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REGULAR ARTICLE

A Multifaceted Approach: Investigating Engineered Nanoparticle Inhalation in Infants Based on Nano Science

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The widespread utilization of engineered nanoparticles (ENPs) in a variety of sectors in recent years has raised concerns regarding possible health effects, especially for vulnerable groups like neonates. The increase in nanotechnology and the capacity to create new nanomaterials have resulted in a rise in the creation and application of ENPs. The field of study into the potential hazardous effects of nanoparticles (NPs) on human health and the environment is in its early stages, despite the fact that nanotechnology and NP production are expanding rapidly. This review will systematically examine the potential exposure of babies to ENPs via respiratory routes, including their sources, kinds, and amounts. To accurately comprehend the nanoparticles' physicochemical characteristics and any toxicological impacts, we will use nano-specific analytical methods for detection and characterization. Toxicological consequences that may arise from nanomaterials must be well characterized. It is also essential to comprehend surface processes that occur on nanoparticles when they come into contact with living things. Directed and specific investigations are required to evaluate real exposure levels and identify harmful health implications in babies and children as the manufacture and usage of ENPs become more prevalent. Future developments will involve the inhalation of ENPs in newborns hold great promise for improving respiratory health and preventing illnesses in this susceptible group.

Keywords: Nanoparticles, Infants, Inhalation, Exposure, Toxicology.

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1. INTRODUCTION

Within the field of nanoscience, the study of engineered nanoparticle (ENP) inhalation in newborns necessitates a multidisciplinary approach to understand the intricate interactions among nanomaterials and the growing respiratory systems of our youngest citizens. A wide range of cutting-edge technologies, including nanotechnology, have the potential to improve medical care. Typically, premade polymers and polymerization processes are used to create nanoparticles (NPs), which are solid particles that contain Nano spheres and Nano capsules [1]. The potential of ENPs to improve therapeutic specificity and disease detection is enormous. Combining biotechnology, nanotechnology, and information technology, nanomedicine is a multidisciplinary field with a wide range of benefits, including in vivo treatments and drug delivery, diagnostic tools, biomarkers, molecular imaging, biosensors, and regenerative medicine [2]. The use of NP based goods and technologies are expanding quickly, there have been substantial concerns raised about human exposure to different types of ENPs and the associated toxicity. The ENPs penetrate the human body and induce toxicity has been a major focus of research on nanobio interactions [3]. Aerosol particle inhalation is a direct medicine delivery method utilized to treat respiratory disorders. However, the size, shape, and breathing capacity of the particles affect it distribute drugs through particle deposition [4]. Thus, it is critical to quantify the effectiveness of inhale medicine therapy as well as the health impacts of air pollution by perceptive of particle deposition in human lung airways. NPs are becoming more and more prevalent in the environment [5]. NPs are an element in many products, for those exposed to a combination of Nano silver and cadmium ions, cells react

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differently than to nanosilver alone. Nature contains cadmium ions everywhere in the globe. Determining how nanomaterials differ from traditional materials in terms of their chemical, biological, and physical properties and how this influences potential negative outcomes represents a challenge [6]. Modern technology and consumer goods include engineered nanoparticles, which are precisely crafted at the nanoscale for a variety of uses.

1.1 Micro plastics and Nanoparticles: Unsolved Issues and Health Risks

Numerous NPs were shown to cross and subsequently cause injury, biological barriers, and enter vital animal organs [7]. The authors further observe that the efficacy of barrier crossing is impacted by the physical and chemical properties of ENPs, alterations made to ENPs in a biofluid, pathological and physiological conditions of the organism. A review is known and what is unknown about the intake, breastfeeding, placental transfer, inhalation, and cutaneous absorption of nano- and microplastics (NMPs) [8]. NMP exposures are significant for children and pregnancy. In addition, it discusses the gaps in understanding of the association between NMP exposures and child health that outline the necessary research for this area of study.

1.2 Improving Aerosol Drug Delivery for Children

The existence of transportation and deposition (TD) NPs in the lungs of newborns, adults, as well as children, and the airflow rates during inhalation correspond to 3 age categories: child, infant, and adult [9]. It has been demonstrated that in the lungs of all 3 age categories, the upper lung airways exhibited less particle accumulation than the lower lung airways. The observations suggest that the Brownian diffusion mechanism is responsible for the increased effectiveness of particle accumulation in lung airways with smaller particles. The nasal canals of neonates and infants are constructed using MIMICS 21.0. To evaluate flow properties like velocity, pressure, and the deposition of micro and nanoparticles during sedentary breathing situations, R^2 uses computational fluid dynamics (CFD). This work facilitates the medical administration of aerosol-based medications to the patient because of the age-appropriate nasal cavity [10].

