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Nanotechnology and Ethical Issues: An Evaluation

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Abstract: *Nanotechnology is predicted to be one of the foremost emerging technologies that will transform the world as part of a technological revolution. Numerous ethical concerns are raised by the implications of nanotechnology, including invasions of privacy, of individual autonomy, environmental contamination, economic exploitation, security, and global justice. To add an ethical dimension to the reflection, we must establish a framework, which is a collection of widely recognized definitions for terms and concepts. In this article, both descriptive and evaluative research methodologies were used. The human sciences, such as philosophy, law, sociology, ethics, and the scientific sciences like physics, chemistry, mathematics, biology, and engineering, urgently need to work together constructively in order to provide moral guidelines for the advancement of nanotechnology. This paper focuses on the primary ethical concerns that emerge with the development of nanotechnology. The following issues will be covered in this article: first, the notion of nanotechnology; second, implications of nanotechnology; third, the ethical reflections; and finally, to present the future perspectives of nanotechnology.*

Keywords: *Nanomaterials, Moral Issues, Nano-ethics, Risks, Environment*

Introduction

Technology has been a major factor in human progress, from the invention of the wheel to the latest advancements in artificial intelligence. Modern technology is advancing at a never-before-seen rate, with advances in biotechnology, robotics, artificial intelligence, and nanotechnology. Generally, technological advancements do not raise moral or ethical concerns by themselves. Yet any application of a technological product can be turned into a moral dilemma. Nanotechnology is one of the fastest-growing technologies and has the potential to be the most significant technological influence since the emergence of the Internet. Examining the possible advantages and disadvantages, as well as the purposes are essential components of ethical reflection.

Nanotechnology has garnered significant attention and ethical concerns in recent years. The possible ethical concerns that nanotechnology may raise

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have been the subject of numerous studies. These ethical concerns include the potential harm that nanotechnology could cause to the environment and human health, particularly from nanoparticles; privacy and control issues that arise from using nanodevices; the potential for treating and improving human diseases and the moral implications of doing so; and issues with equity, global justice, and the distribution of benefits and risks, including moral conundrums involving patents and property rights (Poel, 2008).

In order to make our lives more pleasant and convenient, we have the right to embrace nanotechnology. However, we also have obligations to the current and future generations to ensure their safety. Therefore, moral and ethical factors such as responsibility, duty, justice, fairness and others have an impact on the development of nanotechnology. All scientists, engineers, and stakeholders involved in nanotechnology must be aware of the long-term advantages, constraints, and hazards of nanotechnology to promote its ethical, sustainable, and economic development.

Conceptual Foundations of Nanotechnology

Focusing on extremely small objects, nanotechnology is a relatively young interdisciplinary discipline of technology. The prefix 'nano' comes from the Greek word 'nanos', which means midget, indicating dimensions on the order of magnitude 10 -9. Scientists use this prefix to represent one billionth, or 10 × 9. One billionth of a meter is therefore equal to a nanometer (nm), one billionth of a second to a nanosecond, and so forth. One perspective on this size scale states that a nanometer is around one-hundred times smaller than a human hair's diameter, (Hunt & Mehta, 2006).

Taniguchi Norio, a Japanese scientist, coined the word 'nanotechnology' in 1974, but he did it in the far more specialized field of ultrafine machining. In his book *Engines of Creation: The Coming Era of Nanotechnology* (1986), Drexler portrayed the Feynman hypothesis as a technology that will revolutionize humanity in the future. He developed the term 'nanotechnology', He used in *Engines of Creation,* to refer to a technology that employed assemblers to precisely alter materials at the molecular level in order to produce particular products. According to Drexler, the terms 'nanotechnology' and 'molecular technology' should be used interchangeably (1986, p.5). He restates this vision in a 1990 'Afterword' where he writes: "We are traveling toward assemblers, toward an era of molecular manufacturing that gives thorough and affordable control of the structure of matter" (Drexler, 1990, p. 240). His 1995 work, *Nanosystems*, technically developed his main concept, which was to harness nanoscale methods of molecular assembly to create any chemical that would be valuable to humans (Gordijn & Cutter, 2014).

