ISSN 2063-5346

METAL/METAL OXIDE NANOPARTICLES – A MATTER OF CONCERN FOR FORENSIC ENVIRONMENTAL TOXICOLOGY

Moumita Sinha[1], Faiz Bux[2], I. Arjun Rao[3], Paromita Banerjee[4]

Article History: Received: 01.02.2023 **Revised:** 07.03.2023 **Accepted:** 10.04.2023

Abstract

Environmental toxicology is one of the branches of forensic medicine and toxicology. Nanoparticles are increasingly being used in consumer products and have a wide range of toxic effects on the environment. Metal/metal oxide nanoparticles are used in everyday goods such as cosmetics, electronics, and food. The toxicity of nanoparticles is due to their small size and interaction with living organisms. In order to minimize the impact of nanomaterials on the environment, it is important to ensure that they are designed and manufactured with sustainability in mind. This means looking at how they interact with the environment and the potential for harm before they are released. Additionally, it is important to consider the potential for end-of-life disposal of nanomaterials and consider alternative ways to dispose of them. Finally, it is important to develop appropriate regulations and standards for the manufacturing and disposal of nanomaterials and to monitor their impact on the environment.

Keywords: environmental. toxicology, nanoparticles, metal oxides, human, toxicity.

[1]Assistant Professor, Department of Forensic Science, Kalinga University, Raipur, Chhattisgarh, India, email ID: - moumita.sinha@kalingauniversity.ac.in , https://orcid.org/0000-0002-5610-6520.

[2]Assistant Professor, Department of Botany, Kalinga University, Raipur, Chhattisgarh, India, email ID:- faiz.bux@kalingauniversity.ac.in, https://orcid.org/0000-0002-1929-3742 https://orcid.org/0000-0002-1929-3742.

[3]Assistant Professor, Faculty of Forensic Science, School of Life Sciences, Christ University, Bangalore, Karnataka, India, email ID: - arjun.rao@christuniversity.in , https://orcid.org/0000-0003-1605-468X

[4]Assistant Professor, Department of Microbiology, Kalinga University, Raipur, Chhattisgarh, India, email ID:- paromita.banerjee@kalingauniversity.ac.in. https://orcid.org/0000-0002-6506-5003

Corresponding Author : Paromita Banerjee, Assistant Professor, Department of Microbiology, Kalinga University, Raipur, Chhattisgarh, India, email ID:- paromita.banerjee@kalingauniversity.ac.in

DOI: 10.31838/ecb/2023.12.s1.122

INTRODUCTION

The scientific techniques used to solve crimes are called forensics. The goal of forensic investigation is to identify a suspect by compiling and examining all physical evidence related to crimes. To determine how a crime occurred, investigators will examine blood, fluid, fingerprints, residue, hard drives, computers, or other technologies. Yet, this is only a common definition because there are numerous branches of forensics like- forensic medicine & toxicology, forensic dermatoglyphics, forensic entomology, forensic odontology, forensic anthropology, etc (Buzea et al. 2007).

Environmental toxicology is one of the branches of forensic medicine and toxicology and is the study of how exposure to hazardous substances affects the body and how these effects can be used by law enforcement to investigate crimes, such as murder or industrial accidents. Environmental toxicologists use laboratory analysis of tissue or bodily fluids to determine the presence of toxicants, and their effects on the body. They also analyze environmental samples to determine the extent of contamination and the source of the contaminant. This information can be used to identify suspects and reconstruct crime scenes (Raj et al. 2012). Nowadays the majority of products contains nanomaterials in them and their extensive usage releases nanoparticles in the environment.

Nanoparticles are increasingly being used in consumer products, and their presence in the environment is of growing concern. Nanoparticles can have a wide range of toxic effects on the environment, including effects on water, soil, and air quality. The toxicity of nanoparticles is largely due to their small size, which allows them to move easily through the environment and interact with living organisms. In water, nanoparticles can interact with aquatic organisms, causing physical and chemical changes. In soil, nanoparticles can interact with microorganisms, disrupting their growth and metabolism. In air, nanoparticles can be inhaled by animals and humans, causing respiratory irritation and other health effects. The potential to cause harm increases with the size and dose of the nanoparticles and their chemical composition (Gupta and Xie, 2018).

The present review study discussed the most common nanomaterials we come into contact with routinely and their toxicity. We also talk about their effects on the environment and the human body. Although stringent regulation can encourage the safe usage of nanoparticles in everyday life, we are here calling for more careful handling and management of designed nanoparticles as well as more verification and consistency of nanoparticle toxicity studies.

Metal/ Metal oxide Nanoparticles in Everyday Goods

Metal/metal oxide nanoparticles are used in a variety of everyday goods, including cosmetics, electronics, batteries, and food. Cosmetics often include metal/metal oxide nanoparticles such as titanium dioxide, zinc oxide, and iron oxide, which provide UV protection, increased skin hydration, and improved texture. In electronics, nanoparticles are used to produce smaller, more efficient transistors and other components for computers and other devices. In batteries, metal/metal oxide nanoparticles are used to increase the energy density and power output. Finally, metal/metal oxide nanoparticles are used as food additives to improve texture, shelf life, and nutritional value. Metal/Metal oxide nanoparticles are becoming increasingly popular in everyday goods due to their unique properties. Nanoparticles are incredibly small, measuring between 1 and 100 nanometers, and they can provide a wide range of properties and functions, such as improved strength, durability, conductivity, and optical properties. Additionally, they are more efficient than traditional materials and can be used to replace them in many applications. For example, metal nanoparticles can be used to create stronger, more durable coatings for items like cookware and automotive parts. Metal oxide nanoparticles can also be used to make headphones and other audio equipment sound crisper and clearer. Finally, metal oxide nanoparticles are becoming increasingly popular in sunscreen products as they can help protect against both UVA and UVB radiation (Katz et al. 2015).

