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Review article

Occupational exposure and consequent health impairments due to potential incidental nanoparticles in leather tanneries: An evidential appraisal of south Asian developing countries

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ABSTRACT

The incidental nanoparticles' (INPs) emission at work and the consequent health impairments is a burning issue of occupational toxicology. The present study is a thorough review of available literature marking an assortment of indicators on INPs generation at leather tanneries and measurable occupational ailments. The literature reported evidences unleash a similarity between the mechanisms of leather tannery induced health damages and toxico-kinetics of incidental nanoparticles in human body. The data on physico-chemical characterization of leather tannery surface dust presents presence of stressors like heavy metals, microbes, animal fur and fibers along with organic and inorganic chemicals. Bearing same characteristics, the mechanism of INPs' induced toxicity (inflammation, increased reactive oxygen species and permeability of blood brain barrier), major target organs (lung, heart, brain, skin and liver) and health damages (cancer, DNA damage, blood coagulation, cardiac arrest, platelet alteration) are quite similar to those found among tannery workers. This review also presents the identification of the different types of potential INPs production and process sources in leather tanneries. There is no data found on Particulate size variation and consequent disparity of these characterizations has been established. However, the reported literature furnishes evidences which support the premise that there is a dire need of size based incidental particulates investigation with a special emphasis on nanoparticles.

1. Introduction

Air borne particulate matter is a high multifarious mix of a range of particle sizes. No single investigation alone can verify or negate an association with one or another particle size. It is wise not to disregard any fraction of inhalable particles. Their size discriminates them as large (PM10) and fine particles (PM2.5) (Xia et al., 2009). PM < 0.5 µm in diameter is record accountable for adversative impacts that may intensify with decreasing particle size. Nanoparticle is a physico-chemical structure bigger than normally atomic/molecular size but smaller than 100 nm (Oberdörster et al., 2005). Nanoparticles can be at nano-scale in one, two or three dimensions, found in a sole, merged or accumulated form with diverse shapes such as round or tube-shaped etc. (Buzea et al., 2007). Nanoparticles, not an unearthing of humanity, are originated from natural physical and biological processes and via environmental transfers and transformations of both natural and synthetic materials. With technological advancement, nanomaterials also appeared as anthropogenic pollution, for instance, discharged by diesel fueled cars, from metal smelting and polymer heating etc. (Moore, 2006; Reijnders, 2006). However, the taxonomic names as ultrafine and nanoparticles are not established on the basis of size but on their origins and scientific fields.

a. In toxicological studies, ambient environmental particulates smaller than 100 nm are usually termed to be ***ultrafine particles*** by environmental monitors but in Physics these are called nanoparticles (Singh, 2005; Viitanen et al., 2017).
b. The manmade or ***engineered nanoparticles*** are produced purposefully with specific shape and size typically measured as 100 nm or less (Oberdörster et al., 2005).
c. Third category, the Incidental nanoparticles (INPs) are multipart in composition having lopsided shapes and sizes as compared to engineered nanoparticles produced as a result of multiple process in manufacturing and service industries as intermediates, bye-products

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and waste emissions (Stern and McNeil, 2007; van Broekhuizen et al., 2012a; Viitanen et al., 2017). Toxicological mechanisms of all INPs differ on the basis of characteristics rather than their origin. This review expressly focusses INPs.

In reality, all humans encounter incidental nanoparticles in environment. Many cause the common curable ailments but sometimes an invader leads to significant damage to the victim. Very small sized nanoparticles, being bioavailable via respiratory tract, translocate within, and injure living organisms by penetrating physiological barriers. This capacity principally is attributed by their size, which allows them to enter the blood stream, foldaway and play havoc at subcellular level.

Incidental nanoparticles may or may not possess size based toxic potential like fine particles. For instance, with same size and surface area for a type of NPs, shape becomes major determinant of toxicity (Sajid et al., 2015). They have different physicochemical characteristics like number concentration, surface-area, shape, size, chemical structure, charge, porosity, surface reactivity, crystal structure and solubility (Kelly and Fussell, 2012). The literature advocates that, compared to other sizes of PM, incidental nanoparticles are most hazardous due to their size, deep permeation, great surface area, high content of redox cycling organic chemicals and prolonged withholding in the respiratory tract (Xia et al., 2009). The adsorbing pollutants have more affinity with large surface area of incidental nanoparticles, for instance, oxidants, heavy metals and organic compounds. Incidental nanoparticles have more injuring impacts and unexpected mechanisms as compared to engineered nanoparticle. Table 1 presents their comparison (Xia et al., 2009; Bakand et al., 2012; Donaldson et al., 2005; Sajid et al., 2015; Xia et al., 2016), illustrating their characteristics and characteristic based toxicity. The nanoparticles when emitted from the source, called primary INPs, become airborne and undergo transformations in the air with oxygen, oxides of nitrogen and sulfur, ozone and organic compounds to form secondary nanoparticle having different compositions and features from primary INPs (Kelly and Fussell, 2012; Gwinn and Vallyathan, 2006), for example rapid dilution occurs as INPs move away from source/process of origin (Biswas and Wu, 2005).

