTs)[9]. The SEM micrographs of the soot thus

Table 1. Results of Lung Function Measurements

Parameter of Pulmonary Testing	Test Group (average ±SD)	Control Group (average ±SD)
Tidal volume (ml)	2.686 ± 0.577	2.277 ± 0.676
Frequency of breath/min	107 ± 15	99 ± 12
Lung resistance (cm H_2O/ml/s)	0.0554 ± 0.0044	0.0521 ± 0.0033

Table 2. Results of Bronchoalveolar Lavage Examinations

Parameter of BAL Examination	Test Group (average ±SD)	Control Group (average ±SD)
Total cell count ($\times 10^6$)/BAL-fluid	7.791 ± 4.155	6.069 ± 1.271
Macrophages (%)	59.1 ± 13.1	62.5 ± 16.2
Polymorphonuclear leukocytes (%)	9.6 ± 3.1	8.7 ± 4.1
Lymphocytes (%)	6.0 ± 4.0	7.8 ± 3.2
Losinophils (%)	25.3 ± 17.4	21.0 ± 15.7
Total protein μg/ml BAL-fluid	121 ± 31	144 ± 27

produced are shown in Fig. 1. The morphology of asbestos fibers is also presented for a comparison.

The test group of specific pathogen free guinea pigs (Dunkin Hartley, male, 250 g) were given a single intratracheal instillation totaling 25 mg of CNTs-containing soot suspended in 0.5 ml of sterile saline (with the addition of TWEEN surfactant) under anesthesia with 30 mg/kg of sodium pentobarbital. The control group of animals was administered with a suspension of CNTs-free soot. Four weeks after the treatment, pulmonary function tests were performed by noninvasive respiratory analysis. Finally, the animals were sacrificed, after anesthesia, for bronchoalveolar lavage examination (BAL), performed with 2 × 10 ml of saline according to standard procedure[6]. In BAL-fluid the selected components of inflammatory reaction (total protein concentration and differential cell count) were estimated.

The results of pulmonary testing are shown in Table 1. The test and control animals did not differ in tidal volume, frequency of breath and lung resistance.

Table 2 shows the results of the bronchoalveolar lavage (BAL) examinations. No significant differences in cell distribution and protein concentration between the test and control guinea pigs were observed.

Taken together, our results of this exploratory study show that the intratracheal instillation of fibrous carbon nanostructures does not change pulmonary function and does not induce any measurable inflammation in bronchoalveolar space in CNTs-exposed guinea pigs. Thus, working with soot containing carbon nanotubes is unlikely to be associated with any health risk.

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