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The use of nanotechnology in water purification and Environmental applications

By:
Marwan Mohammed Kadhim

Supervisor:
Prof.Dr. Mohmmed Ali I. Alhashimi

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(من خرج لطلب العلم فهو في سبيل الله حتى يرجع)

Gifting

We owe our college and Professors a lot. Both offered and still offer us valuable knowledge in many fields trying to help us follow the clear & right way that leads to the success & progress of our country.

I acknowledge that the Professors staffhas done the best to help us & in return, we must add a little to the mountain of knowledge made by the sharing of all smart scientists.

Nano science is still new, but quick and firm steps have been achieved in this field of science especially in the minute sciences.

I introduce this small effort as a humble sharing to all our collegeProfessors Who assist me and always remind me that one can overcome the difficulties facing him if he has the will and desire& I never forget my parents who gave me the start to continue my life and to learn from my mistakes, Special thanks for Prof.Dr. Mohammed Ali I.

Marwan Mohammed

PREFACE

Understanding and utilizing the interactions between environment and nanoscale materials is a new way to resolve the increasingly challenging environmental issues we are facing and will continue to face. Therefore, the applications of nanotechnology in environmental engineering have beenof great interest to many fields, and consequently, a fair amount of research on the use of nanoscale materials for dealing with environmental issues has been conducted.(4)

The aim of this Project is to report on the results recently achieved in different countries. We hope that the Peport can provide some useful technological information for environmental scientists and assist them in creating cost-effective nanotechnologies to solve critical environmental problems, including those associated with energy production.(4)

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CAHPTER ONE

Introduction

In early 2007, the United Nations reported that nanotechnology, which then accounted for approximately 0.1% of the global manufacturing economy, would grow to 14% of the market by 2014. This market share would correspond to $2.6 trillion in U.S. dollars . What accounts for this explosive growth? And what does it mean for our environment? This research provides perspective on those questions based on the current state of the science.(1)

Nanotechnology is a field of applied science concerned with the control of matter at dimensions of roughly 1 to 100 nanometers (nm). (1 nm is one-billionth of a meter.) At the particle size of 1 to 100 nm, Nano scale materials may have different molecular organizations and properties than the same chemical substances in a larger size. Nano-sized chemicals can have different properties due to:

- Increased relative surface area per unit mass, which can increase physical strength and chemicalReactivity
- In some cases, the dominance of quantum effects at the nanometer size, which changes basic material properties.(1)

These unique properties offer revolutionary means to optimize a variety of products, including electronics, textiles, paintings and coatings, pharmaceuticals, and personal care products. And these unique properties mean that Nanoscale materials can behave differently in the human body and the environment than the corresponding macro-scale materials. Similarly, revolutionary developments during the past two centuries offer cautionary tales. In the 1800s, gaslights illuminated the Industrial Revolution. Engineers had devised ways to manufacture gas from the pyrolysis of coal or oil. A hundred years later, the residuals of that process stained soils bright blue with cyanide compounds and contaminated groundwater with tar residuals. Those historic manufactured gas plants had come to represent hazardous waste rather than progress. Developments in the 1900s provide a further example. In 1979, suppliers began adding methyl- tertiary-butyl ether (MTBE) to gasoline in the United States to replace lead as an octane enhancer. Later, adding MTBE to gasoline fulfilled the oxygenate requirements in the 1990 Clean Air Act Amendments intended to reduce smog production. The use of MTBE, however, created another set of environmental problems. Liquid and vapor leaks from underground storage tanks have led to widespread MTBE contamination in groundwater.(1)

The U.S. Geological Survey surveyed water quality in nearly all 50 states in the 1990s. Of the 4023 groundwater samples collected, 10% contained detectable MTBE at an average concentration of 280 micrograms per liter (μg/L), well above the U.S. Environmental Protection Agency's Health Advisory of 20 to 40 μg/L in drinking water. These examples illustrate the unintended consequences that can result from rapid industrial progress.[1]

1.1 POTENTIAL REWARDS

Nanotechnology offers the potential for tantalizing rewards. Amid the hyperbole and hype, many experts believe that nanotechnology may offer substantial advantages. Consider the following examples:

- Energy savings. The U.S. Environmental Protection Agency (U.S. EPA) has cited one estimate that the use of nanotechnology could reduce the energy consumption in the U.S. by more than 14%. For example, the use of nanotechnology-based materials such as lightweight composites and thinner paint coatings can reduce the weight of airplanes and automobiles, and thus their fuel usage. Solid-state lighting may use energy more efficiently than conventional lighting. Fuel additives, such as cerium oxide, may increase diesel fuel efficiency.

