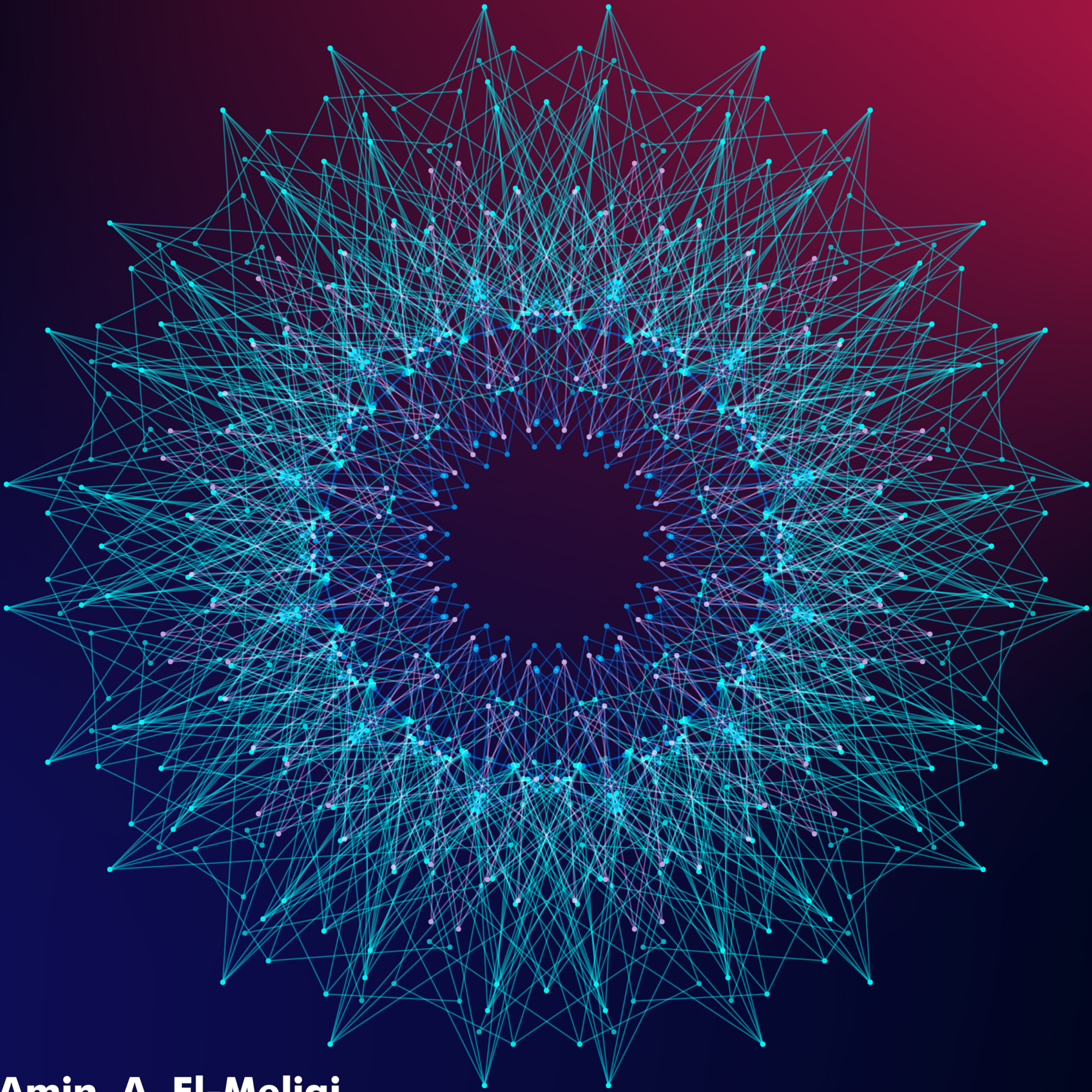
THE ART OF NANOMATERIALS



Amin. A. El-Meligi

Bentham Books

The Art of Nanomaterials

Authored by

Amin. A. El-Meligi

Physical Chemistry Department
Advanced Materials Technology &
Mineral Resources Research Institute
National Research Centre, Egypt

The Art of Nanomaterials

Author: Amin. A. El-Meligi

ISBN (Online): 978-1-68108-970-6

ISBN (Print): 978-1-68108-971-3

ISBN (Paperback): 978-1-68108-972-0

Published by Bentham Science Publishers Pte. Ltd. Sharjah, UAE.

First published in 2022.

BENTHAM SCIENCE PUBLISHERS LTD.

End User License Agreement (for non-institutional, personal use)

This is an agreement between you and Bentham Science Publishers Ltd. Please read this License Agreement carefully before using the ebook/echapter/ejournal (**"Work"**). Your use of the Work constitutes your agreement to the terms and conditions set forth in this License Agreement. If you do not agree to these terms and conditions then you should not use the Work.

Bentham Science Publishers agrees to grant you a non-exclusive, non-transferable limited license to use the Work subject to and in accordance with the following terms and conditions. This License Agreement is for non-library, personal use only. For a library / institutional / multi user license in respect of the Work, please contact: permission@benthamscience.net.

Usage Rules:

1. All rights reserved: The Work is 1. the subject of copyright and Bentham Science Publishers either owns the Work (and the copyright in it) or is licensed to distribute the Work. You shall not copy, reproduce, modify, remove, delete, augment, add to, publish, transmit, sell, resell, create derivative works from, or in any way exploit the Work or make the Work available for others to do any of the same, in any form or by any means, in whole or in part, in each case without the prior written permission of Bentham Science Publishers, unless stated otherwise in this License Agreement.
2. You may download a copy of the Work on one occasion to one personal computer (including tablet, laptop, desktop, or other such devices). You may make one back-up copy of the Work to avoid losing it.
3. The unauthorised use or distribution of copyrighted or other proprietary content is illegal and could subject you to liability for substantial money damages. You will be liable for any damage resulting from your misuse of the Work or any violation of this License Agreement, including any infringement by you of copyrights or proprietary rights.

Disclaimer:

Bentham Science Publishers does not guarantee that the information in the Work is error-free, or warrant that it will meet your requirements or that access to the Work will be uninterrupted or error-free. The Work is provided "as is" without warranty of any kind, either express or implied or statutory, including, without limitation, implied warranties of merchantability and fitness for a particular purpose. The entire risk as to the results and performance of the Work is assumed by you. No responsibility is assumed by Bentham Science Publishers, its staff, editors and/or authors for any injury and/or damage to persons or property as a matter of products liability, negligence or otherwise, or from any use or operation of any methods, products instruction, advertisements or ideas contained in the Work.

Limitation of Liability:

In no event will Bentham Science Publishers, its staff, editors and/or authors, be liable for any damages, including, without limitation, special, incidental and/or consequential damages and/or damages for lost data and/or profits arising out of (whether directly or indirectly) the use or inability to use the Work. The entire liability of Bentham Science Publishers shall be limited to the amount actually paid by you for the Work.

General:

1. Any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims) will be governed by and construed in accordance with the laws of the U.A.E. as applied in the Emirate of Dubai. Each party agrees that the courts of the Emirate of Dubai shall have exclusive jurisdiction to settle any dispute or claim arising out of or in connection with this License Agreement or the Work (including non-contractual disputes or claims).
2. Your rights under this License Agreement will automatically terminate without notice and without the

Bentham Science Publishers Ltd.
Executive Suite Y - 2
PO Box 7917, Saif Zone
Sharjah, U.A.E.
Email: subscriptions@benthamscience.net

CONTENTS

FOREWORD

“The evolution and widespread use of nanotechnology in many facets of everyday life is a fascinating story. The unique physical and chemical properties of materials at the nanoscale allow them to be utilized in ever-growing new applications. We most likely encounter nanomaterials in our daily life unknowingly. The book by Dr. Amin El-Meligi takes the reader through the history of nanomaterials from their appearance in the arts of the ancients, methods of fabrication, and their current utility in medicine and the environment. The author dedicates a chapter to the use of nanomaterials in medicine and the side effects of their use. Dr. El-Meligi also writes on water treatment by nanomaterials as well as the contamination of the environment by nanomaterials such as nanoplastics. The book concludes with a future look into nanotechnology and how it will transform human life. The book is a good read and a reference for researchers and students alike.”

Yehia M. Ibrahim, Ph.D.
Senior Scientist
Biological Sciences Division
Pacific Northwest National Laboratory
Washington
USA

PREFACE

The evolution of nanotechnology started in the middle of 20th century. As stated, the ideas and concepts behind nanoscience and nanotechnology started with a talk titled “There's Plenty of Room at the Bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechnology was used”. Nanotechnology appeared in the art of ancient Egyptian. The beautiful pictures of ancient Egyptians have been discovered with fine, gorgeous blue and other colors. It is important to say that there is an art behind the formation of nanomaterials and their applications in nanotechnology revolution. Nanotechnology applications include many aspects, such as materials protection and environmental protection. Nanomaterials are the backbone of nanotechnological applications. Nanomaterials are characterized by their small grain sizes (1-100 nm) and high volume fraction of grain boundaries, which often give rise to unique physical, chemical and mechanical properties compared with those of their cast counterparts. It can be said that corrosion protection relies on the improvement in the properties of the materials due to nanostructure. Nanomaterials are the basis for nanotechnology. The theme of nanotechnology is the control of matter on an atomic and molecular scale. The application of nanotechnology is confirmed in many fields, such as medicine, cosmetics, lubricants, coats, water purification, environmental protection, and corrosion prevention of metals and alloys. The nanostructures enhance selective oxidation, forming a protective oxide scale with superior substrate adhesion. Nanomedicines have been produced for more efficient healing, nanocosmetics have been developed for highly efficient look, nanolubricants have been developed to increase the efficiency of car parts friction, *etc*. A polymer nanocomposite coating can effectively combine the benefits of organic polymers, such as elasticity and water resistance to that of advanced inorganic materials, such as hardness and permeability. The art of nanomaterials and nanotechnology continues to produce more products for better life, and who knows what will be in the near future. New materials may appear with smaller sizes of atoms than nanosizes such as picomaterials followed by picotechnology. Reaching femto second (10-15 sec) time may support this idea.

Amin A. El-Meligi
Professor of Physical Chemistry
Physical Chemistry Department
Advanced Materials Technology &
Mineral Resources Research Institute
National Research Centre
Egypt

CHAPTER 1

History of Nanomaterials and Nanotechnology

Abstract: The secret of nanomaterials is not the size of the particles, but it is in the applications of nanomaterials and the art of making. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is an amazing field dealing with very small size particles; imagine that a meter of cloth has been cut into a billion pieces (1 meter $=10^9$ nm). Thousands of years ago, the monuments were fabricated and reflected the art and coloures of paints. The Egyptian monuments reflect the beauty and art of paints in the papyrus papers, for example, the ancient pigment known as Egyptian blue may have important new applications in nanotechnology. Lotus flowers were once considered sacred in Egypt and parts of Asia. Significant advances in nanotechnology are helping researchers analyze the type of pigments used to paint mummy portraits in ancient Egypt. Scientists at Boise State University led by a Materials Science and Engineering Professor Darryl Butt, have taken a sliver of wood smaller than a human hair and extracted five extraordinarily tiny fragments—about 20 nanometers wide—and two thin foils of purple paint from a Romano-Egyptian mummy portrait dating to between A.D. 170 and 180. There is a new challenge facing the world, especially in the field of nanotechnology. It was stated by James Canton (2001) that if Nanotechnology, the manipulation of matter at the atomic level, at maturity achieves even a fraction of its promise, it will force the reassessment of global markets and Economies and industries on a scale never experienced before in human history. Nanotechnology will be discussed from all aspects of economics such as wages, employment, purchasing, pricing, capital, exchange rates, currencies, markets, supply and demand. Nanotechnology may well drive economic prosperity or at the least be an enabling factor in shaping productivity and global competitiveness.

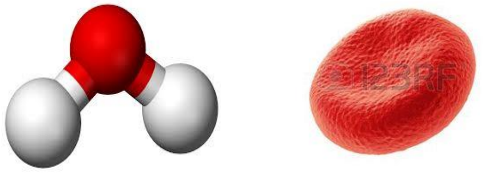
Keywords: Ancient Egyptian, History of Nanomaterials, Nanotechnology, Nanotechnology and Economy, Romano-Egyptian Mummy.

INTRODUCTION

The story of nanotechnology started in the middle of the twentieth century, as stated: the ideas and concepts behind nanoscience and nanotechnology started with a talk titled “There's Plenty of Room at the Bottom” by physicist Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959, long before the term nanotechno-

Amin El-Meligi

logy was used [1]. Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. It is an amazing and very small size; imagine that a meter of cloth has been cut into a billion pieces (1 meter $=10^9$ nm). We can imagine a number of common materials when they are in a nanosize, for example, a water molecule (H_2O) is 0.3 nm across, 10 hydrogen atoms lined up is measured at about 1 nm, a grain of sand is 1 million nm, a red blood cell is nearly 7,000 nm wide, and DNA molecules are 2.5 nm wide, as shown in Fig. (**1**) [2].



(a) Water molecule (b) Red blood cell

Fig. (1). (a) Source: http://en.wikipedia.org, **(b)** Source: http://www.123rf.com [2].

Feynman said People tell me about miniaturization, and how far it is progressed today. They tell me about the electric motors that are the size of the nail in your small finger. And there is a device in the market, they tell me by which, you can write Lord's Prayer on the head of a pin. But that is nothing; that's the most primitive, halting step in the direction I intend to discuss. It is a staggeringly small world that is below. In the year 2000, when they look back at this age, they will wonder why it was not until the year 1960 that began seriously to move in this direction. Why cannot we write the entire 24 volume of Encyclopedia Britannica on the head of a pin [1].

Nanoscience and nanotechnology involve the ability to follow and control individual atoms and molecules. Food, clothes, buildings, homes, and our bodies are made of atoms. About 30 years ago, the nanotechnology era emerged . As stated by Ashby *et al*., Imagine dissociating a human body into its most fundamental building blocks. We would collect a considerable portion of gases, namely hydrogen, oxygen, and nitrogen; sizable amounts of carbon and calcium; small fractions of several metals such as iron, magnesium, and zinc; and tiny levels of many other chemical elements. The total cost of these materials would be less than the cost of a good pair of shoes. Are we humans worth so little? Obviously not, mainly because it is the arrangement of these elements and the way they are assembled that allow human beings to eat, talk, think, and reproduce. In this context, we could ask ourselves: What if we could follow nature and build whatever we want, atom by atom and/or molecule by molecule? [3].

As presented in Wikipedia "The emergence of nanotechnology in the 1980s was caused by the convergence of experimental advances such as the invention of the scanning tunneling microscope in 1981 and the discovery of fullerenes in 1985, with the elucidation and popularization of a conceptual framework for the goals of nanotechnology beginning with the 1986 publication of the book Engines of Creation" [4].

Art of Nanosize

The formation of nanosizes is an art. (Fig. **2**) represents that "medieval stained-glass windows are an example of how nanotechnology was used in the pre-modern era" [4]. Nanomaterials have outstanding mechanical and physical properties due to their fine grain size and high grain boundary [5]. It is stated that Nanotechnology is extremely diverse, ranging from novel extensions of conventional device physics, to completely new approaches based upon molecular self-assembly, to developing new materials with dimensions on the nanoscale, even to speculation on whether we can directly control matter on the atomic scale) [6 - 8].

Fig. (2). Medieval stained-glass windows show the application of nanotechnology in the pre-modern era. (Courtesy: NanoBioNet) [4].

In 2009, Japan's National Institute of Industrial Science and Advanced Technology reported the manufacture of a nanometer-sized "diamond ruler" [9]. The art of nanosize has reached the minimum-scale 0.2 nm by utilization of the crystal structure of diamond.

In 2003, Risch L., a German researcher, developed nanoelectronics research leading to nanodevices, and a nano-transistor (Field-Effect Transistor) that has a gate length of 10 nm [9, 10].

The Chinese National Super Fine Powder Engineering Centre and Shanghai Joatong University have declared their breakthrough with "Nanoair Purifier" that kills germs through optic catalysis, ultraviolet rays, and dust removal [9].

The Infineon Technology AG, Germany, scientists and researchers had developed carbon nanotubes to manufacture power semiconductors. This first carbon nanotube can control light emitting diodes (LEDs) or electric motors [9, 11].

Japan's Toray Industry Inc. developed the world's first film-forming technology. This technology is designed to be used for high-precision lamination of several different types of polymers with molecular arrangements up to several nanometers thick [9].

Ancient Egyptians (Pharaohs) and Nanotechnology

As stated, the rebirth color of the ancient Egyptians was blue. "Today their chemical invention of artificial lapiz lazuli means new advances for lights, lasers and more" [12]. "Researchers at the University of Georgia in Athens, Georgia in the US were surprised to discover that Egyptian blue breaks into thin nanosheets, 1/1000th the width of a human hair which could be printed using ordinary ink-jet printer techniques, as shown in Fig. (**3**). This along with other Egyptian blue properties may have important applications in medical science, telecommunication and lasers" [13].

Fig. (3). The ancient Egyptian blue relates to nanotechnology application [13].

The earth tones of 15,000 year-old cave paintings were created with natural pigments of yellow and red ochre clay, soot, berries, animal parts and blood. Most of the world's languages did not have a word for the color blue 5000 years ago when, before Egypt's fourth dynasty, a crafty Alchemist heated copper, sand and natron. The resulting powder is composed of tiny crystals of calcium copper silicate ($CaCuSi_4O_{10}$)

The Egyptian word for this substance was hsbd-iryt which means artificial lapiz lazuli. Before the discovery of the Egyptian blue, the precious stone lapis lazuli had to be crushed in order to reproduce the colors of the rebirth, irtiu and khshdj.

The color of the heaven, the phoenix, the primeval flood, and the Nile was Egyptian blue. The Greco-Roman scientist adapted Egyptian blue, as shown in Fig. (**4**). The secret of its manufacture was lost during the fourth century A.D. and rediscovered more than 1400 years later by Sir Humphrey Davy of England [13].

Fig. (4). Lotus flowers were once considered sacred in Egypt and parts of Asia. They hold a secret to a clean nanotechnology [12, 13].

Like the ancient blue pigment found in ancient Egypt, old spiritual materials like the lotus flower inspire new environmental science, as shown in Fig. (**4**): "As an assistant professor of Environmental Sciences and Engineering at King Abdulla University of Science and Technology (KAUST)", Dr. Peng Wang seems to embody this Saudi Arabian university's motto, "Through Inspiration, Discovery". His research focuses on the possible uses of environmental nanomaterials in order to solve three of the biggest environmental problems of our time; water scarcity, energy production and pollution. Wang seems to enjoy the fine tuning of the size and form of these tiny materials in order to solve what sometimes seem to be intractable environmental problems [12, 13]. He says, “On a personal note, there is always a lot of fun working with these very tiny materials. Who wouldn’t enjoy studying the lotus effect, pore size modulation and superhydrophobicity? The following is a brief explanation of how environmental nanomaterials can help solve real-world problems”.

Significant advances in nanotechnology are helping researchers analyze the type of pigments used to paint mummy portraits in ancient Egypt. Scientists at Boise State University, led by a Materials Science and Engineering Professor Darryl Butt, have taken a sliver of wood smaller than a human hair and extracted five extraordinarily tiny fragments—about 20 nanometers wide—and two thin foils of purple paint from a Romano-Egyptian mummy portrait dating to between A.D. 170 and 180. “So far we've learned that the paint is a synthetic pigment,” says Butt. “These are very vibrant pigments, possibly heated in a lead crucible. People thought that the process had been developed in the 1800s or so. This could prove it happened a lot earlier.” It is also possible that by understanding more about the pigment, scholars may also be able to learn more about the identity of the deceased, who is currently known only as “Bearded Man.” [14].

Nanomaterials for Artifacts Conservation

As stated, “unique work of arts is indeed an integral part of what makes culture and history so fascinating, and their trade weighs quite heavily in today's economies” [9]. In 2013, the global art market generated approximately EUR 47.42 billion, according to the European Fine Art Foundation [10].

The dispersion of calcium hydroxide nanoparticles in short chain alcohols is for the consolidation of wall paintings, plasters and stone. The artefacts are strengthened without altering their physico-chemical properties [9, 11].

The dispersion of alkaline nanoparticles in short-chain alcohols or water is for pH control for transferred artworks such as paper, parchment, and leather. This material is extremely useful for reducing acid and oxidative deterioration of manuscripts and archives/historical documents [9, 11].

Nanostructured cleaning fluids such as oil-in-water microemulsions have been used to remove unwanted dirt and paint in the artwork. One of the main advantages of using these fluids is that they exhibit a low environmental toxicity impact relative to conventional solvent blends, while still providing high cleaning efficacy [9, 11].

Finally, chemical gels have been developed to deliver and control the release of cleaning fluids on water-sensitive surfaces such as paper, parchment, and leather.

These gels are applied without leaving a residue on the crafts surface, unlike conventional "gel-like" thickeners [9, 11].

Nanotechnology and World Economy

There is no doubt about the significant impact of nanotechnology on the global economy. In fact, the development of materials from the microscopic to the nanoscale requires more research facilities. Therefore, the research budget is crucial in developing high-quality nanomaterials. The high-quality nanomaterials will produce high-quality products. We are in the era of nanotechnology and there is a rapid change in the production of nano products in many industrial sectors, such as nanomedicine, nanolubricants, nanofluides, nanocloth, nanodyes, nanopaints, nanocosmetics, *etc*. As mentioned, the world economy has grown fast in the area of information technology.

There is a new challenge facing the world, especially in the field of nanotechnology. It was stated by James Canton (2001) that "if Nanotechnology, the manipulation of matter at the atomic level, at maturity achieves even a fraction of its promise, it will force the reassessment of global markets and economies and industries on a scale never experienced before in the human history. Nanotechnology will touch all aspects of economics: wages, employment, purchasing, pricing, capital, exchange rates, currencies, markets, supply and demand. Nanotechnology may well drive economic prosperity or at the least be an enabling factor in shaping productivity and global competitiveness".

Also, Canton has said "we are in the midst of a large-system paradigm shift driven by the accelerated exponential growth of new technology. We are witnesses to a faster, more comprehensive change shaped by the new technology than any civilization in the history. This is but the beginning of a new wave of technologies, such as nanotechnology, that will redefine, reshape and eventually transform economies and societies on a global scale. Nanotechnology is a continuation of the next chapter in the acceleration of advanced technology and, perhaps more importantly, it may point towards the transformation of the future global economy. Nanotechnology may become an essential large-systems strategic competency that will require coordination among all sectors of society in order to become a force for enhanced social productivity" [15].

Nanotechnology has shown a great effecton economy. As estimated, German nanotechnology sector generated 33 billion Euros in 2007 and approximately 63,000 total employers have been employed in this sector [9]. In the United State, $ 2.95 trillion dollar was considered the market value of nanotechnology in 2015.

"Announcing the US National Nanotechnology Initiative (NNI) in 2000, President Bill Clinton declared: Imagine the possibilities: materials with ten times the strength of steel and only a small fraction of the weight - shrinking all the information housed at the Library of Congress into a device the size of a sugar cube - detecting cancerous tumors when they are only a few cells in size. Some of our research goals may take 20 or more years to achieve, but that is precisely why there is an important role for the federal government" [16].

There is a connection between the energy crisis and nanotechnology. The demand for energy is increasing day by day, especially with the increase in the world's population. The energy problem will confront the world and it will affect the global economy. Richard Smalley, one of the fathers of nanotechnology, asked a question during one of his lectures about the most pressing issues facing the humanities, to which the audience replied that the most pressing issues were poverty, water, disease, inequality and access to resources. Smalley arranged the list and put energy at the top. Directly, the focus should be on the relationship between energy and the economy because the world's population will reach 9 billion in the near future [16].

Fabrication of Nanomaterials

Fabrication of nanomaterials is an interdisciplinary research direction based on different fields of science, such as chemistry, physics, materials and biology [17].

Forms of Nanomaterials

Nanomaterials have different shapes depending on the methods of manufacture. If, for example, manufacturing techniques use aerosol tools, vapor phase deposition, or noble gas condensation, the dimensions of the materials will be reduced to a nanoscale. This form of nanomaterials can be applied in semiconductor devices and catalysts [5, 17].

The second form of nanomaterials has a thin surface in the nanosize range, and it can be said that it is a coating on the surface of the bulk material. This coating can be formed by using physical vapor deposition (PVD) as a coating technique [18]. There is another technique called chemical vapor deposition (CVD). The CVD is a process of chemical reaction between various gases phases and heated surface of substrates at high temperature up to (~1925° F) in a CVD reactor. This reaction results in a thin film coating on the substrate surface [19]. Thin film coating on the surface has many applications, especially in the field of corrosion protection, hardness, wear resistance or protective coatings. It forms an important subset of this surface region that is laterally organized on the nanometer scale by "writing" a nanometer-sized structural pattern on the free surface; for example, patterns in the form of an array of nanometer-sized islands connected by thin (nanometer scale) wires, nanotubes, *e.g*. TiO_2 nanotube formed on Ti substrate [20]. Patterns of this type can be fabricated by lithography, by local probes (*e.g.*, tip-tunneling microscopy, near field methods, focused electron or ion beams) and/or surface deposition processes. Processes and devices of this kind are expected to play a major role in the production of the next generation of electronic devices such as highly integrated circuits, terrabit memory, single electronic transistors, quantum computers, *etc.* [21, 22].

The third form of nanomaterials includes bulk solids with a microstructure at the nanometer-scale. The bulk solids in which the chemical composition, atomic arrangement, and/or size of the building blocks (*e.g*, crystals or atomic/molecular groups) that make up the solid vary on a length scale of a few nanometers throughout the mass. This form has two types; the first type has a varied atomic structure and/or chemical structure in a space continuously throughout the solid on an atomic scale. This type is applied in many fields, such as glass, implant materials, supersaturated solid solutions, *etc*. This material is manufactured by quenching at high temperatures. The second type of this nanoform is composed of nanoscale building blocks and is micro-heterogeneous with high crystallinity [23]. The nanostructure blocks may differ in their atomic structure, their crystallographic orientation and/or their chemical composition. This inherently heterogeneous structure on a nanometer scale is crucial for many of their properties and distinguishes them from glasses, gels, *etc*. Materials with a nanometer-sized microstructure are called “Nanostructured Materials” or—synonymously—nanophase materials, nanocrystalline materials or supramolecular solids [5, 24].

Methods of Nanofabrication

The fabrication of nanomaterials can be done using different types of reactions and techniques, for example, solid-state reaction and liquid-state synthesis.

Liquid State Synthesis

Liquid state synthesis relies on the precipitation of nanometer-sized particles within a specific solvent. For example, some inorganic metal salts, such as nitride, chloride, fluoride, *etc*, dissolve in water. Hydrated metal cations, such as hydrated aluminum cation, $Al(H_2O)^{3+}$ or hydrated iron cation, $Fe(H_2O)^{3+}$ are mixed with alkaline solutions, such as sodium hydroxide (NaOH). The reaction mixture is condensed, washed, filtered, dried and calcined to obtain the product of nanoparticles.

Fabricating nanoparticles from a solution of chemical compounds can be prepared by different chemical methods, such as (1) sol–gel processing; (2) colloidal methods; (3) water–oil microemulsions method; (4) hydrothermal synthesis; and (5) polyol method [25].

Sol-gel Method

This method is a well-known chemical method for the fabrication of nanoparticles. As defined, a colloidal solution made of solid particles few hundred nm in diameter, and suspended in a liquid phase is called a sol. A solid macromolecule immersed in a solvent is called a gel. A simple process is used to transform a liquid (sol) in a gel state. This method has an advantage of forming highly pure and uniform nanomaterials at low temperature.

Colloidal Method

This method is applied to prepare nanoparticles such metals, metal oxides, organics and pharmaceutical compounds. It is based on the precipitation process in which solutions of different ions are mixed under controlled temperature and pressure to form insoluble precipitates.

Solid State Method

Nanoparticles of materials can be fabricated using solid state pathways, such as stociometric mixing of pure elements and heating at elevated temperature, ball mill of pure substances, *etc*. The solid state reaction of pure elements could form nanoparticles of layered materials, MPS_3, (M=first row of the transition metals), which are ordered in layers with interspacing of 6.4 Å, as shown in Fig. (**5**) [26]. The particle size measured was found to be in the range of 15 to 70 nm of the regular spots, as shown in Fig. (**6**). These materials are crystalline and could be used for many applications, such as, a cathode for the rechargeable batteries, sensors, optical applications, and hydrogen storage [27]. The organic molecules can be intercalated into the interlayer space of the MPS_3 layered materials, such as pyridine and its derivatives. It was observed that the crystallite size of the intercalated materials varies during the phase transformation, as shown in Table **1** [28].

Table 1. Estimated crystallite size of during phases transformation in open air [28].

