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Review Article

Nanomaterials: History, Production, Properties, Applications, and Toxicities

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Environmental sustainability is a pressing issue that needs to be addressed immediately due to problems like climate change, pollution, and disturbances to biodiversity. These environmental problems are significantly influenced by pollutants in the atmosphere and on the ground. Semiconducting metal oxide nanostructures are crucial for the creation of smart materials that are efficient for sensing and purging hazardous chemical pollutants from our environment. Aside from the fact that present energy sources are insufficient to meet modern-day demands, they also have several unfavorable side effects. In this review, we describe how catalytic and photocatalytic processes can assist us in solving these problems in a cost-, energy-, and environmentally-conscious way. This article covers the main concepts of nanotechnology and the terminology related to it. The study presents a brief overview of the several categories of nanomaterials that can be utilised to provide catalytic activity that is both practical and inexpensive. According to projected trends, the study also examines the use of a number of unique approaches to improve the selectivity and sensitivity of metal oxide semiconductors. This study summarises the perspectives and outlook on upcoming developments in the field of metal oxide nanostructure research, as well as a thorough collection of the work done to date to address the challenges and current successes, highlighting the effects of nanotechnology on the environment and society.

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1. Nanomaterials and history

Due to their useful applications in optoelectronic, magnetic, and catalytic instrumentation, an increase in heat transfer rate, electronics, energy generation, and agricultural features, nanomaterials (NMs) have drawn physicists, chemists, and biologists to the same bench [1]. Richard P. Feynman introduced the concept of nanotechnology in his well-known 1959 lecture, "There's Plenty of Room at the Bottom." Since then, the field of nanotechnology has undergone tremendous changes. Nanotechnology includes the production and manipulation of materials at the nanoscale (less than 100 nm), as well as understanding and controlling matter between 1 and 100 nm, where specific phenomena enable novel applications. The Greek or Latin roots of the word nano mean "dwarf".

There has been a lot of work put into using this technology, but there is still room for inventing new, unique NMs in a variety of disciplines for the advancement of civilization. Research on ancient artifacts demonstrates that humans have been abusing NMs since their earliest times. 4500 years ago, the Greeks and Egyptians used NMs based on synthetic chemical processes to create nanoscale hair dye [2]. The earliest synthetic colour, "Egyptian blue," was created by the Egyptians in the third century using sintered glass and quartz [3] which is a finely decorated mixture of glass and quartz. Its widespread application was seen in the ornamentation of archaeological explorations.

The time of metallic NPs is also attributed to the Mesopotamians and Egyptians in the thirteenth and fourteenth centuries BC. The employment of metallic NPs in a Roman glass piece is the best-known example. Dichroic glass, used to make the Lycurgus Cups, a style of Roman glass cup from the fourth century, changes colour depending on the type of light it is exposed to. Light appears red when it comes from the back and green when it comes from the front. The Lycurgus Cups have a 7:3 Ag-Au alloy NP content with an additional 10% Cu, according to recent studies. In the medieval age, red and yellow coloured glass was produced using Au and Ag colloidal NPs, respectively. The presence of Ag and/or Cu NPs in the topmost glaze layers of the material is what gives these antiques their outstanding optical qualities. The study from the transmission electron microscope proved that these NPs existed [4][5][6].

Scientists are baffled by the unusual traits of these ancient objects, which forces them to reconsider utilising modern ideas. Richard Zsigmondy, a chemist who won the 1925 Nobel Prize, developed the idea for this recent study. He was the first to use a microscope to gauge the size of particles like gold colloids, and he also developed the term "nanometer" to describe particle size. Norio Taniguchi, a Japanese scientist, first used the term "nanotechnology" to elaborate on semiconductor processes at the nanoscale 15 years after Richard Feynman's presentation. Scientists have been researching the new nanotechnology developed by Feynman [7]. By learning about fullerenes and Taniguchi's word "nanotechnology" in his 1986 book "Engines of Creation: The Coming Era of Nanotechnology," Kroto, Smalley, and Curl effectively implemented the Feynman idea. The research on NMs was advanced further by a Japanese scientist. Iijima developed carbon nanotubes [8].