- Alternative energy supplies. Nanotechnology offers the potential to decrease the cost of producing solar cells to enable more widespread use of solar power. Advances in battery manufacturing using nanotechnology may allow for more widespread use of electric vehicles. Finally, with respect to hydrogen fuel cells, nanotechnology can provide more efficient fuel storage methods and improve efficiency.

- Efficient use of raw materials. Nanostructured catalysts may decrease the mass of catalysts, particularly platinum, used in some applications. The use of highly effective Nano-sized catalysts also can increase production and decrease waste generation. Nano scale zeolite catalysts, for example, are used now in petroleum cracking. Some nanomaterials may provide sub- stitutes for toxic materials; for example, nanotechnology-based solders can replace lead-based solders.

- Environmental protection. Engineers use nanomaterial's in wastewater treatment and environmental remediation, as described later in this research. Researchers also are studying the use of nanotechnology to treat water pollution. Finally, sensors based on nanotechnology can detect some chemical contaminants.
- Agricultural applications. Increased biological efficiency coulddiminish the amount of pesticides being applied. Similarly, Nanodevices used for "smart" treatment delivery systems holdpromise .Smart field systems detect, locate, and report/apply, as needed, pesticides and fertilizers prior to the onset of symptoms. Nanoparticle delivery systems, including nano-capsules, Nano containers,

and Nano cages, could replace conventional emulsifiable concentrates,

thus reducing organic solvent content in agricultural formulations, and enhancing disparity, wettability, and the penetration strength of the droplets. Enhanced use of smart systems also could diminish runoff and avert unwanted movement of pesticides.

This range of potential benefits illustrates why so many are excited about the promise of nanotechnology and its potential economic importance.[1]

CHAPTER TWO

ENVIRONMENTAL BENEFITS OF NANOTECHNOLOGY

2.1 BENEFITS THROUGH ENVIRONMENTAL TECHNOLOGY APPLICATIONS

2.1.1 Remediation/Treatment

Environmental remediation includes the degradation, sequestration, or other related approaches that result in reduced risks to human and environmental receptors posed by chemical and radiological contaminants such as those found at Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), Resource Conservation and Recovery Act (RCRA), the Oil Pollution Act (OPA) or other state and local hazardous waste sites. The benefits from use of nanomaterials for remediation could include more rapid or cost-effective cleanup of wastes relative to current conventional approaches. Such benefits may derive from the enhanced reactivity, surface area, subsurface transport, and/or sequestration characteristics of nanomaterials.(2)

Chloro-organics are a major class of contaminants at U.S. waste sites, and several nanomaterials have been applied to aid in their remediation. Zero-valent iron (Fig. 2.1) has been used successfully in the past to remediate groundwater by construction of a permeable reactive barrier (iron wall) of zero-valent iron to intercept and dechlorinate chlorinated hydrocarbons such as trichloroethylene in groundwater plumes. Laboratory studies indicate that a wider range of chlorinated hydrocarbons may be dechlorinated using various nanoscaleiron particles (principally by abiotic means, with zero-valent iron serving as the bulk reducing agent), including chlorinated methanes, ethanes, benzenes, and polychlorinated biphenyls (2). Nanoscale zero-valent iron may not only treat

aqueous dissolved chlorinated solvents in situ, but also may remediate the dense nonaqueous phase liquid sources of these contaminants within aquifers[2].

