Chapter 1
Applications of Nanotechnology through the Ages: A Socio & Eco-critical Study for the Welfare of Humanity

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Abstract Nanotechnology is the use of matter on an atomic, molecular, and supramolecular scale for several scientific and industrial purposes. Recent developments in nanoscience and nanotechnology intend new and innovative applications in the various aspects of human lives. The exclusive qualities of non-materials enhance the approach that it can be used in a wide range of fields. The basic innovations that come from nanotechnology have the potential to contribute to the betterment of human health and environmental safety in numerous ways. It involves developed techniques and methods for pollution reduction, treatment of water, sensing of environmental issues, remediation, and ensuring the availability of alternative sources of energy in a more cost-effective and sustainable way. It appears in ancient Indian society being used in the field of medical science, for making weapons related to warfare, tools for agriculture, and work of goldsmiths. Today, it also lowers costs, produces stronger and lighter wind turbines, and improves fuel efficiency which saves energy. This work is the attempt to capture the nanotechnological development in India through the ages by highlighting and critically analyzing its impact upon society and environment. It has also been discussed that how the understanding and pursuing the old-world knowledge in conjunction with modern technological advances yield greater scientific knowledge for the benefit of environment and mankind.

Keywords Nanotechnology · Bhasma · Nanoscience · Environment · Nanoelectronics · Wootz steel · Nanomedicine

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1 Introduction

Human dreams and imagination often give rise to new science and technology. Nanotechnology, a twenty-first century, was born out of such dreams. Besides, human exposure to nanoparticles has occurred throughout human history; it has dramatically increased during the industrial revolution. The study of nanoparticles is not new. Nanosciences and nanotechnologies are leading to a major turning point in our understanding of nature. Such a force has its consequences or in the words of a famous fictional character: every force has its dark side. Our future depends on how we use new discoveries and what risks they bring upon humanity and our natural environment. The ethical implications of this must therefore be discussed. The unique properties of nanomaterials encourage the belief that they can be applied in a wide range of fields, from medical applications to electronics, environmental sciences, information and communication, heavy industries like aerospace, refineries, automobile, consumer, and sports good, etc.

It is a difficult subject to write about since compiling knowledge about nature that has not been recorded in an easily decipherable form, coupled with the possibility of some natural records having been lost during the long periods of history either by nature or by us, makes most information unavailable to us. We realized that apart from nature, human beings have also knowingly or unknowingly fabricated and utilized nanoparticles for various reasons. Looking back through history and searching for the existence of nanoparticles, not visible to the eye, nanotechnology, not yet known to us but seen in nature, has been an interesting journey for us.

It is a novel idea to write about nanotechnology in ancient periods. Since I have been a student of ancient Indian history and culture, it is difficult for me to review science, especially nanotechnology and its effect in ancient times. They have very lucidly described its application in prehistoric times. In ancient India, unknowingly as well as knowingly people have used it in the field of medicine, cosmetics, metallurgy, etc. Nanotechnology flourished in the Indian Civilization, Maya Civilization of South America and also in Roman culture.

The concept of a "nanometer" was first proposed by Richard Zsigmondy, the 1925 Nobel Prize Laureate in chemistry. He coined the term nanometer explicitly for characterizing particle size, and he was the first to measure the size of particles such as gold colloids using a microscope. In 1959, the physicist Richard Feynman, Nobel Prize winner for Physics in 1965, came up with the brilliant concept of the nano when he said "there is plenty of room at the bottom" during a conference of the American Physical Society.

