International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 1, November-December 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Essence of Nanosafety

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ABSTRACT

Although nanotechnology has been recognized as an enabling technology, human and environmental exposure to nanomaterials is inevitable. As such, the need to ensure that the technology and its various applications are safe is paramount. The current concern on the risks of nanotechnology tends to specialize in the potential dangers of nanomaterials and nanoparticles. The ability to predict and mitigate potential health effects is crucial for sustainability of nanotechnology. This paper introduces the reader to safety in nanotechnology.

KEYWORDS: *safety, nanosafety, nanotechnology safety*

How to cite this paper: Matthew N. O. Sadiku | Uwakwe C. Chukwu | Abayomi Ajayi-Majebi | Sarhan M. Musa "Essence of Nanosafety" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-1, December 2021, pp.788-793, URL: www.ijtsrd.com/papers/ijtsrd47873.pdf

IJTSRD47873

INTRODUCTION

We live in exciting times. The innovation and technology will call for the need to change the modus operandi. When we think about the challenges which face, it is evident that we need the very best of scientific and technological innovation to provide solutions in healthcare, medicine, energy, climate change, transport, and other aspects of modern living. Nanotechnogy has potential application in these fields [1]. Nanotechnology has been promoting the development of new commercial products and areas such as catalysts, sensors, environmental remediation, personal care products, baby formulas, cosmetics, medicines, and cosmetics.

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as nanotechnology, the materials or objects themselves are called nanomaterials, and the study and discovery of these materials is known as nanoscience. The word "nano" comes from the Greek for "dwarf."

Nanotechnology enables us to do things better, create new functional materials, and enhance applications. At nanoscale range, materials have unique size-dependent properties, different from the properties of the "bulk" material. They have unique physical, biological, chemical, electrical, mechanical, electronic, thermodynamic, and optical properties. For example, scientists work to make food safer with nanotechnology. Adding nanomaterials to plastic makes it more impenetrable. We can use nanomaterials in a gazillion applications [2].

Since nanotechnology is a new development, the health and safety effects of exposures to nanomaterials and nanoparticles are not yet fully understood. It is critically important to incorporate nanosafety into the development of nanotechnologies and products safety before design. Public confidence in nanotechnology is crucially important if nano products are to achieve commercial success.

OVERVIEW OF NANOTECHNOLOGY

Nanotechnology involves the manipulation of matter at the molecular scale. It can work from the top down (by reducing the size of the smallest structures to the nanoscale) or the bottom up (by manipulating individual atoms and molecules into nanostructures) [3]. Nanotechnology refers to the design, fabrication, and use of nanomaterials whose nanoscale structures range from 1 to 100 nm. In other words, nanomaterials are the natural or engineered substances with dimensions between 1 and 100 nm. Figure 1 shows the relative scale of nanosized objects [4].

Nanomaterials include carbon nanotubes, nanowires, nanoparticles, quantum dots, nanorods, and nanofibers. They can be classified into three groups: nanoparticles, nanofibers, and nanoplates. Nanoparticles are objects with all three external dimensions at the nanoscale. They are ubiquitous in foods, baby formulas, cosmetics, medicines, and the environment. They can occur naturally or man-made in food. They are added to many foods to improve flow properties and color during processing, or to increase shelf life.

They can enter the body by inhalation, ingestion or by dermal penetration. Nanofibers have diameters of less than 100 nm, are produced by the electrospinning process, and are used in food [5]. Figure 2 shows a significant accumulation of nanoparticles (arrows) in rat hepatoma cells [6].

Nanomaterials are increasingly being used in products, such as pharmaceuticals, electronics, missiles, satellites and airplanes, as well as everyday items such as sunscreens, cosmetics, sunscreens, clothing soaps, sporting goods, batteries, and furniture. Nanomaterials are at a critical time in their development and commercialization

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. Nanotechnology is revolutionizing many fields including the military, mechanical industry, electronics, biotechnology, medicine, energy, communication, solar, optics, agriculture, and food [7,8]. Nanotechnology is regarded as a transformative technology, which can stimulate scientific innovation and greatly benefit the society. Research on nanotechnology has skyrocketed over the last decade, leading to numerous applications in virtually every segment of the economy. All potential applications of nanotechnology significantly affect our lives, our health, our convenience, and our environment [9].