Time (hrs) in open air	d12 (d-spacing =12.48 Å)		d10 (d-spacing =10. 84 Å)		d9 (d-spacing =9.7 Å)		d7 (d-spacing =7.34 Å)	
	CS (nm)	LS (%)	CS (nm)	LS (%)	CS (nm)	LS (%)	CS (nm)	LS (%)
1/2	131	0.432	54	1.39	-	-	35	1.292
18	-	-	103	0.897	-	-	33	1.375
27	-	-	82	1.037	234	0.488	32	1.383
48	-	-	47	1.522	185	0.560	-	-
72	-	-	-	-	399	0.360	-	-

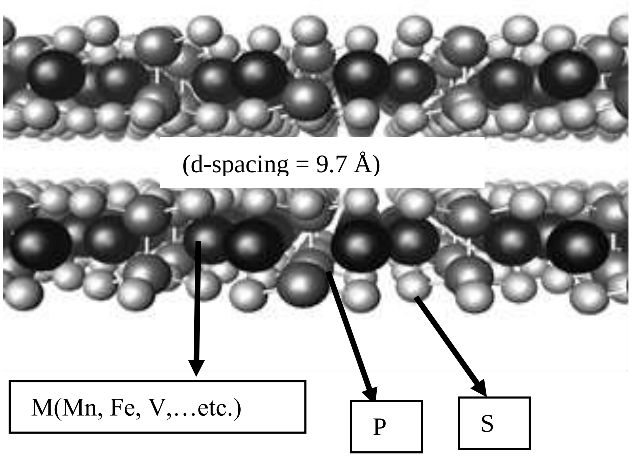


Fig. (5). Layered crystalline materials of MPS_3 [26].

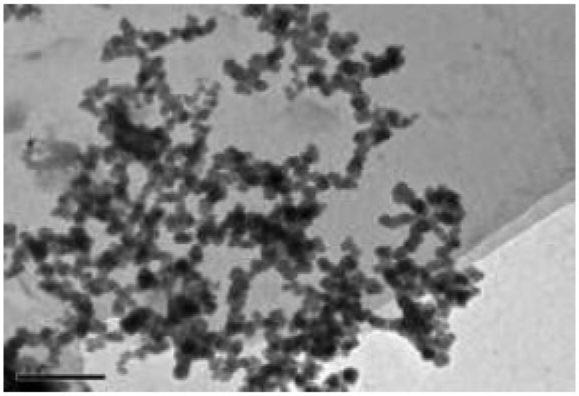


Fig. (6). TEM images of nanostructure of $FePS_3$ [27].

Laser-induced Ablation Method

Another important method exists to manufacture various types of nanoparticles including semiconductor quantum dots, carbon nanotubes, nanowires, and core nanoparticles. This method is called laser-induced ablation. According to this method, nanoparticles are assembled by nucleation and growth of laser-evaporated species in background gas. The extremely rapid cooling of the vapor is beneficial for the production of high purity nanoparticles in the quantum size range (10 nm) [29]. (Fig. **7**) shows the procedures for generating nanoparticles using the laser ablation method.

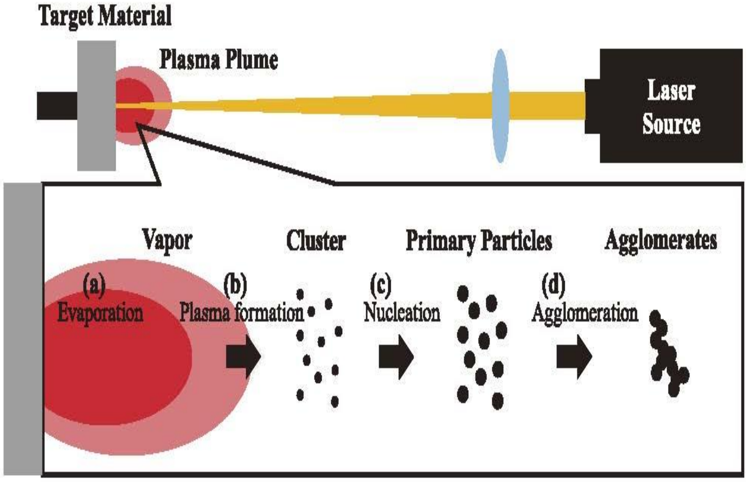


Fig. (7). Schematic diagram of laser ablation method for nanoparticles generation [29].

Conditions Affect Nanostructure

It was observed that the crystal structure of the layered material, MPS_3, remained stable for many years and there was no deformation or noticeable deformation in the materials even after intercalation [25 - 27]. There are a number of conditions that affect the nanostructure of the layered materials. These conditions are the presence of water, stirring, temperature (60 °C), and open atmosphere. As noted, leaving the sample in an open atmosphere for a different period of time had no effect on the crystal structure of the materials before or after intercalation. The layered materials are intercalated with different ions and more complex compounds, such as, K^+, NH^+, cobaltocenium cations, organic molecules to form compounds of general formula $Mn_{1-x}PS_3(G)_{2x}(H_2O)_y$, and G that represents the intercalated ions or compounds [28, 30, 31]. One M^{2+} ion is lost from the intralayer region for every two intercalated guest ions (G^+) present in the interlayer space to maintain the charge balance of the compound after intercalation.

Properties of Nanostructured Materials

A variety of synthesis and processing methods are used to synthesize nanomaterials. Nanomaterials have their grain sizes or the dimensions of their phases in the nanometer size system. The new ultra-fine materials have a special nature due to their diverse physical, chemical and mechanical properties. These properties can also be controlled during synthesis and subsequent procedures. For all these advantages, researchers and companies are interested in these materials. The properties of nanomaterials can be effectively engineered during synthesis and processing, and their demand is increasing day by day. They can also be mass-produced, as nanomaterials have great potential for technological development in a variety of applications [32]. Since the properties of solids depend on the size, atomic structure, and chemical composition, nanostructured materials exhibit new properties due to one or more of the following effects [33]:

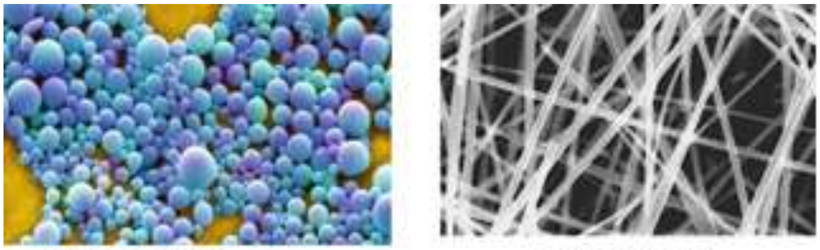
Size Effects

Size effects are seen if the characteristic size of the building blocks of the microstructure (*e.g.* the crystallite size, (Fig. **2**) is reduced to the point where critical length scales of physical phenomena (*e.g.* the mean free paths of electrons or phonons, a coherency length, a screening length, *etc.*) can be compared to the characteristic size of the building blocks of the microstructure [34].

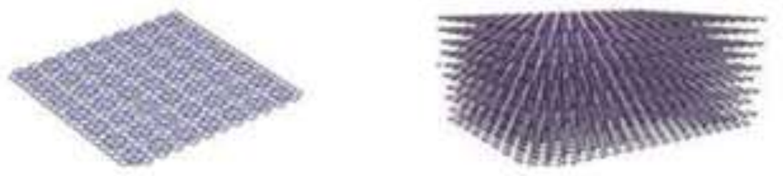
Change of the Dimensionality of the System

If a nanostructured material consists of thin needle-shaped or flat, two-dimensional crystallites [26], only two or one dimensions of the building blocks become comparable with the length scale of a physical phenomenon. In other words, in these cases, the nanostructured material becomes a two- or one-dimensional system with respect to this phenomenon, as shown in Fig. (**8**).

There are different shapes of materials, which have different deminsions, such as wires, rods, and nanofibers having zero deminsions. Other materials have two demsions, such as plates, thin films, and multilayerd materials [35].



0D(Nanoparticle) 1D(Nanowire)



2D Nanomaterials (plate) 3D Nanomaterials

Fig. (8). Nanomaterials types of different dimensions [35].

CONCLUDING REMARKS

Nanomaterials have not been synthesized recently, but history indicated that nanomaterials were synthesized in ancient times, such as ancient Egypt, Roman history, *etc*. Nanomaterials have been included in many fields, such as medicine, polymers, solids, alloys, environment, engineering, *etc*. There is an economic impact of nanotechnology nowadays, and it has become a significant part of the economy of many countries.

CONSENT FOR PUBLICATION

Not applicable

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The author would like to thank all authors who are or are not cited in the chapter, as well as all the organizations, companies, universities and research institutes that are mentioned or cited in the chapter, and those that are not mentioned or cited. The author would also like to thank Bentham Science Publishers Pvt. Ltd. for publishing the book.

REFERENCES

[1] Richard Feynman at an American Physical Society meeting at the California Institute of Technology (CalTech) on December 29, 1959.

[2] NanoBioNet: http://www.nano.gov/nanotech-101/what/definition(Accessed October 2019).

[3] Ashby M, Ferreira P, Schodek D. Schodek; Nanomaterials, Nanotechnologies and Design; Copyright Elsevier Ltd. 2009.

[4] https://en.wikipedia.org/wiki/History_of_nanotechnology (Accessed October 2019).

[5] Nalwa HS, Ed. Handbook of Nanostructured Materials and Nanotechnology, San Diego: Academic Press 2000; Vol. 1.

[6] Drexler K. Engines of Creation: The Coming Era of Nanotechnology. Doubleday 1986.

[7] Drexler K. Eric. Nanosystems: Molecular Machinery, Manufacturing, and Computation. New York: John Wiley & Sons 1992.

[8] Saini Rajiv, Saini Santosh, Sharma Sugandha. Nanotechnology: The Future Medicine. Journal of Cutaneous and Aesthetic Surgery, 2010; 3(1): 32-3.
[http://dx.doi.org/10.4103/0974-2077.63301] [PMID: 20606992]

[9] James A. Harries, Nanotechnology World Economy, Published by Author House. Amazone 2009.

[10] Materials S. Nanotechnology, Great Oaks from Little Acrons, Pictures of the Futures, 2003; p. 19.

[11] Infineon Technology AG. Germany, Infineon Becomes the First Company to Demonstrate Carbon Nanotube Transistor for Power Applications, Feb. 23 2004.

[12] Nitz Brian. Category: Green Tech and Gadgets, Ancient Egyptian Blue Pigment Leads to Nanotech Breakthrough, April 15, 2013.

[13] http://www.greenprophet.com/2013/04/ancient-egyptian-blue-pigment-nanotech/#sthash.d4HTv2hH.dpuf(Accessed November 2020).

[14] Archaeological Institute of America Nanotechnology and Ancient Egyptian Mummies 2014.

[15] Canton J. Canton, J. The Strategic Impact of Nanotechnology on the Future of Business and Economics, Institutes for Global Futures, National Science Foundation Report March 2001, Excerpted from the book Social Implications of Nanoscience and Nanotechnology, Edited by M. Rocco and W. Bainbridge, NSF. 2001.

[16] National Nanotechnology Initiative: Leading to the Next Industrial Revolution - White House Report 2000.

[17] Drexler K. Eric. Engines of Creation: The Coming Era of Nanotechnology. Doubleday 1986.

[18] Drexler K. Eric. Nanosystems: Molecular Machinery, Manufacturing, and Computation. New York: John Wiley & Sons 1992.

[19] Saini R, Saini S, Sharma S. Nanotechnology: The future medicine. J Cutan Aesthet Surg 2010; 3(1): 32-3.
[http://dx.doi.org/10.4103/0974-2077.63301] [PMID: 20606992]

[20] Saji VS. Joice Thomas, Nanomaterials for corrosion control. Curr Sci 2007; 92(1): 51.

[21] Honggang J, Maggy L, Victoria LT, Enrique JL. Synthesis of nanostructured coatings by high velocity oxygen fuel thermal spraying. In: Nalwa HS, Ed. Handbook of Nanostructured Materials and Nanotechnology. San Diego: Academic Press 2000; Vol. 1: pp. 159-209.
[http://dx.doi.org/10.1016/B978-012513760-7/50006-X]

[22] Kumaraguru P. Swaminatha, Development of novel nanostructured materials with superior electrocatalytic and corrosion properties. PhD, University Of South Carolina 2006.

[23] Gleiter H. Gleiter, H. Acta Materialia, Nanostructured materials: basic concepts and microstructure, 2000; 48(1): 1-29.

[24] Hengelein A. Chem Rev 1998; 89: 1861.
[http://dx.doi.org/10.1021/cr00098a010]

[25] Gleiter H. Nanostructured materials: basic concepts and microstructure. Nanostruct Mater 1995; 6: 3.
[http://dx.doi.org/10.1016/0965-9773(95)00025-9]

[26] [Gleiter, H. Nanostruct Mater 1992; 1: 1.

[27] Siegel RW. Synthesis and properties of nanophase materials. Mater Sci Eng A 1993; 168(2): 189-97.
[http://dx.doi.org/10.1016/0921-5093(93)90726-U]

[28] El-Meligi AA. Synthesizing layered material of FePS3 and its intercalation with pyridinum. Mater Chem Phys 2005; 89(2-3): 253-9.
[http://dx.doi.org/10.1016/j.matchemphys.2004.06.041]

[29] Kim M, Osone S, Kim T, Higashi H, Seto T. Synthesis of Nanoparticles by Laser Ablation: A Review. Kona Powder Particle J 2017; 34(0): 80-90.
[http://dx.doi.org/10.14356/kona.2017009]

[30] Ismail N, Temerk YM, El-Meligi AA, Badr MA, Madian M. Synthesis and characterization of MnPS3 for hydrogen sorption. J Solid State Chem 2010; 183(5): 984-7.
[http://dx.doi.org/10.1016/j.jssc.2010.02.021]

[31] Herr U, Jing J, Gonser U, Gleiter H. Alloy effects in consolidated binary mixtures of nanometer-sized crystals investigated by Mössbauer spectroscopy. Solid State Commun 1990; 76(2): 197-202.
[http://dx.doi.org/10.1016/0038-1098(90)90542-J]

[32] Oh JK, Park JM. Iron oxide-based superparamagnetic polymeric nanomaterials: Design, preparation, and biomedical application. Prog Polym Sci 2011; 36(1): 168-89.
[http://dx.doi.org/10.1016/j.progpolymsci.2010.08.005]

[33] Saji VS. Joice Thomas. Nanomaterials for corrosion control. Curr Sci 2007; 92(1): 51.

[34] Kim W-G, Choe H-C. Nanostructure and corrosion behaviors of nanotube formed Ti-Zr alloy. Trans Nonferrous Met Soc China 2009; 19(4): 1005-8.
[http://dx.doi.org/10.1016/S1003-6326(08)60396-9]

[35] Ali S. Ali, Application of Nanomaterials in Environmental Improvement, January 30th 2020 Published: March 6th 2020.
[http://dx.doi.org/10.5772/intechopen.91438]

CHAPTER 2

Nanotechnology and Health

Abstract: Nanomedicine is a reality nowadays. The first generation nanomedical capabilities, in the form of functionalized nanoparticles, comprising a wide range of organic and inorganic materials at various nanoscale dimensions, initially emerged in the early 1990s, and have since undergone dramatically rapid expansion. Nanomedicine is one of the important applications of nanotechnology. The development of smaller, less invasive, smarter, more precise, and more efficient medical devices is a fast-expanding global trend. The creation of specialized nanoparticles for use in medicine, such as magnetic nanoparticles and gold nanoshells, is advancing daily. This development is happening while nanomedicine is still in its early stages. As reported, superparamagnetic iron oxide nanoparticles are being used to specifically target and thermally destroy cancer cells without causing collateral damage to surrounding healthy cells and tissues.

Keywords: COVID19, Drug delivery, Medical Nanobot, Nanomedicine, Nanotechnology and Health.

INTRODUCTION

Nanomedicine has been considered one of the possibilities since, Richard Feynman first introduced the concept of nanotechnology in 1959, in his famous talk at Caltech, “There’s Plenty of Room at the Bottom” [1, 2].

Feynman mentions that one of his friends: “(Albert R. Hibbs) suggests a very interesting possibility for relatively small machines”. Surgery would be exciting if the surgeon could be placed inside the patient's body to perform the surgery, despite the fact that it is a novel and surprising concept. When the mechanical surgeon is positioned inside the blood vessel, enter into the heart, and takes a “look” inside of the organ. (The information must, of course, be fed into it). It detects any valve that has a problem and treats it. Other small machines may be permanently integrated into the body to help some organs that are not working well enough [1, 3]. It is mentioned that despite the emergence of nanoparticles in relation to biomedicine in the late seventies, thousands of research papers have been published in the field of nanomedicine, and the term “nanomedicine” appeared only at the beginning of the twenty-first century. Thirty scientific papers were published in the field of nanomedicine. As reported, the published research

Amin El-Meligi

on nanomedicine has increased significantly until the number of publications reached more than ten thousand in 2015 [4].

In another development in nanomedicine, the idea of repairing cells using certain machines was put forward, and this development can contribute to repairing damaged DNA, organelles and other cellular structures, and this was done with great accuracy in 1986 [1, 5].

Many books have been published, which show a number of applications of nanomedicine, such as diamond-shaped applications and robotics. As mentioned, a large number of research papers have been published that demonstrate different uses for nanomedicine [1, 6].

The field of nanomedicine first emerged in the early 1990s and consists of numerous organic and inorganic materials with various nanoscale dimensions. These nanoparticles are the first of their age to have applications in medicine. These nanomaterials with medicinal capabilities represent the first generation in this important field [1].

Nanomedicine Applications

Nanotechnology affects many areas and has many applications. The transition from macroscale to nanoscale particle size has had an impact on the material characteristics. This is because “nanomaterials” have substantially larger surface areas, making a far larger amount of their chemical composition available for particular interactivity with their environments. For example, nanocatalysts can be doubly more active than their bulk counterparts because they have a very large number of accessible active sites for catalytic reactions. There are many nanoproducts on the market, and the number of these products has reached more than 1,600 nanoproducts. Many essential items we use every day are made of nanomaterials, including glass, highly hydrophobic bathroom tiles, cosmetics, food goods, auto paints, auto lubricants, and carbon nanotube-reinforced car tyres [6].

The following is passage shows how the European Science Foundation defines nanomedicine: “Nanomedicine uses nano-sized tools for the diagnosis, prevention and treatment of disease and to gain increased understanding of the complex underlying patho-physiology of diseases. The ultimate goal is to improve quality of life” [3, 6].

There are many applications of nanotechnology, one of the most important of these applications is nanomedicine. It is important to note that there is a global trend to develop medical nanotechnology to be more effective.

Medical nanomaterials have become more specialized, for example, gold nanoparticles can target cancer cells directly only without affecting healthy cells in the body. This indicates the important and continuous development in the use of medical nanotechnology to treat diseases in its specific place [4, 5]. In addition to the gold nanoparticles discussed earlier, other nanomedicines, such as liposomes and polymeric nanoparticles, can carry pharmaceuticals to infected cells, particularly cancer cells. The resolution of medical images can be improved by using nanoparticles for some materials such as carbon nanotubes and magnetic nanoparticles [4, 5].

Effect of Nanomaterials on Health

Nanomaterials have a significant impact on health. Many nanoparticles exist, including precious metals like gold and silver. Cancer cells are affected by gold atoms, especially after surgery. It was found that gold atoms were able to detect and kill cancer cells [4, 5, 7].

As mentioned, “clusters of gold atoms can detect and kill cancer cells commonly left behind after tumor-removal surgery, according to a study of a new nanotechnology technique”. This application has been tested in a few mice. The researchers are designing a clinical trial that could begin testing the treatment in humans. [7]. To stop the patient's body from developing new tumour cells, surgeons must carefully remove all infected cells. To remove any cancer cells that may have persisted after surgery, it must be followed up with chemotherapy or radiotherapy.

Gold nanoparticles are effectively used in the treatment and diagnostic process. The active use of gold is due to its biocompatibility. In reality, the basis for using any substance in medical treatment is biocompatibility. Additionally, due to their high delivery efficiency, gold nanoparticles can be used in drug delivery applications [8].

The researchers administered the extract of Euphrasia Officinalis to test the anti-inflammatory effects of gold nanoparticles (EO-AuNPs) and an extract of the conventional folk remedy Euphrasia Officinalis on lipopolysaccharide (LPS)-stimulated RAW 264.7 macrophages. The results confirmed the successful synthesis of AuNPs by E. officinalis.

Transmission electron microscopy images showed obvious uptake of EO-AuNPs and internalization into intracellular membrane-bound compartments, resembling endosomes and lysosomes by RAW 264.7 cells [9]. Cell viability assays showed that EO-AuNPs exhibited little cytotoxicity in RAW 264.7 cells at 100 µg/mL concentration after 24 hours. EO-AuNPs significantly suppressed the LPS-induced release of NO, TNF-α, IL-1β, and IL-6 as well as the expression of the iNOS gene and protein in RAW 264.7 cells.

Further experiments demonstrated that pretreatment with EO-AuNPs significantly reduced the phosphorylation and degradation of inhibitor kappa B-alpha and inhibited the nuclear translocation of NF-κB p65. In addition, EO-AuNPs suppressed LPS-stimulated inflammation by blocking the activation of JAK/STAT pathway [9]. In addition to the aforementioned application, it was stated that gold-quercetin nanoparticles could prevent metabolic endotoxemia-induced kidney injury by regulating TLR4/NF-κB signalling and NrF_2 pathway [10].

Due to their numerous inherent benefits, calcium carbonate (CC) nanoparticles are widely used in the biomedical industry. However, bare CC nanoparticles do not allow the development of multifunctional devices suitable for advanced drug delivery in cancer treatment [11]. Both *in vitro* and *in vivo*, the behavioural properties of nanomaterials' particle size are crucial. The CC nanoparticles have a promising application in many fields.

Nanomaterials and Drug Delivery

The non-specificity, severe side effects, burst release, and harm to normal cells of conventional anti-tumor drug delivery systems have all been avoided by the use of nanocarriers. Nanocarriers improve the bioavailability and therapeutic efficiency of antitumor drugs, while providing preferential accumulation at the target site. The nano-drug/gene delivery method is employed in the treatment of cardiovascular and cancerous conditions.

A number of nanocarriers have been developed; however, only a few of them are clinically approved for the delivery of antitumor drugs for their intended actions at the targeted sites. A fascinating study on nanocarriers is available, and it is composed of three main sections: The first part introduces various nanocarriers and discusses how they relate to the delivery of anticancer drugs. The second part discusses targeting mechanisms and surface functionalization on nanocarriers. The third part describes a few tumour types, such as breast, lung, colorectal, and pancreatic tumours, and discusses how relevant nanocarriers have been used in these tumours. The study advances knowledge of tumour treatment through the potentially beneficial application of nanotechnology [12].

Traditional anticancer medication administration has some drawbacks, including serious side effects, a lack of selectivity, an abrupt burst, and harm to healthy cells. These problems could be solved by using nanocarriers [13]. In fact, only few of the developed nanocarriers are clinically approved to deliver antitumor drugs. The first nano-cancer drug approved by the US Food and Drug Administration was Doxil. Since 1995, it has been used to treat adult cancers including ovarian cancer, multiple myeloma, and Karposi's sarcoma (a rare cancer that often affects people with immunodeficiencies such as HIV and AIDS) [14]. The application of nanotechnology in oncology requires further study. Natural products, for instance, have less adverse effects than synthetic medications, making them intriguing options for drug delivery.

In reality, from ancient times, people have relied on natural medicines to heal a variety of illnesses. Approximately 25% of medication compounds, according to estimates, are made from natural products [15, 16]. Natural products show interesting properties such as less toxicity, chemical diversity, and different chemical biological properties. The recent trend in the natural products application is to develop target-based drug discovery and drug delivery, but this step has not been welcomed by pharmaceutical companies. Companies are reluctant to spend money on developing natural product medication delivery systems. This can be as a result of the scarcity of comprehensive investigations on many chemical components present in natural products. There are a number of diseases that can be treated by natural product drugs, such as microbial diseases, diabetes, cancer, cardiovascular and inflammatory diseases [17]. Natural product medications provide a lot of benefits, including affordability, lack of adverse effects, potency in treatment, and low toxicity. Biocompatibility and toxicity of the natural products are the challenges of using them as drugs. As a result, due to issues with biocompatibility and toxicity, many natural product molecules are not allowed for clinical trial phases [18]. In drug delivery, there is a need to deliver the medicine to the organ by using small sized materials. The large sized materials are currently used in drug delivery, but there are a number of challenges that affect the efficiency of these materials. These challenges are poor bioavailability, poor solubility, poor absorption in the human body, *in vivo* instability, poor delivery to a specific target, tonic effectiveness and possibility of drugs' side effects. Accordingly, new drug delivery may solve the aforementioned challenges. Nanomaterials can be a solution, and nanotechnology helps in the drug delivery process with high efficiency.

The biocompatibility and toxicity issues with natural compounds, however, pose a bigger problem for their application in medicine. Because of these issues, many natural substances fail to pass the clinical testing phases [18]. The use of large sized materials in drug delivery poses major challenges, including *in vivo* instability, poor bioavailability, poor solubility, poor absorption in the body, issues with target-specific delivery, tonic effectiveness, and probable adverse effects of drugs. Therefore, using new drug delivery systems for targeting drugs to specific body parts could be an option that might solve these critical issues [19].

As a result, nanotechnology has a significant impact on advanced drug and medical compositions, arena targeting, and controlled drug release. What the technological advances have reached in inventing accurate devices to follow up the human condition has become very important. This gives an important indication that human health can be controlled by the person himself/herself. Scientists have launched a term that reflects this progress, as they said “a doctor inside your body”, as shown in Figs. (**1** and **2**) [20, 21]. Scientists were able to inject very accurate electronic sensors into the patient's body, all as a result of research experiments that reduced the size of molecules to the nanometer. And image 1 of the nanobot shows how important nanomaterials are in making this infinitesimal device so that red blood cells size has been considered.

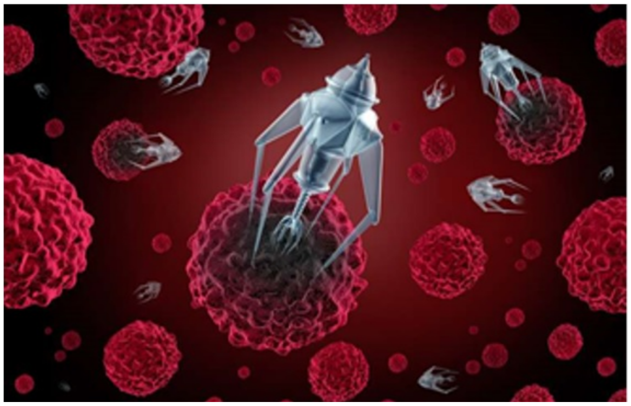


Fig. (1). Medical nanobots. Credit: Shutterstock.com.

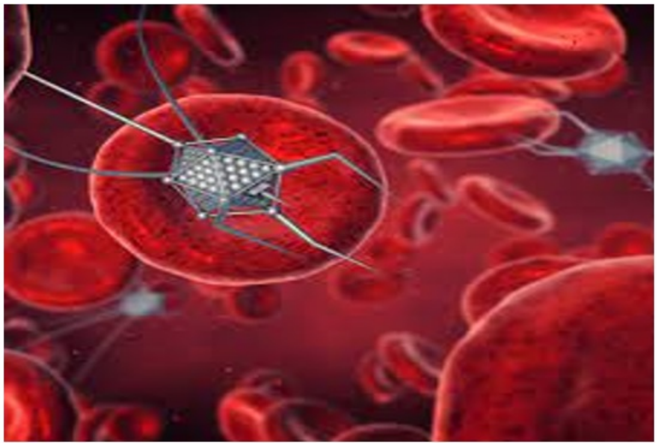


Fig. (2). Therapies on a nano scale rely on engineered nanoparticles designed to package and deliver drugs to exactly where they’re needed. from shutterstock.com.

We know that soldiers always suffer from the pressure of training and military missions, especially if there is war, and therefore the developed countries are interested in following up the soldiers 'vitality and the extent of their ability to withstand the difficulties, for example, the American Defense Department requires scientists to make a tattoo on the bodies of soldiers to track the vitality of the soldiers. This sounds surprising, but more surprising is the presence of electronic devices to monitor patients' conditions after surgeries and control the functions of body organs. And large companies in the health care field spend billions of dollars to develop these devices [22].

Side Effects of Nanoproducts

Nanoproducts of medicine have a wide application in many aspects of life. Their application is safe until there is a side effect that appears. Therefore, the potential risk of nanoparticles is taken into consideration in some studies. For example, they may have a biological effect, and toxic effects on some organs, such as the liver, the lungs, and the brains [23]. In reality, every medicine has a side effect, including medicines made from natural ingredients. Due to the nanoscale, this problem requires consideration in the use of nanomedicine.

It is thought that nanosize may have much effect than microsize. This is because it can accumulate in the fine parts of the body where the microparticles cannot reach. Therefore, the study shows that nanoparticles can go through the blood-testis barrier, placental barrier, and epithelial barrier. These barriers protect reproductive tissues. Nanosize will be easily accumulated in reproductive organs, accordingly, the organs of testis, epididymis, ovary, and uterus can be damaged. The damage will destroy Sertoli cells, Leydig cells and germs cells. Therefore, if the reproductive organs become dysfunctional, this will have adverse effects on sperm quality, quantity, morphology and mobility. Some studies show that nanoparticles can increase inflammation and oxidative stress. These side effects cause damage to molecular and genetic cells which results in cytotoxicity [23].

Human health is seriously impacted by environmental pollution, for example, a particularly dangerous environmental pollutant could be nanosize particulate particles. A group of researchers from China have investigated chronic effects of carbon black nanoparticles, especially, in terms of systematic toxicity, immune suppression and local toxicity [24]. They have made the study on a group of 32 rats. The rates have exposed to carbon black nanoparticles for 90 days. After this time, the lungs of rats were discovered to contain a load of 16 mg of carbon black. They could clear 14% of the carbon black, which has been accumulated in the lung at the end of the exposure period, after 14 days of recovery period. Also, there was a significant decrease in the lung function and it could not recover after a short time recovery. After carbon black inhalation, the damage levels of DNA and apoptosis were significantly increased in the lung cells. The results had shown that there were some damages in other cells. As concluded by this study, the carbon black nanoparticles induced the direct toxicity and systemic immune toxicity. As a result of carbon black inhalation, the combined effect of the direct and systemic immune had damaged the lung.