Definitions

There are several ways to define nanotechnology. Most of these are technological in nature and usually involve the construction of structures smaller than 100

nm, or about 100 times a millionth of a millimeter. As stated by the National Nanotechnology Initiative of the United States (NNI): "research and technology development at the atomic, molecular, or macromolecular levels, in the length scale of approximately 1 to 100 nm range, to provide a fundamental understanding of phenomena and materials at the nanoscale and to create and use structures, devices, and systems that have novel properties and functions because of their small and/or intermediate size" (Furber, 2008). Thus, it appears that this description identifies two prerequisites for nanotechnology. The first concerns scale: objects of a specific size are the focus of nanotechnology. 'Nano' stands for one billionth, and in the context of nanotechnology, that billionth is equivalent to a meter. The appropriate scales for atom size are nanometers. The second problem relates to novelty: nanotechnology must handle minor issues in a way that capitalizes on certain characteristics that are made evident by the nanoscale (Allhoff & Lin, 2008).

Nanotechnology is described by *The Oxford English Dictionary* as "the branch of technology that deals with dimensions and tolerances of less than 100 nanometres, especially the manipulation of individual atoms and molecules." Applications of nanotechnology can be found in many different scientific domains, such as molecular biology, organic chemistry, surface science, energy storage, molecular engineering, molecular physics, and microfabrication. This technology can be used to create new materials and gadgets that have a wide range of potential uses, including consumer goods, biomaterials, electronics, and medicine, thus the phrases 'nanomedicine' and 'nanoelectronics'. However, as is frequently the case with cutting-edge technologies, uses of nanotechnology have sparked a heated discussion among scientists, attorneys, and legislators, over ethical concerns (Voorde, & Jeswani, 2021).

The Applications of Nanotechnology

Nanotechnology is an interdisciplinary science and technology that requires rapid attention from several traditional knowledge disciplines. It can be applied in a variety of fields, including nanomaterials, nanochemistry, nanoelectronics, nanooptics, nano-production, nano-analysis, and nanobiology. This field is a subclassification of technology in physics, chemistry, biology, and colloidal science, as well as other scientific disciplines that concentrate on the investigation of phenomena and the control of materials at the micro-scale. The science, engineering, and technology of materials whose dimensions fall roughly between 1 and 100 nanometers, or the nanoscale, are considered to be within the vast topic of nanotechnology. It touches on physics, biology, engineering, medicine, and chemistry. In the upcoming decades, this multidisciplinary technology is expected to have a positive impact on security, wealth, and health. The main force behind the economy of the twenty-first century and beyond is believed to be this technology (Wako, 2019).

Chemical engineering, biology, robotics, electronics, and other industries can all benefit from nanotechnology. By using nanotechnology, doctors may treat diseases like diabetes, cancer, and heart disease with safer and more efficient drugs and detect ailments in their early stages. Furthermore, scientists are envisioning new technology that will defend individuals and army units from conventional and chemical weapons. While there are still a lot of unsolved scientific issues, nanotechnology is already producing a wide range of practical materials and showing signs of progress in many different industries. According to Mastanrao (2022), it has reduced scientific investigation down to the level of nanoparticles and offers a multitude of new possibilities.

Nanotechnology holds great promise for the development of numerous new materials and gadgets that could be used in the fields of engineering, medicine, information and communication, the environment, and energy. Some of the most urgent issues facing the globe may also be helped by this technology. The following is a quick rundown of the domains where nanotechnology is currently being developed or has ready-made applications:

Medicine and Health Care

The discipline of nanoscience and technology, known as nanomedicine, is very new. Utilizing nanoscale materials for tags and labels in biological tests facilitates rapid and effective testing that aids in early illness detection and prevention, diagnosis, treatment, and follow-up. Fluorescent labels are also utilized as biological detectors of proteins, cancers, and pathogens; they are also used to study DNA structure, medication delivery, tissue engineering, and other topics (Wako, 2019).