WHAT IS NANOSAFETY?

Nanotechnology safety is behaving safely when handling nanomaterials, understanding health effects, and proactively creating safety measures against potential hazards. Safety is a concept with many facets: safety in the production of nanomaterials, safety in working with nanomaterials, safety in detection of nanomaterials, safety from exposure to nanomaterials, safety in case of incidents or accidents involving nanomaterials, and safety in the detection of nanomaterials in the environment [10].

Nanomaterials are most dangerous in powder form; so workers must wear coats, respirators, glasses, and gloves. Concerns on potential harm to human health and the environment posed by nanomaterials in food applications must be adequately evaluated at the developmental stage to ensure consumer's acceptance.

In 2017, the World Health Organization (WHO) released the first guidelines on protecting workers from the potential effects of nanomaterials. The guidelines stress [11]

- Taking a precautionary approach
- Using the hierarchy of controls
- Grouping nanomaterials by toxicity, fibrous characteristics, and granular biopersistence
- Educating and training workers on nanomaterials
- Involving workers in each aspect of assessment and control

The finest practice to be pursued while using nanoparticles include [12]:

- **Hygiene:** Do not eat or store food and beverages in a nanotechnology laboratory. Wash hands regularly to reduce nanoparticle exposure. Touching and ingestion must be prevented.
- **Labeling:** Store in a well-sealed container. Label all chemical containers with the identity of the contents.
- **Clean-up measures and spills:** Watch out for exposure during cleaning. Wear gloves and work in a fume hood while handling nanoparticle and clean the fume hood afterward.

Figure 3 shows the spectrum of research areas feeding into nanosafety [13].

The following are some of the strategies for ensuring nanosafety.

- **Safer-by-Design:** Safe-by-design strategies applied to materials and processes.

They are promising solutions for the preventive management of risk in the production and use of nanoparticles and their products. Safer-by-Design materials and processes and quality control are also among the major challenges facing nanomaterials producers.

- **Administrative Controls:** These are changes to workers' behavior to mitigate a hazard. They include training on best practices for safe handling, storage, and disposal of nanomaterials, proper awareness of hazards through labeling and warning signage, and encouraging a general safety culture. Normal safety procedures such as hand washing, not storing or consuming food in the laboratory, and proper disposal of hazardous waste are also administrative controls. [14].

BENEFITS

Nanotechnology is booming. It is an "enabling technology" that has a tremendous potential to provide answers to societal solutions. Nano-scale science is changing healthcare and food production, and has profound social and environmental implications.

The industry has embraced using tiny particles in everything from consumer products to airplane design. This is what makes nanomaterials exciting.

CHALLENGES

The growing development and production of nanomaterial have caused increased potential risks for workers. The same properties that make nanomaterials and nanoparticles promising for various applications may also present risks to humans and the environment. In addition, many of these properties can change with time. The lack of regulation on nanomaterials and some studies that suggest possible health risks raise red flags. Some scientists claim that nanoparticles may become environmentally problematic since nanoparticles can enter our environment in many ways.

Workers who are involved in using nanotechnology in research or production may be exposed to nanomaterials through inhalation, skin contact, or ingestion. Occupational exposure of nanoparticles may also stem from processing methods, processing equipment, workplace design, pollution-control equipment, handling procedures, and contact with skin. Workers involved in any task with a potential to nanomaterials must wear protective gloves, eye protection, protective clothing, and respiratory protection [15].

Assessing the human and environment risks associated with nanomaterials is never easy The crucial challenge in all cases is to identify the harmful agents and to differentiate them from their innocent counterparts. Lack of toxicological expertise is largely responsible for this predicament. Governments worldwide are still struggling with the regulation of nanomaterials. Some international organizations such NIOSH, UNESCO, ISO, and the WHO are currently working on legislation and guidelines for nanomaterials.

