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View Point

Nanoparticles in Indian environment: Known, unknowns and awareness?

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Nanoparticles have at least one dimension in the 1–100 nm range and may originate by natural, incidental or manufactured processes. Incidental nanoparticles are produced as a side product of anthropogenic processes, while manufactured nanoparticles are deliberately produced with specific properties and both types may enter air, water and soil from a range of routes (Figure 1). Physico-chemical and biologically mediated transformations make nanoparticles highly reactive in both environmental and biological systems and alter their fate, transport and toxicity compared with their bulk counterparts [1]. More than 15% of all global consumer products are nano-enabled, due to have an estimated market of about \$1 trillion per year by 2015 [2]. A thorough hazard assessment of all these products may take decades and this time will increase as next generation nanoparticles are developed [2]. Assessment of such risks is likely to be even more challenging for a densely inhabited country like India which is swelling at a growth rate of 1.7% per annum, with the current population and GDP growth rate being ~1.22 billion and 6.1%, respectively. Rapid urbanisation, industrialisation and technological advance in the past decade have also led to increased use of consumer products containing potentially toxic nanoparticles. This likely emergence of nanoparticles and their release into the air [2], water and soil [3] would be a further significant pressure on health in a country with an already relatively low life expectancy of ~67 years compared with 78-79 years in the USA and Europe. The current lack of knowledge on the environmental occurrence and subsequent transformations, transport, toxicity, exposure pathways and risks related to nanoparticles in India is further exacerbated by the lack of any focused research programme, previous or current anticipatory governance and a generally limited response from the government, industry and public [4].

In India, essentially no research data exist to date regarding the concentrations, fate or impacts of manufactured nanoparticles in air, forcing us to consider incidental nanoparticles or ultrafine particles as a means to interpret possible behaviour of the manufactured nanoparticles. Road vehicles top the list among all sources for incidental nanoparticles, contributing up to 90% of total particles by number in polluted urban environments. India's current vehicle population is ~40 million which is growing at the rate of ~5% per annum, increasing exposure risks to Indian urban dwellers. Close to vehicle exhaust pipes,

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nanoparticle concentrations are generally measured up to $\sim 10^7 \text{ cm}^{-3}$, which are then dispersed and result in ambient concentrations of $\sim 10^4 \text{ cm}^{-3}$ that remain available for exposure through inhalation of polluted air. While studies worldwide have established a good data base on the concentrations of airborne nanoparticles, a handful of research currently exist for Indian cities that report up to ~ 30 times higher roadside concentrations compared to those found in European ambient environments [5]. One of the first preliminary estimates were made recently to assess ambient nanoparticle emissions, concentrations and exposure related excess deaths in Delhi [5]. Notable numbers of excess deaths were reported: ~ 508 deaths per million people in 2010, which was projected to rise to ca. 1900 deaths per million by 2030, under a 'business as usual' scenario. Cumulative impacts to Indian population residing in cities and megacities due to incidental nanoparticle exposures could lead to enormous loss in life expectancy and millions of rupees of equivalent health costs, indicating the hitherto ignored severity of nanoparticle related risks. The role of manufactured nanoparticles in the health of the Indian population may be expected to grow substantially in the near future, perhaps more severely compared with the West. However, the main issue at present is our complete lack of knowledge on sources and subsequent behaviour and effects.

Exposure to nanoparticles, especially manufactured, through other media (water and soil) will further complicate our understanding of this issue. The main pathways to these environments include manufacturing or processing sites, personal care products, paints, landfill seepage or construction debris. Again, there is an almost complete lack of knowledge, but manufactured nanoparticles might be expected to be found in $<1 \mu\text{g L}^{-1}$ concentrations but exposure (e.g. via inadvertent ingestion during recreational activities, drinking water, or sludge-to-soil-to-crops transfer and subsequent consumption of crops, animals or shellfish) to even these low concentrations might have chronic health effects [1]. To date, most research worldwide have modelled the emissions and fate of selected nanoparticles (e.g. TiO_2 , ZnO , Ag , CNT , Fullerenes) in surface-water, waste-water effluent, soil, and sewage but without experimental or analytical validation. A recent study [3] reported the modelled surface water concentrations of TiO_2 nanoparticles varying from $0.012\text{--}0.057 \mu\text{g L}^{-1}$ in Europe, $0.002\text{--}0.010 \mu\text{g L}^{-1}$ in USA, and $0.016\text{--}0.085 \mu\text{g L}^{-1}$ in Switzerland. However, such data is nearly non-existent for Indian environments and, as with incidental atmospheric nanoparticles, we may expect higher concentrations due to rapid industrialisation and an underperforming regulatory environment. Some attempts have been made recently to review the use of nanoparticles in products, their subsequent release and environmental occurrence. Other efforts have reviewed the consequences of the use of nanotechnology and the possible route of risk governance in India [4], highlighting the need for the development of infrastructure, human resources and research and simultaneous monitoring of needs and issues in this area. Beyond this limited research, there is little, if any, data which brings a huge uncertainty in risk assessment in India.

Given that the knowledge on nanoparticle occurrence in India and risk assessment and management lags far behind the USA and Europe, along with the inherent issue that risk assessment is a lengthy process, there is an real and immediate need for focused research programmes; such programmes will underpin the necessary anticipatory governance to ensure the benefits of nanotechnology are not offset by significant but unacknowledged risks. A proactive response in this context is in the best interests of public health, environmental health, the advancement of science, and ultimately the sustainability of relevant industries.

Figure 1. Schematic representation of the complex relationships between sources, environmental mediums, receptor and response measures for nanoparticles related exposure risks.

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