As the fourth industrial revolution, which includes robots, artificial intelligence, machine learning, the Internet of Things (IoT), 3D printing, and more, gets underway, nanotechnology will have a significant impact on how we live and how society functions. So many applications will be possible that we are unable to even begin to imagine them today. In medicine, vaccines based on nanoparticles might eventually offer long-lasting protection against influenza and the common cold. Nanoscale fabrication can be used to create artificial substitutes for bodily tissue, including muscles, tendons, skin, and even organs, imitating natural processes. Pharmaceutical products, including nanoparticles, will intelligently administer chemotherapy medications to particular cells, such as cancer cells (Voorde & Jeswani, 2021).

Environment

Environmental protection could be greatly impacted by nanotechnology through the understanding and management of emissions from a variety of sources, the creation of new green technologies that reduce the production of unwanted byproducts, and the cleanup of existing waste sites and contaminated water sources. Extremely

sensitive and quick measurements are possible using sensor equipment that is less expensive, bulky, and easy to use thanks to nanotechnology (Urmil, 2015).

Equity

The traditional division of nations into developed and developing ones presents a fresh point of debate. Development and technology indeed go hand in hand. Developing nations are particularly concerned about issues including poverty alleviation, energy, water, health, and biodiversity preservation. These nations would benefit from nanotechnology by improving the health and lifestyle of their populations. But putting any idea in this field into action is expensive, and most of the time, there are no funds available. Consequently, these advancements will help industrialized countries more than developing ones. Problems with equitable distribution will arise due to nanotechnology, and these problems will be more severe when it comes to the developing countries (Allhoff & Lin, 2008).

Privacy

The massive innovations that can be made by enhancing surveillance tools or other gadgets have the potential to compromise people's privacy. It is possible for someone to encounter invisible cameras and microphones. Guaranteeing privacy is a major challenge. Wireless monitoring enables patients and healthcare professionals to work on the move and share information as needed, but conversely there is an invasion of privacy. Indeed, new physiological sensors and wireless communication have a huge impact on e-health. The essential conversation about security and privacy is one point that must be made (Allhoff & Lin, 2008).

Security

There will undoubtedly be new and powerful weapons accessible shortly, including invisible cameras and microphones. Will this guarantee new security measures, or will it be included in a possible arsenal of bio-terrorism, techno-terrorism, or even nano-terrorism? In this regard, Mnyusiwalla et al. (2003) have raised questions about who will control the course of research in military nanotechnology for both offensive and defensive purposes. They ask to what extent will government and private NT programs need to be transparent in order to prevent abuses.

Invisible item ownership, control, and surveillance raise some fascinating legal issues as well (Ferreira & Filipe, 2018). Numerous applications of nanotechnology, such as threat detection, cyber security, and materials research, can improve security. If a cyber-attack occurs, materials with self-healing properties can instantly identify and fix the damage. Tiny devices called nano-robots can carry out particular activities at the nanoscale. Protection from both physical and cyber hazards can be offered by coatings and films made possible by nanotechnology.

Terrorism with biological and nuclear weapons

Biological weapons are a subset of a larger category of weapons known as unconventional weapons or weapons of mass destruction, which includes chemical, radioactive, and nuclear weapons. Biological agents such as anthrax, botulinum toxin, and plague can represent a significant public health challenge by inflicting a huge number of deaths in a short period of time (WHO, 2026). The use of biological agents is a serious concern, and the possibility of utilizing them in a terrorist assault is regarded as growing.

The use of biological agents against individuals will have particularly severe consequences if terrorists use germs transported from one person to another. This type of attack will produce inconceivable effects, compounded by the fact that, despite widespread awareness of the threat, only a few countries, cities, and villages are fully prepared for such an outbreak. It appears that, following the World Trade Center attack on September 11, 2001, the consequences of even a single, carefully executed biological attack may be too great to ignore (Michailiuk, 2016). The use of these weapons, even in a remote region, might contribute to the spread of infectious diseases in other countries, which is aided by rapid and widespread movements of people.

The anthrax cases that followed the terrorist attacks in New York and Washington, D.C., appeared to dramatically confirm the views of those who regard the question of whether terrorists can use biological weapons as closed, and who are only concerned with when and how such attacks will occur (Kelle & Schaper, 2003). Indeed, the use of anthrax raises the question of whether terrorist strategy and methods have undergone a paradigm shift, with biological weapons becoming a standard tool in the terrorist repertoire.

