An overview of nanotechnology and its potential risk

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Abstract. Nanotechnology has vastly been investigated due to its potential to increase the field of biotechnology and medical advances. Though, regulatory agencies such as FDA oversee the emerging field of nanotechnology through legislative arrangements. Mechanistic knowledge of nanostructure material behavior in the human body, animals, and environment is significant. This paper investigated the role of nanotechnology and its relevant development and improvement in science. Likewise, it exposes or brings to the limelight the threats associated with nanoparticles and their application in various fields of study, most especially the alarming effects on humans, animals, and the environment when inhaled or consumed in the form of nano-medicine, food, etc

Keywords: Nanotechnology, Potential, Risk, Toxicity, Remediation, Nanoparticles

1. Introduction

Technology plays an important role in our everyday activities and also in engineering applications. Technology is an aspect of knowledge that is dedicated to creating tools, action processing, and extraction of materials [1]. Nanotechnology has vastly been investigated due to its potential to increase the field of biotechnology and medical advances [2]. Although, regulatory agencies such as FDA oversee the emerging field of nanotechnology through legislative arrangements. According to Matthew [3], nanotechnology creates multidimensional impacts on societies as the benefits are manifested daily. Avinash and Mahendra [4], narrates the significance of nanotechnology in science and environmental cleanup of long-term challenges for instance hazardous waste sites. Nanotechnology is simply the science of miniature particles. Nanotechnology is an area of interest where new products are modeled at the atomic and molecular regions [5].

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The easiest way to format your manuscript is to simply download the template, and replace the content with According to EPA [6], nano-technology is regarded as the application of knowledge and control of matter at dimensions of 1-100nm, where exceptional physical properties make unique applications obtainable. Hobson [7], described Nano technology as the advances of man-made or engineered particles which have dimensions in the nanometer range (1-100nm). Jeremy [8], defined nanotechnology as an area of specialty that deals with materials and devices that are structured in the nanoscale. Nanotechnology has become a major drive for electronic devices due to its improvement in computing, communication, and data processing [9]. Jalaja and others [10], cited that nanotechnology has established higher power density to retain the storage charge that is used for different varieties of batteries which have low inflammable probabilities. According to Guntner et al. [11], numerous science-based solutions for converting heat generated from waste into useful energy are being studied at Nano's machines, vehicles, houses, and likewise power stations. More so, solar film solar panels are being built by scientists that can be mounted to machines cases and lightweight piezo-electric nano-wires to produce usable energy from wind, friction, and body heat to operate mobile electronic equipment [5]. Nanoscale and sensors can help to deliver cost-efficient structural control of roads, bridges, trains, parking structures, and flooring over time. In the medical field, nanotechnology is being studied to improve the injuries of the spinal cord or brain cells of nerve cells [12]. According to Xu et al. [13], due to their special physicochemical characteristics, molybdenum disulfide (MoS2) nanoparticles have found extensive use in several industries, including energy storage and conversion, environmental protection, and biomedicine. Unfortunately, such extensive manufacturing and usage of MoS2 nanomaterials will unavoidably discharge into the environment, potentially raising dangers to both humans and wildlife/ecosystems. The physicochemical features, synthetic processes, and environmental attributes of MoS2 nanoparticles and their typical functionalized materials are initially presented in this review and subsequently evaluate any impending health risks by discussing in vivo and in vitro studies, as well as the essential toxicological mechanisms, before summarizing their environmental and biomedical applications. Finally, highlight any unique phenomena regarding the link between applications and potential risks. Based on the most recent advancements in research on MoS2's applications and exerting toxicological data, this study seeks to offer guidance for harm prediction caused by MoS2 nanoparticles and to suggest prevention methods. The production of nanomaterials is on the increase and it has applications in a variety of fields, such as the sustainable chemistry industry (e.g., analysis of the environmental and pollution remediation particularly adsorption and catalytic degradation), medicine (e.g., antimicrobial and diseases therapy), biosensors, cosmetics, and food additives due to their exceptional physicochemical characteristics (e.g., small size, large surface area, high surface activity, and fascinating electronic/magnetic properties). Due to their great potential for use in nanotechnology, two-dimensional (2D) nanomaterials including graphene, boron nitride (BN), carbon nitride (g-C3N4), tungsten disulfide (WS2), and molybdenum disulfide (MoS2) have recently gained growing interest. MoS2 is at the forefront of materials research among these 2D nanomaterials because of its several notable chemical, electrical, catalytic, optical, mechanical, and sensing capabilities. Specifically, single-layer or few-layer MoS2 (FLMoS2) nanosheets have greater characteristics than bulk versions, making them separated and employed. This paper aims to reveal the relevance of nanotechnology and its potential risk.