With the invention of the scanning tunneling electron microscope, which enables the imaging of surfaces with atomic resolution, the study of nanotechnology advanced. Early in the 1980s, K. Eric Drexler created a different plan for the advancement of nanotechnology based on a bottom-up strategy he called molecular engineering, which was solely concerned with biological mechanisms [9]. In the same decade, Kroto, Heath, and Smalley discovered C-60, also known as Buckminsterfullerene or the Buckyball, a novel allotrope of carbon [10].

Published by IOP in the UK, the first journal was founded in 1990 and was titled "Nanotechnology." The term "Nanomedicine" was subsequently coined in a book that Drexler co-authored [11]. As several NP kinds were presented in this book, such as the creation of the carbon nanotube in 1991 and Kataoka's discovery of the polyelectrolyte complex micelle in 1995, systematic advancements in the field of nanotechnology continued to thrive [12].

The highly interagency Working Group on Nanoscience, Engineering, and Technology was established in 1998 as interest in the potential for nanotechnology began to permeate global politics [13]. Table 1 summarizes the efforts taken for the establishment of nanotechnology and its applications for mankind.

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No	Group		Year	Reference
1	Groups	Interagency Working Group on Nanotechnology	1998	[13]
		National Nanotechnology Initiative in, the United States	2000	[14]
		Canadian National Institute for Nanotechnology	1974	[15]
		National Institute of Health National Cancer Institute launched an alliance for nanotechnology	2004	[16]
2	Instrumentation	Design of the STM	1981	
3	Carbon materials	Fullerene and Buckyball	1985	[17]
		Carbon nanotubes	1993	[18]
		Carbon dots (C-dots)	1991	[18]
		Graphene	1962	[18]
4	Main uses	Medical uses		[11]
		Energy uses		[19]
		Textile and petroleum		[20]
		Fuel cell application		[21]

Table 1. Summary of the establishment of nanotechnology and its applications

Recent research on the subject of nanotechnology is concentrated on nanomedicine and environmental pollution. People are immediately impacted by these two issues, which ultimately reduce lifespans and hasten global warming. The majority of these pollutants include harmful metal compounds, substances that are released into the land and water, pesticides and fertilizers, medicines, and dyes. Food and plants absorb these pollutants, which eventually find their way into people's bodies and significantly damage the ecosystem. These harmful substances are detected and degraded using the NMs. It is found that the methods created by NMs are economical and advantageous for the environment. The results based on nanotechnology, which are incredibly precise with astonishing stability, have also led to the invention of practical, controlled, portable, and always-useful systems for the identification of hazardous chemicals [22].

Methyl parathion (MP), an organophosphate contaminant, is widely employed in detonation chemicals and pesticides. Methyl parathion, which can harm the skin and eyes, is present in almost all foods, including water. A functionalized glassy carbon electrode (GCE) was created by catalysis using colloidal tannic acid (TA) doped gold nanoparticles, according to a study conducted by Balasubramanian and co-authors. With a wider linear concentration range of 0.033-167.7 µM, the TA-doped sensor demonstrated good

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electrochemical activity. The disclosed sensor also displayed good reproducibility and stability characteristics [23].

The safety measures for nanomedicine have been significantly improved by the functionalized biodegradable NMs. For use in biological applications, Shi Su and Peter evaluated various biodegradable functionalized NM types and discovered that biodegradable polymers are frequently functionalized for a variety of uses. These materials are employed in tissue engineering, targeted drug administration, implantation, digestion, and kidney function [24].

Nanotechnology is currently the most active area of study. The discovery of novel materials with beneficial and intriguing properties is the goal of the multidisciplinary field of study known as nanotechnology. These brand-new substances are nanoscale compounds, incredibly small in size and with exceptional qualities. They distribute drugs to the area of a person's body that needs them. Materials can be reinforced, powered more efficiently, and solar energy can be converted with the help of NPs. NPs adopt a variety of traits, behave differently than usual, and produce larger building blocks of material. According to logic, these exciting unexpected properties of NPs are more likely due to their tiny size than to the fact that a particle consisting of a relatively small number of molecules interacts and behaves differently with its environment for fundamental physical reasons [25].