Nanoparticles show more reactivity towards living cells and proteins because of charge on them (Deng et al., 2013). Solubility of NPs in a system is one of the most important determinants of their stability and toxicity. They easily enter the living systems due to efficient mobility and considerably small size; here the size, chemical content and concentrations control their stability. The pH of living system solubilizes almost all inorganic and organic NPs while metals, once inside, accumulate within the cell and enhance oxidative stress (Sajid et al., 2015).

The current review aims at summarizing the toxicity; exposure and health impacts induced by nano sized incidental particulate matter in human body. Secondly the undertaken review throws light on potential INPs in leather tanneries. It further describes the mechanisms of reported ailments among tannery workforce due to tannery dust exposures. Finally, this review tends to develop a link between the basic toxic impacts of nano-sized particles and toxic impacts reported among tannery workers, opening a new horizon of occupational toxicological assessments based on exposure to incidental (process released) nanoparticles.

Moreover, the article specifically includes toxic impacts of those nanoparticles, which have the similar composition to that of potential INPs at tanneries as per the reported literature. For this, literature recounted evidences from physicochemical analysis of tannery dusts and source of all particulates in tannery environments, have been thoroughly reviewed and incorporated. Fig. 1 shows a conceptual model fabricated to develop a literature based link between Nano-toxicology and probable exposures to INPs at tanneries. This conceptual model helped devise the search and review methodology.

2. Methods

The review methodology was kept simple due to the lack of data on the current scenario of occupational exposures at leather tanneries. On the other hand an ample literature was available on nanoparticles. Fig. 2 shows methodological sequence as setting search criteria to extract most relevant data, screening, selection and incorporation in the research review.

1. **Search/inclusion criteria**: Three major groups with sub-sets of terms were defined as a key to search the material on the subject. First set being 'Nanoparticles' with sub-key terms as characteristics of nanoparticles, their types and toxicity. Second set of key terms was 'Occupational exposure to potential incidental nanoparticles at leather tanneries' with sub-terms as probable incidental nanoparticles in leather tanneries, composition of particulate matter and dust produced from tannery processes. Third Set was 'Occupational ailments in leather tanneries' with sub key terms as toxic mechanisms, working conditions, exposures and tannery induced diseases. The third set of terms was specifically searched for south Asian developing countries: Pakistan, India and Bangladesh. A broad literature search was done using Web of Science/Knowledge, Google Scholar (http://scholar.google.com), Elsevier ScienceDirect (http://www.sciencedirect.com/) and Springer Online Journals (http://link.springer.com/) with a special emphasis on the peer-reviewed

Table 1
Comparison of Incidental nanoparticles to manufactured nanoparticles.

Characteristics	Incidental nanoparticles	Manufactured nanoparticles	Character specific toxicity mechanisms
Sources	Uncontrolled process emissions specially at workplaces	Controlled synthesis	–
Surface area	High	High	↑ROS, ↑R, ↑T, I, high OS, P-d, DNA-d, ↑cytokine, ↓glutathione, ↓mitochondria, ↓phagocytosis.
Uniformity	Low (shape, dimensions, function, composition)	High (shape, dimensions, function, composition)	Low uniformity causes unpredictable and enhanced mechanisms
Water solubility	Low to high (depending on composition)	Depends on known composition, generally low	↑B at molecular and sub-molecular level, long-term effects
Metal content	High	Controlled	↑B, ↑ROS, ↑R, DNA-d, P-d.
Organic chemicals	High	Low	↑B, long-term effects
Exposure route	Inhalation > skin > eye	Inhalation, skin, ingestion, injection	Inhalation > skin and ingestion
Toxic effects	tPM, increased CI, ↑ROS, ↑R, ↑T, OT, B, I, high OS, P-d, DNA-d, ↑cytokine, ↓glutathione, ↓mitochondria, ↓phagocytosis, ↓synergism, ↑XB entry	tPM, CI varies, ↑T, OT, I, OS, P-d, DNA-d, ↑cytokine, ↓mitochondria, ↓phagocytosis	

Toxic effects codes: Traverse plasma membranes = tPM, cellular injury = CI, increased reactive oxygen species generation = ↑ROS, increased reactivity = ↑R, increased toxicity = ↑T, organ toxicity = OT, bioaccumulation = B, inflammation = I, oxidative stress = OS, protein denaturation = P-d, DNA damage = DNA-d, cytokine production = ↑cytokine, glutathione depletion = ↓glutathione, mitochondrial perturbation = ↓mitochondria, phagocytosis impairment = ↓phagocytosis, increased synergism = ↓synergism, facilitate entrance of other environmental xenobiotics = ↑XB entry.