GLOBAL SAFETY

Nanotechnology is a key enabling technology with billions of dollars in global investment from public and private funding. It is widely regarded as the next global frontier of science. A significant fraction of the total global investment in nanotechnology has been focused on safety aspects. Governments around the world should act to protect workers and consumers from the commercial drive to rapidly expand this technology. We consider how the following nations handle nanosafety.

- **United States:** In the United States, NIOSH [National Institute of Occupational Safety and Health] has taken the lead on researching the effects of nanotechnology on workers. Worker safety is at the core of what NIOSH does. It provides free onsite assessments of labs and manufacturing facilities. Lack of knowledge to ensure the safety and health of those who work with nanomaterials drives the research at NIOSH. NIOSH has published four documents to help employers safeguard their workers who handle nanomaterials [11]:
- **Workplace Design Solutions:** Protecting Workers during Nanomaterial Reactor Operations
- **Workplace Design Solutions:** Protecting Workers during the Handling of Nanomaterials
- **Workplace Design Solutions:** Protecting Workers during Intermediate and Downstream Processing of Nanomaterials
- **Controlling Health Hazards When Working with Nanomaterials:** Questions to Ask Before You Start

It is recommended that companies consult with the FDA before taking nanotech products to market. Each product may require safety reviews on a case-by-case basis.

- **Europe:** The European Commission is considering a new Action Plan for Nanotechnology, addressing the technological and societal challenges. The European NanoSafety Cluster is an initiative of the Research and Innovation Directorate General to bring together current research projects all across Europe that address all aspects of nanosafety The Nanosafety Cluster has the following four main research needs and priorities for the coming 10 years [5]:
- Identification and classification of nanomaterials;

- Evaluation of exposure to nanomaterials and of their transformation during their life cycle;
- Identification of hazard mechanisms related to their effects on human health and the environment;
- Tools for predictive risk assessments and management, including databases and ontologies.

All nanoparticles in chemical substances must meet the requirements of the European Union REACH (Registration, Evaluation and Authorization of Chemicals) Regulation. One crucial issue is a strong commitment from regulators to promote standardization and the involvement of industrial partners that are willing to adopt the safety by design approach. An important building block to facilitate the safe implementation of nanotechnologies and its implementation is crucial for strongly promoting nanosafety within EU [16]. New regulations in Europe will require mandatory labelling of certain nano-containing products.

- **United Kingdom:** The UK Nanosafety Group embraces key experts in the field of nanotechnology and helps to establish links with others working in this rapidly developing field. A core aim of the Group is to assist research labs and academia with their legal obligations with regards to occupational health and safety. The Group has developed guidance to support safe and responsible working practices with nanomaterials. The document aims to provide guidance relating to establishing a safe workplace and good safety practice when working with particulate nanomaterials. It is applicable to a wide range of nanomaterials [17].
- **Australia:** In 2007 the Working Party for Manufactured Nanomaterials, the Organization for Economic Cooperation and Development (OECD), launched an international program to test 13 different types of manufactured nanomaterials to be commercialized. Australia took part. The CSIRO was a major contributor to the Australian effort. This international effort gave clarity on the types of nanomaterial properties needed for toxicity assessments. CSIRO's nanosafety team is currently investigating nanoparticles in sunscreens, the environmental effects of nanoparticles, and whether nanoparticles are produced in bush fires [18]. Researchers in Austrialia want to work with regulators to make sure they are safe. That is basically the mission of Sydney Nano: to discover, develop and harness nanotechnology for the benefit of humanity [19].
- **China:** There are still no safety assessment procedures for nanomaterials and nanoparticles in China. Current methods of evaluating the safety of nanoparticles rely on traditional toxicological assessments. This leads to uncertainties which restrict the accuracy of safety assessments. As such, a scientific basis is provided for the future development of evaluation procedures for NPs in food. Chinese researchers claim that nanoparticles used in printing products have killed workers when they were inhaled by them [20].
- **India:** Several of India's most popular car models, including the famously small Tata Nano, crumpled in independent crash tests. The Indian small cars lack adequate safety standards India's fast growing middle class, has helped fuel a booming auto industry while demanding little in terms of safety. These are all challenges in India, where roads are often unpaved and pockmarked by ditches [21].