2. The potential risk of nanotechnology

Nanotechnology is the manipulation and reorganization of matter at the nanoscale, at the atomic and molecular levels, in the size range of 1-100nm, to produce materials, tools, and systems that, as a result of their minute structure, have entirely novel qualities and capabilities. Nanotechnology has in diverse ways been described as a transformative technology [14]. Risk is a special area of interest in the field of science. However, there are different views and opinions on its true meaning and interpretation [15]. Buchler 2010, [16], defines risk as the measure of uncertainty and the degree of undesired consequences. Likewise, Crouch and Wilson [17], describe the risk as the product of probability and severity. Risk comprises of outcome, namely, likelihood, significance, causal, scenario and population affected (Henley and Kumamoto, 1996). More so, Raz [19], describes risk as the combination of probability and the consequences of the combination of probability and scope of its consequences. In simple terms, risk equates to expected damage [20]. According to Adam [21], risk analysis is the process of evaluating the probability of an adverse event occurring within a system. Also, it involves the process of ascertaining the likely risk that may arise in a system, i.e. the uncertainty of potential risks and their likely effects on engineering systems. Despite the level of success revealed by the adoption and application of nanotechnology, there are still areas of concern that need to be investigated carefully. Hence, some of the potential risks of nanotechnology are discussed below:

Destruction of the lungs: Studies have revealed that nanotechnology can destroy the lungs due to the chemicals and hydrocarbons composed in them. Some researchers have investigated that nanotechnology can cause lung damage in rats. Carbon nanotubes which are similar in shape to asbestos fibers cause mesothelioma. Likewise, these are manifested in fish and dogs in the form of brain damage [22]. The inhalation of airborne material is a noteworthy potential exposure route. According to Andrew [14], aerosol penetration into the skin has been modeled, and nanoparticles once in the respiratory system will deposits in various regions depending on their diameter, shape, and density.

Weakening of the respiratory system: Inhaled nanotubes can stifle the immune system by inhibiting the function of T cells which are originally designed to organize the immune system to fight infections [22].

Neurological effects: Particles on a nanoscale can cause toxic effects in humans. Due to their small size, they have the prospect of crossing the blood-brain barrier which can lead to mass poisoning or brain damage (microscopemaster.com)

Dermal exposure in the skin: There are greater focuses on the skin as potential access into the human body. Whenever engineered nanomaterials are within the reach of the skin, they penetrate the outer protective layers and reach the epidermis. A study by Tinkle and others [23], have shown latex particle smaller than 1 micrometer can penetrate the skin's outer layer. People using skin preparations such as cosmetics and sun-screen contain titanium dioxide nanoparticles. Once nanoparticles are in the human body, they cause damage at the neural and cellular level and possibly into the brain [24].