Moral Issues in the Field of Nanotechnology

The twenty-first century saw an increase in the cutting-edge scientific field of nanotechnology. Even though nanotechnology has permeated every aspect of contemporary life, little attention has been paid to its potential detrimental effects on ecosystems, human safety, and economic globalization. To maintain competitiveness that ensures international cohabitation, ethical considerations in the production and application of nanomaterials are crucial. The primary challenges are information transparency, environmental impact concerns, potential hazards, public trust, and responsible research in nanotechnology and nano science.

In nanotechnology, the manipulation of matter at the nanoscale, whether it be living or inanimate, is the fundamental principle. Because of this, the fundamental components of both fields can be combined in nano biotechnology. In addition to being practical and safe, nanotechnology must also win over the general audience. The public needs to be informed about the advantages, possible hazards, and

precautions that should be taken when using nanotechnology. Encouragement of public discussion is also necessary to assist individuals in developing their own opinions. Scientists should play a significant part in this effort by educating the public on the fundamentals and uses of nanotechnology (Baran, 2016).

When introducing nanotechnologies into practice, we may face moral difficulties coming from the necessity to inform the public. Given some of the unpredictable consequences of nanotechnology, it is difficult to provide users with relevant data, and it is not possible to impose a moratorium until we understand all the risks, because many countries have already invested heavily in the nano-tech industry. As a result, it is debatable how much unresearched innovation should be deployed and how to tell customers. In this perspective, it is vital to discuss the ethical aspect of nanotechnology, as its users will have the ability to alter their health or capacities (Markova, 2015).

Nanotechnology poses significant moral challenges due to the potential for unintended consequences resulting from the manipulation of matter at the atomic and molecular levels, such as harm to the environment, hazards to human health, the potential for misuse in weapons, and issues with equity and access to these technologies. Advanced technologies and communication have raised privacy concerns and the fear of biological weapons made with bio-nanotechnology. In addition, environmental issues emerge with the difficulty of decomposing nano-industry waste. Crops that have undergone genetic engineering need powerful insecticides and herbicides.

Although ethics and nanotechnology face many important challenges, human enhancement stands out as the most significant one. When discussing ethics and nanotechnology, the first thing that springs to mind is the question of human improvement. The term ‘human enhancement’ (Omidiji, 2008) refers to the use of technology to improve the human body and mind; it also covers issues like artificial intelligence and the length of human life. The ultimate objective of nanotechnology is to completely modify atomic and molecular structures, which both humans and nanotechnology share since they have the same fundamental components, thus, they can coexist in the field of nanotechnology in medicine, also known as nanomedicine. This, however, is not the same as using technology to treat human health issues. Nanomedicine raises serious ethical challenges due to worries about potential unintended consequences, unequal access to these cutting-edge treatments, the fundamental manipulation of human biology, and the difficulty in determining the long-term safety of nanomaterials within the body. These issues include patient autonomy, informed consent, and societal equity.

Nanotechnologies in testing are linked to more than just emerging moral dilemmas. Animal experimentation is a problem in nanomaterials research. It is

common practice to introduce various mechanisms into laboratory mice during studies on the effects of nanoparticles on an organism, causing pain or even death. The freedom of animals to live and exist pain-free is emphasized by animal rights activists, who protest such treatments. But scientists who have no other means of testing such medical devices without endangering people are being defended by their opponents.

The dilemma of a nano-scientist's intellectual property, which faces challenges with patenting, is another ethical concern. The possibilities of obtaining a patent are eliminated by the researcher's competitive desire to publish, especially in nations where there is no possibility to register a patent 6 – 12 months after the publication of results. Nanotechnology has a wide range of effects on employment and has the potential to both create and destroy jobs. It may have an effect on the need for skills and the global division of labor. It is anticipated that nanotechnology will affect almost every business. According to the U.S. National Science Foundation, the worldwide nanotechnology market is expected to grow to a value of at least $1 trillion in the next 20 years. The workforce's distribution across industries and geographical areas may be impacted by nanotechnology. Inequality between rich and developing nations may increase as a result. Developing nations may, therefore, see a brain drain as a result of nanotechnology.