NMs′ varied physical and chemical properties have made them significant in science. In comparison to their function over their bulk counterparts, qualities like melting, wettability, thermal and electrical conductivity, catalytic activity, light absorption, and dispersion improved with the aid of nanotechnology. It may be possible to modify properties like thermal and electrical conductivity, colour, chemical reactivity, and elasticity by manipulating the form, size, and internal order of the nanostructures. Recently, China has achieved important strides in the sectors of the nanotechnology industry and relevant publications. America has surpassed China in the field of nanotechnology in terms of the number of research articles published in reputable journals and the average number of citations.

2. NPs and NMs

NMs are unintentional, man-made, or natural particles that can be arranged in an infinite number of ways, according to the European Commission. When 50% or more of the particles are between 1 and 100 nm, they have a significant impact on civilization because of all the uses they have. The field began when Richard P. Feynman predicted that NMs would appear in 1959. He asserted that there is plenty of room at the bottom. He claimed that scaling down to the nanoscale and then beginning at the very bottom was the key to improving technology and progress [26][27]. NMs at present are classified as under:

(a) Carbon-based, (b) Metal-based, (c) Dendrimers, and (d) Composites [28].

Nanomaterials normally exist in different morphologies like tubes, spheres, and ellipsoids.

Nanomaterials that are based on metals are considered quantum dots, such as metal oxides, gold, and silver particles. The combination of NPs or other materials with NPs forms the composites. NPs are being added to products to increase mechanical, thermal-barrier, and flame retardant characteristics [29]. Nanotechnology is also used in food processing, such as packaging and preservation [25][30].

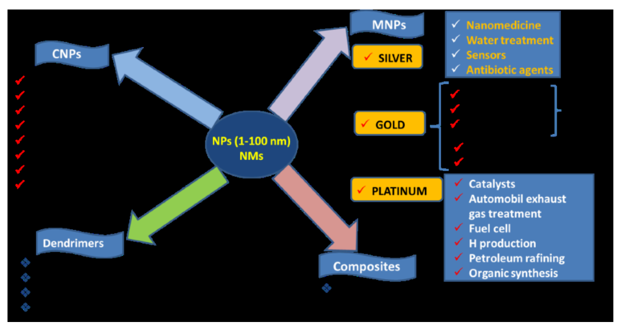

Figure 1. Assembly of large-scale applications of NMs.

3. NMs and their applications

Particularly, Ag, Au, and zinc have exclusive physical and chemical characterizations that have attracted high attention in the field of biomedical, and platinum in energy storage devices. The present curiosity is to use the optical characteristics of Ag NPs as a practical component in various products and detectors. Ag NPs are extremely active in the scattering and absorption of light. They can also be used as antibiotic agents in medical equipment, washing machines, and refrigerators. In drug delivery, enzyme control, bio-sensing, bioengineering, and pollutant control, different NMs based on carbon are used[31].

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a. Catalysis

Catalysis is one of the pioneer applications of NPs. Among others, Al, Fe, and TiO_2 are commonly used as catalysts. Due to their high activity, selectivity, and efficiency, nanocatalysis is a rapidly developing field of science. When compared to metal complexes, metal NPs with a size range of 1 to 10 nm occasionally perform catalytically well. Due to various important factors, such as impact ratio (large surface-to-volume ratio), shape, quantum size, and electrical effect, nanocatalysts are said to work quickly. Metal NPs hovering in solution are efficient heterogeneous catalysts.