1.3 Evaluating the Distribution of Nanoparticles in Fetal and Maternal Organs

To evaluate the dispersion of 49 inhaled titanium dioxide nanoparticles (TiO_2-NP) throughout 50 systemic organs in the mother and fetus. Pregnant Sprague Dawley rats were exposed to either filtered air or nano-TiO_2 aerosols across their complete body on gestational days 4 and 19. 52 The tissues of the mother, placenta, and fetus were extracted on GD 20 and digested to determine the titanium (Ti) content by ICP-MS 53 analysis [11]. The body of research supports the idea that exposure to NPs affects the emergence of human disease [12]. Understanding the pathogenic mechanism by which nanoparticles function is essential for both preventing and treating diseases caused by NPs in humans. NPs are used for several earthly applications. NPs are similar in size to biological molecules like proteins and can be found in nature. Because a nanoparticle can have a maximum size of 100 nanometers, it is far smaller than a human cell [13]. The water ecology, microorganisms, terrestrial food chain, and other factors are impacted by different NPs. New methods, instruments, and concepts must be created with an understanding of the potential risks associated with the use of nanoscale materials to determine how novel engineering nanoparticles may interact with live creatures in food chains and environmental systems [14].

1.4 Effects of Nanoparticles on Environmental Issues and Respiratory Health

Co-exposure to nanoparticles aggravates the malfunctioning of airway epithelial barriers brought on respiratory syncytial virus (RSV). On bronchial epithelial cells, RSV or TiO_2-NP was cultivated together. The structure and function of the epithelial cell barrier were investigated. The role of viral titer and reactive oxygen species production was assessed [15]. Micro plastics are suggestive of physical injury, dangerous chemical ingredients, and contamination vectors about potential health dangers to humans. It is inevitable for humans to come into touch with the vast amounts of micro plastic pollution that human activity has brought about in ecosystems by eating, inhaling, or skin contact [16]. A study on NP utilization in the building industry is conducted. Interestingly, the deliberate addition of nanoparticles to commonplace materials such as asphalt concrete, normal concrete, bricks, timber, and steel highlighted the benefits of using them [17]. Figure 1 shows how engineered nanoparticles, or ENPs, interact with consumer goods like food, clothes, and cosmetics as well as environmental sources including air, water, and soil. These relationships may have an impact on newborns as well as many plant and animal ecosystems that exist on earth.

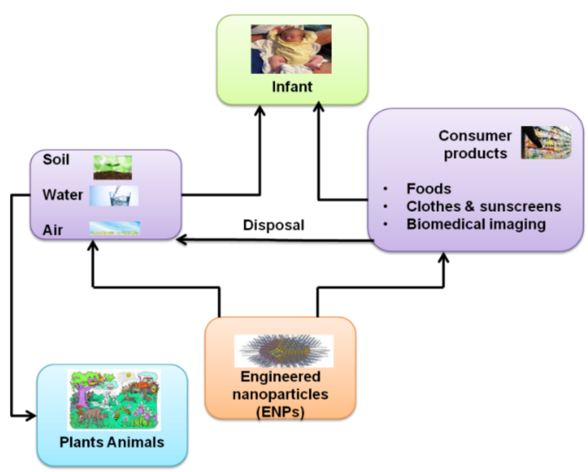

Fig. 1 – Effects of ENPs on infants

2. NANO TOXICOLOGY'S FOUNDATIONS AND PARTICLE TOXICOLOGY

Many different sources can be found at the foundation of the field of Nano toxicology [18]. The establishment of the present paradigm in particle toxicology has been made possible by the convergence of several lines of knowledge that have been accumulated throughout time. Understanding the behavior of nanoparticles may be gained from the radionuclides, toxicology of metal fumes, asbestos, nuisance dust, silica, synthetic vitreous fibers, and rat lung overload more recently, the behavior of air pollution particles has been studied. Furthermore, the disciplines such as virology have added to our comprehension. This document makes references to NPs in several different places. We situate Nano toxicology in this paper in this historical framework because, the present paradigm of nanoparticle toxicology would be unimaginable.

3. EXPOSURE STRATEGIES TO NANOPARTICLES IN INFANTS

For children, babies, and expectant mothers worldwide, plastics are an inevitable requirement. Micro plastics are largely determined in air, food, and refreshments, while early life exposures can happen through breastfeeding, placenta, and food contact materials [19, 20]. It is unknown how significant any of these exposure pathways is in comparison. We highlight important discoveries and missing requirements for child-relevant NMP exposure pathways in the sections that follow. ENPs vary in size and other characteristics, which affect how they behave and how they are relevant for various exposure pathways are depicted in Fig. 2.