Zinc oxide nanoparticles (ZnONPs), titanium dioxide nanoparticles (TiO2NPs), silica nanoparticles (SiO2NPs), silver nanoparticles (Ag-NPs), gold nanoparticles (AuNPs), and polymeric nanoparticles are among the most often observed nanomaterials in human daily lives (PNPs). Several pathways may be in charge of the biological impacts of nanoparticles at the target areas (Gupta and Xie, 2018).

Zinc Oxide (ZnO) Nanoparticles:

A new type of nanoparticle has been developed that is made of zinc oxide. The new zinc oxide nanoparticle has high activity and is effective in treating health problems. It is possible to increase the activity of a nanoparticle by adding it to a solution and using it in a patient's mouth. The new nanoparticle has a high activity because it can interact with cells and cause them to produce health-care products. It is also possible to use the nanoparticle in the treatment of other health problems. There are a number of benefits of nanoparticles that makes them so popular for everyday use. In sunscreens, food additives, pigments, and biosensors, zinc oxide nanoparticles (ZnONPs) are frequently used. In various cell lines and animal models, various researchers have examined the harmful consequences of these created ZnONPs. Both in vitro and in vivo studies have demonstrated ZnONPs' potential for cytotoxicity and genotoxicity. Further research has shown that ZnONPs diminish cell viability in a dose- and time-dependent way. It is believed that ZnONPs increase the expression of the metallothionein gene, a biomarker for metal-induced toxicity. Research has shown the dose-dependent hepatic damage and considerable increase in oxidative stress by an increase in malondial- dehyde (MDA) content and decrease in superoxide dismutase (SOD) and glutathione peroxidase (GPx) enzymes activity in the liver. ZnONPs reportedly increase plasma levels of the enzymes alkaline phosphatase (ALP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT). (Ng et al. 2017; Kononenko et al. 2017; Vinardell et al. 2017; Sahu et al. 2013)

Titanium Oxide (Tio2) Nanoparticles:

TiO2 is a new type of nanoparticle that has received a lot of attention due to its potential for future use in solar energy and related technologies. TiO2 nanoparticles can efficiently and quickly cross-link to form foreign materials that can improve their efficiency in gripping and breaking. Additionally, the nanoparticles have the potential to form new products and attach themselves to objects better than other types of nanoparticles. TiO2 is widely used in cosmetic and skincare products as a pigment, a thickener, and a UV absorber. Osseointegration of artificial medical implants and bone is made possible by TiO2. The toxicity of TiO2NPs has been the subject of numerous investigations. During sub-chronic dermal contact, few studies on hairless mice and porcine skin revealed skin penetration and toxicity of TiO2NPs. Nonetheless, as TiO2NPs from sunscreens do not seem to extensively permeate the skin, the majority of studies think they do not constitute a serious health danger. TiO2NPs have been shown in certain studies to be in vitro carcinogenic and mutagenic in a variety of cell lines, plants, and mouse brains following systemic ingestion. (Wu et al. 2009; Sadrieh et al. 2010; Crosera et al. 2015; Hamzeh and Sunahara, 2013; Ghosh et al. 2010; Mohamed and Hussien , 2016; Ates et al. 2013; Husain et al. 2015)

Silica (SiO_2) Nanoparticles:

Silica (SiO2) nanoparticles are nanoscale particles made of silica, a compound composed of silicon and oxygen atoms. Silica nanoparticles are highly versatile and can be used in a variety of applications, including biomedical, electronics, and energy storage. They are also extremely stable, non-toxic, and inexpensive to produce. The unique properties of silica nanoparticles make them an attractive option for many industries. For many years, synthetic amorphous silica has been a widely used food ingredient. It is frequently used in packaged foods and is listed as a food additive. SiO_2NP is mostly used in the food sector to avoid "caking," or poor flow, especially in powdered goods. Moreover, SiO_2NPs are used to clarify liquids, reduce foaming, thicken pastes, or act as a flavor carrier. SiO_2NP's suitability as a food additive has been assessed by scientists based on its effects on gastrointestinal cells. However, they indicated that long-term in vivo research is required to establish their tolerability. (Herzog et al. 2013; Kokura et al. 2010; Takamiya et al. 2016; Hackenberg et al. 2011; Kawata et al. 2009; Castiglioni et al. 2014)

Silver (Ag) Nanoparticles

Nanoparticles of silver are particles of silver that have a size of only 100 nanometers or less.

Silver nanoparticles are used in a wide variety of applications, including medical treatments, electronics, and water filtration. Silver nanoparticles have unique properties such as: high surface area-to-volume ratio, excellent electrical and thermal conductivity, and excellent optical properties. They are also very biocompatible and non-toxic. Silver nanoparticles are used in medical treatments such as wound healing and antibacterial treatments, and they are also used in air and water filtration systems. AgNPs have been utilized to cure infections in bums, open wounds, chronic ulcers, trophic sores, eczema, and acne. They are effective antibacterial and antiviral agents. AgNPs have also been claimed to be used as an antibacterial agent in toothpaste, shampoo, air sanitizer sprays, detergents, and soaps. AgNPs have also been widely utilised to store and package food items to extend their shelf life. Dental and medical devices have been coated and filled with silver-based resin composites. According to experiments, AgNP might be a safe preservative for cosmetics, however they might permeate human skin if the skin's natural barrier function is compromised. Researchers have confirmed that animals exposed to lower quantities of ammonia and PVP-stabilized AgNPs did not experience cytotoxicity. Yet, in other investigations, AgNPs led to DNA damage, in vitro toxicity, and functional impairment in human cell lines. AgNPs have been examined for their short- and long-term effects on human microvascular endothelial cells, and some researchers have proposed that their cytotoxicity and genotoxicity make them an effective tool for controlling uncontrolled angiogenesis. (Herzog et al. 2013; Kokura et al.2010; Takamiya et al. 2016; Hackenberg et al. 2011; Kawata et al. 2009; Castiglioni et al. 2014)