Catalysts act as exchangers, and the selectivity of nano-catalysts is significantly influenced by their size [32]. Catalytic effects decrease the temperature of conversion and reagent-based waste products [33], therefore boosting selectivity to prevent undesirable side effects that support green technologies. Without a catalyst, it would not be possible to produce diverse goods such as fine chemicals, polymers, fibers, lubricants, fuels, paints, and an infinite number of other useful goods that are necessary to humanity. As a result, catalysts make production efficient, sustainable, and advantageous. Carbon nanotubes are also widely utilised in photo-catalytic processes, catalyzing the oxidation of fuel cells, synthetic methane, and ammonia.

b. Water treatment

NMs are small in size, have a large aspect ratio, high adsorption ability, and reactivities. Different types of nano-materials can remove metal particles, bacteria, organic, and inorganic pollutants [25][34]. Photocatalytic degradation with metal oxide nanoparticles is possible. TiO_2 is an extensively researched metal oxide that is used to degrade pollutants in water and wastewater. It exhibits non-toxic behaviour, is commercially available, chemically stable, and highly photoactive, among other qualities [35]. Contaminants can gradually oxidise into low-molecular-weight intermediate products in the presence of light and a catalyst, and then be distorted into CO_2, H_2O, and anions, for instance, NO^{3-}, $PO_4{}^{3-}$, and Cl^-.

c. Sensors

Detectors and their applications make use of NMs that are growing in vast arrays. These electrochemical sensors are utilised in air quality, food safety, and medical diagnostics [36]. Nanotechnology has had a significant impact on biosensors as well, in part because of their sensitivity, excellent selectivity, and shrinking of detectors. Here, innovative materials with luminous NMs and nanostructures are created. Nanostructural biosensors for the detection of glucose [37] are developed. Diabetes patients commonly utilise blood glucose meters, which use an electrochemical method to detect glucose. Carbon nanotubes can be used to create molecular detecting devices such as gas detectors, nanosensors, and electrochemical sensors. The macro-electrode variation caused by NPs narrows the sensing window and raises the limit of sensitivity and selectivity [38].

d. Energy storage

NM based on platinum (Pt) has potential in environmental catalysis and energy production due to its rich electronic configuration and exceptional catalytic activities, namely, automobile exhaust, gas treatment, fuel cell energy conversion, petroleum and natural gas refining, organic synthesis, and for the production of hydrogen as fuel[39]. The surface area and active sites of the Pt-based NMs have been significantly increased, resulting in improved Pt atom activity. Scientists in rice research used carbon nanotubes to stop the expansion of dendrites on Li metal anodes. They developed carbon nanotubes/graphene-based electrodes with a large surface area and high conductivity. In such a way, every nano-tube bonded, atom to atom, on a graphene substrate is one molecule with a large surface area. This technology is used to create Li-metal batteries, which have higher capacities and faster charging times than Li-ion batteries. Compared to lithium-ion electrodes, which are found in every electrical equipment, including mobile phones and electric vehicles, charges in Li metal occur faster and have 10 times more energy by volume. Hence, with a multi-walled carbon nanotube film, Li-metal foil is coated.

e. Nano-medicine

Silver NPs are employed in nanomedicine and water purification systems for their potent antibacterial properties. Gold nanoparticles are used in nanomedicine because of their appealing size-dependent chemical, electrical, and optical properties for biocompatibility. They are employed in a variety of processes, including photothermal therapy, medication delivery, photodynamic and gene editing, biolabeling, and biosensing. [40].

Nanoparticles with large surface areas and noncytotoxic properties are gold NPs. Au NPs′ high impact ratio renders their surfaces accessible for modification by target molecules. Therefore, Au NPs are preferable to other NPs employed in many medicinal applications. The most effective method of treatment is targeted medication transformation since it just affects the afflicted areas. Consequently, medications used to treat cancer have fewer adverse effects. Drugs used to treat cancer can be administered directly to the cancerous cells, with no adverse effects on healthy cells [30][31][32][33][34]. For the transformation of medicines, Fe_3O_4 is employed as quantum dots. Au NPs are efficient in biosensing, labeling, and bioimaging [41]. Au NPs can be used as contrast agents in cellular imaging for a long period. They are also utilized in biosensing applications, blood glucose detection, and biosensing of bacteria and viruses [42].

f. Photocatalysis

For photocatalytic activity, semiconductors with band gaps between 1.5 and 3.5 eV and absorption wavelengths ranging between 350 and 700 nm are appropriate, mainly because they exhibit visible-light catalytic activity. Typically, semiconductors have a wide variety of band gaps, but for a photocatalyst in the UV-visible region, we only need semiconductors with band gaps between 1.5 and 3.5 eV. This group typically includes metal oxides [43][44][45]. Metal oxides are well suited as photocatalysts due to their wide range of characteristics, including band gap, favourable light absorption, carrier transportation, electronic structure, etc.