Another moral dilemma surrounding the marketing of nanotechnologies is that they are a luxury enjoyed by the wealthy, who can afford better medical care and higher-quality goods. Justice is the most important moral principle in this situation, and standards for redistributing the benefits of nanotechnology must be established.

Nanotechnology in tracking devices, especially the nanoscale devices, leads to concerns of privacy invasion risks and the need for a new paradigm. In addition to tracking a person's location, a new kind of electronic card has made it possible to get health data more easily (Markova, 2015).

The significance of an interdisciplinary approach must be emphasized while addressing the ethical issues raised. Professionals from the fields of natural science and the humanities must collaborate on these issues. Physical, chemical, mathematical, biological, engineering, philosophical, ethical, economic, legal, and sociological interactions are therefore necessary. We define interaction as the comprehension of standard practices and the development of the specified field of nano ethics. Since the aforementioned issues fall under the purview of bioethics, science ethics, technology ethics, business ethics, and so on, it is challenging to define unified applied ethics in this context when addressing the nano-ethical dilemma (Markova, 2015). Since applied ethics are striving for the elaboration of a set of ethical methods, methodology, and tools related to practical use, they may

help ensure ethical standards in the use of nanotechnology during this process. Teaching and developing interdisciplinary and trans disciplinary methods for its endeavors and aspirants is a key scientific and pedagogical goal of applied ethics.

Nano ethics

The field of nano ethics is concerned with the creation of a global code of ethics for these matters. In nano ethics, we combine concepts and vocabulary from both philosophy and science to contribute to the improvement of our code of conduct (Haga, 2021). The three areas of nanotechnology where nano ethics directs societal thought are organization, protection, and direction. The three normative problems that are given focus are: (1) where to go and, thus, what to stimulate; (2) what should be protected and who should be able to actively defend it; and (3) how stimulation and protection might be combined in practice (Voorde & Jeswani, 2021). Additionally, normative answers are needed for these three normative questions. We contend that nano ethics must limit itself to the immediate ramifications of certain nanotechnologies to achieve its objectives and encourage social reflection on the influence of nanotechnology. As with nanotechnology, a broad viewpoint is required for nano-ethics.

The field of nano ethics developed in the context of critical reflection on nanotechnology. Voorde and Jeswani (2021) explain that nano ethics is an interdisciplinary endeavour to investigate ethical and social issues related to nanotechnologies in a philosophically rigorous and scientifically informed manner. It is not a pure philosophical ethics field, like other applied ethics fields (such as bioethics, agricultural ethics, or public health ethics). In doing so, it is not required to establish unique nanotechnology problems or for nano ethics to represent a distinct area of ethics. In nano ethics, certain nanotechnological advancements are connected to broader ethical concerns.

Recommendations for the Future of Nanotechnology

Nowadays, nanotechnology is a widely used term that has many possible future applications. It is a dynamic, multifaceted field with remarkable possibilities for implementation and expansions to new fields. According to the experts, nanotechnology offers potential uses in many different areas with important implications for biodiversity, national security, the atmosphere, and human well-being. However, many of us are unaware of the amazing impact it may have and, to some degree, already does on our daily lives (Voorde & Jeswani, 2021).

We may categorize future ethical concerns about nanotechnology into three groups: threats envisioned in our imagination, future alternatives in the distant future, and ethical problems anticipated in the upcoming years. Public anxiety can be divided into two groups: firstly, reflections in science fiction, which includes fears of uncontrollable robots and auto-replicating systems, and secondly, real-

world threats, such as new biological weapons, nanomaterial toxicity, molecularly naked patients, and invasions of privacy.