de et al. [25], studied a pre- and post-emergence pesticide called atrazine that is used to manage weeds in a variety of crops. It was first launched in the late 1950s, but because of the significant risk of environmental contamination, its usage has been debatable. Atrazine's negative effects on agriculture can be lessened by using sustainable practices. This article discusses several elements of atrazine's environmental consequences, with a particular emphasis on its effects on aquatic species and the potential application of nanoencapsulation to lessen atrazine's effects. Atrazine application causes the chemical to spread beyond the surrounding area, potentially contaminating groundwater, streams, lakes, rivers, seas, plantations, pastures, public supply reservoirs, and even glaciers. Atrazine can change the biota in aquatic ecosystems, which can affect the food chains of many species, including benthic organisms. Atrazine nanoformulations have been created as a strategy to lessen the negative effects of this herbicide on terrestrial and aquatic ecosystems. Ecotoxicological bioassays have demonstrated that these nanoformulations are capable of enhancing the targeted distribution of the active component, resulting in lower dosages to achieve the same effects as conventional formulations. Atrazine-based nanoherbicides' ecotoxicological potential has to be examined in greater depth using representative species from various ecosystems. Figure 1 shows a graphical abstract of what de et al. 2020, reviewed [25].

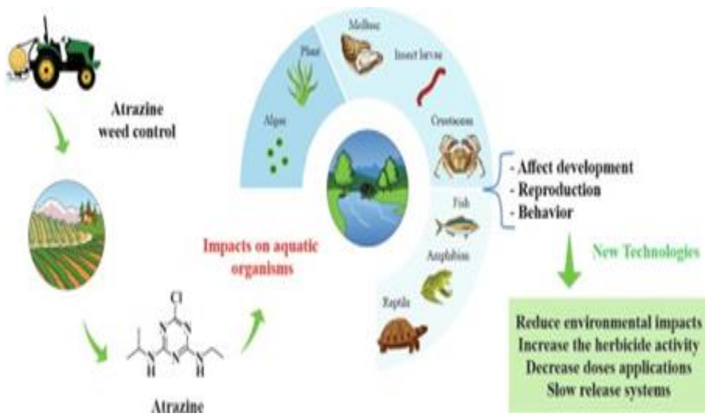

Figure 1: Graphical Abstract. Source: de et al., [25].

According to Karn et al. [26], nanotechnology is employed as an environmental technology to protect the environment via the prevention of pollution, treatment, and cleanup. Although the industrial sectors that manufacture most products that contain nanomaterials are semiconductors, memory and storage technologies, display, optical, and photonic technologies, energy, biotechnology, and health care. This paper concentrate on environmental cleaning in this review and includes a history, overview of recent practice, research findings, social challenges, possibly environmental, health, and safety implications, and future directions for nano remediation. Instead of providing a thorough analysis of the technology's chemistry and engineering applications, they provide a brief overview of their use in environmental restoration. We go into great detail about zerovalent iron at the nanoscale. Nanoremediation can reduce in situ pollutant concentrations to near zero, minimize the necessity for treatment and disposal of contaminated soil, shorten cleanup times, and lower overall costs associated with cleaning up large-scale polluted sites. To avoid any potential negative environmental effects, proper evaluation of Nano remediation especially full-scale ecosystem-wide studies must be carried out. There are two degradation routes for chlorinated solvents: beta elimination and reductive chlorination. Beta elimination occurs mostly when there is an interaction between the contaminant and the Fe particle.

Ndlovu et al. [27], show population growth, climate change, and global food insecurities place tremendous strain on the current agro-food systems. The aforementioned limitations necessitate the application of cutting-edge, goal-oriented scientific breakthroughs. A new and exciting innovation, nanotechnology can considerably and sustainably boost improved agricultural output and spread the effectiveness of food systems. To create customized microscale-based products or technologies, nanotechnology involves the manipulation of matter at the molecular and atomic levels. Precision farming, plant breeding, insect pest, and disease control, waste management, and nutrition management are all examples of how nanotechnology is being used in agriculture. The production, processing, transportation, and packaging of food are all areas where nanotechnology is being used. Although nanotechnologies have a wide range of applications, rising worries about the possible health and environmental problems they pose continue to influence policymakers and consumers. Moreover, the lack of a clear and comprehensive global practice and framework for the use of nanotechnology hinders its widespread acceptance. The primary goal of this paper is to provide a concise overview of the various applications of nanotechnology in the agricultural and food industries, operating a nano-network system for plant monitoring which is shown in Figure 2, with a special focus on the most recent technological developments, their possible advantages, related hazards, and their outlook for the future.