The most fundamental property that a photocatalyst should have is the band gap. The band gap of the product, which should be in the UV-visible area, also affects its cost. In addition to the structure′s huge surface area, capacity to be modified, and reusability, it should also be stable. With these characteristics, the majority of metal oxides, such as titanium, chromium, vanadium, zinc, and cerium, can be used as photocatalysts [45]. When exposed to visible light, the energy of photons is absorbed by an electron (e) in the valence band, and it is excited to the conduction band. This e- /h + pair causes the metal oxide′s surface to undergo the redox process, which breaks down the pollutants [44]. This excited electron is employed to reduce an acceptor, in which a hole is employed to oxidise molecules of the donor. The significance of photocatalysis rests in the fact that a photocatalyst simultaneously creates an oxidation and a reduction environment [46].

In addition to pure metals like gold, platinum, silver, iron, zinc, cerium, thallium, nickel, and cobalt, metal NPs can also be composed of these metals′ hydroxides, oxides, chlorides, phosphates, sulphides, and fluorides. When used as a photocatalyst, silver NPs exhibit a noticeable band gap for photocatalysis [47][48][49]. Both metals and non-metals have a wide band gap and diverse properties depending on how they are manipulated. Due to their wide band gap and exceptional catalytic applicability, semiconductor NPs make the greatest photocatalysts for photocatalytic applications, particularly due to their band gap in the visible area [50][51].

There are two basic types of carbon-based NPs: carbon nanotubes and carbon fullerenes. Carbon nanotubes (CNTs) are essentially rolls of graphene sheets that have been formed into tubes. Single-wall carbon nanotubes (SWCNTs) and multiwall carbon nanotubes are further divisions of CNTs (MWCNTs). Carbon fullerenes, also known as Buckminsterfullerenes, are the second type of carbon-based NPs. These NPs are essentially allotropes of carbon that include sixty or more carbon atoms (C-60). TiO_2@MWCNTs, $C_{60}/Bi_2TiO_4F_2$, $C_{60}/g\text{-}C_3N_4$., have been reported for the degradation of the organic pollutants RhB and MB [52][53][54]. The limitations that restrict the commercial use of carbon-based NMs are their high cost in addition to H_2 separation from O_2, which is accomplished by utilising an O_2 trapping agent during the hydrogen production process [55].

Ceramic NPs are inorganic, solid, oxide-phosphate, and carbonate-based particles[45]. These NPs have great thermal resistance and chemical inertness. These particles are used in photocatalytic activity, medication delivery, dye degradation, and imaging. Manipulating their size and shape, porosity, and surface-to-volume ratio makes them effective drug-delivery agents [56][57]. TiO_2 and ZnO, showing significant photocatalytic applications, can be quoted as examples [58][59][60][61][62].

Organic polymeric NPs are another type of NPs that can be found in nature [45]. Depending on the synthesis methods, these NPs can have a structural form like nanospheres or nanocapsules. Nanospheres have a matrix-like structure, whereas nanocapsular particles have morphologies similar to a core-shell structure. In

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the medical field, these types of NPs are mostly used for drug delivery and diagnostic purposes [63][64].

4. Impact of NMs on the Environment

NMs are used in a variety of industrial, construction, medical, and consumer items, which increases exposure to people and the environment [65]. People come into contact with NMs in a variety of ways, including through their food and air. The unavoidable cause of the accumulation of exposure to NPs in the environment is the excessive usage of NMs in human life. As of now, the likelihood of these NPs may be substantially influenced by their ecological conditions as well as their physical and chemical conditions. Therefore, the NPs' external environment and other physio-chemical traits may affect how they change and how readily they scatter into the environment. However, there is currently no comprehensive setup for developing assessments for potential causes of pollution, including toxicity and NPs in the atmosphere.