In addition to zero-valent iron, other nanosized materials such as metalloporphyrinogenshave been tested for degradation of tetrachlorethylene, trichloroethylene, and carbon tetrachloride under anaerobic conditions[2]. Titanium oxide based nanomaterialshave also been developed for potential use in the photocatalytic degradation of various chlorinated compounds[2].

Enhanced retention or solubilization of a contaminant may be helpful in a remediation setting. Nanomaterials may be useful in decreasing sequestration of hydrophobic contaminants, such as polycyclic aromatic hydrocarbons (PAHs), bound to soils and sediments. The release of these contaminants from sediments and soils could make them more accessible to *in situ* biodegradation. For example, nanomaterials made from poly(ethylene) glycol modified urethane acrylate have been used to enhance the bioavailability of phenanthrene[2].

Metal remediation has also been proposed, using zero-valent iron and other classes of nanomaterials. Nanoparticles such as poly(amidoamine) dendrimers can serve as chelating agents, and can be further enhanced for ultrafiltration of a variety of metal ions (Cu (II), Ag(I), Fe(III), etc.) by attaching functional groups such as primary amines, carboxylates, and hydroxymates[2]. Otherresearch indicates that arsenite and arsenate may be precipitated in the subsurface using zero-valent iron, making arsenic less mobile. Self-assembled monolayers on mesoporous supports are nanoporous ceramic materials that have been developed to remove mercury or radionuclides from wastewater .[2]

Nanomaterials have also been studied for their ability to remove metal contaminants from air. Silica-titaniananocomposites can be used for elemental

mercury removal from vapors such as those coming from combustion sources, with silica serving to enhance adsorption and titania to photocatalytically oxidize elemental mercury to the less volatile mercuric oxide. Other authors have demonstrated nanostructured silica can sorb other metals generated in combustion environments, such as lead and cadmium. Certain nanostructured sorbent processes can be used to prevent emission of nanoparticles and create byproducts that are useful nanomaterials.[2]

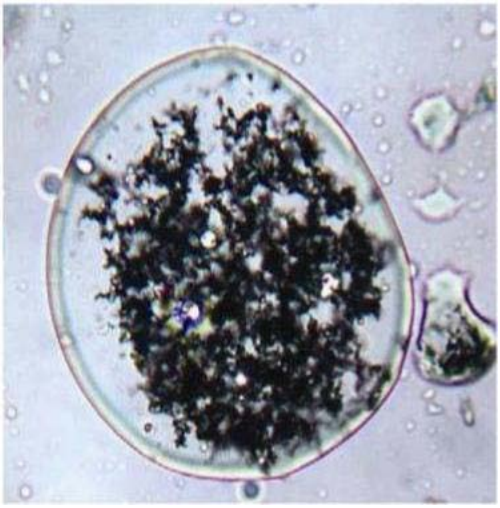

Figure (2.1) Nano scale zero-valent iron encapsulated in an emulsion droplet. These nanoparticles have been used for remdiation of sites contaminated with variuos organic polluta.(Image cortesy of Dr. Jacqueline W. Quinn, Kennedy Space Center, NASA).

2.1.2 Sensors

Sensor development and application based on nanoscale science and technology is growing rapidly due in part to the advancements in the microelectronics industry and the increasing availability of nanoscale processing and manufacturing technologies. In general, nanosensors can be classified in two main categories: (1) sensors that are used to measure nanoscale properties (this category comprises most of the current market) and (2) sensors that are themselves nanoscale or have nanoscale components. The second category can eventually result in lower material cost as well as reduced weight and power consumption of sensors, leading to greater applicability and enhanced functionality.(2)

One of the near-term research products of nanotechnology for environmental applications is the development of new and enhanced sensors to detect biological and chemical contaminants. Nanotechnology offers the potential to improve exposure assessment by facilitating collection of large numbers of measurements at a lower cost and improved specificity. It soon will be possible to develop micro- and nanoscale sensor arrays that can detect specific sets of harmful agents in the environment at very low concentrations. Provided adequate informatics support, these sensors could be used to monitor agents in real time, and the resulting data can be accessed remotely. The potential also exists to extend these small-scale monitoring systems to the individual level to detect personal exposures and *in vivo* distributions of toxicants. Figur2.2shows an example of a nanoscale sensor.(2)