Vaccine with Nanoparticles and COVID19

December 30, 2019 was the date of identifying COVID19. The COVID19 infection was declared a universal pandemic by the World Health Organization (WHO) on March 11, 2020. People's life has been negatively affected since the emergence of COVID19. All aspects of life have changed, especially people's health both physically and mentally. The following photos were published by the National Geographic (NG) showing how people suffer due to COVID19 pandemic [25]. (Fig. **3**) describes the suffering of people as stated about this image in the NG After more than two months without any human touch, Mary Grace Sileo (left) and her daughter, Michelle Grant, and others in their family had a solution. They hung a clothesline and pinned a drop cloth to it in Sileo's yard in Wantagh, New York. With one on each side, they embraced through the plastic. "In spite of everything that we've been facing, we still look for ways to connect," Moran says.

Fig. (3). Photograph by Al Bello, Getty Images, NG [25].

Fig. (**4**) describes suffering of nurses who were a part of the team to treat infected people, as stated about this image in the NG In Mons, Belgium, nursing colleagues take brief refuge in a shift break and each other's company. Like medical facilities around the world, Belgian hospitals were initially overwhelmed by the rush of patients with a virulent new disease. These nurses, pulled from their standard duties, were thrown into full-time COVID-19 work—reinforcement troops for a long battle, as shown in Fig (**4**). These nurses were so caught up in their exhaustion that they hardly noticed Cédric Gerbehaye, a veteran photojournalist who has covered conflicts in Congo and the Middle East.

Fig. (4). Photograph by Cédric Gerbehaye, NG [25].

A number of vaccines have been produced to combat COVID19, and some vaccines show side effects. As mentioned, some people have received the vaccine, but unfortunately they experienced severe allergies. It is suspected that the reason for the allergy-like reactions may be due to the nanoparticles of polyethylene glycol (PEG). It is stated that PEG has never been used before in an approved vaccine. It is reported that PEG is used in making many drugs, but it has side effects. A side effect of PEG is sometimes induced anaphylaxis, a potentially life-threatening reaction that can cause skin rash, low blood pressure, shortness of breath, and rapid heartbeat [26].

Worldwide, some people who received the coronavirus vaccine experienced anaphylaxis. In fact, more research is needed about the allergic effect of PEG. It is stated that “Allergies in general are so common in the population that this could create a resistance against the vaccines in the population” [27].

It is reported that the most effective vaccines for COVID-19 are those that use nanotechnology to deliver mRNA for immune stimulation. It is reported that “Total nano-vaccine purchases per capita and their proportion within the total vaccine lots have increased directly with the GDP per capita of countries” [28]. There were three nano-vaccines out of four procured by rich countries by the end of 2020.

In fact, nano-vaccine can only be offered by rich countries. It will cost a lot of money in middle and low-income countries. It has been argued that nanomedicine can help reduce the gap between the rich and the poor rather than becoming a great technology for the privileged. Two main ways are proposed: (1) the use of qualitative contextual analyses to endorse R&D that positively affects the sociocultural climate; (2) challenging the commercial, competitive realities wherein scientific innovation of the day operates [29].

Cardiovascular Disease and Nanomedicine

Nanomedicine is widely used in the treatment of serious diseases such as cancer, cardiovascular diseases, *etc*. The main advantage of nanomedicine is that it directly targets the affected disease site. As reported, the treatment of cardiovascular diseases (CVDs) with nanomedicine has begun after the treatment of tumors with nanomedicine. As stated, there are 3.9 million deaths per year due to CVDs in Europe, this number accounts for 45% of all deaths in Europe. There is a significant effect of CVDs on the economy of Europe. As estimated, the treatment of CVDs costs the European economy 111 billion Euro a year, so the yearly rate for the overall control of CVDs is 210 billion Euro. According to the World Health Organization (WHO), CVDs are the leading reason of death worldwide. As estimated by WHO, 17.9 million people died due to CVDs in 2019, this number counts for 32% of all deaths in the world [30]. The number of deaths is expected to increase to 23.6 million in 2030. Therefore, nanomedicine is one of the promising medicines to treat CVDs. As per WHO, CVDs are a group of disorders of the heart and blood vessels. As follows: “coronary heart disease, which is a disease of the blood vessels supplying the heart muscle; cerebrovascular disease, which is a disease of the blood vessels supplying the brain; peripheral arterial disease, which is a disease of blood vessels supplying the arms and legs; rheumatic heart disease, which is damage to the heart muscle and heart valves from rheumatic fever, caused by streptococcal bacteria; congenital heart disease, which is a birth defect that affects the normal development and functioning of the heart caused by malformations of the heart structure from birth; and deep vein thrombosis and pulmonary embolism which are blood clots in the leg veins, which can dislodge and move to the heart and lungs” [30].

Risk Factors for CVDs

In fact, there are a number of bad habits that have been considered as risk factors for CVDs such as smoking, drinking alcohols, unhealthy diet, environmental pollution and physical inactivity. These risk factors may lead to high blood pressure, increased blood sugar, high level of blood lipids, and increased probability of obesity and being overweight [31 - 33]. It is very important to follow these risk factors to reduce CVDs.

For the following reasons, smoking is actually one of the most significant risk factors for CVDs:

1-Smoking increases the formation of plaque in blood vessels.

2- Plaque leads to narrowing of the arteries or blockage with clots that lead to coronary heart disease. The narrowing and blockage of the arteries reduce blood flow to the heart muscle.

3- The blood thickens and clots inside veins and arteries due to chemicals in cigarette smoke.

As mentioned, in 2000, more than 1 in 10 deaths globally from CVDs were attributed to smoking [32]. It is estimated that smoking is responsible for 33% of all CVDs deaths and 20% of ischemic heart disease deaths in people over 35 years of age in the USA [33]. Cigarette smoking also affects glucose intolerance and low serum levels of high-density lipoprotein cholesterol. The risk attributable to smoking persisted even when adjustments were made for differences between smokers and non-smokers in the levels of other risk factors [34 - 41]. The effect of cigarette smoking on the risk of coronary heart disease was evident even among people with low cholesterol levels [42].

Drinking alcohol is one of the risk factors for CVDs. As reported “The cardiovascular system is affected by alcohol. At the time of drinking, alcohol can cause a temporary increase in heart rate and blood pressure. In the long-term, drinking above the guidelines can lead to on-going increased heart rate, high blood pressure, weakened heart muscle and irregular heart beat” [43]. In fact, alcohol has a short term and permanent effect on the human body. The short term effect can be observed during the time of drinking and it is accompanied by reduced inhibitions, blackouts and hangovers. The long term or lasting effect of alcohol includes damage to the brain, people’s immune system and the heart [44]. Alcohol does not just affect people in the short-term with reduced inhibitions, blackouts and hangovers. It can also leave a lasting effect on the body, especially our brain, immune system and the heart.

An unhealthy diet is a risk factor for CVDs. In fact, it is difficult to provide a healthy diet to many people around the world. This is due to various reasons, such as poverty, high cost of living for many people, corruption, and desertification. An unhealthy diet may lead to obesity, high blood pressure, uncontrolled diabetes, high cholesterol levels and a diet high in saturated fats. All of these problems can increase the chance of developing cardiovascular diseases [45].

Cholesterol is the most abundant steroid in the body, its structure is shown in Fig. (**5**).

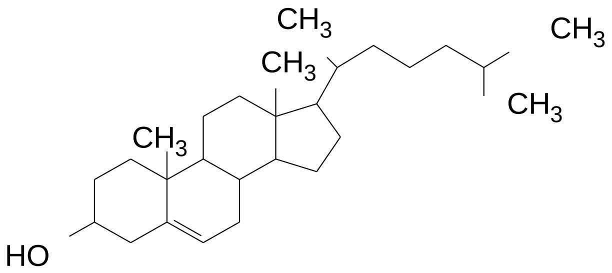
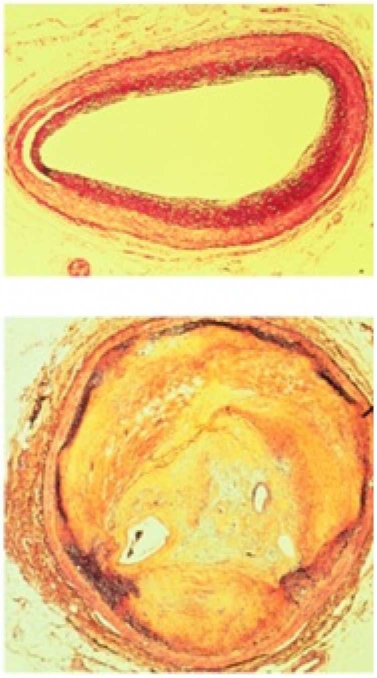


Fig. (5). Chemical structure of cholesterol.

In fact, cholesterol is needed for cell membranes, brain and nerve tissue, steroids hormones, and vitamins D. It can be obtained from eggs, milk, butter, fish and meats, among others, as shown in Table **1** and is synthesized in the liver [46]. It is a lipid with no fatty acid. High level of cholesterol can form plaque that clogs arteries, as shown in Fig. (**6**). The cholesterol is considered high if it exceeds 200 mg/dL in plasma [47].

Table 1. Cholesterol content of some foods [46].

Food	Serving Size	Cholesterol (mg)
Liver (Beef)	3.5 Oz	389
Egg	1	212
Shrimp	3.5 Oz	194
Fried Chicken	3.5 Oz	130
Lamb (foreshank)	3.5 Oz	106
Chicken (no skin)	3.5 Oz	85
Fish (Salmon)	3.5 Oz	63
Whole Milk	1 Cup	33
Yogurt (whole)	1 Cup	29
Butter	1 tsp	11
Vegetable Oils	1 tsp	0



Copyright © 2005 Pearson Education, Inc., publishing as Benjamin Cummings

Fig. (6). Top image represents normal artery, and bottom image represents an artery clogged by cholesterol plaque [47].

Environmental Pollution and CVDs

In fact, one of the most serious risk factors for CVDs is environmental pollution. As reported, “environmental pollution can cause high blood pressure, arrhythmias, enhanced coagulation, thrombosis, acute arterial vasoconstriction, atherosclerosis, ischemic heart diseases, myocardial infarction and even heart failure” [48]. Environmental air pollution is associated with increased risk of cardiovascular diseases. In general, environmental pollution is strongly connected with an increased risk of cardiovascular disease. Environmental pollution exerts its detrimental effects on the heart through the development of pneumonia, systemic inflammation, oxidative stress, endothelial dysfunction and coagulation changes. Environmental agencies must take high-priority steps to control environmental pollution to reduce the spread of cardiovascular diseases.

In general, developing countries especially in Africa, Asia and South America suffer from a high rate of environmental pollution. It is reported that 4 million people and more in these countries die every year due to indoor air pollution. According to the European Commission-funded CUPIDO project, the therapeutic targeting of the heart is tackled *via* small, biocompatible and inhalable NPs. The first hint for the lung-to-heart phenomenon derives from studies on combustion-derived ultrafine (<0.1 μm) NPs, linking air pollution to an increasing number of CVD deaths [49]. Developed countries are also a major source of environmental pollution due to various industries and other activities. There are many studies on the relationship between environmental pollution and various diseases, CVDs are one of them [50 - 54].

CVDs are major contributors to mortality and morbidity in South Asia. Chronic exposure to air pollution is an important risk factor for cardiovascular diseases, although the majority of studies to date have been conducted in developed countries.

Controlling CVDs Risk Factors

In fact, risk factors can be controlled by following healthy habits to decrease CVDs. Healthy habits include cessation of smoking, and consumption of any source of tobacco and alcohol, following a healthy diet, with eating more vegetables and fruits, getting regular exercise and being active, and controlling cholesterol levels (it should be less than 200 mg/dL in plasma). One of the most crucial steps to control CVDs is health policies. The health policies can create conductive environments to make healthy choices affordable and available to reduce CVDs [30]. Also, it is very important to improve living standards of people by reducing poverty, reducing stress factors and improving hereditary factors. There are a number of driving forces for CVDs. These driving forces include globalization, urbanization and ages of people. If these forces are properly managed, the risk factors for CVDs can be reduced. Also, controlling cultural, social and economic changes can help to reduce CVDs.

It is worth mentioning that the nanostructure of drugs can improve their bioavailability, stability and safety. It is reported that “lipid-based NPs, which show low side effects and greater ability to passively accumulate at tissues with higher vascular permeability (enhanced permeation rate), have been largely used since the earlier times of CVDs. Lipid-based nanocarriers solved the issue with the drug Wortmannin in clinical development, which was due to unmet solubility and chemical requirements” [35].

It is stated that “despite promising benefits from the recent increase in therapeutic options and pharmacological advancements (*e.g.*, sacubitril/valsartan), the identification of new and more efficient treatment modalities is still critically required. Nanomedicine, which is among the fastest emerging research areas, is expected to fill this gap by revolutionizing the CVDs care system” [30].

Nanomedicine for CVDs Treatment

As mentioned earlier, nanomedicine for CVDs treatment is rapidly growing and will help to cover the deficiencies of conventional medicine. Nanomedicine treats not only CVDs but also other types of diseases. This is because nanoparticles act as drug carriers to the main affected site in the body. In fact, nanomedicine was firstly used for oncology treatment. As reported, there are "about 7000 hits for 'oncology' and 'nanomedicine' on PubMed" [55]. As reported "several nanomedical products (*e.g.*, Doxil®, Abraxane® and AmBisome®) have been approved by the US FDA and the EMA for their clinical use in humans" [56 - 58]. Nanomedicine for CVDs treatment came after that of oncology. Currently, there is a significant increase in promising lab-scale results for CVDs "(-1200 hits for 'cardiovascular' and 'nanomedicine' on PubMed)". Research in the field of nanomedicine is focused on finding innovative solutions to the challenge of current CVDs treatments.

It is reported that "interesting results have also been obtained with nanomedicine-based formulations loaded with omega-3 polyunsaturated fatty acids (ω-3 PUFAs), well-known dietary factors with beneficial properties for the prevention of CVDs" [59]. Also, the nanostructure of various materials such as carbon nanotubes, polymeric micelles, nanoparticles of silica, nanofibers, quantum dots and nanocrystals represent other sources for controlled drug delivery [60, 61].

It is reported that drug delivery directed in the treatment of disease using nanoparticles is possible through active or passive means: active targeting requires conjugation of the therapeutic agent to a tissue- or cell-specific ligand, whereas passive targeting involves the coupling of the therapeutic agent to a high-molecular-weight polymer that has enhanced permeation and retention to vascular tissue [62].

As reported, "most small molecule drugs are absorbed from the intestines, metabolized in the liver, delivered to the bloodstream, and excreted from the kidneys, that is, drugs need to overcome the physiological barriers to achieve effective concentration in the blood and tissue" [63].

There are a number of characteristics of nanoparticles loaded drugs. They should be protected from systemic degradation, have very low toxicity or neglected toxicity and immunogenicity, have ameliorated pharmacokinetics and increased half-life, show increased bioavailability, and accurate biodistribution [63, 64].

As reported in 2019, less than 20 clinical trials were registered at ClinicalTrials.gov (searched terms 'nanoparticle' and 'cardiovascular') and as of yet no CVN products have been approved by the FDA and EMA. In addition, despite great interest in the direct treatment of the diseased heart, the current CVN trials remain limited toward the monitoring, detection and treatment of atherosclerosis (*e.g.*, BLAST, NANOM, Nano-Athero), occurring in the vasculature [65].

CONCLUDING REMARKS

Nanomaterials have been included in the field of medicine. The application of nanomaterials in medicine is making a remarkable difference, especially in the field of drug delivery, and complex and sensitive surgeries. Nanobot was used to perform surgeries. Also, the nanobot has been applied to deliver nanomedicine inside the human body. A component of the COVID-19 vaccine is nanomaterials. Although some immunizations have side effects that can be managed. Moreover, CVDs can be treated utilizing nanomedicines.

CONSENT FOR PUBLICATION

Not applicable

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The author would like to thank all authors who have been or not cited in the chapter, as well as all the organizations, companies, universities and research institutes that are mentioned or cited in the chapter. The author would also like to thank Bentham Science Publishers Pte. Ltd. for publishing the book.

REFERENCES

[1] Richard Feynman Introduces the World to Nanotechnology with Two Seminal Lectures 1984.

[2] Bayda S, Adeel M, Tuccinardi T, Cordani M, Rizzolio F. The History of Nanoscience and Nanotechnology: From Chemical–Physical Applications to Nanomedicine. Molecules 2019; 25(1): 112.
[http://dx.doi.org/10.3390/molecules25010112] [PMID: 31892180]

[3] Zheng YB, Kiraly B, Huang TJ. Molecular machines drive smart drug delivery. Nanomedicine (Lond) 2010; 5(9): 1309-12.
[http://dx.doi.org/10.2217/nnm.10.111] [PMID: 21128714]

[4] Astruc D. Introduction to Nanomedicine. Molecules 2015; 21(1): 4.
[http://dx.doi.org/10.3390/molecules21010004] [PMID: 26791291]

[5] Drexler KE. Engines of creation. Garden City, N.Y: Anchor Press/Doubleday 1986.

[6] Boehm Frank. Nanomedicine – past, present and future: an interview with Frank Boehm, CEO NanoApps Medical Inc. Interview by Cashin-Garbutt, BA Hons, Medical News, March 2015.

[7] Shrestha B, Wang L, Zhang H, *et al.* Gold Nanoparticles Mediated Drug-Gene Combinational Therapy for Breast Cancer Treatment. Int J Nanomedicine 2020; 15: 8109-19. [http://dx.doi.org/10.2147/IJN.S258625] [PMID: 33116521]

[8] Patra JK, Das G, Fraceto LF, *et al.* Nano based drug delivery systems: recent developments and future prospects. J Nanobiotechnology 2018; 16(1): 71. [http://dx.doi.org/10.1186/s12951-018-0392-8] [PMID: 30231877]

[9] Liu Y, Kim S, Kim YJ, *et al.* Green synthesis of gold nanoparticles using *Euphrasia officinalis* leaf extract to inhibit lipopolysaccharide-induced inflammation through NF-κB and JAK/STAT pathways in RAW 264.7 macrophages. Int J Nanomedicine 2019; 14: 2945-59. [http://dx.doi.org/10.2147/IJN.S199781] [PMID: 31114201]

[10] Xu MX, Wang M, Yang WW. Gold-quercetin nanoparticles prevent metabolic endotoxemia-induced kidney injury by regulating TLR4/NF-kB signaling and Nrf2 pathway in high fat diet fed mice. Int J Nanomedicine 2017; 12: 327-45. [http://dx.doi.org/10.2147/IJN.S116010] [PMID: 28115850]

[11] Wang C, Chen S, Bao L, Liu X, Hu F, Yuan H. Size-Controlled Preparation and Behavior Study of Phospholipid–Calcium Carbonate Hybrid Nanoparticles 2020; 15: 4049-62.

[12] Wang R, Song B, Wu J, Zhang Y. Potential adverse effects of nanoparticles on the reproductive system 2018. [http://dx.doi.org/10.2147/IJN.S170723]

[13] Chu C, Zhou L, Xie H, *et al.* Pulmonary toxicities from a 90-day chronic inhalation study with carbon black nanoparticles in rats related to the systemical immune effects, 2019, 14, 2995-3013.

[14] Alexandru Mihai Grumezescu. Nanomaterials for Drug Delivery and Therapy. 1st ed., Elsevier 2019.

[15] Din F, Aman W, Ullah I, *et al.* Effective use of nanocarriers as drug delivery systems for the treatment of selected tumors. Int J Nanomedicine 2017; 12: 7291-309. [http://dx.doi.org/10.2147/IJN.S146315] [PMID: 29042776]

[16] Rodrigues T, Reker D, Schneider P, Schneider G. Counting on natural products for drug design. Nat Chem 2016; 8(6): 531-41. [http://dx.doi.org/10.1038/nchem.2479] [PMID: 27219696]

[17] Siddiqui AA, Iram F, Siddiqui S, Sahu K. Role of natural products in drug discovery process. Int J Drug Dev Res 2014; 6(2): 172-204.

[18] Beutler JA. Natural products as a foundation for drug discovery. Curr Protocols Pharmacol 2009; 46(1): 11.1-, 21. [http://dx.doi.org/10.1002/0471141755.ph0911s46] [PMID: 20161632]

[19] Thilakarathna S, Rupasinghe H. Flavonoid bioavailability and attempts for bioavailability enhancement. Nutrients 2013; 5(9): 3367-87. [http://dx.doi.org/10.3390/nu5093367] [PMID: 23989753]

[20] Bonifácio BV, Silva PB, Ramos MA, Negri KMS, Bauab TM, Chorilli M. Nanotechnology-based drug delivery systems and herbal medicines: a review. Int J Nanomedicine 2014; 9: 1-15. [PMID: 24363556]

[21] Watkins R, Wu L, Zhang C, Davis RM, Xu B. Natural product-based nanomedicine: recent advances and issues. Int J Nanomedicine 2015; 10: 6055-74. [PMID: 26451111]

[22] https://www.wired.com/2013/03/sensor-tattoos/

[23] Jaishankar M, Tseten T, Anbalagan N, Mathew BB, Beeregowda KN. Toxicity, mechanism and health effects of some heavy metals. Interdiscip Toxicol 2014; 7(2): 60-72. [http://dx.doi.org/10.2478/intox-2014-0009] [PMID: 26109881]

[24] Yuan X, Zhang X, Sun L, Wei Y, Wei X. Cellular Toxicity and Immunological Effects of Carbon-based Nanomaterials. Part Fibre Toxicol 2019; 16(1): 18. [http://dx.doi.org/10.1186/s12989-019-0299-z] [PMID: 30975174]

[25] NG. Unforgatable images https://www.nationalgeographic.com/photography/2020/12/10

[26] Science News, 2020, https://www.sciencemag.org/news/2020. (Accessed June 2021).

[27] Allergic Reactions Including Anaphylaxis After Receipt of the First Dose of Pfizer-BioNTech COVID-19 Vaccine — United States. 2021.

[28] Szebeni Janos. Janos Szebeni, an immunologist at Semmelweis University in Budapest, Hungary, 16 December 2020.

[29] Uskoković V. Nanomedicine for the poor: a lost cause or an idea whose time has yet to come? Nanomedicine (Lond) 2021; 16(14): 1203-18. [http://dx.doi.org/10.2217/nnm-2021-0024] [PMID: 33988035]

[30] https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds), Accessed Dec. 8, 2021.

[31] Centers for Disease Control and Prevention (US); National Center for Chronic Disease Prevention and Health Promotion (US). 2010.https://www.ncbi.nlm.nih.gov/books/NBK53012/

[32] Annual smoking-attributable mortality, years of potential life lost, and productivity losses--United States, 1997-2001. MMWR Morb Mortal Wkly Rep 2005; 54(25): 625-8. [PMID: 15988406]

[33] Shaper AG, Pocock SJ, Walker M, Phillips AN, Whitehead TP, Macfarlane PW. Risk factors for ischaemic heart disease: the prospective phase of the British Regional Heart Study. J Epidemiol Community Health 1985; 39(3): 197-209. [http://dx.doi.org/10.1136/jech.39.3.197] [PMID: 4045359]

[34] Shaten BJ, Kuller LH, Neaton JD. Association between baseline risk factors, cigarette smoking, and CHD mortality after 10.5 years. Prev Med 1991; 20(5): 655-69. [http://dx.doi.org/10.1016/0091-7435(91)90061-8] [PMID: 1758844]

[35] Freund KM, Belanger AJ, D'Agostino RB, Kannel WB. The health risks of smoking the framingham study: 34 years of follow-up. Ann Epidemiol 1993; 3(4): 417-24. [http://dx.doi.org/10.1016/1047-2797(93)90070-K] [PMID: 8275219]

[36] Neaton JD, Wentworth D. Serum cholesterol, blood pressure, cigarette smoking, and death from coronary heart disease. Overall findings and differences by age for 316,099 white men. Arch Intern Med 1992; 152(1): 56-64. [http://dx.doi.org/10.1001/archinte.1992.00400130082009] [PMID: 1728930]

[37] Cremer P, Nagel D, Mann H, *et al.* Ten-year follow-up results from the Goettingen Risk, Incidence and Prevalence Study (GRIPS). I. Risk factors for myocardial infarction in a cohort of 5790 men. Atherosclerosis 1997; 129(2): 221-30. [http://dx.doi.org/10.1016/S0021-9150(96)06030-3] [PMID: 9105565]

[38] Gartside PS, Wang P, Glueck CJ. Prospective assessment of coronary heart disease risk factors: the NHANES I epidemiologic follow-up study (NHEFS) 16-year follow-up. J Am Coll Nutr 1998; 17(3): 263-9. [http://dx.doi.org/10.1080/07315724.1998.10718757] [PMID: 9627913]

[39] Jacobs DR Jr, Adachi H, Mulder I, *et al.* Cigarette smoking and mortality risk: twenty-five-year follow-up of the Seven Countries Study. Arch Intern Med 1999; 159(7): 733-40. [http://dx.doi.org/10.1001/archinte.159.7.733] [PMID: 10218754]

[40] Wannamethee SG, Shaper AG, Walker M, Ebrahim S. Lifestyle and 15-year survival free of heart attack, stroke, and diabetes in middle-aged British men. Arch Intern Med 1998; 158(22): 2433-40. [http://dx.doi.org/10.1001/archinte.158.22.2433] [PMID: 9855381]

[41] Blanco-Cedres L, Daviglus ML, Garside DB, *et al.* Relation of cigarette smoking to 25-year mortality in middle-aged men with low baseline serum cholesterol: the Chicago Heart Association Detection Project in Industry. Am J Epidemiol 2002; 155(4): 354-60.
[http://dx.doi.org/10.1093/aje/155.4.354] [PMID: 11836200]

[42] https://www.google.com/search

[43] Carmona M. Does Alcohol Affect the Cardiovascular System?. The Recovery Village 2020.

[44] https://www.betterhealth.vic.gov.au/health/conditionsandtreatments/heart-disease-and-food

[45] University of California San Francisco, https://www.ucsfhealth.org/education/cholesterol-content--f-foods. (Accessed Dec. 16, 2021).

[46] Timberlake KC. Chemistry: An Introduction to General, Organic, and Biological Chemistry. 5th ed., USA: Pearson Education Inc. 2016.

[47] Meo SA, Suraya F. Effect of environmental air pollution on cardiovascular diseases. Eur Rev Med Pharmacol Sci 2015; 19(24): 4890-7.
[PMID: 26744881]

[48] Rajagopalan S, Al-Kindi SG, Brook RD. Air pollution and cardiovascular disease: JACC state-of-t-e-art review. J Am Coll Cardiol 2018; 72(17): 2054-70.
[http://dx.doi.org/10.1016/j.jacc.2018.07.099] [PMID: 30336830]

[49] Yamamoto SS, Phalkey R, Malik AA. A systematic review of air pollution as a risk factor for cardiovascular disease in South Asia: Limited evidence from India and Pakistan. Int J Hyg Environ Health 2014; 217(2-3): 133-44.
[http://dx.doi.org/10.1016/j.ijheh.2013.08.003] [PMID: 24064368]

[50] Junaid M, Syed JH, Abbasi NA, Hashmi MZ, Malik RN, Pei DS. Status of indoor air pollution (IAP) through particulate matter (PM) emissions and associated health concerns in South Asia. Chemosphere 2018; 191: 651-63.
[http://dx.doi.org/10.1016/j.chemosphere.2017.10.097] [PMID: 29078189]

[51] Wong CM, Vichit-Vadakan N, Vajanapoom N, *et al.* Part 5. Public health and air pollution in Asia (PAPA): a combined analysis of four studies of air pollution and mortality. Res Rep Health Eff Inst 2010; (154): 377-418.
[PMID: 21446215]

[52] Romieu I, Gouveia N, Cifuentes LA, *et al.* Multicity study of air pollution and mortality in Latin America (the ESCALA study). Res Rep Health Eff Inst 2012; (171): 5-86.
[PMID: 23311234]

[53] Le TG, Ngo L, Mehta S, *et al.* Effects of short-term exposure to air pollution on hospital admissions of young children for acute lower respiratory infections in Ho Chi Minh City, Vietnam. Res Rep Health Eff Inst 2012; (169): 5-72.
[PMID: 22849236]

[54] Nasser Z, Salameh P, Nasser W, Abou Abbas L, Elias E, Leveque A. Outdoor particulate matter (PM) and associated cardiovascular diseases in the Middle East. Int J Occup Med Environ Health 2015; 28(4): 641-61.
[http://dx.doi.org/10.13075/ijomeh.1896.00186] [PMID: 26216305]

[55] Wolfram J, Ferrari M. Clinical cancer nanomedicine. Nano Today 2019; 25: 85-98.
[http://dx.doi.org/10.1016/j.nantod.2019.02.005] [PMID: 31360214]

[56] Wolfram J, Zhu M, Yang Y, *et al.* Safety of nanoparticles in medicine. Curr Drug Targets 2015; 16(14): 1671-81.
[http://dx.doi.org/10.2174/1389450115666140804124808] [PMID: 26601723]

[57] Etheridge ML, Campbell SA, Erdman AG, Haynes CL, Wolf SM, McCullough J. The big picture on nanomedicine: the state of investigational and approved nanomedicine products. Nanomedicine 2013;

9(1): 1-14.
[http://dx.doi.org/10.1016/j.nano.2012.05.013] [PMID: 22684017]

[58] Bobo D, Robinson KJ, Islam J, Thurecht KJ, Corrie SR. Nanoparticle-based medicines: a review of FDA-approved materials and clinical trials to date. Pharm Res 2016; 33(10): 2373-87.
[http://dx.doi.org/10.1007/s11095-016-1958-5] [PMID: 27299311]

[59] Serini S, Cassano R, Trombino S, Calviello G. Nanomedicine-based formulations containing ω-3 polyunsaturated fatty acids: potential application in cardiovascular and neoplastic diseases. Int J Nanomedicine 2019; 14: 2809-28.
[http://dx.doi.org/10.2147/IJN.S197499] [PMID: 31114196]

[60] Chandarana M, Curtis A, Hoskins C. The use of nanotechnology in cardiovascular disease. Appl Nanosci 2018; 8(7): 1607-19.
[http://dx.doi.org/10.1007/s13204-018-0856-z]

[61] Nadimi AE, Ebrahimipour SY, Afshar eg, *et al.* Nano-scale drug delivery systems for antiarrhythmic agents. Eur J Med Chem 2018; 157: 1153-63.
[http://dx.doi.org/10.1016/j.ejmech.2018.08.080] [PMID: 30189397]

[62] Patel DN, Bailey SR. Nanotechnology in cardiovascular medicine. Catheter Cardiovasc Interv 2007; 69(5): 643-54.
[http://dx.doi.org/10.1002/ccd.21060] [PMID: 17390307]

[63] Katsuki S, Matoba T, Koga J, Nakano K, Egashira K. Anti-inflammatory Nanomedicine for Cardiovascular Disease. Front Cardiovasc Med 2017; 4: 87.
[http://dx.doi.org/10.3389/fcvm.2017.00087] [PMID: 29312961]

[64] Martín Giménez VM, Kassuha DE, Manucha W. Nanomedicine applied to cardiovascular diseases: latest developments. Ther Adv Cardiovasc Dis 2017; 11(4): 133-42.
[http://dx.doi.org/10.1177/1753944717692293] [PMID: 28198204]

[65] Iafisco M, Alogna A, Miragoli M, Catalucci D. Cardiovascular nanomedicine: the route ahead. Nanomedicine (Lond) 2019; 14(18): 2391-4.
[http://dx.doi.org/10.2217/nnm-2019-0228] [PMID: 31456471]

CHAPTER 3

Future of Nanomedicine

Abstract: There is no doubt that nanomedicine has a bright future and that it is being produced with increasing efficiency. It should be mentioned that the immune system is being improved by nanomedicine, and drug resistance can be managed since bacteria and viruses will be destroyed using a variety of techniques, including mechanical and thermal methods. This is done by continuous monitoring of the immune system. It will also benefit the technological development of nanomedicine in astronaut clothing. Spacecraft will contain a nanomedicine spacesuit to provide effective treatment to astronauts. Technological development, especially in the field of artificial intelligence, will be used to maximize nanomedicine use.