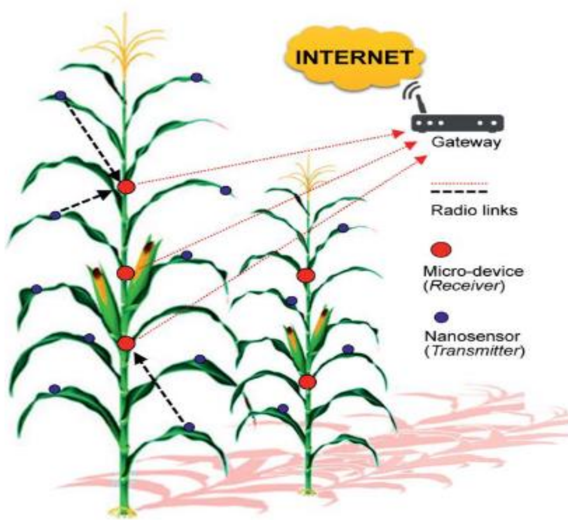

Figure 2: Operating a Nano-network System for Plant Monitoring. Source: Marchiol, 2018)

Hofmann et al. [28] show that among the potential answers offered by nanotechnology for sustainable agriculture are ways to improve pest management effectiveness, mitigate the effects of climate change, and lessen the negative environmental impacts on agricultural food production. Numerous interesting nanotechnologies have been developed and assessed at various levels, but before they can be widely used, several operational hurdles must be overcome, including effective field delivery, regulatory and safety issues, and customer acceptance. In this paper, obstacles and rate the technological preparedness and possible effects of a wide range of nanotechnology-related agricultural applications were examined. Numerous approaches to get through these obstacles and create efficient, secure, and palatable nanotechnologies for agriculture were suggested.

Khan et al. [29], said that the availability of sufficient resources has decreased as the world's population has grown. The promotion of pollution-free technology for the restoration of the environment and clean energy sources for the long-term development of human society is crucial at this period. The development of "cleaner" and "greener" technologies with major advantages for the environment and public health can be greatly influenced by nanotechnology. The potential of nanotechnology's uses to control, reduce, and clean up various forms of pollution such as land, air, and environmental pollution, as well as to enhance the efficiency of current technologies used in environmental cleanup of the environment, was investigated. The branch of nanotechnology known as "green nanotechnology" aims to promote sustainability through a variety of uses. The themes linked to green nanotechnology for sustainable development are covered in this study This study provided an overview of the uses of nanotechnology utilized to address environmental challenges by lowering the total energy consumption throughout the synthesis and process of manufacturing, enabling the recycling of items after use, and creating and utilizing eco-friendly materials. The sections have been separated based on the uses of green nanotechnology. In-depth discussions have been held regarding wastewater treatment using green chemistry principles, green synthesis of nanomaterials, and nano-manufacturing methods. To address environmental concerns, nanotechnology now offers significant promise, however, it is impossible to ignore how harmful nanoparticles are to the environment and people's health. Despite nano-remediation technology's outstanding effectiveness and low cost, a sophisticated study is required to comprehend and prevent any potential negative environmental repercussions, including ecosystem-wide implications. The green chemistry concepts that affect the life cycle of nano-products from conception to disposal are highlighted in this chapter. The different uses and restrictions of green nanotechnology have been examined in the context of sustainable green chemistry concepts.

Pandey et al. [30], in their studies, reveal that the scientific principles that underpin technological advancements ensure that the advantages to society surpass any costs or risks associated with them. But occasionally, the invention either poses a risk in and of itself or introduces some risk elements. The benefits remain the main emphasis of innovation for the majority of the journey from its inception to public acceptance and implementation. The obvious expenses and risks were not considered, it is unavoidably necessary to address the fundamental risk factors and learn how to properly communicate about them in advance. Many different plants, microorganisms, chemical compounds, metals, and metal alloys can be used to create nanoparticles due to their exceptionally small size and large surface area. Nanoparticles are demonstrating their value in nearly every industry, including the food industry, healthcare industry, agro-industry, construction industry, fashion, electronics manufacturing industry, computers, and environmental remediation, which is illustrated in Figure 3. But what about the costs and risks involved? Nanotechnology has unknowingly become an essential part of our daily lives. We must acknowledge these issues and difficulties, which calls for cooperation between academics, researchers, businesses, the government, and non-governmental organizations, to engage the public in conversations to address the issues.