In the environmental applications field, nanosensor research and development is a relatively uncharted territory. Much of the new generation nanoscale sensor development is driven by defense and biomedical fields. These areas possess high-need applications and the resources required to support exploratory sensor research. On the other hand, the environmental

measurement field is a cost sensitive arena with less available resources for leading-edge development. Therefore, environmental nanosensor technology likely will evolve by leveraging the investment in nanosensor research in related fields.(2)

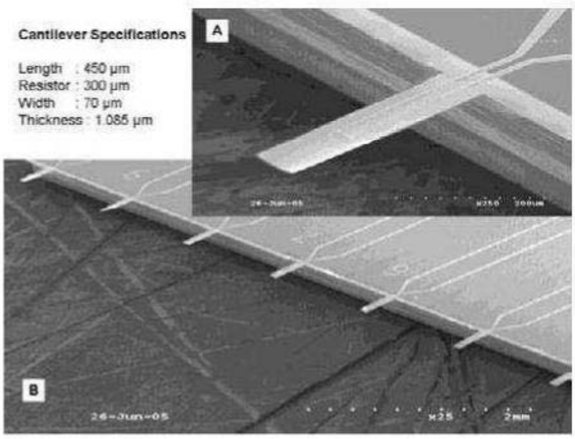

Figure (2.2)Piezo resistive cantilever sensor.

Devices such as these may be used to detect low levels of a wide range of substances, including pollutants, explosives, and biological or chemical warfare agents.(Image courtesy of Dr. Zhiyu Hu and Dr. Thomas Thundat, Nanoscale Science and Device Group, Oak Ridge National Laboratory)

2.2 BENEFITS THROUGH OTHER APPLICATIONS THAT SUPPORT SUSTAINABILITY

Nanotechnology may be able to advance environmental protection by addressing the long-term sustainability of resources and resource systems. Listed in Table 2 are examples describing actual and potential applications relating to water, energy, and materials. Some applications bridge between several resource outcomes. For example, green manufacturing using nanotechnology (both top down and bottom up) can improve the manufacturing process by increasing materials and energy efficiency, reducing the need for solvents, and reducing waste products.(2)

Many of the following applications can and should be supported by other agencies. However, EPA has an interest in helping to guide the work in these areas.(2)

Table (2). Outcomes for Sustainable Use of Major Resources and Resource Systems(2)

sustain water resources of quality and availability for desired uses	**Water**
generate clean energy and use it efficiently	**Energy**
use material carefully and shift to environmentally preferable	**Materials**
protect and restore ecosystem functions, goods, and services	**Ecosystems**
support ecologically sensitive land management and development	**Land**
sustain clean and healthy air	**Air**

EPA Innovation Action Council, 2005

2.2.1 Water

Nanotechnology has the potential to contribute to long-term water quality, availability, and viability of water resources, such as through advanced filtration that enables more water re-use, recycling, and desalinization. For example, nanotechnology-based flow-through capacitors (FTC) have been designed that desalt seawater using one-tenth the energy of stateof-the art reverse osmosis and one-hundredth of the energy of distillation systems. The projected capital and operation costs of FTC-based systems are expected to be one-third less than conventional osmosis systems.(2)

Applications potentially extend even more broadly to ecological health. One long-term challenge to water quality in the Gulf of Mexico, the Chesapeake Bay, and elsewhere is the build up of nutrients and toxic substances due to runoff from agriculture, lawns, and gardens. In general with current practices, about 150% of nitrogen required for plant uptake is applied as fertilizer (Frink et al., 1996). Fertilizers and pesticides that incorporate nanotechnology may result in less agricultural and lawn/garden runoff of nitrogen, phosphorous, and toxic substances, which is potentially an important emerging application for nanotechnology that can contribute to sustainability. These potential applications are still in the early research stage. Applications involving dispersive uses of nanomaterials in water have the potential for wide exposures to aquatic life and humans. Therefore, it is important to understand the toxicity and environmental fate of these nanomaterials.(2)