Gold (Au) Nanoparticles:

Gold nanoparticles are particles of gold with a diameter of less than 100 nanometers. These particles are used in a variety of applications, such as medical imaging, diagnostics, drug delivery, and sensing. Gold nanoparticles have unique properties that make them particularly useful for these applications. They are highly stable, non-toxic, and can be easily modified to create nanostructures with desired properties. Gold nanoparticles are also able to interact with light in ways that can be exploited for sensing and imaging purposes. The biomedical use of AuNPs is based on the addition of bio functional groups (peptides, sugars) to the cap that have the ability to regulate cellular functions. Many studies are being conducted on the uses of AuNPs for photothermal treatment and medication delivery. Co-administration of medications and AuNPs can also improve the effectiveness of therapy. The capacity of AuNPs to reflect light and the surface plasmon resonance phenomenon support their use in diagnostics. For the development of AuNPs as a vector for different pharmaceuticals and biological substances, surface functionalization of AuNPs and their capacity to bind with thiol and amine groups were exploited. AuNP is heavily researched to understand their toxicity profiles due to their immense medicinal and analytical potential. Nearly, 86% of peptide-capped AuNPs were discovered in the rat liver while researching how surface coating affected the biodistribution profile. The endocytosis rate was highest for spherical AuNPs, according to studies to determine the shape influence in cellular uptake of PE-Gylated AuNPs. Spherical AuNP internalized at the fastest rate, then cubic, rod-like, and finally disk-like particles. PEG-coated AuNPs have also demonstrated size-dependent organ accumulation, but their in vivo toxicity was not size-dependent. Due to their ease of passage across a negatively charged cell membrane, studies also showed that positively charged AuNPs had a stronger impact on cellular toxicity. Spherical AuNP takes on at a rapid speed, preceded by cubic, rod-shaped, and finally disk-shaped particles. PEG-coated AuNPs have also demonstrated size-dependent organ accumulation, but their in vivo toxicity was not size-dependent. Due to their ease of passage across a negatively charged cell membrane, studies also showed that positively charged AuNPs had a stronger impact on cellular toxicity. (Rengan et al. 2015; Bastús et al. 2009; Javed et al. 2016; Cheng et al. 2014; Ghosh et al. 2008; Villiers et al. 2010; Fraga et al. 2013; Morais et al. 2012; Li et al. 2015; Zhang et al. 2011; Goodman et al. 2014)

Polymeric Nanoparticles in Drug Delivery

Polymeric nanoparticles are an emerging technology in drug delivery. They are particles composed of polymers that range in size from 10 to 1000 nm (nanometers). These particles can be used to carry drugs and other therapeutic agents to specific sites within the body. They can also be used to deliver drugs to specific types of cells or tissues. The nanoscale size of these particles gives them the ability to cross cellular and tissue barriers, allowing for the targeted delivery of drugs and other therapeutic agents. Additionally, their small size allows for better drug absorption and increased bioavailability. Polymeric nanoparticles are being used in a variety of drug delivery applications, including targeted cancer therapies, gene therapy, and drug delivery for diseases such as HIV/AIDS. The most common carriers for targeted and regulated medication delivery systems are biocompatible and biodegradable. The interplay of such PNPs with living organisms are still not well understood, though. PNPs with a size range of 10 to 200 nm not only avoid biliary excretion and renal filtration, but they also build up in tumors due to effects on increased permeability and retention (EPR). Particles larger than 200 nm are quickly cleared by the liver and recognized by the reticuloendothelial system (RES). A common technique to keep PNP from being cleared so that it stays in the systemic circulation for a longer time is PEGylation. Electrostatic binding may result in indiscriminate interactions with nonspecific cells or opsonizing proteins in the blood compartment after in vivo delivery of cationic PNPs, which may result in unforeseen cytotoxicity. The efficacy of using several biodegradable polymers as nanoparticles has been researched. Regardless of their surface charge, Poly(lactic-co-glycolic acid) (PLGA) nanoparticles were proven to be harmless on the bronchial epithelium. Moreover, some researchers found that polymeric PLGA-NP was hazardous to human-like macrophages when coated with chitosan (CS), poloxamer 188 (PF68), or poly(vinyl alcohol) (PVA). (Gustafson et al. 2015; Mura et al. 2011; Grabowski et al. 2015; Hu et al. 2011; Eidi et al. 2010; Cabeza et al. 2017)

Some of the benefits of metal/ metal oxide nanoparticles in everyday goods:

1. Improved Durability: Metal and metal oxide nanoparticles can be used to increase the durability of everyday goods such as clothing, furniture, and electronics by making them more resistant to wear and tear.

2. Improved Efficiency: Metal and metal oxide nanoparticles can be used to increase the efficiency of everyday goods such as solar panels and batteries by increasing their performance.

3. Enhanced Sensitivity: Metal and metal oxide nanoparticles can be used to enhance the sensitivity of everyday goods such as medical diagnostic equipment, sensors, and security systems.