The term "nano" which is one-billionth of a meter, originated from Greek word, "nanos" which means dwarf [1]. Nanotechnology can be defined as the technology used for design and synthesis of materials which is having at least one spatial dimension in non-orange, i.e., 1–100 nm (10–9 to 10–7 m). As mentioned above, the concept of nanotechnology was first put forward by physicist Richard Feyman in 1959 in his talk entitled "There's plenty of room at the bottom" [2]. New properties

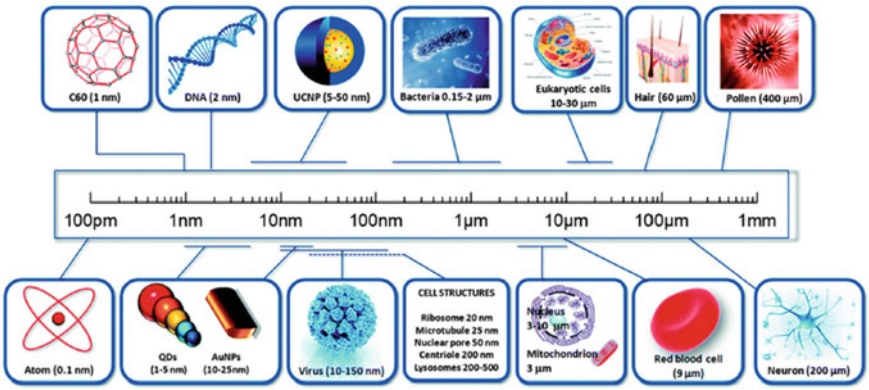

Fig. 1 Size of nanomaterial on scale

are incorporated to the matter at the nanoscale, which makes it suitable for the development of new products with new functions [3]. Nanotechnology may appear new in every aspects and a contemporary world's invention, but there are many historical references which claim that ancient India was well acquainted with this technology [4].

Nanotechnology is defined as the understanding and control of matter at dimensions between 1 and 100 nm, where unique phenomena enable novel applications. Nanoscience is the study of structures and molecules on the scales of nanometers ranging between 1 and 100 nm, and the technology that utilizes it in practical applications such as devices is called nanotechnology [5]. As a comparison, one must realize that a single human hair is 60,000 nm thickness and the DNA double helix has a radius of 1 nm [6] (Fig. 1).

The US National Nanotechnology Initiative defines the nanotechnology as: nanotechnology is the understanding and control of matter at dimensions of roughly 1–100 nm, where unique phenomena enable novel applications. Encompassing nanoscale science, engineering, and technology involves imaging, measuring, modeling, and manipulating matter at this length scale. According to the Japan: second Science and Technology Basic Plan (2001–2005) of Japan, nanotechnology is an interdisciplinary S&T that encompasses IT technology, the environmental sciences, life sciences, material sciences, etc. It is for controlling and handling atoms and molecules in the order of nanometer (1/1 000 000 000), enabling discovery of new functions by taking advantage of its material characteristics unique to nano-size, so that it can bring technological innovation in various fields.

2 Classification of Nanotechnology

Nanomaterials can be vastly classified as naturally occurring and man-made nanomaterials. Materials such as viruses, proteins, nucleic acids fall under the naturally occurring materials. The materials that are anthropogenic could be produced unintentionally from combustion of hydrocarbons or through a defined synthesis procedure. Nanotechnology basically deals with intentionally produced nanomaterials. "Moreover, nanomaterials are also present in nature in the form of various minerals produced by erosions and volcanic eruptions, in the multilayered nano- structures in the butterfly wings and feet of gecko, and the epicuticular wax crystal structures on lotus leaf surface" [7].

3 Evolution and Continuity of Nanotechnology

While nanosciences seem to be a new research field which appeared only in these past decades, it must be noted that chemical synthesis of metallic nanoparticles has been performed since a long time. Indeed, scientists have analyzed a lot of antiquities, for which the unusual colors have been attributed to the presence of metallic nanoparticles.

Though the development of electron microscopic techniques has been largely responsible for the dynamic growth in this sector, there have been records on the use of nanomaterials from the ancient times. Nanoparticles were primarily used as colorants in tumblers, ornamental glassware, and medieval paintings. "Thus, the use of metallic nanoparticles seems to have started with the beginning of glass-making in Egypt and Mesopotamia back in the fourteenth and thirteenth centuries BCE. Indeed, the red color of some glasses is explained by the presence either of metal copper nanoparticles or of cuprous oxide nanoparticles, as revealed by several chemical analyses performed on these ancient pieces" [8]. Antimony is almost always present: Generally used as opacifier, it could have also non-deliberately served as a reducing agent, allowing the formation of copper nanoparticles from cupric ions. Such pieces with copper nanoparticles have been found in this region until the sixth century BCE.