Keywords: Artificial Intelligent and Medicine, Future of Nanomedicine, Nanobot and Complex Surgeries, Nanotechnology and Health.

INTRODUCTION

As expected, nanomedicine will work on common diseases and this proves that nanomedicine is the future. The human body will be protected from all forms of infections. Nanomedicine helps to strengthen the immune system. Bacteria and viruses will be managed by nanomedicine, according to one futuristic vision, as a result of which, drug resistance will be overcome. In addition, nanodevices are expected to be smaller than a typical human body cell size. This expectation will give other advantages of nanomedicine to work efficiently in treating various diseases [1]. As stated, space travel will be easy with the help of nanomedicine. Nanomedicine will make it possible to treat any unforeseen diseases in space and to overcome any emergency. And this is always the case with new inventions.

Recent Research in Nanomedicine

One of the most serious diseases is cancer, and its therapy is still not ideal or very effective. This is a result of the side effects of chemotherapy. Accordingly, there is a need to have efficient medicine with very minimal side effects. Gold is one of the precious metals. Human beings have been using it without any problem from ancient times to the present [2]. Gold nanoparticles have been developed as a drug delivery mediator for a specific cancer drug. The polyethyleneimine coating on gold nanoparticles makes it easier for a specific compound to assemble on the sur-

Amin El-Meligi

face. There is an improvement in treatment due to the synergistic effect of drug and gene delivery together on their individual delivery [3].

Nanotechnology actually offers a big advantage because it improves current drug delivery technologies. This occurs due to the high surface area and passive targeting capabilities of the nanomaterials. Many types of nanomaterials have been studied for drug delivery, photothermal therapy, imaging, tissue engineering, and electroporation [4 - 9].

Wound healing is an important issue especially after surgeries. A new type of multifunctional wound dressing is being developed by combining graphene oxide/copper nanocomposites with chitosan/hyaluronic acid. This manufacturing provides great opportunities for wound repair, especially wounds at risk of infection with bacteria [10]. The combination of the aforementioned materials has acceptable biocompatibility and antimicrobial efficacy both *in vitro* and *in vivo*. Also, this combination accelerates the healing process of wounds, especially of bacteria-infected wounds. The wound healing has improved by using magnetic nanoparticles and exosomes extracted from bone mesenchymal stem cells [11]. In reality, a well-structured integration of cell migration and proliferation, collagen synthesis and deposition, angiogenesis, re-epithelialization, and wound remolding is necessary for skin wound healing. [12, 13].

Drug delivery systems for nanoparticles allow controlled drug release over time, especially for prolonged therapeutic treatments [14]]. In fact, most of the research suggest not to use a single or a few doses with low nanoparticles' concentrations. This research has screened a number of nanoparticles compounds, either polymeric or lipid-based, in a repeated dose toxicity study, to estimate the safety and tissue distribution of promising nanocarriers to be used in the treatment of chronic diseases. The results show that nanoparticles accumulate in different tissues. There was no sign of toxicity or any disease.

Radiotherapy is actually one of the most significant cancer treatments, but it also includes side effects that are common to practically all medications. Due to an X-ray flaw, radiation has a side effect. The shortcoming of X-rays is the high value of the oxygen enhancement ratio [15]. Additional radiotherapy side effects include tardiness, nausea and vomiting, hair loss, and rough skin. Synergistic radiosensitivity could be increased by functionalized nanoparticles of polyethylene glycol composed of metallic elements such as gold (Au) and platinum (Pt). The nanoparticles of Au and Pt exhibited enzyme-mimicking activities by catalyzing the decomposition of endogenous hydrogen peroxide (H_2O_2) to oxygen (O_2) in the solid tumor [15].

The applications and challenges of mesoporous silica nanomaterials in the field of the diagnosis and therapy of Atherosclerosis (AS) have been summarized. The classification, synthesis, formation mechanism, surface modification and functionalization of mesoporous silica nanomaterials, which were closely related to the theranostic effect of AS, have also been included. Mesoporous silica nanoparticles as a nanocarrier for drug delivery have received extensive attention due to their flexible size, high specific surface area, controlled pore volume, high drug loading capacity and excellent biocompatibility [16].

A natural product is a good source of vitamins, minerals, and nutrients. Okra or Abelmoschus esculentus is an important source of natural products. It was reported that the okra flowers could help as extract-mediated silver nanoparticles [17]. The silver nanoparticles showed significant activities *in vitro* tests, especially *in vitro* cytotoxic and antiproliferative tests against cancer cell lines. The antibacterial effect of silver nanoparticles on different types of bacteria was studied. It was observed that the nanoparticles showed a higher level of antibacterial activity, cytotoxicity and apoptosis at minimal concentrations.

Artificial Intelligence and Nanomedicine

The eventual emergence of artificial intelligence (AI) is expected to provide a clear way to recognize the full potential of combinatorial nanomedicine [18 - 27]. This expectation is because of the fact that AI-determined combination parameters can achieve globally optimal therapeutic outcomes independent of complex disease mechanism information.

In fact, the combination medicine strategy could be realized by the industry as an essential way of treating various diseases, such as pulmonary hypertension, cardiovascular disease, diabetes, arthritis, COPD, HIV, tuberculosis, and oncology [28 - 36]. A challenge in the combination medicine strategy is that the synergy of medicine is time-dependent, dose-dependent, and specificity of patients at any given treatment point. The link between AI and nanomedicine in order to continue to improve or maintain the effectiveness of nanomedicine in treating many diseases has become an established fact. This is because nanomedicine is important to treat many diseases [31 - 36]. AI can practically recognize the full potential of nanomedicine, if drug and dosage standards of combinatorial nanomedicine are optimized [21].

Nanomedicine Transformation Using AI

There are two stages to obtaining the highest benefit from nanomedicine. In the first stage, the drug space and dosage should be investigated in order to characterize the drugs and their identical dosages that ensure efficacy and safety.

In the second stage, the synergy process becomes automatic and changes over time, if the combination therapy is successfully processed. It is necessary to know the dose-dependent synergistic nature of the patient and hence the dynamic dosage of combination therapies in order to maintain improvement during the course of treatment [18]. Addressing the above stages in a clinical setting requires the use of neutral and AI-enabled approaches that depend on important factors such as drug targeting, proportional delivery, and other characteristics enabled by nanotechnology-mediated delivery as well as patient response effectively to the therapeutic process.

There are challenges facing nanomedicine that can be overcome. As known, AI has witnessed important developments. For example, deep learning algorithms developed to diagnose melanoma have shown comparable accuracy with clinician-approved standards of care diagnostic procedures [37 - 39].

AI will have an increasing role in improving nanotechnology-based drug delivery. An attempt to combine automation and AI gives the ability to optimize targeted therapeutic nanoparticles for unique cell types and patients [40, 41].

Nanomedicine and Economy

There is a significant relationship between nanotechnology and the economy. Despite the ongoing COVID19 pandemic, the global nanotechnology market is estimated at $54.2 billion and is estimated at $16 billion in the USA in 2020. The Global Nanotechnology Market is expected to reach US$126.8 Billion and in US$22.1 Billion trailing a Compound Annual Growth Rate (CAGR) of 12.4% in China in the year 2027. Japan and Canada are estimated to grow at 11.4% and 11% respectively in the period 2020-2027. The European nanotechnology market is estimated to reach US $22.1 Billion in the year 2027 excluding Germany, which is estimated to reach about 9.4% alone CAGR. Market trends in nanomedicine indicate that nanotechnology is revolutionizing pharmaceuticals and healthcare, and also the nanomedicine market to achieve explosive growth, increasing the demand for nano healthcare and nano devices [42].

June 25, 2021 (America News Hour) (The report is shown as published) – “In a recently published report, Kenneth Research has updated the market report for Nanomedicine Market for 2021 till 2030. The report further discusses the various strategies to be adopted or being adopted by the business players across the globe at various levels in the value chain. In view of the global economic slowdown, we further estimated that China, India, Japan and South Korea will recover the fastest amongst all the countries in the Asian market. Germany, France, Italy, and Spain are expected to take the worst hit and this hit is expected to regain 25% by the end of 2021- Positive Growth in the economic demand and supply” [43].

U.S. Market recovers fast. In a release on May 4th 2021, the U.S. Bureau and Economic Analysis and U.S. Census Bureau mentions the recovery in the U.S. International trade in March 2021. Exports in the country reached $200 billion, from $12.4 billion in Feb 2021. Following the continuous incremental trend, imports tallied at $274.5 billion, picked up by $16.4 billion in Feb 2021". However, as COVID19 still haunts the economies across the globe, year-ove--year (y-o-y) average exports in the U.S. declined by $7.0 billion from March 2020 till March 2021 whilst imports increased by $20.7 billion during the same time. This definitely shows how the market is trying to recover back and this will have a direct impact on the Healthcare/ICT/Chemical industries, creating a huge demand for Nanomedicine Market products [43].

According to a report by the World Health Organization (WHO), the total health spending is growing with an annual average rate of 6% in the low- and middle-income nations and close to 4% in the high-income countries. Further, in the year 2016, the expenditure made on health reached close 10% of the GDP of the world and crossed a value of USD 7 trillion [43].

Overview: Nanomedicine is an offshoot of nanotechnology, and refers to highly-specific medical intervention at the molecular scale for curing diseases or repairing damaged tissues. Nanomedicine uses nano-sized tools for the diagnosis, prevention and treatment of diseases, and to gain increased understanding of the complex underlying pathophysiology of the disease. It involves three nanotechnology areas of diagnosis, imaging agents, and drug delivery with nanoparticles in the 1-1,000 nm range, biochips, and polymer therapeutics [43].

The majority of nanomedicines used now allow oral drug delivery and its demand is increasing significantly. Although these nanovectors are designed to translocate across the gastrointestinal tract, lung, and blood-brain barrier, the amount of drug transferred to the organ is lower than 1%; therefore, improvements are challenging". "Nanomedicines are designed to maximize the benefit/risk ratio, and their toxicity must be evaluated not only by sufficiently long term *in vitro* and *in vivo* studies, but also pass multiple clinical studies [43].

The major drivers of the nanomedicine market include its application in various therapeutic areas, increasing R&D studies about nanorobots in this segment, and significant investments in clinical trials by the government as well as the private sector. The Oncology segment is the major therapeutic area for nanomedicine application, which comprised more than 35% of the total market share in 2016. A major focus in this segment is expected to drive the growth of the nanomedicine market in the future [43].

Market Analysis: The Global Nanomedicine Market is estimated to witness a CAGR of 17.1% during the forecast period 2017-2023. The nanomedicine market is analyzed based on two segments - therapeutic applications and regions [43].

Regional Analysis: The regions covered in the report are the Americas, Europe, Asia Pacific, and the Rest of the World (ROW). The Americas is set to be the leading region for the nanomedicine market growth followed by Europe. The Asia Pacific and ROW are set to be the emerging regions. Japan is said to be the most attractive destination and in Africa, the popularity and the usage of various nano-drugs are expected to increase in the coming years. The major countries covered in this report are the US, Germany, Japan, and Others [43].

Therapeutic Application Analysis: Nanomedicines are used as fluorescent markers for diagnostic and screening purposes. Moreover, nanomedicines are introducing new therapeutic opportunities for a large number of agents that cannot be used effectively as conventional oral formulations due to poor bioavailability. The therapeutic areas for nanomedicine application are oncology, cardiology, neurology, anti-inflammatory, anti-infective, and various other areas. Globally, the industry players are focusing significantly on R&D to gain approval for various clinical trials for future nano-drugs to be commercially available in the market. The FDA should be relatively prepared for some of the earliest and most basic applications of nanomedicine in areas such as gene therapy and tissue engineering. The more advanced applications of nanomedicine will pose unique challenges in terms of classification and maintenance of scientific expertise [43]".

Key Players: Merck & Co. Inc., Hoffmann-La Roche Ltd., Gilead Sciences Inc., Novartis AG, Amgen Inc., Pfizer Inc., Eli Lilly and Company, Sanofi, Nanobiotix SA, UCB SA and other predominate & niche players [43].

Competitive Analysis: At present, the nanomedicine market is at a nascent stage but, a lot of new players are entering the market as it holds huge business opportunities. Especially, big players along with the collaboration with other SMBs for clinical trials of nanoparticles and compounds are coming up with new commercial targeted drugs in the market and they are expecting a double-digit growth in the upcoming years. Significant investments in R&D in this market are expected to increase and collaborations, mergers and acquisition activities are expected to continue [43].

Benefits: The report provides complete details about the usage and adoption rate of nanomedicines in various therapeutic verticals and regions. With that, key stakeholders can know about the major trends, drivers, investments, vertical player's initiatives, government initiatives towards nanomedicine adoption in the upcoming years along with the details of commercial drugs available in the market. Moreover, the report provides details about the major challenges that are going to impact the market growth. Additionally, the report gives complete details about the key business opportunities to key stakeholders to expand their business and capture the revenue in the specific verticals to analyze before investing or expanding the business in this market [43].

Impact on Employment

It was stated that there were 200 identified active nanomedicine companies worldwide in 2004. There were also 159 start-ups and SMEs [44]. There are 41 major pharmaceutical and medical device companies that have nanomedicine products on the market or operate research projects in which nanotechnology plays a role. These numbers of companies working in nanomedicine are a good source of job creation.

CONCLUDING REMARKS

In fact, the future of nanomaterials and nanotechnology is well established to continue uninterruptedly. The combination of nanomedicines is expected to make a significant effect on people's health. AI will be a promising trend in the field of nanomedicine and in treating various diseases. The nanomedicine market has a significant impact on the global economy and job creation.

CONSENT FOR PUBLICATION

Not applicable

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGEMENTS

The author would like to thank all authors who have been or are not cited in the chapter. All the organizations, companies, universities and research institutes that are mentioned or cited in the chapter, as well as those that are not mentioned or cited, are acknowledged. The author would also like to thank Bentham Science Publishers Pte. Ltd. for publishing the book.

REFERENCES

[1] Boehm Frank. Nanomedicine – past, present and future: an interview with Frank Boehm, CEO NanoApps Medical Inc. Interview by Cashin-Garbutt, BA Hons, Medical News, March 2015.

[2] Shrestha B, Wang L, Zhang H, Hung CY, Tang L. Gold Nanoparticles Mediated Drug-Gene Combinational Therapy for Breast Cancer Treatment. Int J Nanomedicine 2020; 15: 8109-19. [http://dx.doi.org/10.2147/IJN.S258625] [PMID: 33116521]

[3] Shrestha B, DeLuna F, Anastasio MA, Yong Ye J, Brey EM. Photoacoustic imaging in tissue engineering and regenerative medicine. Tissue Eng Part B Rev 2020; 26(1): 79-102.
[http://dx.doi.org/10.1089/ten.teb.2019.0296] [PMID: 31854242]

[4] Betal S, Dutta M, Shrestha B, *et al.* Cell permeation using core-shell magnetoelectric nanoparticles. Integr Ferroelectr 2016; 174(1): 186-94.
[http://dx.doi.org/10.1080/10584587.2016.1196332]

[5] Betal S, Shrestha B, Dutta M, *et al.* Magneto-elasto-electroporation (MEEP): *In-vitro* visualization and numerical characteristics. Sci Rep 2016; 6(1): 32019.
[http://dx.doi.org/10.1038/srep32019] [PMID: 27562291]

[6] Roux Brianna M, *et al.* iPSC-derived endothelial networks accelerate vascularization but not bone regeneration. Tissue Engineering ja 2020; 13

[7] Shrestha B, Stojkova K, Yi R, Anastasio MA, Ye JY, Brey EM. Gold nanorods enable noninvasive longitudinal monitoring of hydrogels *in vivo* with photoacoustic tomography. Acta Biomater 2020; 117: 374-83.
[http://dx.doi.org/10.1016/j.actbio.2020.09.048] [PMID: 33010515]

[8] Shrestha B, Brown J, Brey EM. Controlled Delivery of Angiogenic Proteins Controlled Drug Delivery Systems. CRC Press 2020; pp. 147-62.
[http://dx.doi.org/10.1201/9780429197833-9]

[9] Yang Y, Dong Z, Li M, *et al.* Graphene Oxide/Copper Nanoderivatives-Modified Chitosan/Hyaluronic Acid Dressings for Facilitating Wound Healing in Infected Full-Thickness Skin Defects 2020; 15: 8231-47.

[10] Wu D, Kang L, Tian J, *et al.* Exosomes Derived from Bone Mesenchymal Stem Cells with the Stimulation of Fe_3O_4 Nanoparticles and Static Magnetic Field Enhance Wound Healing Through Upregulated miR-21-5p. Int J Nanomedicine 2020; 15: 7979-93.
[http://dx.doi.org/10.2147/IJN.S275650] [PMID: 33116513]

[11] Rodrigues M, Kosaric N, Bonham CA, Gurtner GC. Wound healing: a cellular perspective. Physiol Rev 2019; 99(1): 665-706.
[http://dx.doi.org/10.1152/physrev.00067.2017] [PMID: 30475656]

[12] Singer AJ, Clark RAF. Cutaneous wound healing. N Engl J Med 1999; 341(10): 738-46.
[http://dx.doi.org/10.1056/NEJM199909023411006] [PMID: 10471461]

[13] Fonseca-Gomes J, Loureiro JA, Tanqueiro SR, *et al. in vivo* Bio-Distribution and Toxicity Evaluation of Polymeric and Lipid-Based Nanoparticles: A Potential Approach for Chronic Diseases Treatment. Int J Nanomedicine 2020; 15: 8609-21.
[http://dx.doi.org/10.2147/IJN.S267007] [PMID: 33177821]

[14] Yang S, Han G, Chen Q, *et al.* Au-Pt Nanoparticle Formulation as a Radiosensitizer for Radiotherapy with Dual Effects 2021; 16: 239-48.

[15] Rafael R. Castillo, Daniel Lozano, María Vallet-Regí. Mesoporous Silica Nanoparticles as Carriers for Therapeutic Biomolecules, pharmaceutics, 2020; 12: 432.

[16] Vallet-Regi M, Rámila A, del Real RP, Pérez-Pariente J. A New Property of MCM-41: Drug Delivery System. Chem Mater 2001; 13(2): 308-11.
[http://dx.doi.org/10.1021/cm0011559]

[17] Devanesan S, AlSalhi MS. Green Synthesis of Silver Nanoparticles Using the Flower Extract of *Abelmoschus esculentus* for Cytotoxicity and Antimicrobial Studies. Int J Nanomedicine 2021; 16: 3343-56.
[http://dx.doi.org/10.2147/IJN.S307676] [PMID: 34017172]

[18] Dean Ho. Peter Wangc; Theodore Kee. Artificial intelligence in nanomedicine: Nanoscale Horiz., 2019, 4, 365.[19] Lee, D.-K.; Chang, V. Y.; Kee, T.; Ho C.-M.; Ho, D. SLAS Technol 2017; 22: 276-88.

[20] Rashid MBMA, Toh TB, Hooi L, Silva A, Zhang Y, Tan ALPF, *et al.* Sci Transl Med 2018; 10.

[21] Leber A, Hontecillas R, Abedi V, *et al.* Modeling new immunoregulatory therapeutics as antimicrobial alternatives for treating Clostridium difficile infection. Artif Intell Med 2017; 78: 1-13. [http://dx.doi.org/10.1016/j.artmed.2017.05.003] [PMID: 28764868]

[22] Cai R, Liu M, Hu Y, *et al.* Identification of adverse drug-drug interactions through causal association rule discovery from spontaneous adverse event reports. Artif Intell Med 2017; 76: 7-15. [http://dx.doi.org/10.1016/j.artmed.2017.01.004] [PMID: 28363289]

[23] Jia X, Li Y, Sharma A, *et al.* Cheng, Y.; Ding, X. Artificial intelligence in nanomedicine, Comput. Biol. Chem., 2017; 67: 34-243.

[24] Lee C, Luo Z, Ngiam KY, Zhang M, Zheng K, Chen G, *et al.* Handbook of Large-Scale Distributed Computing in Smart Healthcare. Cham: Springer International Publishing 2017; pp. 11-41. [http://dx.doi.org/10.1007/978-3-319-58280-1_2]

[25] Weiss A, Nowak-Sliwinska P. Current trends in multidrug optimization: an alley of future successful treatment of complex disorders. SLAS Technol 2017; 22(3): 254-75. [http://dx.doi.org/10.1177/2472630316682338] [PMID: 28027446]

[26] Ho D, Wang CHK, Chow EKH. Nanodiamonds: The intersection of nanotechnology, drug development, and personalized medicine. Sci Adv 2015; 1(7)e1500439 [http://dx.doi.org/10.1126/sciadv.1500439] [PMID: 26601235]

[27] Jha S, Topol EJ. Information and artificial intelligence. J Am Coll Radiol 2018; 15(3): 509-11. [http://dx.doi.org/10.1016/j.jacr.2017.12.025] [PMID: 29398501]

[28] Buckley MS, Staib RL, Wicks LM. Combination therapy in the management of pulmonary arterial hypertension. Int J Clin Pract 2013; 67(179): 13-23. [http://dx.doi.org/10.1111/ijcp.12136] [PMID: 23578069]

[29] Smith R, McCready T, Yusuf S. Combination therapy to prevent cardiovascular disease: slow progress. JAMA 2013; 309(15): 1595-6. [http://dx.doi.org/10.1001/jama.2013.3180] [PMID: 23529576]

[30] Derosa G, Sibilla S. Optimizing combination treatment in the management of type 2 diabetes. Vasc Health Risk Manag 2007; 3(5): 665-71. [PMID: 18078018]

[31] Dale J, Alcorn N, Capell H, Madhok R. Combination therapy for rheumatoid arthritis: methotrexate and sulfasalazine together or with other DMARDs. Nat Clin Pract Rheumatol 2007; 3(8): 450-8. [http://dx.doi.org/10.1038/ncprheum0562] [PMID: 17664952]

[32] Tashkin DP, Ferguson GT. Combination bronchodilator therapy in the management of chronic obstructive pulmonary disease. Respir Res 2013; 14(1): 49. [http://dx.doi.org/10.1186/1465-9921-14-49] [PMID: 23651244]

[33] Passaes CP, Sáez-Cirión A. HIV cure research: Advances and prospects. Virology 2014; 454-455: 340-52. [http://dx.doi.org/10.1016/j.virol.2014.02.021] [PMID: 24636252]

[34] Mitchison D, Davies G. The chemotherapy of tuberculosis: past, present and future [State of the art]. Int J Tuberc Lung Dis 2012; 16(6): 724-32. [http://dx.doi.org/10.5588/ijtld.12.0083] [PMID: 22613684]

[35] Maitland ML, Hudoba C, Snider KL, Ratain MJ. Analysis of the yield of phase II combination therapy trials in medical oncology. Clin Cancer Res 2010; 16(21): 5296-302. [http://dx.doi.org/10.1158/1078-0432.CCR-10-0669] [PMID: 20837695]

[36] Wu M, Sirota M, Butte AJ, Chen B. Characteristics of drug combination therapy in oncology by analyzing clinical trial data on ClinicalTrials.gov. Pac Symp Biocomput 2015; 20: 68-79.
[PMID: 25592569]

[37] Harrison C. University of California's first CRISPR patent win. Nat Biotechnol 2018; 36(8): 673.
[http://dx.doi.org/10.1038/nbt0818-673b] [PMID: 30080834]

[38] Prevedello LM, Erdal BS, Ryu JL, *et al.* Automated Critical Test Findings Identification and Online Notification System Using Artificial Intelligence in Imaging. Radiology 2017; 285(3): 923-31.
[http://dx.doi.org/10.1148/radiol.2017162664] [PMID: 28678669]

[39] Dilsizian SE, Siegel EL. Artificial intelligence in medicine and cardiac imaging: harnessing big data and advanced computing to provide personalized medical diagnosis and treatment. Curr Cardiol Rep 2014; 16(1): 441.
[http://dx.doi.org/10.1007/s11886-013-0441-8] [PMID: 24338557]

[40] Khong J, Wang P, Tiffany RX, *et al.* The role of artificial intelligence in scaling nanomedicine toward broad clinical impact. In: Eun Ji Chung, Lorraine Leon, Eds. Micro and Nano Technologies, Nanoparticles for Biomedical Applications. Elsevier 2020; pp. 385-407.

[41] Egorov E, Pieters C, Korach-Rechtman H, Shklover J, Schroeder A. Robotics, microfluidics, nanotechnology and AI in the synthesis and evaluation of liposomes and polymeric drug delivery systems. Drug Deliv Transl Res 2021; 11(2): 345-52.
[http://dx.doi.org/10.1007/s13346-021-00929-2] [PMID: 33585972]

[42] Global Nanotechnology Industry. 2020.https://www.globenewswire.com/news-release/2020/07/16/2062964/0/en/Global-Nanotechnology-Industry.html

[43] Kenneth Research Report, American News Hour. 2021.https://www.kennethresearch.com/sample-request-10085217

[44] Exploring the quantative dimensions of the economic impact of nanomedicine, Inter. Symposium on Assessing the Economic Impact of Nanotechnology, 27-28 March 2012.

CHAPTER 4

Nanotechnology and Water

Abstract: The environment is one of the hot issues nowadays because of pollution, global warming, and other issues. The main sources of energy are still non-renewable resources. Therefore, there is a need to solve environmental problems before it is too late to solve them. All living things on earth suffer because of environmental problems. The United Nation works with all countries to control environmental problems to protect the earth. Researchers pay great attention to help solve environmental problems. In addition to traditional methods of research, researchers use advanced technologies such as nanomaterials and nanotechnology. For example, in the near future, researchers will be able to use nanomaterials to extract energy from the air. Recently, attention has been paid to the relationship between nanoparticles and the environment, especially the impact of nanoparticle emission into the atmosphere on human health. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, size, morphology and interaction of nanomaterials.

Keywords: Heavy Metals in Water, Nanotechnology and Water, Nanomaterials and Water Purification, Water and Contamination.

INTRODUCTION

Nanomaterials have special properties that could enable new technologies for microbial control, decontamination, sensing and monitoring, and resource recovery. The special properties of nanomaterials, which are extremely high surface area, high reactivity, and catalytic properties, are expected to greatly enhance the kinetics and efficiency of various chemical and physicochemical processes used in water and wastewater treatment [1]. Accordingly, the size of the system also reduces chemicals and energy consumption.

Aqueous nanoparticles play an important role in the processes that occur in the atmosphere, but so far, researchers have not reached to explain the shifts in the ice and non-liquid equilibrium and the structures that form upon freezing completely. Here we use molecular dynamics simulation with the model of water to examine unparalleled freezing and dissolve the equilibrium of aqueous nanoparticles with a

Amin El-Meligi

radius of R between 1 and 4.7 nanometers and a crystallization ice structure at temperatures between 150 and 200 K, (Fig. **1**) shows ice nucleation and growth [2].