4. Improved Appearance: Metal and metal oxide nanoparticles can be used to improve the appearance of everyday goods such as jewelry, car parts, and kitchen appliances by giving them a more luxurious look.

5. Improved Safety: Metal and metal oxide nanoparticles can be used to improve the safety of everyday goods such as sunscreen and food packaging by making them more resistant to bacteria and other contaminants.

Consequences of Metal/ Metal oxide Nanoparticle's presence in Everyday Goods:

1. Metal nanoparticles may be toxic to humans. Exposure to high concentrations of metal nanoparticles can lead to irritation of skin, eyes, and respiratory systems, as well as other potential health risks.

2. Metal nanoparticles can cause environmental damage. Due to their small size, metal nanoparticles can easily enter the environment and contaminate soil and water. This can lead to a decrease in the quality of drinking water, as well as an increase in toxicity levels in the environment.

3. Metal nanoparticles can cause corrosion. Metal nanoparticles can react with the material they are in contact with, causing corrosion and weakening of the material. This can lead to a decrease in the durability of everyday goods, such as cars and buildings.

4. Metal nanoparticles can cause air pollution. Metal nanoparticles can become airborne and enter the atmosphere, leading to an increase in air pollution. This can lead to an increase in

respiratory problems, as well as an increase in global warming.

Metal/metal oxide nanoparticles can be hazardous to humans, animals, and the environment. The particles are so small that they can enter our bodies easily, and may cause damage to our cells. They can also accumulate in our organs and tissues, causing inflammation, oxidative stress, and organ damage. Ingestion of the nanoparticles may lead to neurological, reproductive, and developmental problems. In animals, metal/metal oxide nanoparticles can cause kidney, liver, and heart damage. In the environment, nanoparticles can accumulate in the soil and water, and may affect the fertility of the soil and the health of aquatic life.

Metal/Metal oxide nanoparticles can be toxic to humans if ingested, inhaled, or absorbed through the skin. They are extremely small, so they can easily penetrate the cell walls of the body and enter organs, where they can cause damage. They can also cause inflammation, oxidative stress, and DNA damage, leading to health problems such as cancer, neurological diseases, and reproductive issues. Therefore, it is important to avoid their presence in everyday goods, such as food, cosmetics, and personal care products, to protect human health.

Some common health consequences due to Metal/ Metal oxide Nanoparticle's presence in Everyday Goods:

1. Skin irritation and rashes: Metal and metal oxide nanoparticles have been found to cause skin irritation and rashes, leading to an increased risk of allergic contact dermatitis.

2. Respiratory irritation: Inhaled nanoparticles have been linked to an increased risk of respiratory irritation and inflammation.

3. Cancer: Long-term exposure to metal and metal oxide nanoparticles has been linked to an increased risk of cancer, such as lung cancer.

4. Nervous system damage: Long-term exposure to metal and metal oxide nanoparticles has been linked to an increased risk of nerve damage and neurological disorders.

5. Immune system damage: Long-term exposure to metal and metal oxide nanoparticles has been linked to an increased risk of immune system damage and autoimmune diseases.

6. Reproductive issues: Long-term exposure to metal and metal oxide nanoparticles has been linked to an increased risk of infertility and birth defects.

People who consume metals and metal oxide nanoparticles directly or indirectly can be exposed to polluted air, water, and soil. Polluted air can come from companies that produce the nanoparticles, from people who breathe the air, and from the materials that are used in manufacturing the nanoparticles. Polluted water can come from water pipes that contain metals and metal oxide nanoparticles, from the water that is used to drink, and from the soil that is used to make products like hardware and vehicles. Polluted soil can come from the mining and manufacturing process of metals and metal oxide nanoparticles, from the use of chemicals to clean up sites where metals and metal oxide nanoparticles are used, and from the cleanup of sites where metals and metal oxide nanoparticles are used.

Effect of nanoparticles on the environment

The nanoparticles may be discharged into the environment in a variety of ways, including as industrial waste, directly into the air, water, and soil systems, or through the cleaning up of polluted land.

Aquatic Systems with Nanoparticles

Obliquely, via surface drainage from soils, or immediately, through industrial discharges or wastewater treatment effluents, nanoparticles can enter aquatic systems. The environment may be exposed to possibly harmful components as nanoparticles dissolve. These nanoparticles can occasionally form heteroaggregates or homoaggregates with other nanoparticles that are already present in the environment, which can substantially change how they connect with the biota and their potential toxicity. Because homoaggregates often sediment more slowly, heteroaggregation is the primary mechanism through which aquatic nanomaterials accumulate in bottom sediments. By changing a number of the features of metallic nanoparticles (MNPs), like suspension stabilization, the bioavailability of metal ions from MNPs, electrostatic interactions and steric repulsion between MNPs and organisms, and MNP-induced generation of reactive oxygen species, natural organic matter can alter the toxicity of MNPs. Nanomaterials' harmful effects on aquatic biota include adsorption on cell surfaces and interference with membrane transport. (Jang et al. 2014; Rocha et al. 2015; Chen et al. 2011; Batley et al. 2013)

Soil with nanoparticles

With the use of fertilizers or plant preservation chemicals, or via by being applied to goods used in wastewater or land remediation, like filth or biosolids, nanoparticles can enter soils immediately. These nanoparticles can have a variety of harmful impacts on soil organisms by bioaccumulating, tropically transferring, and even biomagnifying in some environments. Furthermore, their undesirable impacts on plant-fungi and plant-bacteria have previously been documented; therefore, additional studies on other possible associations (such as competition and predation) are required to determine any potential hazards. Many studies have demonstrated the detrimental impact of nanoparticles on the biogeochemical cycles of nitrogen and other elements. (Tourinho et al. 2012; Peralta-Videa et al. 2014; Zhao et al. 2015; Moghaddasi et al. 2017)