Keerthana & Kumar [31] reviewed that, well-known metal oxide nanoparticles with numerous uses in the fields of cosmetics, medicine, and chemistry include zinc oxide nanoparticles. However, numerous investigations have revealed that it can also be hazardous, including to the liver, lungs, nervous system, and immune system. We have therefore examined the advantages and disadvantages of ZnO nanoparticles in this study. The information about the hazards and advantages of zinc oxide nanoparticles was taken from

PubMed (from January 2007 to August 2019). During this time, 3,892 papers on zinc oxide nanoparticles have been published in total, based on the inclusion/exclusion criterion, 277 studies were used to analyze the hazards and advantages. Recent studies have shown that zinc oxide nanoparticles can have both negative and positive effects under in vitro and in vivo circumstances, depending on the dose and period of exposure. In conclusion, zinc oxide nanoparticles may be useful in the treatment of a variety of disorders, but their safety at a certain effective dose needs to be carefully considered. Although the industrial sectors that produce a large percentage of products that contain nanomaterials are semiconductors, memory and storage technologies, display, optical, and photonic technologies, energy, biotechnology, and health care [32].

The expense of detecting significant health and environmental effects after a technology has become widely utilized can be avoided by taking risk into account early on.

A key example is nanotechnology, which involves substances and objects with a size of less than 100 nm. In this article, a review of the allocation of Federal Environmental Nanotechnology R&D funds, research interest in this area, and the research goals mentioned by several interest groups concerned with the environmental impact of nanotechnology were analyzed. Federal funding for environmental research and development is now scarce and primarily goes toward the beneficial uses of nanotechnology for the environment rather than fundamental understanding, tools for nano environmental study, or potential concerns. The situation started to improve in 2004 when federal R&D funding for the environmental effects of artificial nanomaterials saw a large increase. Although there are numerous pieces of literature on the exposure, transportation, and toxicity of nano-size particles, nothing has been written about the environmental issues that arise due to nanoparticles [33].

Sustainable agriculture has the potential to benefit greatly from nanotechnology. This article discusses recent advancements in nanotechnology's use in the agro-industry, encompassing the production, and protection of crops, with a focus on nanobiosensnano pesticidescides, nano biofertilizers, and nano-enabled soil remediation techniques. Nanomaterials are crucial elements of numerous biotic and abiotic remediation systems and play a significant impact on the fate, mobility, and toxicity of soil contaminants.

This paper also critically examines how the characteristics of nanomaterials and how they interact with soil constituents substantially influence their efficacy and fate. Research on the nanoparticle's application in soil remediation and their fate in soil are still occasional and primarily restricted to laboratory experiments. Nanomaterials may have an impact on soil quality and plant growth once they are incorporated into the soil system. This is examined about their impacts on the release of nutrients in targeted soils, soil biota, s organic oil matter, and morphological and physiological responses of the plant. There has also been a discussion of the defense systems connected with the uptake and transport of nanomaterials within plants. The direction of future research has been determined to advance the study of the sustainable development of nano-enabled agriculture. [34].