To address the impending ethical risks certain steps could be taken which are described below. Defining the topic and goal of nano-ethics is a crucial undertaking that ought to be the first step in resolving moral dilemmas related to nanotechnology. The same is true with nanotechnology, which is the outcome of multidisciplinary collaboration. It has sparked debates about whether nano ethics is a legitimate subfield of applied ethics that is both autonomous and multidisciplinary. The ethical issues of nanotechnology are qualitatively new, according to the concept's proponents (Markova, 2015). Haga (2021) emphasized that social morality is one of the concerns that nanotechnology must address. This is because nanotechnology has the potential to revolutionize human existence, yet the toxicity of nanomaterials has not been thoroughly established. Nano ethics is the study of social morality and ethics in the context of nanotechnology development. He argued that nano ethics is concerned with three types of challenges (Haga, p.343). The first category deals with individual rights in society, the second with global interactions, and the third with interactions between humans and other living things. Therefore, it is expected that establishing a framework in which the nano-manufacturing sector collaborates with government authorities to undertake risk assessments and disclose the results to society will help to facilitate nanotechnology-related social morality.

Regulation of nanotechnology and products derived from it is one of the suggested remedies for the moral dilemmas it faces. Current development of nanotechnology has prompted an increased awareness of the need for efficient regulatory frameworks. Presently there is no systematic classification for items that contain nanoparticles or that are the result of nano-processes, nor is there any comprehensive legislation to oversee such research and the commercial application of nanotechnologies. The question of who should be in charge of regulating nanotechnology is a matter of dispute. Although certain non-nanotechnology organizations now enforce the laws in place, there are gaps in their purview (Omidiji, 2008).

Researchers from a variety of disciplines are now studying nanotechnology. Since nanotechnology is a diverse field, there is no universally accepted set of ethical standards that these practitioners adhere to. Engineers and scientists have varied ideas on what ethics are; differing ideas are even produced by distinct scientific subfields. Codes of ethics are often a significant component of the professionalization process. Given the wide range of backgrounds among nanotechnologists, it is unclear how the area may develop a disciplinary identity and code of ethics.

Codes of ethics reflect the seriousness with which a group of professionals takes its goals and effects. The development of a discipline or a sub-discipline is significantly influenced by the rise of professional associations and standards

of ethics. They assist in giving a field of study a professional identity. Given its multiplicity, nanotechnology should be developed to meet the goals of the several other disciplines it encompasses. But this interdisciplinary cooperation also adds complexity and difficulty to the development or 'professionalization' (Shew, 2008) of this sector.

There are many opportunities to address some of the issues facing emerging nations thanks to nanotechnology. By using nanomaterials, we can improve healthcare quality, make it easier to extract natural resources, or raise living standards. The usage of nanotechnology could become reliant on a nation's level of wealth, which belongs to the second group of risks (Markova, 2015). Therefore, resolving the distributive justice issue is also becoming essential in a larger context. As poverty in emerging nations continues to rise, we may have to soon discuss ethical issues with nanotechnologies on a worldwide basis.

Conclusion

Nanotechnology is a dynamic, multidimensional field that demands immediate attention from several traditional knowledge disciplines. By its very nature, nanotechnology poses moral dilemmas, and these ethical issues are entirely new. Ethical considerations include independent and impartial risk assessment, privacy protection, autonomy, fairness, environmental effect concerns, and promoting respect for human dignity. Recognizing the ethical concerns involved undoubtedly helps with proper decision-making. Therefore, it is crucial that decision-makers understand these challenges, especially employers, employees, investors, and health authorities.

The manufacture and use of nanomaterials must take ethics into account in order to preserve competitiveness that guarantees global cohabitation. To encourage the ethical, sustainable, and economic development of nanotechnology, all scientists, engineers, and stakeholders working in the field must be aware of its long-term benefits, limitations, and risks. The development and commercialization of nanotechnology should involve every member of society because it will affect everyone. In this case, ethical considerations highlight the significance of nanotechnology to society and the potential repercussions that its advancement may have on humanity in the future.

The future use of nanotechnology will be guided and managed by the distinct ethical issues surrounding it. Since nanotechnology's moral implications are comparable to those of other cutting-edge technologies, there are opportunities to rethink how moral and societal issues might coexist with the many diverse forces propelling technical advancement, particularly in the field of nanotechnology. It is morally imperative for us to respond to the development of nanotechnology for the benefit of both the current and future generations. The ethical principles

of responsibility, obligation, duty, justice, fairness, and so forth are all involved in the development of nanotechnology. More than its drawbacks, we expect that nanotechnology will advance constructively and helpfully.

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