Air with nanoparticles

Nanoparticles floating around in the air have the potential to travel great distances after being released, exposing people to levels that are unmanageable as well as having ecotoxicological effects on aquatic or terrestrial biota. Because to their immobility, the nanoparticles released into terrestrial ecosystems become less probable to propagate, but they can still enter people's bodies through ingestion or direct skin contact. According to the qualities of the nanoparticles and the absorbing medium, nanoparticles can experience a wide range of potential alterations while scattered in the environment, including dissolution, aggregation, or other reactions with biomacromolecules. (Biswas et al. 2005; Lowry et al. 2012)

Metal/Metal oxide nanoparticles in the environment and their accumulation in humans causing chronic toxicity.

The health effects of nanomaterials in the environment have become important due to the increasing use of nanomaterials in consumer products. Metal nanoparticles, which are relatively abundant in the environment, can pose a risk to human health if they are inhaled, ingested, or absorbed through the skin. Inhaled metal nanoparticles can cause oxidative stress, inflammation, and damage to the respiratory tract. Ingested metal nanoparticles can cause chronic poisoning, as they can accumulate in the body over time and cause long-term damage. Studies have shown that chronic exposure to metal nanoparticles can lead to DNA damage, cell death, and organ damage. In addition, metal nanoparticles can interact with other pollutants in the environment, leading to the formation of more toxic compounds. Therefore, it is important to understand the potential health risks posed by metal nanoparticles in order to protect human health and the environment.

Although all metal nanoparticles in the environment do not usually cause chronic poisoning in humans. While some metal nanoparticles, such as those containing certain heavy metals, can be toxic to humans. The nanoparticles of metals such as lead, cadmium, arsenic, and mercury have been linked to chronic poisoning in humans. Hand-to-mouth contact between manufacturing employees, engineers, and scientists working on cutting-edge goods in labs is the main cause of external ingestion of manufactured nanoparticles. As an option, these nanoparticles can be consumed immediately through food, water, medications, or medication supply networks. Furthermore, after leaving the respiratory system via the mucociliary escalator, nanoparticles can enter the gastrointestinal (GI) tract. Some other significant way that nanoparticles enter the human body is through breathing. Fine particles (1–5 mm) that are not collected in the nasopharyngeal region are deposited in the tracheobronchial region, primarily via deposition. Bigger particles are typically accumulated in the nasopharyngeal region (5–30 m) by the inertial impaction process. Mucociliary clearance may allow for additional absorption or removal of the particles. Ultimately, the remaining submicron particles (1 m) and nanoparticles (100 nm) with the lowest particles size enter the alveolar region profoundly, possibly evading removal processes. The likelihood of negative health impacts as a consequence of particle tissue and particle-cell connections increases with the depth at which the particles are accumulated in the lung. Nanosized particles can efficiently enter the lungs' alveolar area and make direct contact with the alveolar epithelium. These incredibly tiny particles can easily breach the blood-air-tissue barrier after particles are accumulated and enter the bloodstream, where they may easily access the physiological function of other organs.

Insoluble particles may also stay in the lungs permanently. Long-term particle retention in the lung can cause damage and trigger biological reactions. Because of their exceptionally small size, ingested ultrafine particles (UFPs) may also settle in the olfactory mucosa before moving on to the central nervous system (CNS), where they could potentially induce neurotoxicity. Current research suggests that the CNS could be a potentially important site for nanoparticle exposure by inhalation or intranasal deposition. Inflammation, asthmatic flare-ups, metal vapour fever, fibrosis, chronic inflammatory lung disorders, and carcinogenesis are only a few of the acute and chronic impacts of nanoparticle contact. Several research have shown that administered or breathed nanoparticles can travel to multiple tissues and organs and reach systemic circulation.

While there is still much to learn about the potential effects of metal nanoparticles in the environment, research is ongoing. Studies have found that exposure to these nanoparticles can cause a range of health effects, including damage to the liver, kidneys, and reproductive organs. In addition, metal nanoparticles can cause inflammation, oxidative stress, and other changes to the body. It is important to reduce exposure to these particles in order to protect the health of both humans and the environment.

A study published in the journal Nano Letters found that when human cells were exposed to nanoparticles, they died due to chronic poisoning. The study found that the nanoparticles were able to enter cells and damage them. This damage led to cell death, which then caused the cells to die in a mass. The study found that this type of cell death is likely to be a cause of sudden death in humans. Many studies have been conducted on the toxicity of various NPs. The particles' micro size allows them to enter tissues and organs via the circulatory and lymphatic systems (Sharma et al. 2012; Radad et al. 2012).

Metallic nanostructures, which are made up of just one metal element, are frequently rather stable and do not easily dissolve. In contrast, when exposed to a physiological environment, metal oxide, and metal alloy-based nanomaterials typically display a lesser degree of stability and are more prone to breakdown and ion release, which causes the creation of reactive oxygen species (ROS) and oxidative stress to the cell (Levard et al. 2012; Maurer-Jones et al. 2013).