New water filtration technologies have been created using nanomaterials, or materials with at least one dimension in the 1-100 nm size range. This comprises photocatalysts, nanomembranes, nanosized adsorbents, etc. However, its unchecked discharge may put biota in danger across a range of environmental domains, including soil and water systems. In this paper, the advantages of using nanomaterials for water filtration as well as the negative environmental impacts of such minute contaminants were highlighted. An overview of the existing understanding regarding the benefits and drawbacks of such systems could be useful for their improved implementation, even though there is still a significant need to further identification of the prospective harms of nanomaterials via thorough laboratory experiments or even field works. In this review, the potential uses of nanoparticles for cleaning up water as well as the risks associated with their release into various environmental areas, such as soils and water bodies were critically examined. For a decade, beginning in 2010 (figure 1), a search in the "ISI Web of Knowledge" database on the key subjects to be covered in the review of recent pieces of literature, namely "Nanomaterials for The Treatment of Water" and " Impacts of Nanomaterials on The Environment," yielded 222 and 63 related articles, correspondingly. This graph shows that during the last decades, the number of articles on the earlier subject—nanomaterials for water treatment—has grown dramatically. The second subject, namely the impacts of nanomaterials on the environment, has, in contrast, received less research. This result indicates the necessity to devote more time and money to identify the potentially harmful effects and environmental risks of nanoparticles that have been mostly ignored. [35]

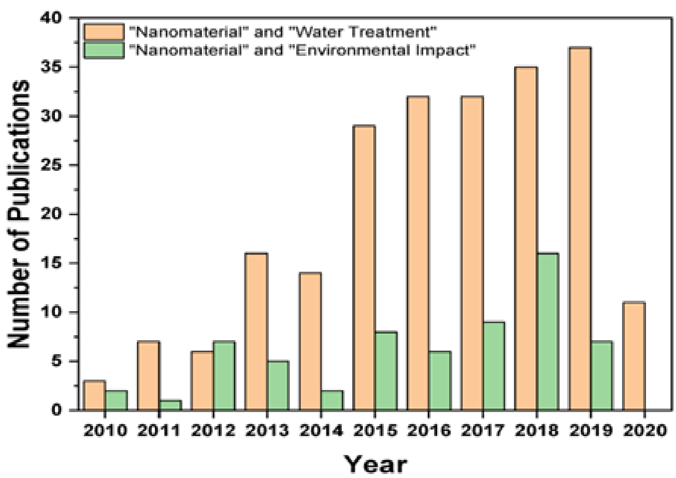

Figure 3: According to ISI Web of Knowledge, the number of publications each year during the past ten years on the primary keywords of the current review (7 April 2020). Source: Ghadimi (2020) [35].

Polymeric nanoparticles (NPs) are tiny particles with a dimension between 1 and 1000 nm with the capacity to encompass or possess active elements surface-adsorbed onto the polymeric core. Both nanospheres and nanocapsules are categorized under the “nanoparticles," which are described by their structural morphology. For the targeted delivery of drugs employed to treat numerous disorders, polymeric NPs have exhibited significant promise. The most common techniques engaged in the production and characterization of polymeric NPs, the effectiveness of the active element’s link with the polymeric core, and the in vitro release mechanisms were examined in this review. In addition, the toxicity and ecotoxicology of nanoparticles for humans and the environment are discussed due to the fact safety of nanoparticles has become a top priority. [36].

Nanotechnology is recognized as a crucial technology due to its ability to improve societal welfare and economic growth in a variety of industrial areas.

A viable structure for environmental risk assessment (ERA) that perfectly draws on procedures founded on conventional chemicals to guarantee alignment and avoid replication is required for sustainable nanotechnology to foster innovation.

Nano-specific ERA benefits from exposure assessment designed as a tiered method just like other chemical classes. Here, we discuss the expanding body of knowledge, relevant issues, and fundamental ideas required to support exposure assessments for manufactured nanomaterials for legal and scientific uses. [37].

Through the many stages of a product's life cycle, numerous stakeholders are growing more concerned about the possible toxicity and other concerns related to nanomaterials (e.g., development, production, use, disposal). Due to the recent challenge in determining the pertinent physio-chemical and biological nature that sufficiently portrays the materials, risk assessment methods and tools that have been created and applied to bio-chemical materials cannot be easily applicable to nano-size materials. The significant differences in the original material's characteristics resulting from different manufacturing techniques used to produce nanomaterials also contribute to this uncertainty. A decision support system for categorizing nanomaterials into several risk categories to direct scientists and engineers in their research and application of nanomaterials as well as to encourage the proper handling and material usage will be necessary. The categorization approach is founded on an array of performance index that assesses the toxicity, physio-chemical properties, and anticipated environmental effects of the initial materials over the course of the product life cycle.