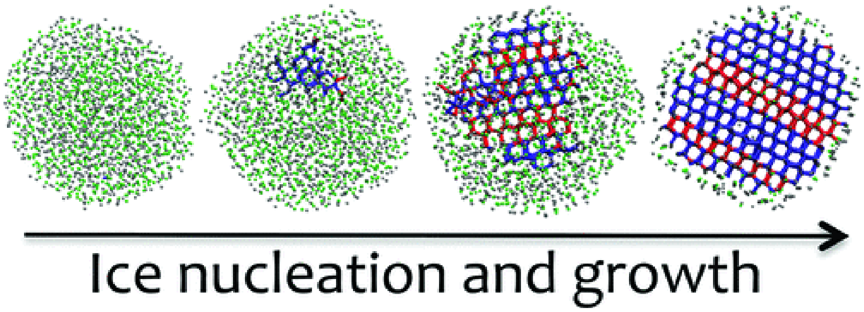


Fig. (1). Water ice nucleation and growth.

Water Purification

Water is essential for life, and all living things on the earth can't survive without water. If there is no pure and clean water, life will be in danger. The purification of water is well known using normal technology, such as chlorination, flocculation boiling and filtration. As mentioned, these water purification steps can reduce 30-40% of diarrheal diseases [3].

Accordingly, nanomaterials can help increase the degree of water purification as many nanomaterials can help through different mechanisms [4]. The mechanisms include removing heavy metals and other pollutants, inactivation of pathogens and removal and transformation of toxic materials into less toxic compounds. The treatment of water is improved by incorporation of nanomaterials in nanostructured catalytic membranes.

Also, some materials such as carbon nantubes, tiania, zero-valent iron, dendrimers (highly ordered, and branched polymeric molecules) and silver nanomaterials, could be used for water purification. In fact, traditional water purification methods are not safe, especially the formation of byproducts of chlorination, which cause various diseases due to carcinogenic disinfection byproducts [5]. Therefore, nanomaterials show many advantages over traditional microstructured materials for water purification [6]. Nanoporous membrane has shown an art in its formation; this can be seen in the nanoporous alumina membrane, which is coated by a large pore size of zinc oxide, as shown in Fig. (**2**) [6]. Also, nanoporous membranes could remove harmful matters in water such as arsenic, nitrates, organic materials, and viruses from groundwater and surface water [7].

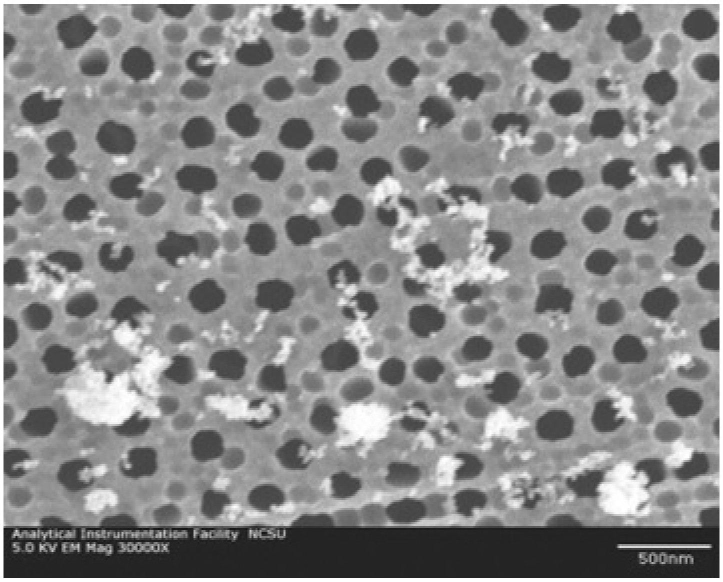


Fig. (2). Plan-view scanning electron micrograph obtained from the large pore side of a zinc oxide-coated 20 nm pore size nanoporous alumina membrane [6].

It was demonstrated that viruses and bacteria could be removed by using a membrane containing carbon nanotubes walls [8]. In fact, there are some defects of the membrane, such as the formation of biofilms on the membrane due to microorganisms in the water. Biofilms affect the permeability of the membrane and increase the cost of water purification [9 - 11]. In addition, water quality may deteriorate due to some microorganisms that may release biological toxins and metabolic products [12, 13]. Therefore, there has been research to address this issue through the use of nano water technologies and of wastewater treatment processes. This includes nanomaterials, such as nanoadsorbents, nanometals, nanomembranes and photocalaysts [14]. (Fig. **2**) shows a scanning electron micrograph of a large pore size of 20 nm ZnO-coated ZnO nanofilm. The usefulness and marketing of these materials have been reported. The arid regions of North Africa and nearly half of the European countries (about 70% of the population) face water shortages. Even industrialized countries such as the United States of America, which provide very innovative technologies for saving and purifying water, show the difficulty of depleting water tanks due to the fact that more water is extracted rather than refilled. In the People's Republic of China, 550 of the 600 largest cities suffer from water shortages, as the largest rivers are highly polluted and their use for irrigation, not to mention drinking water treatment, must be eliminated.

During the past decade, nanofiltration has made a breakthrough in the production of drinking water to remove contaminants. The combination of new standards for drinking water quality and continuous improvement of the nanofiltration process have led to new insights, potential applications and new projects at the laboratory, experimental and industrial scale. The research provides an overview of applications in the drinking water industry that have already been achieved or that have been proposed on the basis of laboratory-scale research.

Applications can be found in the treatment of surface water as well as groundwater. The possibility of using NF for the removal of hardness, natural organic material (NOM), micropollutants such as pesticides and VOCs, viruses and bacteria, salinity, nitrates, and arsenic will be discussed. Some of these applications have proven to be reliable and can be considered as well-known technologies. Other laboratory-wide applications are still being studied. Modelling is difficult due to effects of fouling and interaction between different components [7].

Water Desalination

We have to agree on the importance of desalination as a very important source of fresh water. In fact, out of 71% of the surface water of the Earth, salt water constitutes about 97.4% of the total water on Earth and fresh water constitutes about 2.6%. There is a shortage of fresh water all over the world. The distribution of water on Earth is shown in the following (Fig. **3**) [15]. In fact, water is the feedstock for many industries such as oil and gas industry, electric generation industry, agriculture industry, food and drinks industry. It is not only the industry but also the increase of the world's population that has increased the need for water, global climate change, urbanization, among others [16].

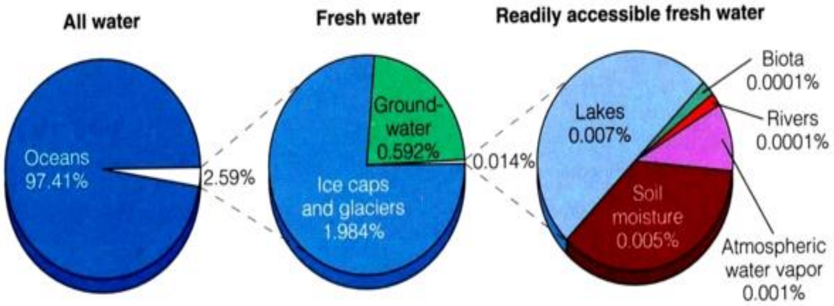


Fig. (3). Water distribution on the earth [15].

Also, fresh water is limited. Accordingly, water consumption is increasing year after year, and it is reported that the annual water consumption by industry will increase by 50% from its level in 1995 by 2025 [17, 18]. In addition, there is a prediction from the United Nations that approximately 2 to 7 billion people worldwide will experience water scarcity in the mid-21st century [19]. The serious impact of water scarcity is the impact on various aspects of human life such as health and economic growth. There will be a lack of interest to maintain the food and beverage hygiene, which will cause a number of epidemics such as diarrhea, cholera, foot and mouth, coronavirus, among others.

As we have faced the attack of the coronavirus in January 2020, more than 500 million people have been infected worldwide and more than half a million people have died. The attack of the virus is still going on and no one knows when it will be stopped. The main reason for the spread of the coronavirus is the lack of food hygiene by eating unusual foods. The World Health Organization states that a lack of clean and safe water can cause 3.1% of deaths worldwide. This trend will increase year by year [20].

As known, traditional water treatment does not clean the water to be ready to drink, but only organic matter and nutrients will be removed; also, they are not efficient to reduce the salinity. Although, desalination is a good option for covering the gap between the available capacities and the increasing demands. It is the process of removing salts and minerals to produce freshwater [21]. Seawater desalination processes are basically classified into four main categories – thermal energy, mechanical energy, electrical energy, and chemical energy as discussed by Mohamed in his final technical report written in the year 2011 [17]. However, the widespread applications of these desalination processes are limited due to self-contamination, huge power requirements, and, utilization of intense resources and not being economically viable [20]. Accordingly, there was a need to have efficient methods for water desalination; the nanotechnology has fulfilled this need. The traditional methods of desalination are no longer sustainable [22]. Nanomaterials are used for water and wastewater treatment applications in disinfection and control of microbes, adsorption, membrane filtration, photocatalysis, *etc*. Also, these materials are applied for sensing and monitoring the purity of water. There are different types of nanomaterials such as noble metals, carbon nanotubes, zeolites, metal oxides, among others.

Carbon Based Nano-Adsorbents

The main function of carbon nanotubes (CNTs) is the adsorption of various organic substances in water. Carbon nanotubes show higher adsorption efficiency of organic compounds compared to activated carbon [23]. The advantage of CNTs is that they have a large specific surface area and diverse interactions between them and the contaminants [24]. CTNs are hydrophobic because of their graphitic surface, so they form free bundles and aggregates in the aqueous stage. In fact, as explained by Pan *et al.*, the aggregates of CNTs have interstitial grooves and spaces. These grooves and spaces have high adsorption energy sites for organic compounds [23, 25]. Although the activated carbon has a significant number of micropores, but the drawback of activated carbon methods is that the large organic compounds such as pharmaceuticals and antibiotics cannot access these micropores [26]. Therefore, CNTs' adsorption capacity for some large organic compounds is higher than activated carbon. This is because of their larger pores in bundles and more accessible sorption sites.

In addition to the aforementioned disadvantage of activated carbon and the advantages of carbon nanotubes, they have a low adsorption affinity for low molecular weight polar organic molecules. The CNTs have high adsorption affinity for many of the polar organic compounds. This is because of the diverse interactions of contaminants and CNTs including hydrophobic effect, hydrogen bonding, covalent bonding, and electrostatic interactions [24]. The energy orbital of carbon atom plays a role in the high adsorption of CNTs for polar organic compounds. As explained, the surface of CNTs is rich in p electrons that allows p-e-p interactions with organic compounds containing Cs bonds or benzene rings, such as polycyclic aromatic hydrocarbons and polar aromatic molecules [27, 28]. Also, CNTs, which donate electrons, can form a hydrogen bond with organic acids (COOH), organic compounds of OH, and organic compounds of NH_2 functional groups. (Fig. **4**) shows the location of ions near the functional group in CNTs [29, 30]. Adsorption of positively charged organic compounds by CNTs is due to the electrostatic attraction at an appropriate pH [26].

Removal of Heavy Metals

Oxidized carbon nanotubes have high adsorption capacity for metal ions at fast kinetics. This is due to the major adsorption sites for metal ions on the surface of CNTs, which are carboxyl, hydroxyl and phenol functional groups. The adsorption occurs through chemical bonding and electrostatic attraction [31]. A number of studies present that activated carbon is a lower adsorbent than CNTs for heavy metals of Cu, Pb, Cd, and Zn [32, 33]. This is due the kinetics of adsorption is fast on CNTs. The CNTs have highly accessible adsorption sites and have short intraparticle diffusion distance.

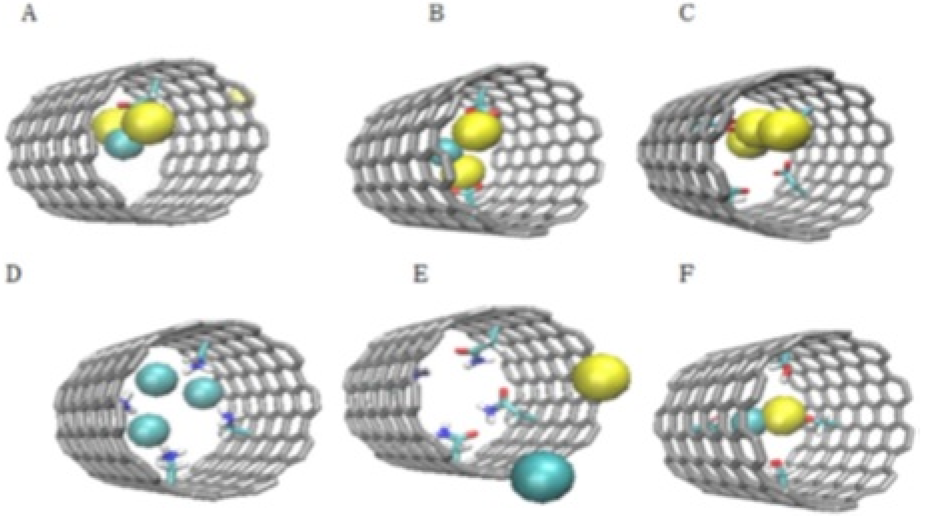


Fig. (4). Location of ions near the functional group. Snapshots from membrane distillation simulations are shown to indicate the location and buildup of Na^+ (yellow) and Cl^- (blue) ions near the functional group of the functionalized CNTs. Results are shown for CNTs with **(A)** 1 COO– **(B)** $2COO^-$**(C)** 4 COO^-**(D)** 4 NH_3^+**(E)** 4 $CONH_2$ and **(F)** 4OH [30].

Metal Oxide Nanoadsorbents

Metallic elements, such as Fe, Ti, and Al, react with oxygen to form iron oxide, titanium oxide, and aluminum oxide (alumina). Nanomaterials for these oxides have important applications as low-cost absorbent materials. The absorption process depends on the complex formation between dissolved metals and oxygen in metal oxides [34]. The process of sorption is completed in two steps: The first step is fast adsorption of metal ions on the external surface, and the second step is the rate limiting particles diffusion along the micropore walls [35].

Nanoparticles of these oxides have higher adsorption capacity and faster kinetics than microparticles. These advantages of nanoparticles are due to the higher specific area, shorter interaparticle diffusion distance and larger number of surface reaction sites. The reaction sites are composed of corners, edges and vacancies [35]. For example, if the nanomagnetite has decreased from 300 to 11 nm, the arsenic adsorption capacity increased more than 100 times [36]. This is attributed to the “nanoscale effect” in which magnetite surface structure is changed to create a new sites of adsorption [37].

Some nano-oxide has the advantage of size-dependent magnetism. For example, nanomagnetite and nanomaghemite can be supermagnetic. Reducing particle size has a significant impact on the magnetic properties of materials. As the particle size decreases, it becomes supermagnetic. The superparamagnetic nature of the particles could be easily separated and recovered by a low gradient external magnetic field [38]. In fact, these nanoparticles with superparamaganetic properties could be either used directly as adsorbents or as the core materials that help in the magnetic separation, as shown in Fig. (**5**).

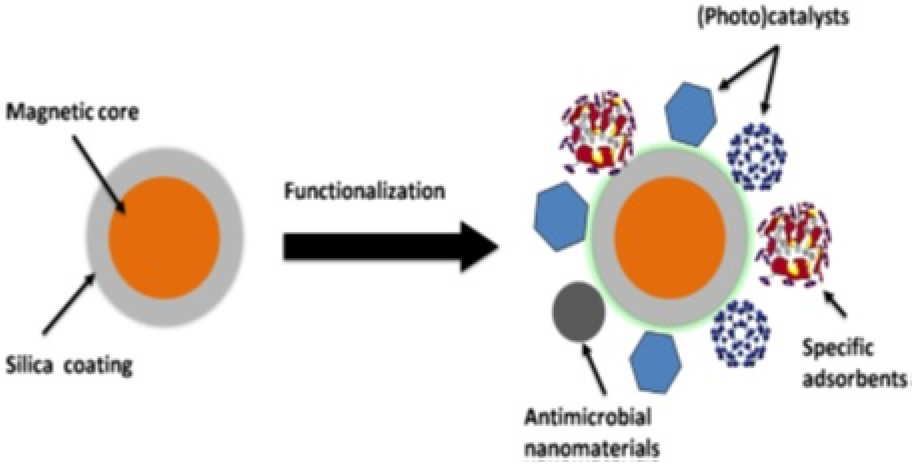


Fig. (5). Multifunctional magnetic nanoparticles [38].

Pressure has affected metal oxide nanocrystals, especially when they are compressed into porous pellets. Under moderate pressure, surface area of the compressed pellets is not affected [39]. The consolidation pressure can control pore volume and pore size. Therefore, the nanocrystals of metal oxides can be applied either as fine powders or porous pellets forms. These two forms are preferable to be used in industry.

Heavy metals, such as mercury, lead, arsenic, copper, chromium, nickel, cadmium, *etc*., can be removed by using nanomaterials of metal oxides. These nanooxides have shown high potential to outcompete traditional activated carbon. It is stated that the regeneration and reuse of the nanomaterials of metal oxides are easy processes by changing the pH of the solution [40]. The process of regeneration and reuse of nanooxides adsorbents are investigated by researchers, and there are two results. The first was conducted by Hu *et al*. and they concluded that the adsorption capacity of nanooxides remained unchanged after many regeneration and reuse cycles [41], and the second was conducted done by Deliyanni *et al*., and they reported that nanooxide adsorption capacity reduced after regeneration [42]. Nanooxide adsorbents have some technological and economic advantageous, such as high adsorption capacity, low cost, easy separation, regeneration and reuse.

Importance of Heavy Metals Removal

The process of purifying water from heavy metals is one of the most important stages that must be completed before reaching the consumption stage. The most important heavy elements that must be removed from the water before consumption are listed below.

The element that caught the attention of researchers to remove it from the water is arsenic. Arsenic is a semi-metal and is found in the fifth group of the main groups in the periodic table. The fifth group also contains important elements such as nitrogen, phosphorous, *etc*.

The word arsenic has its origin in the Syriac word □□□□□□ □□ (al) zarniqa [41,[from Arabic al-zarnīḵ الزرنيخ ‘the orpiment’, based on Persian zar ‘gold’ from the word زرنيخ zarnikh, meaning “yellow” (literally “gold-colored”) and hence (yellow) orpiment. It was adopted into Greek as arsenikon (ἀρσενικόν), a form that is folk etymology, being the neuter form of the Greek word arsenikos (ἀρσενικός), meaning “male”, “virile”. The Greek word was adopted in Latin as arsenicum, which in French became arsenic, from which the English word arsenic is taken [43]. Arsenic sulfides (orpiment, realgar) and oxides have been known and used since ancient times [44]. Zosimos (circa 300 AD) describes roasting sandarach (realgar) to obtain cloud of arsenic (arsenic trioxide), which he then reduced to grey arsenic [45]. As the symptoms of arsenic poisoning are not very specific, it was frequently used for killings until the advent of the Marsh test, a sensitive chemical test for its presence. (Another less sensitive but more general test is the Reinsch test.) Owing to its use by the ruling class to kill one another and its potency and discreetness, arsenic has been called the “poison of kings” and the “king of poisons” [46].

During the Bronze Age, arsenic was often included in bronze, which made the alloy harder (so-called “arsenical bronze”) [47, 48]. The isolation of arsenic was described by Jabir ibn Hayyan before 815 AD [49]. Albertus Magnus (Albert the Great, 1193–1280) later isolated the element from a compound in 1250, by heating soap together with arsenic trisulfide [50]. In 1649, Johann Schröder published two ways of preparing arsenic [51]. Crystals of elemental (native) arsenic are found in nature, although rare. The aforementioned information about arsenic is quoted from: https://www.ptable.com/ [52].

It has been mentioned that arsenic could be removed by using nanooxides, such as titanium oxide and magnetite, which has shown good performance of arsenic adsorption superior to activated carbon [52, 53]. Nanoparticles of metal hydroxide/oxide can be permeated onto activated carbon skeleton or other porous compounds to attain removal of arsenic and organic co-contaminants, simultaneously, which favours the point of use applications [54, 55].

The presence of arsenic in polluted groundwater represents the greatest threat to people's health. A number of countries have high levels of arsenic, such as China, India, Bangladesh, Chile, USA, and Mexico. Also, some sources of arsenic are irrigated crops, food prepared with water containing arsenic, and drinking water [55 - 58]. Also, some foods, such as fish, shelfish, meat, poultry, dairy products and cereals are sources of arsenic, but much lower than exposure to contaminated water. According to the World Health Organization (WHO), about 140 million or more people in 50 countries drink water contaminated with arsenic and this exceeds WHO levels (10 μg/L) [55, 59, 60]. A report published by the WHO in 2002 stated that the lack of clean and safe water for drinking and other uses accounts for 3.1% of deaths worldwide. This percentage is expected to increase year after year [61].

Arsenic has health effects on humans, and inorganic arsenic compounds are a confirmed carcinogen. It is one of the most important chemical pollutants in drinking water globally [55]. The inorganic compounds of arsenic are highly toxic. In fact, arsenic reacts to form organic compounds, but they are less toxic than inorganic compounds. Symptoms of acute arsenic poisoning can be seen immediately such as vomiting, diarrhea and abdominal pain. These symptoms are followed by serious illnesses that include numbness and tingling of the extremities, and cramping of muscles. In some extreme cases, it may cause death [55].

All in all, and according to the WHO, the following key facts about arsenic are listed [55]:

- Arsenic is naturally present at high levels in the groundwater of a number of countries.
- Arsenic is highly toxic in its inorganic form.
- Contaminated water used for drinking, food preparation and irrigation of food crops poses the greatest threat to public health from arsenic.
- Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. It has also been associated with cardiovascular disease and diabetes. In utero and early childhood exposure has been linked to negative impacts on cognitive development and increased deaths in young adults.
- The most important action in affected communities is the prevention of further exposure to arsenic by provision of a safe water supply.

Lead

Lead is one of the heavy metals that must be removed from water before consuming it. It is a metal and is found in the fourth group of main groups in the periodic table.

Lead (/ˈlɛd/) is a chemical element with the symbol Pb (from the Latin plumbum) and atomic number 82. It is a heavy metal that is denser than most common materials. Lead is soft and malleable, and also has a relatively low melting point. When freshly cut, it is silvery with a hint of blue; it tarnishes to a dull gray color when exposed to air. Lead has the highest atomic number of any stable element and three of its isotopes are endpoints of major nuclear decay chains of heavier elements [51].

Lead is a relatively unreactive post-transition metal. Its weak metallic character is illustrated by its amphoteric nature; lead and lead oxides react with acids and bases, and it tends to form covalent bonds. Compounds of lead are usually found in the +2 oxidation state rather than the +4 state common with lighter members of the carbon group. Exceptions are mostly limited to organo lead compounds. Like the lighter members of the group, lead tends to bond with itself; it can form chains and polyhedral structures.

Lead is easily extracted from its ores; prehistoric people in Western Asia has this knowledge. Galena is a principal ore of lead which often bears silver. Interest in silver helped initiate widespread extraction and use of lead in ancient Rome. Lead production declined after the fall of Rome and did not reach comparable levels until the Industrial R evolution. In 2014, the annual global production of lead was about ten million tonnes, over half of which was from recycling. Lead's high density, low melting point, ductility and relative inertness to oxidation make it useful. These properties, combined with its relative abundance and low cost, resulted in its extensive use in construction, plumbing, batteries, bullets and shot, weights, solders, pewters, fusible alloys, white paints, leaded gasoline, and radiation shielding.

In the late 19th century, lead's toxicity was recognized, and its use has since been phased out of many applications. However, many countries still allow the sale of products that expose humans to lead, including some types of paints and bullets. Lead is a neurotoxin that accumulates in soft tissues and bones; it damages the nervous system and interferes with the function of biological enzymes, causing neurological disorders, such as brain damage and behavioral problems. The aforementioned information about arsenic is quoted from: https://www.ptable.com/ [52]”.

Mercury

Mercury is one of the heavy metals that must be removed from water before consuming it. It is one of the transition metals found in group 12 or 2B in the periodic table.

Mercury is a chemical element with symbol Hg and atomic number 80. It is commonly known as quicksilver and was formerly named hydrargyrum (/haɪˈdrɑːrdʒərəm/ hy-DRAR-jər-əm). A heavy, silvery d-block element, mercury is the only metallic element that is liquid at standard conditions for temperature and pressure; the only other element that is liquid under these conditions is halogen bromine, though metals such as caesium, gallium, and rubidium melt just above the room temperature.

Mercury occurs in deposits throughout the world mostly as cinnabar (mercuric sulfide). The red pigment vermilion is obtained by grinding natural cinnabar or synthetic mercuric sulfide.

Mercury is used in thermometers, barometers, manometers, sphygmomanometers, float valves, mercury switches, mercury relays, fluorescent lamps and other devices, though concerns about the element's toxicity have led to mercury thermometers and sphygmomanometers being largely phased out in clinical environments in favor of alternatives such as alcohol- or galinstan-filled glass thermometers and thermistor- or infrared-based electronic instruments. Likewise, mechanical pressure gauges and electronic strain gauge sensors have replaced mercury sphygmomanometers.

Mercury remains in use in scientific research applications and in amalgam for dental restoration in some locales. It is also used in fluorescent lighting. Electricity passed through mercury vapor in a fluorescent lamp produces shortwave ultraviolet light, which then causes the phosphor in the tube to fluoresce, making the light visible. Mercury poisoning can result from exposure to water-soluble forms of mercury (such as mercuric chloride or methylmercury), by inhalation of mercury vapor, or by ingesting any form of mercury. The aforementioned information about arsenic is quoted from: https://www.ptable.com/ [52]".

Graphene Adsorbent

CNTs have advantages of high adsorption affinity, but the cost of CNTs production is high. The high cost has limited their commercial applications. Graphene is a carbon-based new class 2D nanomaterial. The graphene is composed of 2D sheet of allotrope carbon atoms. It consists of one layer thick lattice arranged in hexagonal configuration. Graphene has excellent properties and has an economical application better than CNTs [62].

Graphene has an advantage of a huge theoretical specific area of 2600 m^2/g. This huge area is twice than that of the finely divided activated carbon [50, 63]. Carbon has four valence electrons, which allows it to form four bonds, three σ bonds with the three neighbours and one π bond that is oriented out of the plane. The carbon atoms in graphene are tightly bonded together because of Sp2 suborbital hybridization. This character makes graphene the strongest material ever tested. Also, graphene has an excellent electrical conductivity of 7200 S/m at RT [64, 65]. The aforementioned advantageous of graphene make it suitable to be applied for water desalination.

Graphene was demonstrated for the first time by Mishra & Ramaprabhu to be used for desalination of seawater [66]. It was reported that graphene could remove 65% arsenic and 66% sodium for water containing sodium arsenate. The process of removal is done by using functionalized hydrogen exfoliated graphene (f-HEG).

Synthesis of functional graphene nanocomposite was done by Wang *et al*., and it was used as an electrode in capacitive deionization (CDI). Graphene could wrap nanostructured electrode of MnO_2, as shown in Fig. (**6**), which had revealed high efficiency, about 93%, of salt removal, high electrosorptive capacity (5.01 mg/L), specific capacitance of 292 F/g, and distinctive recyclability [67].

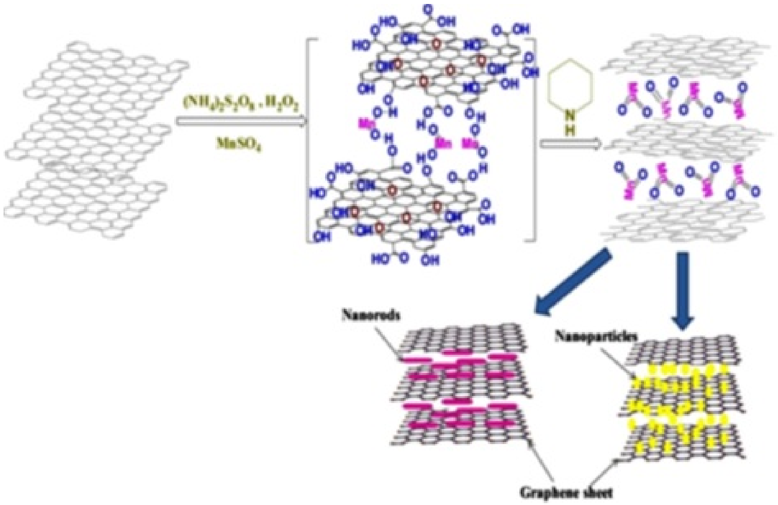


Fig. (6). Schematic illustration of the one-pot synthesis procedure of MnO_2-nanostructures@graphene sheets as a sandwich structure [67].

The specific capacitance and efficiency of salt removal of the synthesized graphene wrapped nanostructured electrode of MnO_2 produced a number of CDI electrodes as presented by El-Deen *et al*., in Table **1** [68].

Table 1. Comparison of capacity and desalination performance of different entire CDI electrode materials recently published [68].