There is limited evidence that metal/metal oxide nanoparticles are a cause of sudden death in humans. However, the potential for metal/metal oxide nanoparticles to cause skin and other organ damage is a concern for forensic toxicologists. A recent study showed that nanoparticles and organ damage can occur when they are combined. The study found that when nanoparticles are combined with organic materials, they can cause serious damage to cells and organs. The study found that when nanoparticles are combined with reactive molecules, they can also cause damage to cells and organs. Organ damage can be caused by nanoparticles when they are ingested, inhaled, or absorbed through the skin. Nanoparticles can be small enough to enter the body easily and cause damage to the body’s cells and organs. When these particles reach a high enough concentration, they can cause damage to the cells and organs. This damage can be caused by PF7, a chemical that is known to cause health problems in humans.

Nanomaterials may possibly engage with metabolic systems and biological components once they are in the environment. By investigating the effects of these nanoparticles on terrestrial and aquatic ecosystems and establishing their environmental relevance, suitable safeguards must be taken due to the complexity of natural ecosystems. In general, waste products made from nanomaterials are disposed of in the same way as regular waste, with no additional safeguards or care. Before disposal, these nano wastes should be neutralized because they could be extremely dangerous and/or chemically reactive. (Kahru and Dubourguier, 2010)

Some suggestions are given below in order to manage the toxicity of nanomaterials in environment:

1. Improve regulation of nanoparticle production and use: Governments and manufacturers should create and enforce tighter regulations on the production and use of nanoparticles.

2. Increase research on nanoparticle toxicity: More research should be conducted to understand the potentially toxic effects of nanoparticles on humans and the environment.

3. Develop alternative materials: Manufacturers should explore alternatives to nanoparticles in order to reduce the potential for toxicity.

4. Utilize safer manufacturing processes: Companies should use safer manufacturing processes that minimize the release of nanoparticles into the environment.

5. Encourage recycling and reuse: Recycle and reuse of nanoparticles should be encouraged to reduce the number of nanoparticles released into the environment.

6. Use protective gear: People working with nanoparticles should always wear appropriate protective gear to minimize exposure.

7. Increase public awareness: The public should be educated about the potential risks of nanoparticles and how to minimize exposure.

Conclusion

In order to minimize the impact of nanomaterials on the environment, it is important to ensure that they are designed and manufactured with sustainability in mind. This means looking at how they interact with the environment and the potential for harm before they are released. Additionally, it is important to consider the potential for end-of-life disposal of nanomaterials and consider alternative ways to dispose of them. Finally, it is important to develop appropriate regulations and standards for the manufacturing and disposal of nanomaterials and to monitor their impact on the environment.

References

Ates M, Demir V, Adiguzel R, Arslan Z. Bioaccumulation, sub-acute toxicity, and tissue distribution of engineered titanium dioxide (TiO2) nanoparticles in goldfish (Carassius auratus). J Nanomater. 2013;2013:460518.

Bastús NG, Sánchez-Tilló E, Pujals S, Farrera C, Kogan MJ, Giralt E, Celada A, Lloberas J, Puntes V. Peptides conjugated to gold nanoparticles induce macrophage activation. Mol Immunol. 2009;46(4):743–8.

Batley GE, Kirby JK, McLaughlin MJ. Fate and risks of nanomaterials in aquatic and terrestrial environments. Acc Chem Res. 2013;46(3):854–62.

Biswas P, Wu CY. Nanoparticles and the environment. J Air Waste Manag Assoc. 2005;55(6):708–46.

Buzea C, Pacheco II, Robbie K. Nanomaterials and nanoparticles: sources and toxicity. Biointerphases. 2007;2(4):MR17–71.

Cabeza L, Ortiz R, Prados J, Delgado Á, Martín-Villena MJ, Clares B, Perazzoli G, Entrena JM, Melguizo C, Arias JL. Improved antitumor activity and reduced toxicity of doxorubicin encapsulated in poly(ϵ-caprolactone) nanoparticles in lung and breast cancer treatment: an in vitro and in vivo study. Eur J Pharm Sci. 2017;102:24–34.

Castiglioni S, Caspani C, Cazzaniga A, Maier JA. Short-and long-term effects of silver nanoparticles on human microvascular endothelial cells. World J Biol Chem. 2014;5(4):457–64.

Chen J, Xiu Z, Lowry GV, Alvarez PJ. Effect of natural organic matter on toxicity and reactivity of nano-scale zero-valent iron. Water Res. 2011;45(5):1995–2001.

Cheng Y, Dai Q, Morshed RA, Fan X, Wegscheid ML, Wainwright DA, Han Y, Zhang L, Auffinger B, Tobias AL, Rincón E, Thaci B, Ahmed AU, Warnke PC, He C, Lesniak MS. Blood-brain barrier permeable gold nanoparticles: an efficient delivery platform for enhanced malignant glioma therapy and imaging. Small. 2014;10(24):5137–50.

Crosera M, Prodi A, Mauro M, Pelin M, Florio C, Bellomo F, Adami G, Apostoli P, De Palma G, Bovenzi M, Campanini M. Titanium dioxide nanoparticle penetration into the skin and effects on HaCaT cells.

Int J Environ Res Public Health. 2015;12(8):9282–97.

Eidi H, Joubert O, Attik G, Duval RE, Bottin MC, Hamouia A, Maincent P, Rihn BH. Cytotoxicityassessment of heparin nanoparticles in NR8383 macrophages. Int J Pharm. 2010;396(1–2):156–65.

Fraga S, Faria H, Soares ME, Duarte JA, Soares L, Pereira E, Costa-Pereira C, Teixeira JP, de Lourdes Bastos M, Carmo H. Influence of the surface coating on the cytotoxicity,genotoxicity and uptake of gold nanoparticles in human HepG2 cells. J Appl Toxicol. 2013;33(10):1111–9.