In addition to accumulating in the atmosphere, nanostructures also disrupt the lifecycle of living things in the environment. These are just a few of the ways that nanostructures are impacting the atmosphere. Additionally, the cluster of these NPs interacting in the environment is currently unexpected due to the lack of a quantitative investigation technique to locate pertinent NPs. The repetitive examination of NPs in the atmosphere necessitates the sequential application of various mechanisation [65][66]. We analyze the NMs by microscope, chromatography, centrifuge, and filtration techniques. A single NM is analyzed by an electron microscope. Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) can be used to assess the shape, size, and accretion status of NMs below 10 nm. NPs can infiltrate aquatic environments immediately through industrial discharge and wastewater treatment emissions.

a. Positive Impacts on the Environment

In comparison to those unconfined in other portions, processed NMs' exhaust in the environment was exposed to sunshine and ultraviolet radiation at dramatically higher levels [67]. Such exposure probably enhances the outcomes of photochemical changes to NMs. Good and bad influences on the atmosphere may be summarized as follows:

Examples of nanotechnology's beneficial effects on the environment include the condensation of low volatility compounds, weight reduction of aircraft, stronger and lighter wind turbine blades, air and water purification, food processing packaging, food supplements, nanosensors to detect pesticides, and nano fertilizers. Additionally, nanotechnology has detrimental effects on the environment, including DNA damage, genotoxic effects, decreased plant development, biological systems, and aquatic life.

NMs are utilised as an alternative to traditional composites to lighten aircraft and reduce fuel consumption by thousands of tonnes. NNs are also used to make the blades of wind turbines strong and light, enhancing their energy exchange efficiency ratio as a result. NMs are being used in petroleum distillation and automotive exhaust systems, thus increasing chemical reactions by decreasing operating costs and pollution [68]. The use of NMs for decontaminating air and water has proven successful, thanks to adsorption, filtration, and oxidation processes. In comparison to conventional techniques, such technology requires high efficiency. From Gram-positive to Gram-negative bacteria, silver nanoparticles exhibit antibacterial effects. Decontaminating air and water has proven successful, thanks to adsorption, filtration, and oxidation processes. It works well as an antifungal agent. The application of nanotechnology in food safety nowadays has received significant attention.

Although diverse building processes are used in detection systems that rely on nanotechnology, they all pursue the same objective, explicitly, timely, and precise exposure to a trace or additional contaminant [69]. Several fields like the agro-food industry, food processing, packaging, and food supplements are based on nanotechnology. Applications of nanotechnology include nano-sensors. Sensors are used in livestock health (pigs, sheep), organizing soil nurturing circumstances, and sensing pesticides in crops[70].

The use of nanotechnology in agriculture has altered animal and agricultural potential thanks to careful control and preservation of plant input. The use of zinc oxide NPs in nano-fertilizers is capable of producing a high yield [71]. De la Rosa et al. [72] reported that the biomass of alfalfa, tomato, cucumber, and other agricultural products can be improved by using foliar sprays of zinc oxide (NPs). Claudia and coworkers found that the use of copper NPs and potassium silicate NPs has changed the enzymatic and non-enzymatic levels of agricultural products, which are crucial for the defensive system and increasing tolerance. This bacteria reduces the yield by 16.1% without the use of NPs[73].