CONCLUSION

The rapid development of nanotechnology has increased fears about the potential health risks of nano products. Since nanotechnology is an emerging development, the health and safety effects of exposures to nanomaterials and nanoparticles are subjects of ongoing investigation. Toxicological assessment of nanomaterials has become a high priority. Companies that are rushing to commercialize nanotech products have neglected taking necessary steps needed to reduce the health risks of these products. As work in nanotechnology continues to skyrocket, additional studies will be conducted on nanomaterials so that workers can be better protected. Workers and employers should be aware of potential hazards of nanomaterials in their workplaces and employers should take appropriate actions to minimize worker's exposure. More information about nanosafety can be found in the books in [22-28].

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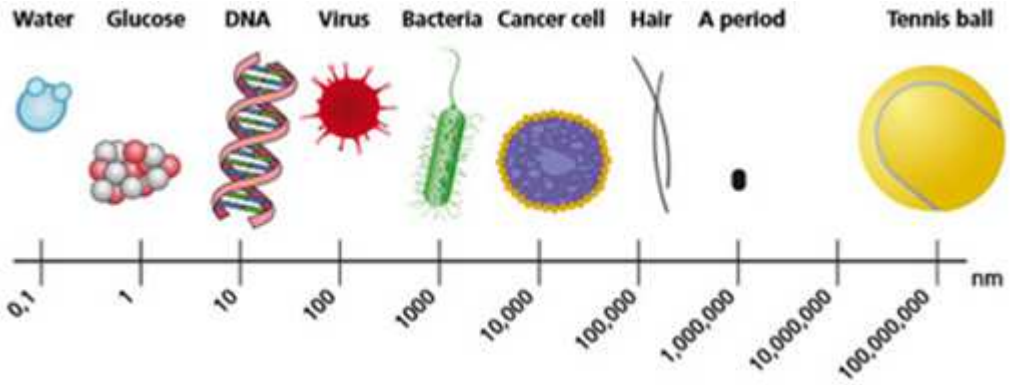

Figure 1 The relative scale of nanosized objects [4].

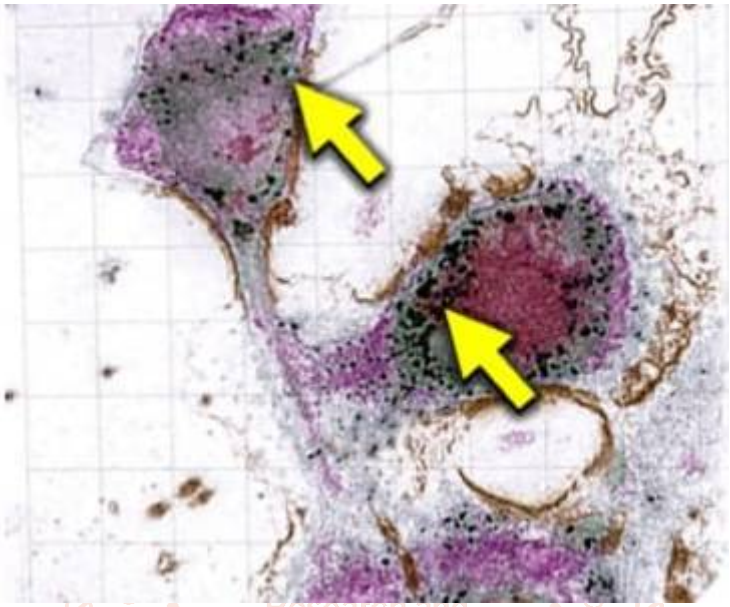

Figure 2 A significant accumulation of nanoparticles (arrows) in rat hepatoma cells [6]

Figure 3 Spectrum of research areas feeding into nanosafety [13]