Ghosh M, Bandyopadhyay M, Mukherjee A. Genotoxicity of titanium dioxide (TiO2) nanoparticles at two trophic levels: plant and human lymphocytes. Chemosphere. 2010;81(10):1253–62.

Ghosh PS, Kim CK, Han G, Forbes NS, Rotello VM. Efficient gene delivery vectors by tuning the surface charge density of amino acid-functionalized gold nanoparticles. ACS Nano. 2008;2(11):2213–8.

Goodman CM, McCusker CD, Yilmaz T, Rotello VM. Toxicity of gold nanoparticles functionalized with cationic and anionic side chains. Bioconjug Chem 2004;15(4):897–900.

Grabowski N, Hillaireau H, Vergnaud J, Tsapis N, Pallardy M, Kerdine-Römer S, Fattal E. Surface coating mediates the toxicity of polymeric nanoparticles towards human-like macrophages. Int J Pharm. 2015;482(1–2):75–83.

Gupta, R.; Xie, H. Nanoparticles in daily life: Applications, toxicity, and regulations. J. Environ. Pathol. Toxicol. Oncol. 2018, 37, 209–230.

Gustafson HH, Holt-Casper D, Grainger DW, Ghandehari H. Nanoparticle uptake: the phagocyte problem. Nano Today. 2015;10(4):487–510.

Hackenberg S, Scherzed A, Kessler M, Hummel S, Technau A, Froelich K, Ginzkey C, Koehler C, Hagen R, Kleinsasser N. Silver nanoparticles: evaluation of DNA damage, toxicity and functional impairment in human mesenchymal stem cells. Toxicol Lett. 2011;201(1):27–33.

Hamzeh M, Sunahara GI. In vitro cytotoxicity and genotoxicity studies of titanium dioxide (TiO2) nanoparticles in Chinese hamster lung fibroblast cells. Toxicol In Vitro. 2013;27(2):864–73.

Herzog F, Clift MJ, Piccapietra F, Behra R, Schmid O, Petri-Fink A, Rothen-Rutishauser B. Exposure of silver-nanoparticles and silver-ions to lung cells in vitro at the air-liquid interface. Part Fibre Toxicol. 2013;10:11.

Hu YL, Qi W, Han F, Shao JZ, Gao JQ. Toxicity evaluation of biodegradable chitosan nanoparticles using a zebrafish embryo model. Int J Nanomed. 2011;6:3351–9.

Husain M, Wu D, Saber AT, Decan N, Jacobsen NR, Williams A, Vogel U, Halappanavar S. Intratracheally instilled titanium dioxide nanoparticles translocate to heart and liver and activate complement cascade in the heart of C57BL/6 mice. Nanotoxicology. 2015;9(8):1013–22.

Jang MH, Bae SJ, Lee SK, Lee YJ, Hwang YS. Effect of material properties on stability of silver nanoparticles in water. J Nanosci Nanotechnol. 2014;14(12):9665–9.

Javed I, Hussain SZ, Shahzad A, Khan JM, Ur-Rehman H, Rehman M, Usman F, Razi MT, Shah MR, Hussain I. Lecithin-gold hybrid nanocarriers as efficient and pH selective vehicles for oral delivery of diacerein—in vitro and in vivo study. Colloids Surf B Biointerf. 2016; 141:1–9.

Kahru A, Dubourguier HC. From ecotoxicology to nanoecotoxicology. Toxicology. 2010;269(2-3):105–19.

Katz LM, Dewan K, Bronaugh RL. Nanotechnology in cosmetics. Food Chem Toxicol. 2015;85:127–37.

Kawata K, Osawa M, Okabe S. In vitro toxicity of silver nanoparticles at noncytotoxic doses to HepG2 human hepatoma cells. Environ Sci Technol. 2009;43(15): 6046–51.

Kokura S, Handa O, Takagi T, Ishikawa T, Naito Y, Yoshikawa T. Silver nanoparticles as a safe preservative for use in cosmetics. Nanomedicine. 2010;6(4):570–4.

Kononenko V, Repar N, Marušič N, Drašler B, Romih T, Hočevar S, Drobne D. Comparative in vitro genotoxicity study of ZnO nanoparticles, ZnO macroparticles and ZnCl2 to MDCK kidney cells: size matters. Toxicol In Vitro. 2017;40:256–63.

Levard C., Hotze E. M., Lowry G. V., Brown G. E., Jr. (2012). Environmental transformations of silver nanoparticles: impact on stability and toxicity. Environ. Sci. Technol. 46, 6900–6914. 10.1021/es2037405.

Li Y, Kröger M, Liu WK. Shape effect in cellular uptake of PEGylated nanoparticles:comparison between sphere, rod, cube and disk. Nanoscale. 2015;7(40):16631–46.

Lowry GV, Gregory KB, Apte SC, Lead JR. Transformations of Nanomaterials in the Environment. Environ Sci Technol. 2012;46(13):6893–9.

Lowry, G.; Gregory, K.; Apte, S.; Lead, J. Transformations of nanomaterials in the environment. Environ. Sci. Technol. 2012, 46, 6893–6899.

Maurer-Jones M. A., Gunsolus I. L., Murphy C. J., Haynes C. L. (2013). Toxicity of engineered nanoparticles in the environment. Anal. Chem. 85, 3036–3049. 10.1021/ac303636s.

Moghaddasi S, Fotovat A, Khoshgoftarmanesh AH, Karimzadeh F, Khazaei HR, Khorassani R. Bioavailability of coated and uncoated ZnO nanoparticles to cucumber in soil with or without organic matter. Ecotoxicol Environ Saf. 2017;144:543–51.