The most iconic example of the use of nanotechnology in ancient artifact is the Lycurgus Cup dating from the fourth century CE, showing a mythological frieze depicting the legend of Roman King Lycurgus and exposed in the British Museum in London (Fig. 2). "The most remarkable aspect of this cup relies on its dichroism: the cup resembles jade with an opaque greenish-yellow tone when it is illuminated from outside—reflected light—whereas the cup turns to a translucent ruby color when it is illuminated from inside—transmitted light" [9].

In India, the concept of reduction in particle size of precious metals has been prevalent since ancient times. It is clearly evident from the oldest classical text in

Fig. 2 Lycurgus Cup, illuminated from outside (left) or from inside (right) Trustees of the British Museum

Aryuveda, "Charak Samhita". "Bhasmas are unique herbo-metallic/mineral formulation, prescribed in very minute dosage for treatment of variety of chronic diseases since seventh century. These are nontoxic, easily digestible and absorbed in the body" [10]. Bhasmas, an ash, is claimed to be biologically produced nanomaterials. These are prepared by purification of starting material (process is known as shodhana) followed by the incorporation of mineral/herbal extracts in the next step, i.e., reaction phase [11]. The material prepared in pallet form is further subjected to incineration to obtain a nontoxic, lustureless ash, known as bhasma. Swarna ash (gold bhasma) has been characterized to contain particle size of 56–57 nm. "The bhasmas are useful in maintaining optimum alkalinity in body, stronger bones & teeth, maintaining mineral balance and metabolizing iron in body etc. Lauha bhasma (Iron) is documented to possess good potential as therapeutic agents" [12].

Chemistry's Noble Laureate Robert Floyd Curl Jr. (1996) explained that the concept of nanotechnology was utilized over 2000 years ago in India by the craftsmen in the manufacturing of **Wootz steels** and paintings. Carbon nanotubes and cementite nanowires have been found in a sample of Wootz steel with the aid of high-resolution microscopy. "Wootz steel was manufactured by unique smelting process, which led to nanotization, giving it a long-lasting edge. It also had 1.5% carbon, incorporated by wood and organic matter, during fabrication. The presence of these nanostructures has high impact upon mechanical properties" [13]. It can be clearly seen in the reference made to the sword of Tipu Sultan, an eighteenth-century king of Southern India, where the strength of sword can now be explained by nanotechnology [14]. Carbon nanotubes were also found in Ajanta paintings. These nanotubes are cylindrical fullerenes with extraordinary strength in terms of elastic modulus and tensile strength (Fig. 3).

Fig. 3 Wootz steel sword

According to Robert Floyd Curl Junior, Indian craftsman used nanotechnology in Wootz steel as well as in paintings. In 1952, Russian scientists told about carbon nanotubes, but they were present in sword of Tipu Sultan as well as in Ajanta paintings. Curl also claimed in 95th Indian Science Congress that Indian ancestors have been using this technology for over 2000 years and carbon nanotubes for about 500 years. Indian craftsman used unique smelting techniques to manufacture the Damascus blades which led to nanotization giving them a unique long-lasting edge. Wootz also had a high parentage of carbon, which was introduced by incorporating wood and other organic matter during fabrication. India, for ages, was a leading exporter of this steel which was used to make Persian daggers which were quite popular in Europe.

4 Nanomaterials in Medicine

Various nanomaterials were being used extensively by humans for several centuries, and they have been found in nature in inanimate as well as in various animals, insects, and plants. These natural nanostructured materials can help us understand their amazing properties and help us in gaining inspiration for designing and engineering high-performance materials. With the advent of electron microscopy and various synthetic approaches, nanotechnology is finding itself growing at a very fast rate [15].