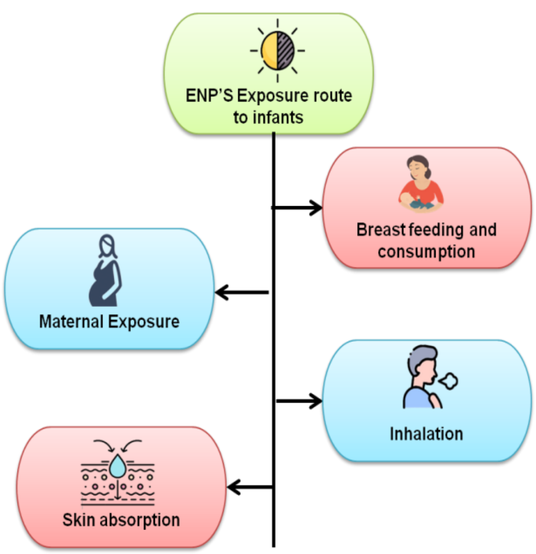

Fig. 2 – Various exposure pathways of ENPs to infants

3.1 Breastfeeding and Consumption

Breastfeeding can transmit chemical pollutants from mother to infant. The body load of the infant is a reflection of the mother's exposure, contingent upon the length of healthcare. It is unknown how much NPs may be passed on during breastfeeding. A child can breathe in and ingest dust containing NP while they are infants at home. NPs and related pollutants can be exposed through the eating, licking, and tasting of plastic toys and fabrics. In one study, the concentration of polyethylene terephthalate (PET) micro plastics in baby waste was found to be higher than that of adult waste, a finding the authors primarily attributed to ingestion. In contrast, the concentration of polycarbonate micro plastics in baby waste did not significantly differ from that of adult waste. Furthermore, it is important to the possibility that baby bottles and infant food containers made of plastic contain NPs and plastic chemicals. Shaking a plastic baby bottle with heated water can release range of 16.5 million micro plastics per liter, and reports that sterilizing as well as using hot water boosted the discharge of plastic particles from the bottle.

3.2 Maternal Exposure

The health of an infant can be influenced by the mother's exposure. During pregnancy and lactation, a mother's body may discharge toxins that mother was previously exposed to or that mother has retained for years. Within the framework of nanomaterial health and safety, a variety of experimental investigations have been conducted on the maternal transfer of polystyrene NPs. Using Raman micro spectroscopy have recently found micro plastics in the human placenta that range in size from around 6 to 10 µm. Pigmented microplastic particles were found on the fetal and maternal sides, in addition to the chorioamniotic membranes. It remains unknown, nonetheless, how NP enters the body, travels through the blood, and eventually enters the placenta. The placenta and meconium following a cesarean section were found to contain microplastics larger than 50 µm, who noted that researchers should assess the possibility of sample contamination via air fallout. Studies indicate that as gestational age increases, the extent of particle transfer through the placenta varies across the pregnancy. The pathways that the delivery of NPs to the fetus or embryo may initiate are not well understood.

3.3 Skin Absorption

In pharmaceutical and cosmetic formulations, C_{60}-, TiO_2-, and ZnO-NPs are used as additions to improve medication delivery, cure skin conditions, or promote systemic access. Tin in children's swimming pools has been reported to range from 22 to 61 μg/L, most likely from sunscreen. AgNPs are the primary ENPs used as antibacterial agents in the fabric and textile sectors. A moderate amount of Ag is typically found in garments. A preliminary estimate of the quantity of dermal exposure to newborns or children was around 15.8 and 25 $\mu g/m^2$ of Ag that were transferred into dermal wiping, respectively, from the surface of soft toys and baby blankets. Table 1 provides a detailed overview of the use of NPs in cosmetic goods as well as consumption patterns and industry predominance in the beauty sector. This information is a useful tool for comprehending how widely NPs are included in different cosmetic formulas.

Table 1 Nanoparticles in cosmetics products

Nanoparticles in cosmetics	**Values (%)**
Ag	40
TiO_2	16
ZnO	11
Au	11
Cu	7
Others	15

4. CHARACTERIZATION OF NANOPARTICLES

To quantify toxicological endpoints, it is necessary to comprehend and characterize the starting point of the nanomaterial. Otherwise, contaminants and other components might be held accountable, making it difficult to directly link any potential harmful consequences to a particular nanomaterial feature or even the nanomaterial itself. As a result, understanding the initial material's characteristics is crucial. Due to inefficient production methods and the resulting wide variability in material characteristics (such as size, shape, etc.), this has not been the case with industrially generated nanoparticles. As nanotechnology develops, more sophisticated production techniques are created, resulting in nanomaterials with consistent and uniform characteristics. Nanomaterials and nanoparticles in particular have been categorized based on their "softness" and "hardness," in addition to the categorization of nanomaterials based on the position of the nanostructure. For bionano and nanomedicine applications, soft materials like polymer-, latex-, dendrimer-, or protein-based NPs are gaining interest, while conductors and semiconductors are regarded as hard.