Mohamed HR, Hussien NA. Genotoxicity studies of titanium dioxide nanoparticles (TiO2NPs) in the brain of mice. Scientifica (Cairo) 2016;2016:6710840.

Morais T, Soares ME, Duarte JA, Soares L, Maia S, Gomes P, Pereira E, Fraga S, Carmo H, Bastos Mde L. Effect of surface coating on the biodistribution profile of gold nanoparticles in the rat. Eur J Pharm Biopharm. 2012;80(1):185–93.

Mura S, Hillaireau H, Nicolas J, Le Droumaguet B, Gueutin C, Zanna S, Tsapis N, Fattal E. Influence of surface charge on the potential toxicity of PLGA nanoparticles towards Calu-3 cells. Int J Nanomed. 2011;6:2591–605.

Nano biomedical Centre. Available online: http://cnbm.amu.edu.pl/en/nanomaterials (accessed on 2 February 2020).

National Nanotechnology Initiative. Available online: https://www.nano.gov/you/nanotechnology-benefits (accessed on 2 February 2020).

Ng CT, Yong LQ, Hande MP, Ong CN, Yu LE, Bay BH, Baeg GH. Zinc oxide nanoparticles exhibit cytotoxicity and genotoxicity through oxidative stress responses in human lung fibroblasts and Drosophila melanogaster. Int J Nanomedicine. 2017;12:1621–37.

Peralta-Videa JR, Hernandez-Viezcas JA, Zhao L, Diaz BC, Ge Y, Priester JH, Holden PA, GardeaTorresdey JL. Cerium dioxide and zinc oxide nanoparticles alter the nutritional value of soil cultivated soybean plants. Plant Physiol Biochem. 2014;80:128–35.

Radad K., Al-Shraim M., Moldzio R., Rausch W. D. (2012). Recent advances in benefits and hazards of engineered nanoparticles. Environ. Toxicol. Pharmacol. 34, 661–672. 10.1016/j.etap.2012.07.011.

Raj S, Jose S, Sumod US, Sabitha M. Nanotechnology in cosmetics: opportunities and challenges. J Pharm Bioallied Sci. 2012;4(3):186–93.

Rengan AK, Bukhari AB, Pradhan A, Malhotra R, Banerjee R, Srivastava R, De A. In vivo analysis of biodegradable liposome gold nanoparticles as efficient agents for photothermal therapy of cancer. Nano Lett. 2015;15(2):842–8.

Rocha TL, Gomes T, Sousa VS, Mestre NC, Bebianno MJ. Ecotoxicological impact of engineered nanomaterials in bivalve molluscs: an overview. Mar Environ Res. 2015;111:74–88.

Sadrieh N, Wokovich AM, Gopee NV, Zheng J, Haines D, Parmiter D, Siitonen PH, Cozart CR, Patri AK, McNeil SE, Howard PC, Doub WH, Buhse LF. Lack of significant dermal penetration of titanium dioxide from sunscreen formulations containing nano- and submicron-size TiO2 particles. Toxicol Sci. 2010;115(1):156–66.

Sahu D, Kannan GM, Vijayaraghavan R, Anand T, Khanum F. Nanosized zinc oxide induces toxicity in human lung cells. ISRN Toxicol. 2013;2013:316075.

Sharma P., Jha A. B., Dubey R. S., Pessarakli M. (2012). Reactive oxygen species, oxidative damage, and antioxidative defense mechanism in plants under stressful conditions. J. Bot. 2012:217037 10.1155/2012/217037.

Takamiya AS, Monteiro DR, Bernabé DG, Gorup LF, Camargo ER, Gomes-Filho JE, Oliveira SH, Barbosa DB. In vitro and in vivo toxicity evaluation of colloidal silver nanoparticles used in endodontic treatments. J Endod. 2016;42(6):953–60.

Tourinho PS, van Gestel CA, Lofts S, Svendsen C, Soares AM, Loureiro S. Metal-based nanoparticles in soil: fate, behavior, and effects on soil invertebrates. Environ Toxicol Chem. 2012;31(8):1679–92.

Villiers C, Freitas H, Couderc R, Villiers MB, Marche P. Analysis of the toxicity of gold nano particles on the immune system: effect on dendritic cell functions. J Nanopart Res. 2010;12(1):55–60.

Vinardell MP, Llanas H, Marics L, Mitjans M. In vitro comparative skin irritation induced by nano and non-nano zinc oxide. Nanomaterials (Basel). 2017;7(3):56.

Wu J, Liu W, Xue C, Zhou S, Lan F, Bi L, Xu H, Yang X, Zeng FD. Toxicity and penetration of TiO2 nanoparticles in hairless mice and porcine skin after subchronic dermal exposure. Toxicol Lett. 2009;191(1):1–8.

Zhang XD, Wu D, Shen X, Liu PX, Yang N, Zhao B, Zhang H, Sun YM, Zhang LA, Fan FY. Sizedependent in vivo toxicity of PEG-coated gold nanoparticles. Int J Nanomed. 2011;6:2071–81.

Zhao L, Sun Y, Hernandez-Viezcas JA, Hong J, Majumdar S, Niu G, Duarte-Gardea M, Peralta Videa JR, Gardea-Torresdey JL. Monitoring the environmental effects of CeO2 and ZnO nanoparticles through the life cycle of corn (Zea mays) plants and in situ μ-XRF mapping of nutrients in kernels. Environ Sci Technol. 2015;49(5):2921–8.