Ayurveda, the science of life, was established and developed over thousands of years ago. Ayurveda works on the principle that mind and body are connected, and it is one of the most sophisticated and powerful holistic healing systems in the world. The Ayurvedic records can be traced back to 5000 BCE. It is considered to be an auxiliary knowledge in Vedic tradition. "The origin of Ayurveda is said to be found in Atharvaveda as well. It is also believed that Sage Agnivesha is the founder of Ayurveda and all his research is compiled in Agnivesa Samhita. Charaka, a physician in 300 BC, simplified Agnivesha's compilation and popularized it. Sushruta, an ancient Indian physician, also known as the father of surgery, authored a treatise titled Susruta Samhita. Susruta Samhita is considered to be the institutional text for Ayurveda" [16]. Very accurate and detailed surgical accounts have been be found in this epic treatise. Nagarjuna is credited with updating the Sushruta Samhita. Atreya Punarvasu, one of the great Hindu sages, was a renowned Ayurvedic scholar, and it is believed that the six branches of early Ayurveda are based on his teachings. He is credited as the author of Bhela Samhita [17]. The Charaka Samhita, the Sushruta Samhita, and the Bhela Samhita are the three principle early texts on Ayurvedic practice. Ayurveda burgeoned during the Middle Ages in India. The works of Charaka and Sushruta were translated into Chinese and Persian languages. These translational were found to have influenced various European schools of medicine as well [18].

Nanotechnology, in current state, is a revolutionary technology, so profound that it touches all parts of human society. The properties of nanomaterials differ significantly from bulk material. Nanoparticles possess enhanced structural integrity as well as unique optical, chemical, electronic, magnetic, and mechanical properties owing to which nanomaterials have become significant in recent years. Newly synthesized nanoproducts are coming to market rapidly for the betterment of our society, human health, and environment.

5 Nanoscience: Human Health

A fair assessment of the risks of any new technology must also consider positive contributions to increased safety. The basic innovations that come from nanotechnologies have the potential to contribute to human health and environmental safety in many ways. "They have the potential to contribute to solve urgent issues like the provision of clean drinking water or more efficient energy conversion and energy storage. The potential of nanotechnologies regarding economic benefits, the potential to create jobs, wealth and wellbeing is very high. At the moment, public awareness about nanotechnology is limited. What happens over the next few years will determine how the public comes to view it. A transparent discussion of benefits and risks will help people reach a considered, balanced view. This will enable a greater public acceptance, which, in turn, will enable society as a whole to profit from these fundamental technological developments while, at the same time, the risks are kept under control. Especially in the field of medicine there are quite a few technological developments that promise enhanced diagnostic possibilities, new ways to monitor

patients, new ways to treat diseases like cancer and to reduce side effects." To give a few examples:

- Nanoparticles can be used as carriers for targeted drug delivery. Their ability to penetrate certain protective membranes in the body, such as the blood brain barrier, can be beneficial for many drugs.
- This could open the way for new drugs from active substances that have not been able to pass clinical trials due to less precise delivery mechanisms.
- Nanosensors and lab-on-a-chip technologies will foster early recognition and identification of diseases and can be used for continuous monitoring of patients with chronic diseases.
- New therapeutic methods for the treatment of cancer with the help of nanoparticles are investigated.

Ultrasensitive detection of substances will have implications for safety in many other areas such as in the industrial medicine, environmental medicine, and food safety. To give one example: It has recently been shown that bacterial pathogens can be detected in very low concentrations with the help of nanoparticles. Quick and accurate testing is crucial for avoiding potential infections, but in order to be effective, many current tests require time-consuming amplification of samples.

6 Nanotechnology and the Environment

As nanotechnologies move into large-scale production in many industries, it is a just a matter of time before gradual as well as accidental releases of engineered nanoparticles into the environment occur. The possible routes for an exposure of the environment range over the whole life cycle of products and applications that contain engineered nanoparticles:

- Discharge/leakage during production/transport and storage of intermediate and finished products.
- Discharge/leakage from waste.
- Release of particles during use of the products.
- Diffusion, transport, and transformation in air, soil, and water.