5. HARMFULNESS OF INHALED NANOPARTICLES

Any material that is discharged into the environment has dangers to human health that are proportionate to the amount of exposure to that substance and the hazard it poses to persons. Therefore, if a guarantee of zero exposure could be provided, there would be no need to be concerned about any harmful threat. As seen by the aforementioned cases, unintentional exposure scenarios cannot be ruled out when it comes to goods based on nanoparticles. Examining the effects of ENPs on health is becoming more and more important as more items containing NPs enter the market. The necessity to evaluate the health impacts of NPs from burning fossil fuels and cigarettes has largely motivated research on human toxicity. Although combustion particles can differ greatly from ENPs, these studies offer a useful initial set of data for assessing their dangers. By inhaling, airborne particles can enter the human body and settle in the alveoli, conducting airways, and upper respiratory tract. As expected by reliable models, the deposited fraction in the various human respiratory tract regions. As the alveoli are more likely to experience harmful consequences, it appears that nanoparticles in the 5–50 nm size range are deposited. Particle deposition in the lung is governed, like in most filters, by the physical processes of diffusion, interception, and inertial deposition. Particulate matter less than 10 nm causes pulmonary deposition to decrease because 5-nm particles exhibit fast diffusional mobility and eliminated from the stream in the upper airways and nose. Table 2 depicts the disease caused by nanoparticles.

Table. 2 Disease caused by inhalation of nanoparticles

Disease	**Affecting value (%)**
Cancer	69.0
Gastrointestinal	10.5
Genitourinary	4.2
Integumentary	2.8
Immune	1.8
Nervous	1.3
Other	5.0
Respiratory	3.2

6. DISCUSSION

The advantages and disadvantages of innovations and technologies, particularly the employment of ENPs, must be considered. Because multinational corporations are making significant investments in nanotechnology to produce a wide range of nano products, ENPs are very important. We must make sure that there are no unintended risks in the applications, even if some ENPs show tremendous promise in the treatment of pediatric illnesses and the creation of effective nanomedicine and nanovaccines for young children. The use of ENPs poses a new toxicological difficulty. In terms of evolution, ENPs are entirely new [39]. The data indicates that ENP enters the body, by inhalation, and then moves at low concentrations to different parts of the body. Fibrous ENPs are not created naturally or by the burning of organic material, they belong to a new group [40]. The comparison with silica has been facilitated by the significant nanotoxicity of nanofibres and the overall significance of nanoparticle shape for toxic effects.

7. CONCLUSION

The development and use of ENPs have increased as a result of advances in nanotechnology and the ability to synthesize novel nanomaterials. However, the environment can get contaminated or discharged with these compounds as ENPs are utilized more and more, endangering public health. This research aims to give a comprehensive overview of the state of the art on nanoparticle toxicity, methods for exposing newborns to nanoparticles and their possible health effects, as well as the characterization and harmfulness of nanoparticles. The potential toxicological effects of nanoparticles need to be investigated. The challenge of quantifying and describing nanoparticles in biological tissues makes efforts to develop a conclusive risk assessment much more challenging. Future developments involving the inhalation of ENPs in newborns hold great promise for improving respiratory health and preventing illnesses in this susceptible group.

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Вплив штучностворених наночастинок на організм немовлят

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Широке використання штучностворених наночастинок (ШНЧ) у різноманітних секторах протягом останніх років викликало занепокоєння щодо можливого впливу на здоров’я, особливо для вразливих груп, таких як новонароджені. Розвиток нанотехнологій і потенціал для створення нових наноматеріалів призвели до зростання створення та застосування ШНЧ. Поле дослідження потенційно небезпечного впливу наночастинок (НЧ) на здоров’я людини та навколишнє середовище знаходиться на початковій стадії, незважаючи на те, що нанотехнології та виробництво НЧ швидко розширюються. У цьому огляді систематично вивчається потенційний вплив ШНЧ на немовлят через респіраторні шляхи, включаючи їх джерела, типи та кількості. Щоб точно зрозуміти фізико-хімічні характеристики наночастинок і будь-який токсикологічний вплив, ми будемо використовувати наноспецифічні аналітичні методи для виявлення та характеристики. Токсикологічні наслідки, які можуть виникнути через наноматеріали, повинні бути добре охарактеризовані. Також важливо розуміти поверхневі процеси, які відбуваються на наночастинках, коли вони контактують з живими істотами. Потрібні спрямовані та спеціальні дослідження для оцінки реальних рівнів впливу та виявлення шкідливих наслідків для здоров’я немовлят і дітей, оскільки виробництво та використання ШНЧ стає все більш поширеним.

Ключові слова: Наночастинки, Немовлята, Вдихання, Вплив, Токсикологія.