Materials	Capacity (F/g)	Salt removal efficiency (%)	Applied voltage (V)
Mesoporous carbon	87 (0.1 M NaCl 5 mV/s)	50.7	1.2
Ordered mesoporous carbon/ carbon nanotube (OMC/ CNT)	Ordered mesoporous carbon/ carbon nanotube (OMC/ CNT)	79.4	1.2
Manganese oxide (MnO2)/ nanoporous carbon	204 (1 M NaCl, 1 mV/s)	81.5	1.2
Graphene	149 (1 M NaCl, 5 mV/s)	83.4	2
Graphene/mesoporous carbon (GE/MC)	40 (1 M NaCl, 10 mV/s)	88.8	2
Graphene/CNT	68 (1 M NaCl, 10 mV/s)	77.1	2
Hollow carbon nanofibers (HCNFs)	222 (1 M NaCl, 5 mV/s)	86.03	1.2
Multi-channels carbon nanofibers (MC-CNFs)	237 (1 M NaCl, 10 mV/s)	89.04	1.4
Graphene Nanorods (GNS)@ MnO_2 sandwich	292 (1 M NaCl, 10 mV/s)	92.9	1.2

Monolayer of graphene was tested to be transferred to two commercial microfiltration membranes. This membrane is polypropylene and polyvinyl difloride for desalination of water [68]. It was explained that the graphene layer was attached to the surface of the target substrate by sandwiching the copper-graphene-membranes. This process was followed by wet etching of the copper surface and a monolayer of graphene could be left on the membrane surface.

Potassium chloride ions were used to test transport properties of the resulted graphene membranes using side by side diffusion cell.

The application of molecular and ionic membrane uses graphene with artificially created nanosized holes. This is due to the development of nanopores where the hydrophobicity inherent in graphene can show the capillary force of water penetration as shown in Fig. (**7**) [69].

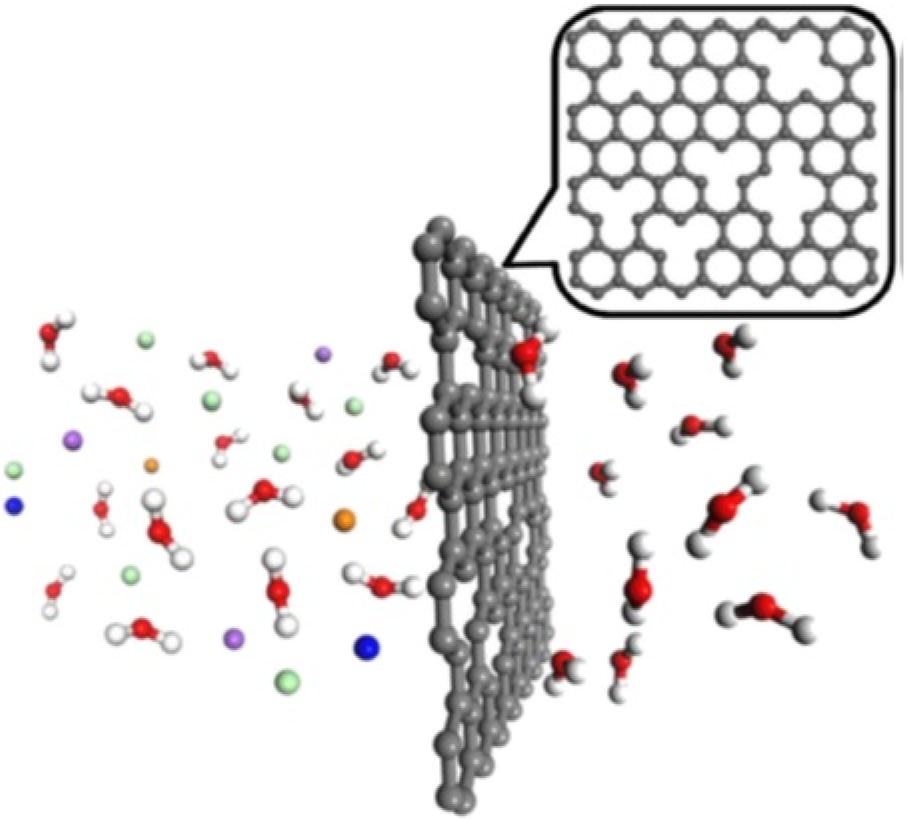


Fig. (7). Nanoporous graphene for water molecules to pass through while hinder the permeation of large hydrated salt ions [69].

As stated, 57% of KCl ions rejected by graphene-polypropylene membrane (G-PPM), and 40% of KCl ions rejected by graphene-polyvinyl difloride membrane (G-PVDFM). This data may suggest the presence of defects within graphene membranes. This defect was sealed *via* interfacial polymerization of Nylon 6,6 using a Franz Cell. The process of sealing with Nylon 6,6 has increased the efficiency of KCl rejection to 67% for both membranes, G-PPM and G-PVDFM [69].

Pristine graphene is pure graphene having an unoxidized structure. It is a lamellar substance with an ambiguous structure due to material complexity. It is highly impermeable to gases or liquid. Accordingly, the oxidation of graphene was created by Nair *et al*., to from graphene oxide (GO) film, which stacked on membrane. The GO film has permeability characteristics that allow water to permeate through the developed nanochannel between each GO layer. The selectivity of the GO layer hinders the permeation of hydrated salt ions [70].

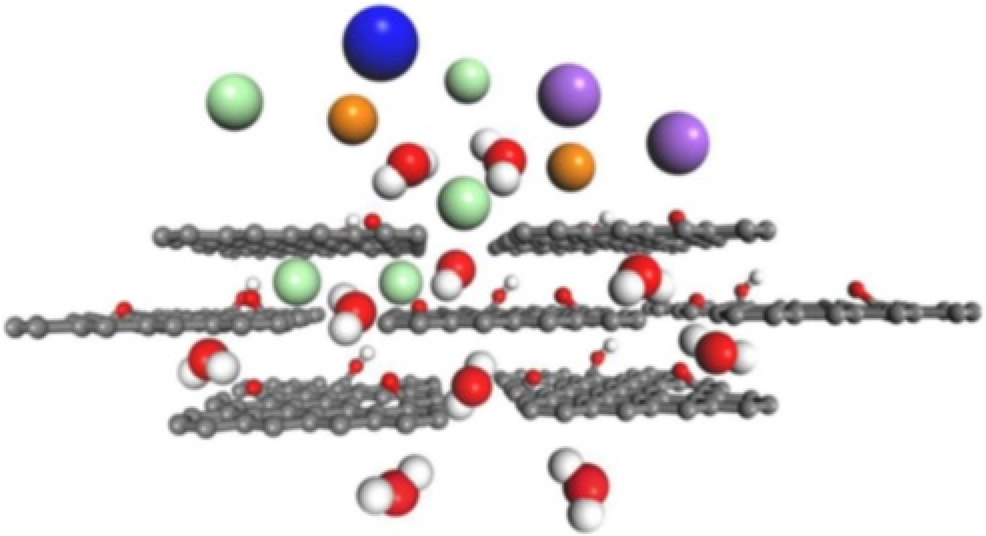


Fig. (8). The layers of graphene oxide for water permeation and hindering hydrated salt ions [70].

The GO nanosheets have oxygen-containing functional groups, therefore, GO has better dispersibility in H_2O as a polar solvent or any other polar solvent than graphene [71, 72]. In fact, the interesting structural features of GO could create relatively arranged channels for H_2O penetration thus granting the GO privilege for H_2O treatment and fabrication membrane.

There are a number of attempts to develop GO based membranes after a pioneering innovation by Nair *et al*. [70]. In 2013, ultrathin GO membranes with a nanosize of 22-53 nm and 2D nanochannels were created by Han *et al*., using a simple filtration assisted assembly strategy. They have successfully applied them as a nanofilm membrane for H_2O purification [73]. High water flux of 21.8 L/m^2 h bar or more and moderate retention rates about 20-60% of salts were achieved.

Further studies were conducted where graphene oxide was deposited on an active polyurethane (PU) layer and on a porous polyamide (PA) substrate [74, 75]. The deposition on PU was performed by electrostatic self-assembly and on the porous substrate of PA by electrostatic self-assembly, followed by the formation of the PA layer on top of the GO layer by conventional interfacial polymerization.

GO membrane desalting performance was adapted using carboxylation reaction in one step [76]. The carboxylation process occurs through nucleophilic substitution reaction between epoxy groups of GO and amino groups of glycine. The highly ordered membrane of amino acid glycine-GO (GO-COOH) was created using the pressure-assisted self-technique. The GO-COOH membrane has two advantages: 1-it exhibits high permeability of 4.89 L/m^2 h, and 2-it has high rejection of NaCl compared with the commercial membrane.

The stability of the aggregated graphene oxide layer has been a concern when applied to water desalination. Accordingly, hybrid organic-inorganic TFC membrane was developed by Ali *et al*. [77]. The membrane was developed by incorporating GO nanosheets into the IP PA skin layer.

Zeolites Adsorbent

Zeolites are chemical crystalline aluminosilicate compounds. They contain elements of group 1A of the periodic table (alkali metals), such as sodium, and elements of group 2A (alkali-earth metals), such as magnesium. The crystalline structure of zeolite is a 3-demintional tetrahedral framework. The oxygen atom in the structure of zeolite is shared by two tetrahedral to form regular intra-crystalline cavities and molecular dimensions channels. The framework of zeolite with cavities and channels inside allows the easy drift of the resident ions and molecules into and out of the structure. In fact, zeolite has a novel surface selectivity due to its specific chemical and physical properties. Therefore, zeolite is useful for H_2O desalination because of its high adsorption capacity, sieving characteristic, and ion exchange property [78 - 82].

Zeolite's porous structure with channels and many cavities has the ability to absorb different materials [83]. Sodium chloride from sea water has been removed by using naturally modified zeolites [84]. Zeolites have been modified by heating at 60°C for 12 hrs and have been treated with silver nitrate reagent. As a result of studies, natural zeolites have great potential as cost-effective sorbent materials for seawater desalination. It is stated that the membrane of zeolite as a special material in the desalination field has the ability to remove ions from the aqueous saline solution and leads to high rejection of ions [85].

Nanomaterials and Water Purification

Silver nanoparticles (Ag NPs) are highly toxic to microorganisms and therefore have strong antibacterial effects against a wide range of microorganisms, including viruses [86], bacteria, and fungi [87]. As a good antimicrobial agent, silver nanoparticles have been widely used for the disinfection of water.

The mechanism of the antimicrobial effects of Ag NPs is not clearly known and remains under debate. In recent years, several theories have been put forward. Ag NPs have been reported to be able to adhere to the bacterial cell wall and subsequently penetrate it, resulting in structural changes of the cell membrane and thus increasing its permeability [88]. Besides, when Ag NPs are in contact with bacteria, free radicals can be generated. They have the ability to damage the cell membrane and are considered to cause the death of cells [89]. In addition, as DNA contains abundant sulfur and phosphorus elements, Ag NPs can act with it and thus destroy it. This is another explanation for the death of cells caused by Ag NPs [90]. Moreover, the dissolution of Ag NPs will release antimicrobial Ag^+ ions, which can interact with the thiol groups of many vital enzymes, inactivate them, and disrupt the normal functions in the cell [91].

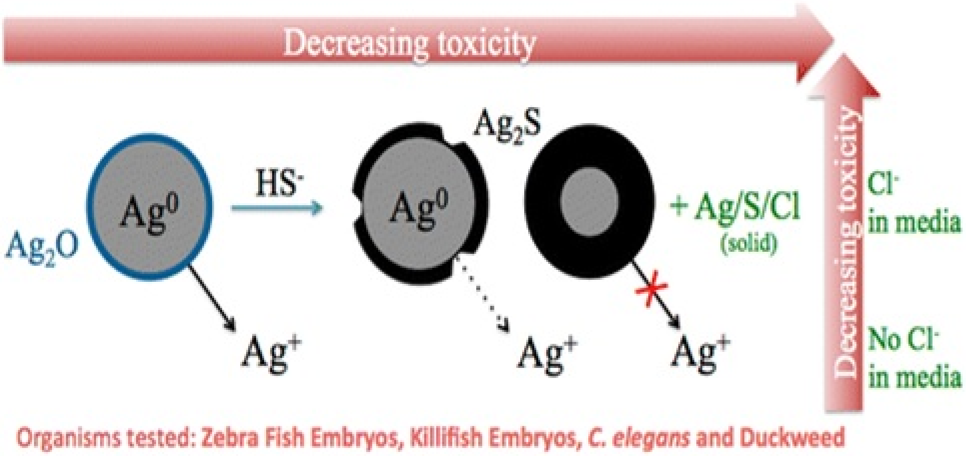


Fig. (9). Steps of toxicity reduction of AgNP [87].

Nanomaterials for Wastewater Treatment

Water treatment is a necessity for safe drinking water. The world's population is growing rapidly and there is a shortage of drinking water. Safe drinking water is needed using new technology. Accordingly, nanotechnology has a significant impact on making safe drinking water available by designing an innovative centralized and decentralized water treatment system [92].

Water treatment processes, such as nano-sorbents, photocatalysts, microbial disinfectants and membranes, are discussed. Extensive implementation of nanotechnology for water treatment requires overcoming the high cost of nanomaterials by enabling their reuse and regeneration. This would also ensure that potential environmental exposures are reduced. Potential advances in nanotechnology must go hand in hand with environmental health to mitigate any undesirable consequences for humans [92]. High reactivity and high degree of functionality, size-dependent properties, large specific area *etc*., make nanomaterials suitable for application in wastewater treatment and water purification [93]. Some nanomaterials are used in the field of wastewater treatment such as zeolite, metal oxide, carbon compounds, filtration membranes, *etc*.

Pollution affects water due to various contaminants such as organic/inorganic materials, pathogens, heavy metals or other toxins making it unsafe for the ecosystem. The contaminants have altered physical, chemical, and biological properties of water. Therefore, there is a need to remove pollutants to have pure water. Nanotechnology is the solution for this problem, which offers the possibility of efficient removal of pollutants as the nanoparticles have a smaller size and highly adsorptive surface area [94]. In the past few years, nano iron oxides such as magnetite, magnetite, and hematite have been used to separate and remove organic and inorganic pollutants. Iron oxide nanomaterials have been used over the last few years for the removal of dyes, heavy metals and aromatic compounds.

The nanocomposite material has a specific surface area of between ≈150 and 300 m^2/g regardless of the synthesis temperature. New hybrid materials of both micro- and mesopores have been confirmed by using measurement tools such as XRD, IR, and solid-state nuclear magnetic resonance spectroscopy, which suggest the formation of several new bonds in the materials upon reaction of the precursors. The presence of carbonaceous matter was confirmed by using measurement tools of Thermo gravimetric analysis/differential thermal analysis and elemental analysis. This new nanocomposite is stable up to 900 ^0C. It has reasonable efficiency as an adsorbent for removing water micropollutants, 4-nitrophenol, and pathogens, and E-coli, from an aqueous medium, indicating that applications in water treatment are possible [95].

Nanomaterials and Wastewater Purification

Nanomaterials are used in many applications, such as lubricants, cosmetics, medicines, *etc*. Nanoparticles can escape into wastewater and they can negatively impact the purification of wastewater [96]. As mentioned, cosmetic nanoparticles escape to a large extent in wastewater. The amount of nanomaterial entering wastewater cannot be measured, but computer-based simulation models are used to estimate the amount of released nanomaterials present in wastewater. In fact, the idea of the models is to simulate the life cycle of the nanoproducts and make the calculation about the expected nanoparticles escapes into wastewater. As known, there are different chemical compounds that could be prepared in nanoscale, such as layered materials ($MnPS_3$, $FePS_3$, *etc*.), different types of oxides, such as titanium dioxide, zinc oxide, iron oxides, *etc* [97 - 99]. Model simulations of nanomaterials in wastewater show the presence of large amounts of nanomaterials, especially titanium oxide and zinc oxide [100].

Wastewater Treatment

The main objective of wastewater treatment is to remove nanoparticles and compounds that affect the environment. The wastewater treatment process consists of some stages to clean the sewage, the first of which is the mechanical stage to remove solids, and the second is the biological stage to get rid of organic compounds, followed by some stages to remove nitrogen and phosphorous, as shown in Fig. (**10**).

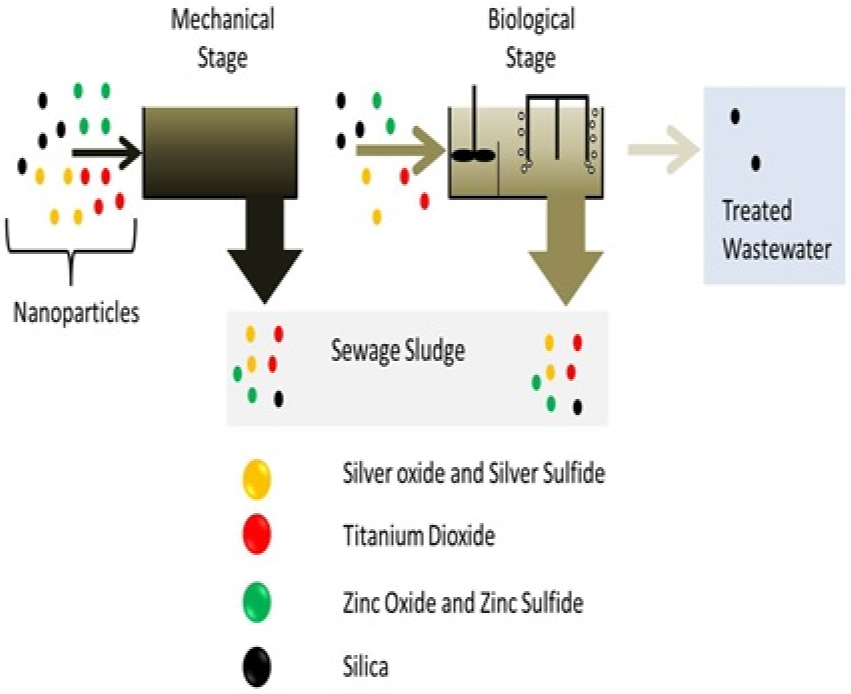


Fig. (10). Removal of nanoparticles during the different stages of wastewater treatment plants [29].

After the sewage treatment process is finished, the treated sewage is mixed with natural water. Solids are included in the separated sewage sludge. There are different solid nanomaterials such as silver nanoparticles, titanium dioxide nanoparticles or zinc oxide [100]. In addition, untreated wastewater can escape into the environment, this is because sewage is not linked to the sewage treatment system. Also, heavy rain can carry sewages into the environment. These materials are separated by about 90 to 95% from wastewater. According to the simulation models, it is predicted that wastewater is one of the main sources of nanomaterials for freshwaters, in fact, the untreated wastewater can increase the amount of nanomaterials in the water [101].

CONCLUDING REMARKS

Nanomaterials have been included in the field of water purification and waste treatment. The application of nanomaterials in water purification makes a big difference, especially removal of heavy and toxic metals. Different types of nanomaterials have been discovered, especially graphene oxide membrane. As reported, wastewater is one of the main sources of nanomaterials to freshwaters. Silver nanoparticles can be used to purify water. Wastewater treatment is important to get rid of harmful nanoparticles in water.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

The author would like to thank all authors who have been or are not cited in the chapter, as well as all the organizations, companies, universities and research institutes that are mentioned or cited in the chapter, as well as those that are not mentioned or cited. The author would also like to thank Bentham Science Publishers Pte. Ltd. for publishing the book.

REFERENCES

[1] IWA. Nano-and-water-application-of-nanoparticles-nanoengineered-materials-and-nanotechnology. https://iwa-network.org/groups2020.

[2] Johnston JC, Molinero V. Crystallization, melting, and structure of water nanoparticles at atmospherically relevant temperatures. J Am Chem Soc 2012; 134(15): 6650-9. [http://dx.doi.org/10.1021/ja210878c] [PMID: 22452637]

[3] Sobey MD, *et al.* Environ Sci Technol 2008; 42: 4261. [http://dx.doi.org/10.1021/es702746n] [PMID: 18605542]

[4] Ghasemzadeh G, Momenpour M, Omidi F, Hosseini MR, Ahani M, Barzegari A. Applications of

nanomaterials in water treatment and environmental remediation. Front Environ Sci Eng 2014; 8(4): 471-82.
[http://dx.doi.org/10.1007/s11783-014-0654-0]

[5] Narayan R. Use of nanomaterials in water purification. Mater Today 2010; 13(2): 3.

[6] Savage N, Diallo MS. Nanomaterials and Water Purification: Opportunities and Challenges. J Nanopart Res 2005; 7(4-5): 331-42.
[http://dx.doi.org/10.1007/s11051-005-7523-5]

[7] Van der Bruggen B, Vandecasteele C. Removal of pollutants from surface water and groundwater by nanofiltration: overview of possible applications in the drinking water industry. Environ Pollut 2003; 122(3): 435-45.
[http://dx.doi.org/10.1016/S0269-7491(02)00308-1] [PMID: 12547533]

[8] Srivastava A, Srivastava ON, Talapatra S, Vajtai R, Ajayan PM. Carbon nanotube filters. Nat Mater 2004; 3(9): 610-4.
[http://dx.doi.org/10.1038/nmat1192] [PMID: 15286755]

[9] Hilal N, Kochkodan V, Al-Khatib L, Levadna T. Surface modified polymeric membranes to reduce (bio)fouling: a microbiological study using E. coli. Desalination 2004; 167: 293-300.
[http://dx.doi.org/10.1016/j.desal.2004.06.138]

[10] Kochkodan V, Tsarenko S, Potapchenko N, Kosinova V, Goncharuk V. Adhesion of microorganisms to polymer membranes: a photobactericidal effect of surface treatment with TiO2. Desalination 2008; 220(1-3): 380-5.
[http://dx.doi.org/10.1016/j.desal.2007.01.042]

[11] Liu CX, Zhang DR, He Y, Zhao XS, Bai R. Modification of membrane surface for anti-biofouling performance: Effect of anti-adhesion and anti-bacteria approaches. J Membr Sci 2010; 346(1): 121-30.
[http://dx.doi.org/10.1016/j.memsci.2009.09.028]

[12] Park N, Kwon B, Kim I, Cho J. Biofouling potential of various NF membranes with respect to bacteria and their soluble microbial products (SMP): Characterizations, flux decline, and transport parameters. J Membr Sci 2005; 258(1-2): 43-54.
[http://dx.doi.org/10.1016/j.memsci.2005.02.025]

[13] Upadhyayula VKK, Deng S, Mitchell MC, Smith GB. Application of carbon nanotube technology for removal of contaminants in drinking water: A review. Sci Total Environ 2009; 408(1): 1-13.
[http://dx.doi.org/10.1016/j.scitotenv.2009.09.027] [PMID: 19819525]

[14] Gehrke I, Geiser A, Somborn-Schulz A. Innovations in nanotechnology for water treatment. Nanotechnol Sci Appl 2015; 8: 1-17.
[http://dx.doi.org/10.2147/NSA.S43773] [PMID: 25609931]

[15] Newcastle University. Sustainability Resource Guide: Natural Resources. libraryhelp@ncl.ac.uk2005.

[16] Qu X, Brame J, Li Q, Alvarez PJJ. Nanotechnology for a safe and sustainable water supply: enabling integrated water treatment and reuse. Acc Chem Res 2013; 46(3): 834-43.
[http://dx.doi.org/10.1021/ar300029v] [PMID: 22738389]

[17] Teow YH, Mohammad AW. New generation nanomaterials for water desalination: A review. Desalination 2019; 451: 2-17.
[http://dx.doi.org/10.1016/j.desal.2017.11.041]

[18] Clough G. Statement of the United Nations Industrial Development Organization at the Commission on Sustainable Development. New York: UNIDO 2008.

[19] Mohamed MB. Final Technical Report: Low Cost Nanomaterials for Water Desalination and Purification. United Nations Educations, Scientific and Cultural Organization. 2011.

[20] World Health Organization. The World Health Report 2002: Reducing Risks, Promoting Healthy Life. 2002.

[21] Misdan N, Lau WJ, Ismail AF. Seawater Reverse Osmosis (SWRO) desalination by thin-film composite membrane—Current development, challenges and future prospects. Desalination 2012; 287: 228-37.
[http://dx.doi.org/10.1016/j.desal.2011.11.001]

[22] Qu X, Alvarez PJJ, Li Q. Applications of nanotechnology in water and wastewater treatment. Water Res 2013; 47(12): 3931-46.
[http://dx.doi.org/10.1016/j.watres.2012.09.058] [PMID: 23571110]

[23] Pan B, Xing B S. Adsorption mechanisms of organic chemicals on carbon nanotubes. Environmental Science and Technology 2008; 42(24): 9005e9013.
[http://dx.doi.org/10.1021/es801777n]

[24] Yang K, Xing B S. Adsorption of organic compounds by carbon nanomaterials in aqueous phase: Polanyi theory and its application. Chemical Reviews. 2010; 110(10): 5989e6008.

[25] Pan B, Lin D H, Mashayekhi H, Xing B S. Adsorption and hysteresis of bisphenol A and 17 alpha-ethinyl estradiol on carbon nanomaterials. Environmental Science and Technology 2008; 42(15): 5480-5.

[26] Ji L L, Chen W, Duan L, Zhu D Q. Mechanisms for strong adsorption of tetracycline to carbon nanotubes: a comparative study using activated carbon and graphite as adsorbents. Environmental Science and Technology 2009; 43(7): 2322-7.
[http://dx.doi.org/10.1021/es803268b]

[27] Chen W, Duan L, Zhu D Q. Adsorption of polar and nonpolar organic chemicals to carbon nanotubes. Environmental Science and Technology 2007; 41(24): 8295-300.
[http://dx.doi.org/10.1021/es071230h]

[28] Lin D H, Xing B S. Adsorption of phenolic compounds by carbon nanotubes: role of aromaticity and substitution of hydroxyl groups. Environmental Science and Technology 2008; 42(19): 7254-9.
[http://dx.doi.org/10.1021/es801297u]

[29] Yang K, Wu W H, Jing Q F, Zhu L Z. Aqueous adsorption of aniline, phenol, and their substitutes by multi-walled carbon nanotubes. Environmental Science and Technology 2008; 42(21): 7931-6.
[http://dx.doi.org/10.1021/es801463v]

[30] Li Q, Yang D, Shi J, Xu X, Yan S, Liu Q. Biomimetic modification of large diameter carbon nanotubes and the desalination behavior of its reverse osmosis membrane. Desalination 2016; 379: 164-71.
[http://dx.doi.org/10.1016/j.desal.2015.11.008]

[31] Rao G P, Lu C, Su F. Sorption of divalent metal ions from aqueous solution by carbon nanotubes: a review. Separation and Purification Technology 2007; 58(1): 224-31.
[http://dx.doi.org/10.1016/j.seppur.2006.12.006]

[32] Li Y H, Ding J, Luan Z K, *et al.* Competitive adsorption of Pb2þ, Cu2þ and Cd2þ ions from aqueous solutions by multiwalled carbon nanotubes. Carbon 2003; 41(14): 2787-92.

[33] Lu C S, Chiu H, Liu C T. Removal of zinc(II) from aqueous solution by purified carbon nanotubes: kinetics and equilibrium studies. Industrial & Engineering Chemistry Research 2006; 45(8): 2850-5.

[34] Koeppenkastrop D, Decarlo E H. Uptake of rare-earth elements from solution by metal-oxides, Environmental Science and Technology. 1993; 27(9): 1796-802.

[35] Trivedi P, Axe L. Modeling Cd and Zn sorption to hydrous metal oxides. Environmental Science and Technology 2000; 34(11): 2215-23.
[http://dx.doi.org/10.1021/es991110c]

[36] Yean S, Cong L, Yavuz C T, *et al.* Effect of magnetite particle size on adsorption and desorption of arsenite and arsenat. Journal of Materials Research 2005; 20(12): 3255-64.

[37] Auffan M, Rose J, Bottero J Y, Lowry G V, Jolivet J P, Wiesner M R. Towards a definition of

inorganic nanoparticles from an environmental, health and safety perspective. Nature Nanotechnology 2009; 4(10): 634-41.

[38] Yavuz C T, Mayo J T, Yu W W, *et al.* Low-field magnetic separation of monodisperse Fe_3O_4 nanocrystals. Science 2006; 314(5801): 964-7.

[39] Lucas E, Decker S, Khaleel A, *et al.* Nanocrystalline metal oxides as unique chemical reagents/sorbents, Chemistry-A European Journal. 2001; 7(12): 2505-10.

[40] Sharma Y C, Srivastava V, Singh V K, Kaul S N, Weng C H. Nano-adsorbents for the removal of metallic pollutants from water and wastewater. Environmental Technology 2009; 30(6): 583-609. [http://dx.doi.org/10.1080/09593330902838080]

[41] Hu J, Chen G H, Lo I M C. Selective removal of heavy metals from industrial wastewater using maghemite nanoparticle: performance and mechanisms. Journal of Environmental Engineering-Asce 2006; 132(7): 709-15. [http://dx.doi.org/10.1061/(ASCE)0733-9372(2006)132:7(709)]

[42] Deliyanni E A, Bakoyannakis D N, Zouboulis A I, Matis K A. Sorption of As(V) ions by akaganeite-type nanocrystals, Chemosphere. 2003; 50(1): 155-63.

[43] Harper, Douglas. arsenic. Online Etymology Dictionary. Retrieved 15 May 2010.

[44] Bentley R, Chasteen TG. Arsenic Curiosa and Humanity. Chem Educ 2002; 7(2): 51-60. [http://dx.doi.org/10.1007/s00897020539a]

[45] Holmyard John Eric. Makers of Chemistry. Read Books 2007.