b. Negative impacts on the environment

The NMs react with biomolecules, body cells, and organisms unexpectedly, resulting in negative impacts [74]. This impact varies for materials and has a positive impact on many other materials and the environment [75]. The size, nature, and aggregations of NPs have a deep influence on the toxicity of NPs. Presently, some pieces of literature have reported the negative influence of NPs on aquatic organisms with the emergence of solution-based NPs or at an aqueous interface [76]. The chemical dangers that produce NPs on food plants cause free radicals to form in living tissue, which damages DNA. As a result, before using nanotechnology in agriculture more extensively, it should be carefully evaluated [77]. Scientists have now investigated how Ag_2S NPs affect the environment. Consumption of NPs causes genes to be overexpressed, which decreases plant growth. The leaves held the majority of the Ag_2S NPs, consequently increasing the likelihood that such structures will be transmitted across the food chain. Transport of TiO_2 NPs originates genotoxic causes (0.25 mM dose) to break DNA (large concentrations, e.g., Allium-cepa and Nicotiana-tabacum in plants). NMs were used to confirm the use of modest to significant toxicity results in aquatic life. By toxicological analysis, NMs influence unicellular aquatic structures (like fish and Daphnia). Different research reveals that the release of silver ions into cells is what causes silver NPs to be harmful. AgNPs and Ag ions both communicate similar cytotoxicity. Ag NPs should be ionised in the cells, even if the specifics of toxicity are still unknown. Ion channels therefore open and alter the cell membrane's permeability. Potassium and sodium interact with mitochondria in this manner. Consequently, the production of reactive oxygen species causes cell death.

5. Societal impacts of NMs

The way that institutions, organisations, corporations, or individuals act impacts the surrounding society, and this is known as societal impact. Any new technology has social repercussions that can be felt by those who are directly involved with the organisations, individuals, or people in question in many civilizations and nations. The current state of knowledge suggests that NPs and their uses could come with inherent risks which may vary depending on the specific NMs and uses. In order to find instances of noncompliance with safety norms and regulations, it is crucial to conduct studies on the potential effects of nanotechnology concepts, processes, and applications [78].

The development and validation of techniques and tools for identifying, classifying, and analysing NMs, as well as the evaluation of NM exposure and the creation of comprehensive information on the dangers associated with them, are now the main challenges [79]. Consideration of the new industrial opportunities and potential environmental and health risks connected with particles at the nanoscale is prudent [80][81][82][83][84].

Nanomedicine is another field of nanotechnology where ethical and social questions are raised{Abbasi, 2019 #604}. Without the notion of immortality, robots that can repair DNA, super-intelligence, and other hypes, it is possible to assume that nanomedicine does not significantly differ from conventional medicine; consequently, this leads to an imbalance in the field of therapeutic research. The poor may likely suffer more from the imbalance that the shift will cause if adequate preventive measures are not taken [78].

NM research requires highly skilled labour, necessitating large investments [85]. The pace of innovation in this field should be sped up by the availability of human resources with technical skills. Consequently, it is essential to have a supply of a highly skilled technical workforce to carry out the necessary research [86]. Funding is one of the significant societal challenges connected to the science and technology sector. A well-funded area of science and technology might sometimes influence experts to change their research focus [87]. Because each piece of knowledge practically has to be paid for, industrial growth has become more expensive and difficult, further widening the technical gap between developed and developing nations that formerly profited from knowledge made freely available to the public [80][81][82][83][84].

Although the examples of ethical problems with nanotechnology that have been raised are by no means exhaustive, it is clear that ethical problems with nanotechnology are caused by a variety of factors, including social conditions that exist in particular nanotechnology laboratories, the nature of time-dependent job markets where researchers structure their research, and other factors. Research projects that disseminate the knowledge necessary for deliberate policymaking should be supported; citizens should be educated on the various benefits and drawbacks of a given technology to facilitate informed public technology evaluation; and people should be involved in the governance of technology to decrease the incidence of nanotechnology-related disputes [78].

6. Conclusion

We conclude that innovative NMs, despite their development and enhancement, have both beneficial and harmful effects on the environment and people. Consequently, NMs may be considered drugs since they have desired and undesired influences on human life and the environment. NMs are now being researched for use in a variety of applications, including catalysis, sensing, photovoltaic energy, environment, and biology. But the level of NMs in the atmosphere is continuously increasing. NMs are dangerous to microbes, plants, and animals, hence indirectly influencing human beings. We should concentrate on the progress of new NMs as the awareness of these NPs is yet in its early years. Aspects like composition, shape, and size of the NPs have an important impact on their functioning and potential hazards to human health. Generally, a rigorous study is required for a complete understanding, such as their characterization, synthesis, and probable toxicity of NMs.

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