The basis for this job was stochastic multicriteria acceptability analysis (SMAA-TRI), a proper decision analysis technique. Based on our present understanding of the physicochemical properties of nanomaterials, the variety in generated material, and our best expert judgments, this method permits the grouping of distinct nanomaterials into diverse ecological risk groups. In evaluating the robustness of the grouping of nanomaterials for risk management reasons, SMAA-TRI uses Monte Carlo simulations to investigate all plausible values for weights, criterion measurements, and other model parameters. [38].

Zhang [39], mentioned that nanotechnology and nanomaterials have quickly advanced and found widespread use in antibacterial, biosensors, nanomedicine, reinforcement, water treatment, and other fields. However, using and producing nanomaterials and nanotechnology also comes with a lot of issues and difficulties. Are they safe enough to allow for human health? Pollution of the environment is it their fault? And how can nanotechnology and nanomaterials be developed sustainably? This study discussed the uses, risks, and dangers that could arise, as well as the advancement and future of nanotechnology and nanomaterials, in this review. The advancement of materials science has significantly raised the standard of living for people. These materials are constantly utilized. They are essential for things like food, clothes, housing, and transportation. The manufacturing of novel materials often results in notable advancements in the high-tech sector, in addition to the innovation of conventional processing techniques and tools. Nanomaterials are one such, and both academia and business place great value on their study and development. It is without a doubt the gem of materials science. The award-winning quantum physicist Richard Feynman forecasted in the 1960s that hadn’t humans influenced object configuration on a small scale, we would have the ability to create products with a wide range of exotic properties and observe that the applications of the material produce a valuable variety of changes.

Through nano-gene chips, humans may identify the genetic codes that cause genetic disorders and deformities. They can also utilize nanotechnology to reorganize the genetic code on a nanoscale and even add beneficial genes to strengthen themselves. However, misusing the technology, for as by identifying a fetus' sex using nanotechnology, would result in gender inequality and a host of social issues. Better children are also produced by conditional parents, which will increase social inequality. Children should be welcomed without conditions rather than being seen as the product of parental design and reform. Particularly crucial to the intergenerational interaction is the mindset of the parents. The use of new technologies to alter children's genes puts pressure on parents to use them, which broadens the definition of what constitutes a disability and what constitutes discrimination. [40].

3. Contribution

This paper has examined the role of nanotechnology by highlighting the major trends of its successes, particularly in medicine which has improved human performance in various ways. Notwithstanding, the negative effects of nanotechnology are also noteworthy to address as the lives of humans, plants, and animals are likewise significant. Furthermore, the existing literature is clear on the negative effects associated with nanoparticles and the administration of nano-medicine to humans. Also, nanotechnology's development has prepared the path for new advancements in several industries, including electronics, agriculture, food, medicine, etc, while many of these are still in the laboratory stage, several of them have already been established and marketed. Hence, this study has further strengthened this consciousness by drawing the attention of the public to the potential risks of nanotechnologies and their severities.

4. Conclusion

Many benefits of nanotechnology depend on its possibilities to transform materials at an extremely small scale to achieve specific properties which would greatly materials science toolkit. However, the potential risks of nanotechnologies should be properly investigated and scrutinized. Though the updated and amended literature makes it clear that there is a growing need for the development of practical methodologies to examine the ecotoxicity of engineered nanomaterials. This review has described that nanotechnology can be effectively utilized to manufacture consumer goods for the pharmaceutical industry, electronics manufacturing industry, food and packaging industry, agroindustry, aviation, construction industry, security industry, and remediation of the environment, which are advantageous in their characteristics. This study has done this by critically reviewing numerous studies and articles on nanotechnology. Regarding the potential market growth of nanotechnology, we must concentrate on risk assessment and management. and recommends further research gaps.

Acknowledgment

The Authors acknowledged the financial support by the founder of Afe Babalola University in this research

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