[46] Vahidnia A, van der Voet GB, de Wolff FA. Arsenic neurotoxicity — A review. Hum Exp Toxicol 2007; 26(10): 823-32. [http://dx.doi.org/10.1177/0960327107084539] [PMID: 18025055]

[47] Lechtman H. Arsenic Bronze: Dirty Copper or Chosen Alloy? A View from the Americas. Journal of Field Archaeology 1996; 23(4): 477-514. [http://dx.doi.org/10.2307/530550]

[48] Charles J A. Early Arsenical Bronzes—A Metallurgical View. American Journal of Archaeology 1967; 71(1): 21-6. [http://dx.doi.org/10.2307/501586]

[49] Sarton George. Introduction to the History of Science. We find in his writings preparation of various substances (*e.g*., basic lead carbonatic, arsenic and antimony from their sulphides). 1975.

[50] Emsley J. Nature's Building Blocks: An A-Z Guide to the Elements. Oxford: Oxford University Press 2001.

[51] A general system of chemical knowledge, and its application to the phenomena of nature and art. 2001; 84.

[52] https://www.ptable.com/

[53] Daus B, Wennrich R, Weiss H. Sorption materials for arsenic removal from water: a comparative study. Water Research 2004; 38(12): 2948-54.

[54] Mayo J T, Yavuz C, Yean S, *et al.* The effect of nanocrystalline magnetite size on arsenic removal. Science and Technology of Advanced Materials 2007; 8(1e2): 71-5. [http://dx.doi.org/10.1016/j.stam.2006.10.005]

[55] Hristovski K D, Nguyen H, Westerhoff P K. Removal of arsenate and 17-ethinyl estradiol (EE2) by iron (hydr)oxide modified activated carbon fibers. Journal of Environmental Science and Health Part A-Toxic/Hazardous Substances & Environmental EngineeringJournal of Environmental Science and Health Part A-Toxic/Hazardous Substances & Environmental Engineering 2009; 44(4): 354-61.

[56] Hristovski K D, Westerhoff P K, Moller T, Sylvester P. Effect of synthesis conditions on nano-iron (hydr)oxide impregnated granulated activated carbon. Chemical Engineering Journal 2009; 142(2): 237-43.

[57] World Health Organization. https://www.ptable.com

[58] Quansah R, Armah FA, Essumang DK, *et al.* Association of arsenic with adverse pregnancy outcomes/infant mortality: a systematic review and meta-analysis. Environ Health Perspect 2015; 123(5): 412-21.
[http://dx.doi.org/10.1289/ehp.1307894] [PMID: 25626053]

[59] Farzan SF, Karagas MR, Chen Y. In utero and early life arsenic exposure in relation to long-term health and disease. Toxicol Appl Pharmacol 2013; 272(2): 384-90.
[http://dx.doi.org/10.1016/j.taap.2013.06.030] [PMID: 23859881]

[60] Tolins M, Ruchirawat M, Landrigan P. The developmental neurotoxicity of arsenic: cognitive and behavioral consequences of early life exposure. Ann Glob Health 2014; 80(4): 303-14.
[http://dx.doi.org/10.1016/j.aogh.2014.09.005] [PMID: 25459332]

[61] Ravenscroft P, Brammer H, Richards K. Arsenic Pollution: A Global Synthesis. Wiley-Blackwell 2009.
[http://dx.doi.org/10.1002/9781444308785]

[62] World Health Organization. The World Health Report 2002: Reducing Risks, Promoting Healthy Life. 2002.

[63] Yang K, Xing B. Adsorption of fulvic acid by carbon nanotubes from water. Environ Pollut 2009; 157(4): 1095-100.
[http://dx.doi.org/10.1016/j.envpol.2008.11.007] [PMID: 19084305]

[64] Stoller MD, Park S, Zhu Y, An J, Ruoff RS. Graphene-Based Ultracapacitors. Nano Lett 2008; 8(10): 3498-502.
[http://dx.doi.org/10.1021/nl802558y] [PMID: 18788793]

[65] Li X, Wang X, Zhang L, Lee S, Dai H. Chemically derived, ultrasmooth graphene nanoribbon semiconductors. Science 2008; 319(5867): 1229-32.
[http://dx.doi.org/10.1126/science.1150878] [PMID: 18218865]

[66] Mishra AK, Ramaprabhu S. Functionalized graphene sheets for arsenic removal and desalination of sea water. Desalination 2011; 282: 39-45.
[http://dx.doi.org/10.1016/j.desal.2011.01.038]

[67] Wang Z, Dou B, Zheng L, Zhang G, Liu Z, Hao Z. Effective desalination by capacitive deionization with functional graphene nanocomposite as novel electrode material. Desalination 2012; 299: 96-102.
[http://dx.doi.org/10.1016/j.desal.2012.05.028]

[68] El-Deen AG, Barakat NAM, Kim HY. Graphene wrapped MnO_2-nanostructures as effective and stable electrode materials for capacitive deionization desalination technology. Desalination 2014; 344: 289-98.
[http://dx.doi.org/10.1016/j.desal.2014.03.028]

[69] Dumée L, Lee J, Sears K, Tardy B, Duke M, Gray S. Fabrication of thin film composite poly(amide)-carbon-nanotube supported membranes for enhanced performance in osmotically driven desalination systems. J Membr Sci 2013; 427: 422-30.
[http://dx.doi.org/10.1016/j.memsci.2012.09.026]

[70] Cohen-Tanugi D, Grossman JC. Water desalination across nanoporous graphene. Nano Lett 2012; 12(7): 3602-8.
[http://dx.doi.org/10.1021/nl3012853] [PMID: 22668008]

[71] Nair RR, Wu HA, Jayaram PN, Grigorieva IV, Geim AK. Unimpeded permeation of water through helium-leak-tight graphene-based membranes. Science 2012; 335(6067): 442-4.

[http://dx.doi.org/10.1126/science.1211694] [PMID: 22282806]

[72] Wu L, Liu L, Gao B, *et al.* Aggregation kinetics of graphene oxides in aqueous solutions: experiments, mechanisms, and modeling. Langmuir 2013; 29(49): 15174-81.
[http://dx.doi.org/10.1021/la404134x] [PMID: 24261814]

[73] Kim S, Yoo J. An aggregation-mediated assembly of graphene oxide on amine-functionalized poly (glycidyl methacrylate) microspheres for core-shell structures with controlled electrical conductivity. J Mater Chem 2014; 2(32): 6462-6.

[74] Han Y, Xu Z, Gao C. Ultrathin graphene nanofiltration membrane for water purification. Adv Funct Mater 2013; 23(29): 3693-700.
[http://dx.doi.org/10.1002/adfm.201202601]

[75] Choi SH, Kim DH, Raghu AV, *et al.* Properties of graphene/waterborne polyurethane nanocomposites cast from colloidal dispersion mixtures, J. Macromol. Sci. Part B 2012; 51(1): 197-207.

[76] Choi W, Choi J, Bang J, Lee JH. Layer-by-layer assembly of graphene oxide nanosheets on polyamide membranes for durable reverse-osmosis applications. ACS Appl Mater Interfaces 2013; 5(23): 12510-9.
[http://dx.doi.org/10.1021/am403790s] [PMID: 24219033]

[77] Yuan Y, Gao X, Wei Y, *et al.* Enhanced desalination performance of carboxyl functionalized graphene oxide nanofiltration membranes. Desalination 2017; 405: 29-39.
[http://dx.doi.org/10.1016/j.desal.2016.11.024]

[78] Ali MEA, Wang L, Wang X, Feng X. Thin film composite membranes embedded with graphene oxide for water desalination. Desalination 2016; 386: 67-76.
[http://dx.doi.org/10.1016/j.desal.2016.02.034]

[79] Kim SG, Hyeon DH, Chun JH, Chun BH, Kim SH. Nanocomposite poly(arylene ether sulfone) reverse osmosis membrane containing functional zeolite nanoparticles for seawater desalination. J Membr Sci 2013; 443: 10-8.
[http://dx.doi.org/10.1016/j.memsci.2013.03.065]

[80] Dahe GJ, Teotia RS, Bellare JR. The role of zeolite nanoparticles additive on morphology, mechanical properties and performance of polysulfone hollow fiber membranes. Chem Eng J 2012; 197: 398-406.
[http://dx.doi.org/10.1016/j.cej.2012.05.037]

[81] Rezakazemi M, Shahidi K, Mohammadi T. Hydrogen separation and purification using crosslinkable PDMS/zeolite A nanoparticles mixed matrix membranes. Int J Hydrogen Energy 2012; 37(19): 14576-89.
[http://dx.doi.org/10.1016/j.ijhydene.2012.06.104]

[82] Ma J, Wei R, Liao C Y. Tang, Zeolite-polyamide thin film nanocomposite membranes: towards enhanced performance for forward osmosis. J Membr Sci 2012; 406-5.

[83] Fathizadeh M, Aroujalian A, Raisi A. Effect of added NaX nano-zeolite into polyamide as a top thin layer of membrane on water flux and salt rejection in a reverse osmosis process. J Membr Sci 2011; 375(1-2): 88-95.
[http://dx.doi.org/10.1016/j.memsci.2011.03.017]

[84] Lenarda M, Da Ros M, Casagrande M, Storaro L, Ganzerla R. Post-synthetic thermal and chemical treatments of H-BEA zeolite: effects on the catalytic activity. Inorg Chim Acta 2003; 349: 195-202.
[http://dx.doi.org/10.1016/S0020-1693(03)00032-X]

[85] Wajima T, Shimizu T, Yamato T, Ikegami Y. Removal of NaCl from seawater using natural zeolite. Toxicol Environ Chem 2010; 92(1): 21-6.
[http://dx.doi.org/10.1080/02772240902762958]

[86] Ma R, Levard C, Judy JD, *et al.* Fate of zinc oxide and silver nanoparticles in a pilot wastewater treatment plant and in processed biosolids. Environ Sci Technol 2014; 48(1): 104-12.
[http://dx.doi.org/10.1021/es403646x] [PMID: 24266610]

[87] Gogos A, Thalmann B, Voegelin A, Kaegi R. Sulfidation kinetics of copper oxide nanoparticles. Environ Sci Nano 2017; 4(8): 1733-41.
[http://dx.doi.org/10.1039/C7EN00309A]

[88] Levard C, Hotze EM, Colman BP, *et al.* Sulfidation of silver nanoparticles: natural antidote to their toxicity. Environ Sci Technol 2013; 47(23): 13440-8.
[http://dx.doi.org/10.1021/es403527n] [PMID: 24180218]

[89] YuYang; Yifei Wang; Paul Westerhoff; Kiril Hristovski; Virginia Jinc; Mari-Vaughn V.Johnson; Jeffrey G. Arnolde. Metal and nanoparticle occurrence in biosolid-amended soils. Sci Total Environ 2013; 485–486: 441-9.

[90] Brunetti G, Donner E, Laera G, *et al.* Fate of zinc and silver engineered nanoparticles in sewerage networks. Water Res 2015; 77: 72-84.
[http://dx.doi.org/10.1016/j.watres.2015.03.003] [PMID: 25841090]

[91] Donner E, Scheckel K, Sekine R, *et al.* Non-labile silver species in biosolids remain stable throughout 50 years of weathering and ageing. Environ Pollut 2015; 205: 78-86.
[http://dx.doi.org/10.1016/j.envpol.2015.05.017]

[92] Prathna TC. Saroj; Kumar Sharmaa Maria Kennedy, Nanoparticles in household level water treatment: An overview. Separ Purif Tech 2018; 199: 260-70.
[http://dx.doi.org/10.1016/j.seppur.2018.01.061]

[93] Bora T, Dutta J. Applications of nanotechnology in wastewater treatment--a review. J Nanosci Nanotechnol 2014; 14(1): 613-26.
[http://dx.doi.org/10.1166/jnn.2014.8898] [PMID: 24730286]

[94] Saharan P, Chaudhary GR, Mehta SK, Umar A. Removal of water contaminants by iron oxide nanomaterials. J Nanosci Nanotechnol 2014; 14(1): 627-43.
[http://dx.doi.org/10.1166/jnn.2014.9053] [PMID: 24730287]

[95] Unuabonah EI, Nöske R, Weber J, Günter C, Taubert A. New micro/mesoporous nanocomposite material from low-cost sources for the efficient removal of aromatic and pathogenic pollutants from water. Beilstein J Nanotechnol 2019; 10: 119-31.
[http://dx.doi.org/10.3762/bjnano.10.11] [PMID: 30680284]

[96] Information about nanomaterials and their safety assessment. 2020. https://www.nanopartikel.info/en/nanoinfo/cross-cutting/2764-nanomaterials-in-the-wastewater-treatment-plant

[97] El-Meligi AA, Al-Saie AM, Al-Buflasa H, Bououdina M. Effect of pyridine intercalation on semiconductor crystalline mnps $_3$ materials phase transformation. Int J Nanosci 2010; 9(3): 215-23.
[http://dx.doi.org/10.1142/S0219581X10006612]

[98] Meligi AAE, Saie AMA, Bououdina M. Formation of iron oxides nanoparticles on low carbon steel under controlled conditions. International Journal of Nanoparticles 2010; 3(1): 22.
[http://dx.doi.org/10.1504/IJNP.2010.033219]

[99] El-Meligi AA, Al-Saie AM, Al-Buflasa H, Bououdina M. Formation of composite nanomaterial MnPS3 layered structure intercalated with pyridine. J Alloys Compd 2009; 488(1): 284-90.
[http://dx.doi.org/10.1016/j.jallcom.2009.08.106]

[100] Sun TY, Gottschalk F, Hungerbühler K, Nowack B. Comprehensive probabilistic modelling of environmental emissions of engineered nanomaterials. Environ Pollut 2014; 185: 69-76.
[http://dx.doi.org/10.1016/j.envpol.2013.10.004]

[101] Westerhoff P, Song G, Hristovski K, Kiser MA. Occurrence and removal of titanium at full scale wastewater treatment plants: implications for TiO_2 nanomaterials. J Environ Monit 2011; 13(5): 1195-203.
[http://dx.doi.org/10.1039/c1em10017c] [PMID: 21494702]

CHAPTER 5

Nanotechnology and the Environment

Abstract: There is no doubt that the environment is one of the hot issues nowadays because of pollution, global warming, and other issues. The main sources of energy are still non-renewable resources. Therefore, there is a need to solve environmental problems before it is too late to solve them. All living things on earth suffer because of environmental problems. The United Nation works with all countries to control environmental problems to protect the earth. Researchers pay great attention to help solve environmental problems. In addition to traditional methods of research, researchers use advanced technologies such as nanomaterials and nanotechnology. For example, in the near future, researchers will be able to use nanomaterials to extract energy from the air. Recently, attention has been paid to the relationship between nanoparticles and the environment, especially the impact of nanoparticle emission into the atmosphere on human health. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, size, morphology and interaction of nanomaterials.

Keywords: Environmental Pollution, Nanomaterials and Environment, Nanoparticles emission, Nanowaste.

INTRODUCTION

As known, nanoparticles have special physicochemical characteristics and functionalities that are not similar to their bulk counterparts [1]. Recently, the relationship between nanoparticles and the environment has been a concern, especially the effect of the nanoparticle's emission to the atmosphere on human health. There is an adverse effect of nanoparticles on human health [2]. There is evidence that exposure to nanoparticles has a detrimental effect on human health [3].

There is no doubt that there are risks in handling nanomaterials. Risk assessment is important not only to determine the potential hazards of nanomaterials but also their mode of release, fate and behavior in the environment, and the resulting exposure [4].

Nanomaterials are used to improving the environment, but the improvement depends on the type of application, for example, coating the exterior of a building

Amin El-Meligi

using nanomaterials, producing clean energy using solar cells, *etc*. In fact, the challenge in this era is to find environmental-friendly energy sources to reduce environmental pollution [5 - 7].

Nanostructure and Energy

Researchers have worked to obtain fuel cells that are less expensive and more efficient. A team of researchers from UCLA's Henry Samueli College of Engineering and Applied Sciences has found a way to make fuel cells more durable, efficient, and less expensive. The team created a nanostructure consisting of a compound of three metals. Using this nanostructure, the team believes they can make a much better fuel cell than conventional models [8].

Doing so could unlock a bright new future for fuel cell technology. Researchers have found that the nanostructures they have developed, which are comprised of a platinum-nickel-molybdenum compound, are 81% more efficient than the conventional catalysts that fuel cells use.

Conventional catalysts use a large amount of platinum, which makes them expensive. By reducing the amount of platinum used to make these catalysts, researchers have found a way to cut costs and make fuel cells more affordable, efficient, and durable.

In the near future, researchers will be able to use nanomaterials to extract energy from the air. New nanomaterials and concepts are being developed that show the potential to produce energy from motion, light, changes in temperature, glucose, and other sources with high conversion efficiency.

The electronic transistor and the microphone were invented more than seventy years ago, their size was very small, and with advances in technology, they became even smaller, and today one electronic chip can contain more than five billion transistors. And if technological progress continues to accelerate, we can reach driving a car at three hundred thousand miles per hour [8].

Nanomaterials and the Environment

Nanomaterials have been found on Earth for thousands of years, and humans have used them for various works such as paintings on temple walls. This means that humans have been exposed to and affected by these substances. It can be said that the impact of these substances on the environment extended for thousands of years, but this effect may not have been significant due to the lack of research tools to detect them [9].

Scientists have reached advanced stages in the production and use of nanomaterials, as it was reported that the world was producing about 2,000 tons of nanomaterials, and in 2020 it is expected to produce about 58 thousand tons of these materials [10].

With the steady increase in the production of nanomaterials, the impact of these materials on the environment and on humans will be significant. This was manifested in the technological progress that led to the measurement of the presence of these substances as well as the discovery of their impact on human health.

The emergence of oil, gas and coal had a significant impact on the environment, particularly the combustion process in factories, automobiles, and other human activities. The combustion process produces various substances, especially small volatile particles in the air, which are classified as nanomaterials. These particles appear as thick black smoke [11].

The following equation shows the process of combustion of hydrocarbon materials, such as methane, ethane, propane, *etc*.

$$CH_4 + 2O_2 = CO_2 + 2H_2O \qquad \textbf{(1)}$$

Incomplete combustion of fossil fuels results in so-called soot, and because it is so small, it flies through the air, as well as deposited in water and soil. The nanoparticle uptake rate is controlled by some parameters such as nanoparticle's size, distribution, aggregation and deposition in the cell. Endothelial cells or phagocytes can absorb nanoparticles.

Detecting Nanomaterials in the Environment

Nanomaterials are released into the environment. There is a possibility that the nanomaterials may cause a harmful effect on the environment. In fact, nanoparticles may be released intentionally and unintentionally, for example, iron nanoparticles are used as a treatment agent and are intentionally released into groundwater to remove harmful chemicals. Inadvertent disposal of nanomaterials from wastewater treatment plants occurs. There are a number of factors that can cause nanomaterials to adversely affect the ecosystem, for example, nanoparticles' concentration, their size, morphology and interaction [12].

Nanoparticles can be detected by analytical methods in different environments, such as in the rivers, soil, waste water and fresh water. Some methods can only detect pure nanomaterials at high concentrations. In fact, the detection of nanomaterials faces some challenges. The first challenge is that some methods need a high concentration of nanoparticles to be detected. The second challenge is to differentiate between the high amount of different natural particles and manufactured nanoparticles. The natural particles bind to the nanomaterials under test and cover them thereby complicating the unambiguous and doubtless identification of engineered nanomaterials.

Manufactured nanoparticles can be identified from the natural nanoparticles by using a number of methods, such as, electron microscopy, but these methods cannot ensure quantitative detection of the particles. There are some analytical methods that can offer quantitative detection, but they cannot differentiate between manufactured nanoparticles and natural nanoparticles [13 - 15].

Nanoplastic and the Environment

There is no doubt that plastic has been used in many aspects of our daily life such as, for packaging, for keeping food, house tools, *etc*. Organic compounds of alkene and alkyne polymers, and their derivatives are used to form different types of plastics.

What is Nanoplastic?

Nanoplastics are polymer-based particles (*e.g*. Polyethylene terephthalate (PET) or polystyrene) in the nanometre size range. They are used to manufacture (primary nanoplastic particles) different products (*e.g*. medical devices, drugs or electronics) with a defined size and composition or formed by the degradation of larger plastic items (*e.g*. bottles; Secondary nanoplastics). Fig. (**1**) shows size classification of plastic particles [17].

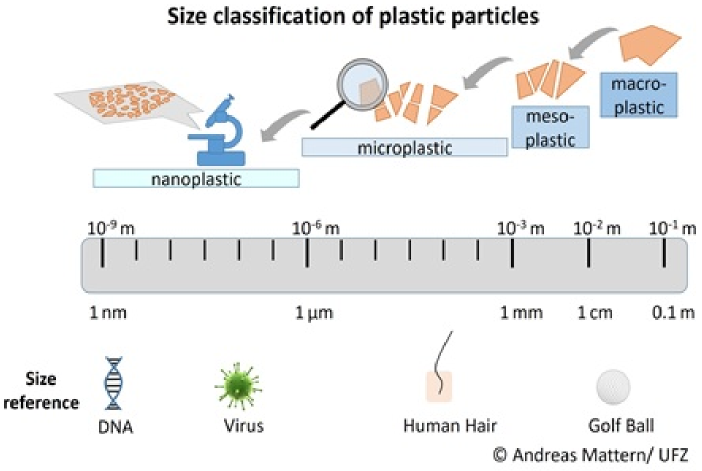


Fig. (1). Size calssification of plastic particles [17].

Some Types of Plastics

Polyvinyl Choloride

Polyvinyl chloride (PVC) is formed by the polymerization reaction of vinyl chloride monomer or chloroethene monomer, as shown in the following (Fig. **2**) [16, 17]:

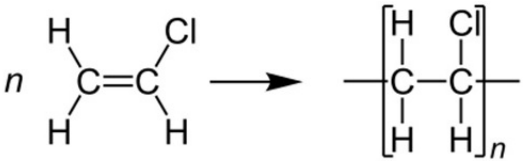


Fig. (2). Polymerization of vinyl chloride.

It is reported that PVC is the world's third-most widely produced synthetic plastic polymer (after polyethylene and polypropylene) [18]. About 40 million tons of PVC are produced each year. Pure polyvinyl chloride is a white, brittle solid. It is insoluble in alcohol but slightly soluble in tetrahydrofuran. PVC has two forms, a rigid form and a flexible form. The rigid form, which is abbreviated RPVC, has many applications, such as making pipes, doors and windows, as shown in Fig. (**3**). RPVC is used to make bottles , bank cards, packaging of non-food items, and sheets for food covering [16]. RPVC can be turned softer and flexible by adding plasticizers, such as phthalates. After making RPVC softer and flexible, it is applied in electrical cable insulation, imitation leather, plumbing, signage, phonograph records, inflatable products, and other applications because it can replace rubber [19 - 21].

Fig. (3). Pipes made of PVC [16].

PVC has excellent chemical resistance, nonflammability, low cost of production and easy modification. These properties of PVC make it suitable to be used as the matrix in the nanocomposites [21, 22]. Although PVC has a wide application as electric cables, membrane separation, furniture, healthcare, medical gloves, flooring and clothing, as shown in (Figs. **4** and **5**), it has a drawback due to its low thermal stability, and poor processability [23]. Also, PVC causes environmental problems because of nonbiodegradability in normal environment and brittleness. These properties make it environmentally prohibited [24]. Therefore, a nanocomposite film of PVC containing ZrO_2 nanoparticles has been prepared to improve thermal, mechanical and optical properties [25]. In fact, ZrO_2 nanoparticles are used to improve the properties of PVC because of their excellent properties such as high oxygen ion conductivity, high refractive index and band gap, biocompatibility, high thermal stability, and mechanical stability [23, 26].

Fig. (4). Plasticized PVC is used for making medical gloves [16].

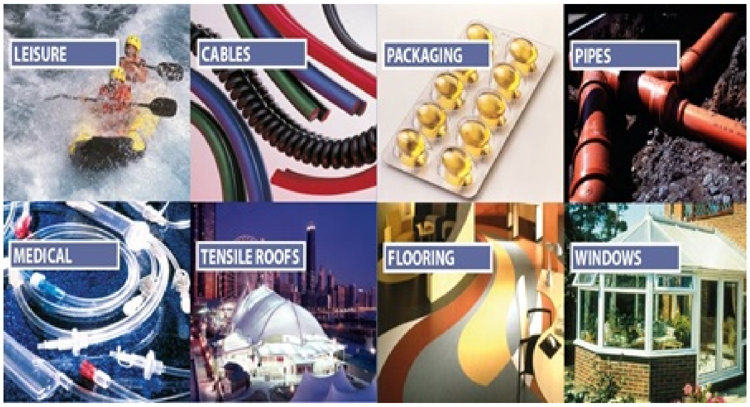


Fig. (5). Applications of polyvinyl choloride [21].

Polyethylene

Polyethylene or polythene (PE) is formed from ethene monomer, as shown in Fig. (**6**). It has the chemical formula $(C_2H_4)n$. PE has two forms: 1-low density, and 2-high density. The low density is formed at high pressure (1000-5000 atm) and high temperature (530 K). The high density is achieved at low pressure (6-7 atm) and low temperature (333-343 K).

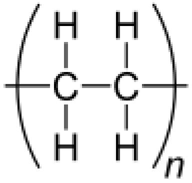


Fig. (6). Ethene monomers to for polyethylene.

PE is the most common plastic in application nowadays. More than hundred million tons of PE was produced in 2017, which accounted for 34% of all plastics in the market [27, 28]. PE has applications in different areas such as plastics bags, plastics films, geomembranes and containers including bottles, *etc*.

Nanopolyethylene can be formed under specific conditions. Nanofibers, nanosheets, and floccules of polyethylene are produced by controlling the polymerization conditions, such as Al/Zr molar ration and time. TiO_2 nanotube supports metallocene catalytic system [29]. Silica is used as a catalyst to prepare the nanosheet of polyethylene [30].

Polypropylene

Polypropylene or polypropene (PP) is made up of propene monomer and it is a thermoplastic polymer, as shown in the following (Fig. **7**).

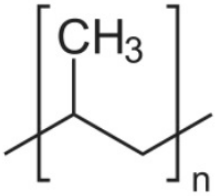


Fig. (7). Polymerization of propylene.

Polypropylene (PP), also known as polypropene, is a thermoplastic polymer used in a wide variety of applications. It is produced *via* chain-growth polymerization from the monomer propylene. PP has many applications such as packaging for consumer products, plastic parts for various industries including the automotive industry, special devices like living hinges, and textiles, as shown in the following (Fig. **8**) [31].

Fig. (8). Plastics products of polypropylene [31].

Polypropylene and Nanoparticles

The biocompatibility of polypropylene is improved by adding gold nanoparticles. This is because PP is prone to degradation in body fluids, which is aggressive and causes a reaction. After making a composite of PP and gold, “a WST-1 cell culture study showed an increase in cellularity on the gold nanoparticle-polypropylene mesh as compared to pristine mesh” [32]. Nanocomposites of PP and SiO_2 have also been produced to improve their properties, especially the Young's modulus and the tensile strength without largely sacrificing the melt viscosity of PP [33].

The electrical properties of PP are improved by adding different nanoparticles of the oxides, MgO, TiO_2, ZnO and Al_2O_3. Nanocomposites of PP and these oxides are formed. As per a study “the dielectric permittivity increases with the increase of nanoparticle content, only the dielectric loss of TiO_2/PP nanocomposites increases. For MgO and TiO_2 nanocomposites, the DC volume resistivity increases with the increase of nanoparticles’ content and then decreases, while it continues to increase for Al_2O_3 nanocomposite” [34]. Considering the electrical properties investigated, the optimal content for MgO, TiO_2, ZnO and Al_2O_3

nanoparticles is about 3, 1, 1 and 1 phr, respectively. Among these four kinds of nanoparticles, MgO and TiO_2 nanoparticles are more capable than ZnO and Al_2O_3 nanoparticles to modify the electrical properties of PP.

Polystyrene

Polystyrene (PS) is an aromatic hydrocarbon, and it is made from styrene monomer, as shown in the following (Fig. **9**) [35]:

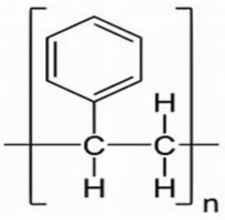


Fig. (9). Formation of Polystyrene from styrene monomer [35].

PS has many applications such as in different types of foams, which are used as insulators, food service containers, cushioning for shipping delicate electronics, bowls, eating plates, containers and rigid trays, as shown in Fig. (**10**) [36]. PS is insoluble in water as many organic compounds, and it is non-biodegradable. It can be dissolved in many organic solvents and chlorinated solvents.

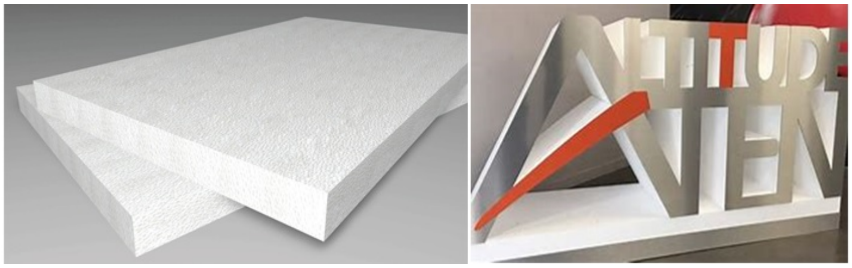


Fig. (10). Different images of polystyrene foam [35].