Some applications like cosmetic products or food ingredients will be diffused sources of nanoparticles.

In addition, certain applications such as environmental remediation with the help of nanoparticles could lead to the deliberate introduction of nanoparticles into the environment. This is an area which will probably lead to the most significant releases in terms of quantity of nanoparticles in the coming years.

The main criteria used to assess the risks of chemicals for the environment and indirectly for human health are toxicity, persistence, and bioaccumulation. Substances that can cause direct damage to organisms (high toxicity) that decay in very slow

environment (high persistence) and that can concentrate in fatty tissues (high potential for bioaccumulation) are of particular concern. For engineered nanoparticles, the particular characteristics of nanomaterials will have to be considered for a specific risk assessment. The existing information about properties of the bulk material will not be sufficient to classify the environmental risk of the same material in the form of nanoparticles. "The possible environmental effect will therefore have to be assessed specifically for each type/class of nanomaterial. Only few studies on this very complex subject exist. From a scientific point of view, the results should be seen as indications rather than a sound basis for decision making".

"In the first study on the toxic effects of manufactured nanoparticles on aquatic organisms, fish (largemouth bass) were exposed to uncoated fullerene carbon-60 (C60) nanoparticles [19]. The fullerenes are one type of manufactured nanoparticle that is being produced by tons each year. Significant lipid peroxidation (oxidation of fats) was found in the brain of the animals after exposure to 0.5 ppm uncoated nC60. The study demonstrates that manufactured nanomaterials can have adverse effects on aquatic and possibly other organisms. Nanoscale iron particles have been investigated as a new generation of environmental remediation technology [20]. Due to their high surface reactivity and large surface area they can be used to transform and detoxify environmental contaminants like PCBs. Field tests in the US have shown that the nanoparticles remain reactive in soil and water for several weeks and that they can travel in groundwater as far as 20 m. The risks associated with free nanoparticles on ecosystems was not discussed in the original publication, but should be looked at in sufficient detail before environmental applications are brought to the market."

The Royal Society has called for the prohibition of the use of free nanoparticles in environmental applications until appropriate research has been undertaken. "A very specific environmental issue in the case of nanoparticles is their propensity to bind with other substances, possibly toxins in the environment such as Cadmium. Their high surface area can lead to adsorption of molecular contaminants. Colloids (natural micro- and nanoparticles) are known for their transport and holdings capacity of pollutants. The adsorbed pollutants could possibly be transported over longer distances/periods of time by nanoparticles. On the other hand, nanoparticles are less mobile than we intuitively might think. It seems that their movement is very case specific and that that are generally less mobile than larger particles. Here again their large surface area and their maximized chemical interaction comes into play. Their sticky nature considerably slows their transport through porous media like soil. In summary, the information about nanoparticles and the environment is only at an early stage. Among the research needs, there are topics like the effect of nanoparticles on species other than humans, about how they behave in the air, water or soil, or about their ability to accumulate in food chains." Taking into account the high number of parameters that characterize nanoparticles (like size, shape, specific surface treatment, chemical composition) as well as the variety of nanoparticles, it will need considerable research efforts to close the knowledge gaps. For cost-efficient and quicker results, harmonization of research is required that focuses on the most important materials and parameters and to concentrate on nanoparticles that are more likely to be produced.

By the summarizing the knowledge and awareness about nanotechnology, the evidences from past prove that ancient India was familiar with the manufacturing of nanomaterials, although they were unaware of the term nanotechnology. In this discussion, we can observe that the nanotechnological development in India through the ages was well established and profound. Its impact upon society and environment and the various initiatives are undertaken by the establishment from time to time to promote basic awareness and applications of nanotechnology in a sustainable approach and emphasizing the forthcoming opportunities for its application in the natural environmental systems. It has also been discussed that how the understanding and pursuing the old-world knowledge in conjunction with modern technological advances yield greater scientific knowledge for benefit of the environment and mankind. In today's world, nanotechnology is an emerging scientific field which has the potential to radically generate new products and processes by using nanomaterials and characterize the use of sophisticated instruments.

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