Polystyrene nanoparticles

PS is biocompatible and its nanoparticles are not expected to adversely affect its interactions with the biological system. PS nanoparticles can be applied as biosensors, in photonics and in self-assembling nanostructures [35]. Generally, nanoparticles of plastics are not safe and cause environmental problems. Plastics are degraded into micro and nanoparticles. The nanoparticles of plastics have been detected in the air, water and soil [37]. It is mentioned that NPs are surrounded by "protein corona" that allows them penetrating cellular membranes and interacting with cellular structures. There is no study to confirm the effect of PS-NPs on health and they are not classified as a carcinogenic material. In fact, dichloroethylene has been classified as a potentially carcinogenic material. The production of plastics has increased through years, and plastic nanoparticles find their way into living things as shown in Fig. (**11**) [37, 38].

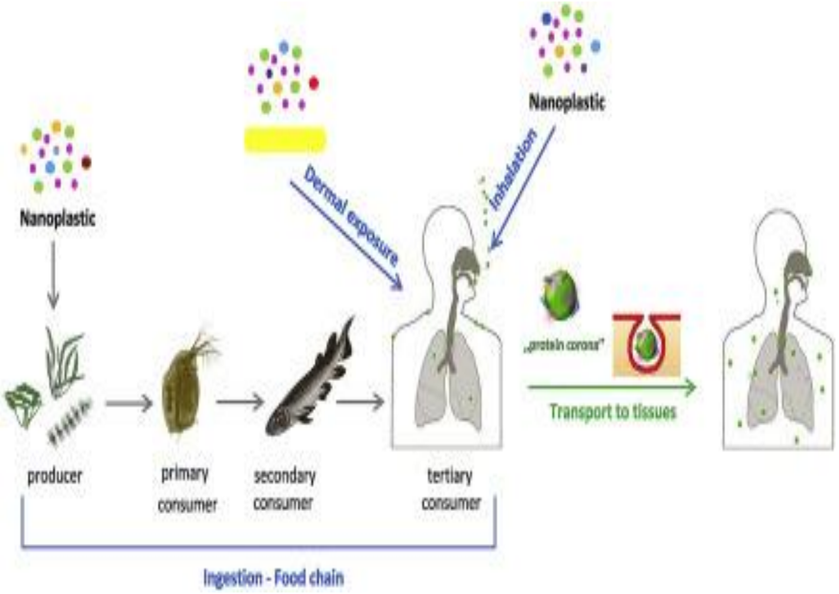


Fig. (11). The routes of plastic nanoparticles into living things [37].

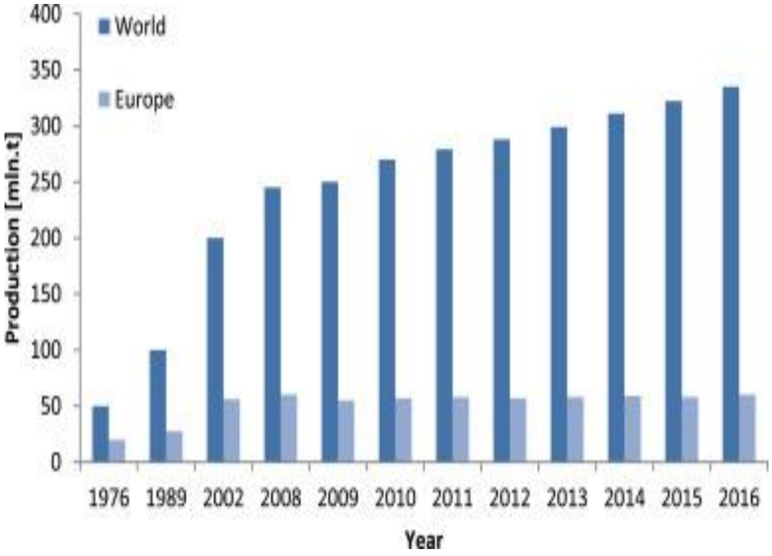


Fig. (12). Plastic production in Europe and in the World [38].

Polydichloroethylene

Polydichloroethylene (PDE) is formed from dichloroethylene monomer, as shown in the following Fig. (**13**):

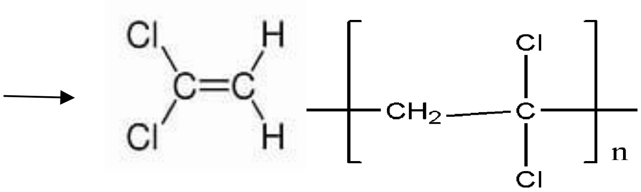


Fig. (13). Formation of polydichloroethylene from dichloroethylene monomer [35].

PDE is poorly soluble in water like many organic compounds, but it is soluble in organic solvents. It is a colorless liquid with a sharp odor. It has different applications such as a co-monomer in the polymerization of vinyl chloride, acrylonitrile, and acrylates. It is also used in semiconductor device fabrication for growing high purity silicon dioxide (SiO_2) films [35].

Nanowaste and the Environment

There is no doubt that the application of nanomaterials will produce nanowaste particles. These nanowaste particles can be released in the environment whether in the atmosphere or in the underground. In fact, the nanowaste term is new and there is no specific definition of the nanowatse. Although there is a proposed definition of the nanowaste, and it is stated that “separately collected or collectable waste materials which are or contain engineered nanomaterials” [38]. There are different sources of the nanowaste, which can access the waste system, such as industrial waste, cosmetic products, household waste, medicine waste and waste from research laboratories. Therefore, the nanowaste needs to be properly disposed of. The disposal should be safe and should be controllable. In fact, the knowledge on the release of nanomaterials to the environment is little up to date. We evaluate the amount of nanoparticles in the atmosphere using different models [38]. Although there has been an attempt made to estimate the nanomaterials released into environment through modeling but it is still not easy to detect synthetic nanomaterials directly in the environment. The researches will continue addressing this issue and there will be good results in the near future. For example, exposure modeling is a promising tool to estimate the amount of nanomaterials in the environment. It is stated that the exposure modeling has already been successfully used to detect a number of pollutants, which are not nanowastes [39 - 42].

CONCLUDING REMARKS

Nanomaterials have been included in the field of environment. The application of nanomaterials in the environment field makes a big difference, especially in plastic formation. Millions of tons of plastics are produced every year and plastic nanoparticles make their way into the environment. Plastic production cannot be stopped, but it must be handled wisely to preserve the environment.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENTS

The author would like to thank all authors who have been or are not cited in the chapter, as well as all the organizations, companies, universities and research institutes that are mentioned or cited and or not cited in the chapter. . The author would also like to thank Bentham Science Publishers Pte. Ltd. for publishing the book.

REFERENCES

[1] Baig N, Kammakakam I, Falath W. Nanomaterials: a review of synthesis methods, properties, recent progress, and challenges. Materials Advances 2021; 2(6): 1821-71.
[http://dx.doi.org/10.1039/D0MA00807A]

[2] Ashok K. Engineered Nanoparticles: Structure, Properties and Mechanisms of Toxicity. Academic Press 2015.

[3] Borm PJA, Robbins D, Haubold S, *et al.* The potential risks of nanomaterials: a review carried out for ECETOC. Part Fibre Toxicol 2006; 3(1): 11.
[http://dx.doi.org/10.1186/1743-8977-3-11] [PMID: 16907977]

[4] Nanomaterials in the environment Current state of knowledge and regulations on chemical safety. German Environment Agency 2006.

[5] Greeley J, Markovic NM. The road from animal electricity to green energy: combining experiment and theory in electrocatalysis. Energy Environ Sci 2012; 5(11): 9246.
[http://dx.doi.org/10.1039/c2ee21754f]

[6] Iqbal N, Khan I, Yamani ZH, Qurashi A. Sonochemical assisted solvothermal synthesis of gallium oxynitride nanosheets and their solar-driven photoelectrochemical water-splitting applications. Sci Rep 2016; 6(1): 32319.
[http://dx.doi.org/10.1038/srep32319] [PMID: 27561646]

[7] Khan I, Saeed K, Khan I. Nanoparticles: Properties, applications and toxicities. Arab J Chem 2019; 12(7): 908-31.
[http://dx.doi.org/10.1016/j.arabjc.2017.05.011]

[8] Guzmán KAD, Taylor MR, Banfield JF. Environmental risks of nanotechnology: National Nanotechnology Initiative funding, 2000-2004. Environ Sci Technol 2006; 40(5): 1401-7. [PMID: 16568748]

[9] Roco MC. Environmentally responsible development of nanotechnology. Environ Sci Technol 2005; 39(5): 106A-12A. [http://dx.doi.org/10.1021/es053199u] [PMID: 15787356]

[10] Blackford DB, Simons GR. Particle-size analysis of carbon-black. Part Charact 1987; pp. 112-7.

[11] https://nanopartikel.info/en/basics/cross-cutting/2020. https://byjus.com/chemistry/polystyrene

[12] https://en.wikipedia.org/wiki/Polyvinyl_chloride

[13] Chanda M, Roy SK. Plastics technology handbook. CRC Press 2006; pp. 1-6. [http://dx.doi.org/10.1201/9781420006360]

[14] Allsopp MW, Vianello G. Poly(Vinyl Chloride). Ullmann's Encyclopedia of Industrial Chemistry. Weinheim: Wiley-VCH 2012. [http://dx.doi.org/10.1002/14356007.a21_717]

[15] Barton FC. Victrolac Motion Picture Records. Journal of the Society of Motion Picture Engineers 1932; 18(4): 452-60. [http://dx.doi.org/10.5594/J01337]

[16] Titow, W. V. PVC technology. Springer. 1984; 6. ISBN 978-0-85334-249-6. [http://dx.doi.org/10.1007/978-94-009-5614-8]

[17] https://www.bpf.co.uk/plastipedia/polymers/pvc.aspxhttps://nanopartikel.info/en/basics/cross-cutting/nanoplastic-in-the-environment/2021.

[18] Mallakpour S, Mani L. Preparation and characterization of reinforced poly(vinyl alcohol) films by a nanostructured, chiral, L-leucine based poly(amide-imide)/ZrO2 nanocomposite through a green method. Prog Org Coat 2015; 78: 35-41. [http://dx.doi.org/10.1016/j.porgcoat.2014.10.008]

[19] Rabiee H, Farahani MHDA, Vatanpour V. Preparation and characterization of emulsion poly(vinyl chloride) (EPVC)/TiO2 nanocomposite ultrafiltration membrane. J Membr Sci 2014; 472: 185-93. [http://dx.doi.org/10.1016/j.memsci.2014.08.051]

[20] Mallakpour S, Nezamzadeh Ezhieh A. A simple and environmentally friendly method for surface modification of ZrO_2 nanoparticles by biosafe citric acid as well as ascorbic acid (vitamin C) and its application for the preparation of poly (vinyl chloride) nanocomposite films. Polym Compos 2015. [http://dx.doi.org/10.1002/pc.23746]

[21] Yang C, Gong C, Peng T, Deng K, Zan L. High photocatalytic degradation activity of the polyvinyl chloride (PVC)–vitamin C (VC)–TiO2 nano-composite film. J Hazard Mater 2010; 178(1-3): 152-6. [http://dx.doi.org/10.1016/j.jhazmat.2010.01.056] [PMID: 20138426]

[22] Mallakpour S, Shafiee E. The synthesis of poly(vinyl chloride) nanocomposite films containing ZrO_2 nanoparticles modified with vitamin B_1 with the aim of improving the mechanical, thermal and optical properties. Des Monomers Polym 2017; 20(1): 378-88. [http://dx.doi.org/10.1080/15685551.2016.1273436] [PMID: 29491809]

[23] Krishnamoorthy K, Natarajan S, Kim SJ, Kadarkaraithangam J. Enhancement in thermal and tensile properties of ZrO2/poly (vinyl alcohol) nanocomposite film. Mater Express 2011; 1(4): 329-35. [http://dx.doi.org/10.1166/mex.2011.1036]

[24] Wilkes, Charles E.; Summers, James W.; Daniels, Charles Anthony; Berard, Mark T. PVC Handbook. Hanser Verlag. 2005; p. 414. ISBN 978-1-56990-379-7.

[25] What is PVC Archived 18 July 2017 at the Wayback Machine. 2017.

[26] Hu Z, Liu C, Wu Y, Liu R, He Y, Luo S. TiO_2 nanotube supported metallocene catalysts for the

preparation of nanofiber, nanosheet, and floccule of polyethylene. J Polym Sci, B, Polym Phys 2011; 49(11): 812-7.
[http://dx.doi.org/10.1002/polb.22252]

[27] Dong X, Wang L, Zhou J, Deng L, Huo J, Zhang C. Preparation of nanosheet polyethylene with heterogeneous metallocene catalyst and formation mechanism of nanosheet polyethylene. J Phys Chem B 2006; 110(26): 13045-9.
[http://dx.doi.org/10.1021/jp062527p] [PMID: 16805612]

[28] https://www.creativemechanisms.com/blog/all-about-polypropylene-pp-plastic2021.

[29] Grant DN, Benson J, Cozad MJ, *et al.* Conjugation of gold nanoparticles to polypropylene mesh for enhanced biocompatibility. J Mater Sci Mater Med 2011; 22(12): 2803-12.
[http://dx.doi.org/10.1007/s10856-011-4449-6] [PMID: 21979166]

[30] Taniike T, Toyonaga M, Terano M. Polypropylene-grafted nanoparticles as a promising strategy for boosting physical properties of polypropylene-based nanocomposites. Polymer (Guildf) 2014; 55(4): 1012-9.
[http://dx.doi.org/10.1016/j.polymer.2014.01.016]

[31] Zhou Y, Hu J, Dang B, He J. Effect of different nanoparticles on tuning electrical properties of polypropylene nanocomposites. IEEE Trans Dielectr Electr Insul 2017; 24(3): 1380-9.
[http://dx.doi.org/10.1109/TDEI.2017.006183]

[32] https://www.bing.com/search?q=Polysterene2021.

[33] https://byjus.com/chemistry/polystyrene2021.

[34] Kik K, Bukowska B, Sicińska P. Polystyrene nanoparticles: Sources, occurrence in the environment, distribution in tissues, accumulation and toxicity to various organisms. Environ Pollut 2020; 262: 114297.
[http://dx.doi.org/10.1016/j.envpol.2020.114297] [PMID: 32155552]

[35] Plastics-The Facts, An Analysis of European Plastics Production, Demand and Waste Data. 2017.
https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf

[36] Information about nanomaterials and their safety assessment. 2020. https://www.nanopartikel.info/en/nanoinfo/cross-cutting/2764-nanomaterials-in-the-wastewater-treatment-plant

[37] Nowack B. Evaluation of environmental exposure models for engineered nanomaterials in a regulatory context. NanoImpact 2017; 8: 38-47.
[http://dx.doi.org/10.1016/j.impact.2017.06.005]

[38] Sun TY, Bornhöft NA, Hungerbühler K, Nowack B. Dynamic Probabilistic Modeling of Environmental Emissions of Engineered Nanomaterials. Environ Sci Technol 2016; 50(9): 4701-11.
[http://dx.doi.org/10.1021/acs.est.5b05828]

[39] Wang Y, Kalinina A, Sun T, Nowack B. Probabilistic modeling of the flows and environmental risks of nano-silica. Sci Total Environ 2016; 545-546: 67-76.
[http://dx.doi.org/10.1016/j.scitotenv.2015.12.100]

[40] Sun TY, Gottschalk F, Hungerbühler K, Nowack B. Comprehensive probabilistic modelling of environmental emissions of engineered nanomaterials. Environ Pollut 2014; 185: 69-76.
[http://dx.doi.org/10.1016/j.envpol.2013.10.004]

[41] Prodromakis T. Five ways nanotechnology is securing your future by Themis Prodromakis https://phys.org/news/2016-03-ways-nanotechnology-future.html

[42] http://www.hydrogenfuelnews.com/researchers-find-a-way-to-make-fuel-cells-less-expensive-and-more-efficient/8522456/

CHAPTER 6

Future of Nanotechnology

Abstract: In reality, nanotechnology is transforming many areas of human life. It is a crucial component of many applications, including those that deal with environmental pollution, nanomedicine and health, water purification, and waste treatment. Nanotechnology has a significant role in the economy of many countries. The global nanotechnology market is expected to be more than $ 125 billion in 2024. In fact, this expectation is not fixed, but it can be changed anytime. As known, COVID-19 emerged in 2019 and 2020, and some companies, banks, *etc*. have gone bankrupt. Due to the COVID-19 pandemic, plans and estimates have obviously changed. As reported, there are four generations of nanotechnology. The first generation is concerned with improved nanostructures, and the second generation is concerned with the application of nanostructures, such as drug delivery. The third and fourth generation are concerned with the further integration of nanomaterials applications, such as the use of nanobots in drug delivery.

Keywords: Environment and nanotechnology, Future of Nanotechnology, Nanoarts, Nanomedicine, Nanotechnology and Economy, Water purification.

INTRODUCTION

Human aspiration for technical progress knows no bounds: in practice, there is immense evidence of how technology affects everyday life. As humans reached space and settled on Earth, they created machines to perform tasks previously performed by humans, such as robots that drive cars, serve food and drinks, and perform other tasks. Nanomaterials are of particular interest, and technology companies are constantly looking for new and exciting things. Researchers have been able to employ these materials in a variety of products that we use, including medicines and cosmetics. Some nuts now contain nanometer-sized compounds made of gold. Scientific research will never stop until matter becomes smaller than a nanometer. Therefore, the future of nanotechnology is becoming clear to researchers and investors.

Nanotechnology and Economy

The impact of nanotechnology on the global economy has become evident, and the manufacture of nanomaterials has become easy in all research laboratories

Amin El-Meligi

prepared for that. The growth of nanotechnology has an impact on almost every area of the global economy, including energy, water, the environment, medicine, electronics, the military, transportation, and agriculture. According to a report by Lux Research, Inc., released in October 2004, the nanotechnology value chain cuts from nanomaterials to nanointermediates to nano-enabled products [1, 2]. Lux report predicted that by 2014, emerging nanotechnologies would be incorporated into all computers and consumer electronics devices, 23 percent of drugs, and 21 percent of automobiles and that nanotechnologies would result in \$2.6 trillion in product revenue corresponding to 15% of the global gross manufacturing output. It is reported that the global nanotechnology market is expected to exceed US\$ 125 billion by 2024 [3]. In fact, the estimated numbers may change due to different circumstances, such as environmental pollution, social and economic problems, and health problems. For example, the COVID-19 pandemic that emerged in 2019 and 2020 caused a number of difficulties and unforeseen changes in the world economy. Worldwide, numerous businesses and banks have declared bankruptcy. Plans and estimations have unquestionably changed as a result of the COVID-19 pandemic.

What is next?

It is obvious that technology will continue to advance. There is a new invention every day. After focusing on macroscale for many years, research has now moved on to nanoscale materials. As of today, the smallest unit of time is the femtosecond, which is equal to 10^{-15} seconds, though it could get even smaller.

Nanotechnology is an emerging science that is expected to have rapid and powerful future developments. It is expected to contribute significantly to economic growth and job creation in the European Union in the coming decades. Scientists predict that nanotechnology has four distinct generations of advancement. As mentioned, the world is currently in the first generation or may be in the second generation of nanotechnology [4]. The four generations are divided as follows: The first generation includes materials science with improved properties that are achieved by incorporating “passive nanostructures”. For example, nano-coating and carbon nanotubes are used to strengthen plastic, *etc*. The usage of active nanostructures has advanced further in the second generation; for instance, nanostructure has made it easier to deliver a medicine to a particular target cell or organ in the human body. The nanoparticles of medicine could be coated with specific proteins as a means of reaching this goal. The complexity of the nanosystem has increased in the third and fourth generations.

Nanotechnology for Securing the Future

The humans have progressed from one evolution to another, according to history. The electronic transistor and microchips are two minor inventions that have helped nations work and live for the past 70 years [5]. Both of them were created in 1940. All current electronic devices were inspired by these two discoveries. The size has changed due to technological improvements, becoming smaller and smaller. Today, a single chip can have up to 5 billion transistors [5].

Not only transistors and microchips, but also many inventions have been developed, such as nanorobots, nanomedicines, nanoparticle science, nanofibers, nanolubricants, and carbon nanotubes.

All these inventions of nanomaterials secure the future of humanity, for example, the invention of nanobots is like a doctor in the human body, who can deliver medicine to the affected site in the human body, and can help in carrying out complex operations. To improve eye vision, tiny sensors can be implanted in specific places on the human body, such as retina implants. These tiny sensors can also record crucial data without endangering the patient, assisting medical professionals in developing precise illness treatments. Nanomaterials could be used to create incredibly fine and tiny sensors. The applications of sensors nearly cover most areas that concern people.

Materials' nanostructures alter their physical characteristics and produce some astonishing features.Nanoparticles can quickly migrate to fill up material cracks, acting as a self-healing mechanism that can repair the gaps without the need to shut down the plant. Self healing will be very helpful in the big design such as areoplane to small design such as microelectronics. The advantage of the self-healing is to stop small factures from getting bigger and from becoming a big problem [5]. In addition to the aforementioned advantages of sensors, very tiny sensors can make big data possible by producing more information than we have ever had to deal with before. Huge amounts of data are stored in traffic sensors, which can be utilised to manage traffic. Statistical data can be used to avoid accidents and crimes.

In reality, nanotechnology aids in the development of high-capacity memories that enable the storage of this enormous data, which is a vast resource of knowledge. This also provides inspiration for highly efficient algorithms for data processing, encryption and transmission without changing the authentication of this data. There are many natural examples of big data operations that are efficiently performed in real time by minute structures, such as the parts of the eye and ear that convert external signals and scenes into information for the brain. There is also the special part of the human brain, which stores millions of information and keeps it for many years.

Climate Change and Nanotechnology

Perhaps a question comes to mind, is there a relationship between climate change and nanotechnology? In fact, there is a close and important relationship between climate change and nanotechnology, especially in the field of energy. It is known that climate change is closely related to energy, especially non-renewable energy, which directly affects climate change through gaseous emissions and other materials that are produced from energy sources.

It is important to remember that nanotechnology has a direct impact on the production of renewable energy. Many of the materials used to create various forms of renewable energy, like solar energy, hydrogen energy, *etc*., are now nanomaterials. There is a need to find new ways to generate and to use energy. Nanomaterials are very important to help in this issue. Nanotechnology helps produce devices with important applications, such as batteries and solar cells, as shown in Fig. (**1**). The nanostructure of the materials has substantially increased the efficiency of batteries and solar cells.

Fig. (1). The Scene nanotechnology and global warming. Credit: Shutterstock [5].

The main advantage in the application of batteries and solar cells is the use of a nanostructure (*e.g*. nanowires or carbon nanotubes), and due to the nanostructure, a flat surface is transformed into a three-dimensional surface with a much larger surface area. This means that there is more space for interactions that allow energy to be stored or generated, and thus the efficiency of the devices is greatly increased.

Indeed, future indications of nanotechnology hold promise for the creation of unconventional sources of energy, where energy can be harvested from the environment using nanotechnology. There is also the possibility of developing new nanomaterials and concepts that show the potential to produce energy from motion, light, changes in temperature, glucose and other sources with high conversion efficiency.

Nanotechnology and Agriculture

In reality, because agriculture is the primary source of food, the entire world's population is dependent on its production. The agriculture is an important reason for reducing poverty, increasing income, increasing workers, and supporting livelihoods. Additionally, food for the poor, especially those who reside in developing nations, is provided *via* agriculture. (Fig. **2**) shows an image of the land [6]. Therefore, it is important that we improve agricultural production by all possible means. One of these important means is nanotechnology, which can contribute to improving agricultural production through nanomaterials, especially in the field of improving agricultural soil, improving fertilizers and seed quality. It is known that agriculture uses about 70% of the fresh water worldwide. In fact, the world suffers from a shortage of fresh water. Therefore, there is a need to increase the amount of fresh water. As discussed in the chapter on nanotechnology and water, nanotechnology plays a vital role in water purification and desalination.

Agriculture uses about seventy percent of the freshwater all over the world. As it is known, the world is witnessing rapid population growth, and it has been estimated that by the year 2050, the global population will reach about nine billion people, meaning that the world needs food to feed this huge number of people, and this will need an estimated increase of 50% in agricultural production and a 15% increase in water consumption. However, agricultural production is under threat in many areas in the world, especially in the Middle Eastern countries that rely heavily on imported food commodities due to land restrictions and water scarcity, along with climate change. Here comes the role of nanotechnology to help in solving these problems facing agriculture worldwide. A Norwegian company has discovered an innovative way to solve all these problems: poor-quality sandy soil can be converted into high-yield farmland using Liquid NanoClay (LNC) technology [6]. The reason for making this invention is the desertification. As known, desertification results from decreasing water resources.

As reported about 40% of the Earth's land, which accommodates about 2 billion people, is drylands. As reported, the degradation of the land costs the world economy a lot every year. It is estimated that about US$ 10.6 trillion is spent annually due to the degradation of the land [6]. Therefore, the new technology, which has been developed by the Norwegian company, is to reduce desertification and convert deserts into cultivated land.

Fig. (2). Image of the land, picture from earth.org [6].

Liquid Nanoclay Innovation

The Norwegian company's innovation is called Liquid NanoClay (LNC), which is based on mixing clay and water of irrigation. The clay and water should be mixed on site. The way the LNC works is to spread the LNC over sandy soils using conventional systems of irrigation such as sprinklers or water carts. Individual clay flakes are attached to the surface of the sand particles with a Van der Waals force, and the mixture seeps out of the ground to a depth of root. The capacity of the soil to keep water nutrients significantly increases, and creates conditions for fertile land.

In fact, there is a need to reduce desertification by restoring areas of the world historically considered bread baskets, because these areas suffer from erosion, lost crops and poor water quality. Farmers and government authorities need fast-acting solutions for land management and conservation. As mentioned earlier, real application has successfully shown that LNC treatment can reduce the need for irrigation by up to 77% and increase soil fertility up to 40% resulting in increased yields by 416% [6].

Nanotechnology Expectations

In reality, nanotechnology continues to advance. In addition to using advanced nanotechnology to create vaccines, it has been stated that anti-fog applications have also been created using this technology. This illustrates the benefits of nanoparticles, which have a wide range of applications in this field. As explained, this application has been designed to manage the differences between internal and external temperature, it is a nanocoating that is suitable for different surfaces, such as plastic and glass surfaces. This application of nanotechnology works to treat and to maintain the surface [7]. It is also reported that advanced nanotechnology works to develop anti-bacterial and anti-virus nano-coating applications.

Future industries will place a greater emphasis on nanotechnology, and the health sector will benefit more from it than ever before. The countries that lead the world in the field of nanotechnology will remain the same in recent years, these countries are the USA, Japan, Europe, China, and South Korea [7]. As mentioned, the USA is the number one market and countries such as Japan, Germany, Finland and France are at the forefront of nanotechnology.

CONCLUDING REMARKS

Future breakthroughs in the field of nanotechnology are anticipated to be swift and significant. The reality is that nanotechnology is a flexible technology that will likely become vital in more and all sectors in the future, whether they be industrial or consumer.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The author declares no conflict of interest, financial or otherwise.

ACKNOWLEDGEMENT

The author would like to thank all authors who have been cited or not in the chapter. Also all the organizations, companies, universities and research institutes that are mentioned or cited in the chapter, as well as those that are not mentioned or cited are acknowledged. The author would also like to thank Bentham Science Publishers Pte. Ltd. for publishing the book.

REFERENCES

[1] National Research Council A Matter of Size: Triennial Review of the National Nanotechnology Initiative. Washington, DC: The National Academies Press 2006. [http://dx.doi.org/10.17226/11752]

[2] Lux Research, Inc. Sizing Nanotechnology's Value Chain. New York: Lux Research, Inc. 2004.

[3] Research and Market, Global Nanotechnology Market 2018-2024: Market is Expected to Exceed US$ 125 Billion, DUBLIN, May 2 2018.

[4] EUON The future of nanotechnology https://euon.echa.europa.eu/the-future-of-nanotechnology

[5] Prodromarkis T. Five ways nanotechnology is securing your future 2016.https://phys.org/news/2016-03-ways-nanotechnology-future.html

[6] Making Earth Green Again with Liquid Nano Clay European Comission https://cordis.europa.eu/project/id/876908

[7] Nanotechnology A. The future of nanotechnology https://www.advancednanotechnologies.com/nanotechnology-products/anti-fog-coating/

SUBJECT INDEX

Amin El-Meligi

Amin A. El-Meligi

Dr. Amin A. El-Meligi is a Professor of Physical Chemistry, Advanced Materials Technology & Mineral Resources Research Institute, National Research Center, Egypt. He received his BSc and MSc from Cairo University. He received his PhD from UMIST (Currently University of Manchester)-Manchester, UK and Cairo University, Egypt under a joint supervision system. Professor El-Meligi has over 30 years of research and teaching experience. He was the Director of Research Office, Dean of Student Affairs, and VP of Academic Affairs at University of Technology Bahrain. His research interests include electrochemistry and corrosion, renewable energy, hydrogen storage and hydrogen production, and nanomaterials. He participated in a number of national and international research projects. Professor El-Meligi is a member of international and national organizations, especially, International Centre for Diffraction Data (ICDD), USA. He was a visiting scientist from the University of Durham, Chemistry Dept. UK. He is a frequent keynote speaker and speaker in national and international conferences. Professor El-Meligi received the award and honor from a number of organizations -The International Biographical Centre, Cambridge, England, nominated him as one of the “International Scientist of the Year for 2006” -The International “MARQUES” Organization in USA Selected him to be the represented in the Series “Who’s Who in The World”, 2006, this is due to his Scientific Contribution. Misr El-Kheir Foundation, Egypt, which is dedicated to lead the civil society to promote, foster and support scientific research, awarded him one of the first annual Scientific Publications Awards-2010. His research studies are on international spot and received international recognition, such as on Research Gate, Google Scholar, and SCOPUS.