2.2.2 Energy

There is potential for nanotechnology to contribute to reductions in energy demand through lighter materials for vehicles, materials and geometries that contribute to more effective temperature control, technologies that improve manufacturing process efficiency, materials that increase the efficiency of electrical components and transmission lines, and materials that could contribute to a new generation of fuel cells and a potential hydrogen economy. However, because the manufacture of nanomaterials can be energy-intensive, it is important to consider the entire product lifecycle in developing and analyzing these technologies.(2)

Table (3) illustrates some potential future nanotechnology contributions to energy efficiency. Brown (2005a,b) estimates that the eight technologies could result in national energy savings of about 14.5 quadrillion BTU‘s (British thermal units, a standard unit of energy) per year, which is about 14.5% of total U.S. energy consumption per year.(2)

The items in Table (3) represent many different technology applications. For instance, one of many examples of molecular-level control of industrial catalysis is a nanostructured catalytic converter that is built from nanotubes and has been developed for the chemical process of styrene synthesis. This process revealed a potential of saving 50% of the energy at this process level. Estimated energy savings over the product life cycle for styrene were 8-9% . Nanostructured catalysts can also increase yield (and therefore reduce energy and materials use) at the process level. For example, the petroleum industry now uses nanotechnology in zeolite catalysts to crack hydrocarbons at a significantly improved process yield.(2)

Table(3). Potential U.S. Energy Savings from Eight Nanotechnology Applications, (2)

Estimated Percent Reduction in Total Annual U.S. Energy Consumption**	Nanotechnology Application
6.2 *	Strong, lightweight materials in transportation
3.5	Solid state lighting (such as white light LED‘s)
2.1	Self-optimizing motor systems (smart sensors)
1.2	Smart roofs (temperature-dependent reflectivity)
0.8	Novel energy-efficient separation membranes
0.3	Energy efficient distillation through supercomputing
0.2	Molecular-level control of industrial catalysis
0.2	Transmission line conductance
14.5	**Total**

*Assuming a 5.15 Million BTU (corresponding to reformulated gasoline – from EIA monthly energy review, October 2005, Appendix A)
**Based on U.S. annual energy consumption from 2004 (99.74 Quadrillion Btu/year) from the Energy
Information Administration Annual Energy Review 2004

There are additional emerging innovative approaches to energy management that could potentially reduce energy consumption. For example, nanomaterials arranged in superlatticescould allow the generation of electricity from waste heat in consumer appliances, automobiles, and industrial processes. These thermoelectric materials could, for example, further extend the efficiencies of hybrid cars and power generation technologies .[(2)]

In addition to increasing energy efficiency, nanotechnology also has the potential to contribute to alternative energy technologies that are environmentally cleaner. For example, nanotechnology is forming the basis of a new type of highly efficient photovoltaic cell that consists of quantum dots connected by carbon nanotubes .[(2)] Also, gases flowing over carbon nanotubes have been shown to convert to an electrical current, a discovery with implications for novel distributed wind power .[(2)]

While nanotechnology has the potential to contribute broadly to energy efficiency and cleaner sources of energy, it is important to consider energy use implications over the entire product lifecycle, particularly in manufacturing nanomaterial's. Many of the manufacturing processes currently used and being developed for nanotechnology are energy intensive. In addition, many of the applications discussed here are projected applications. There are still some technical and economic hurdles for these applications.[(2)]

2.2.3 Materials

Nanotechnology may also lead to more efficient and effective use of materials. For example, nanotechnology may improve the functionality of catalytic converters and reduce by up to 95% the mass of platinum group metals required. This has overall product lifecycle benefits. Because platinum group metals occur in low concentration in ore, this reduction inuse may reduce ecological impacts from mining. However, manufacturing precise nanomaterial's can be material-intensive.(2)

With nanomaterial's‘ increased material functionality, it may be possible in some cases to replace toxic materials and still achieve the desired functionality (in terms of electrical conductivity, material strength, heat transfer, etc.), often with other life-cycle benefits in terms of material and energy use. One example is lead-free conductive adhesives formed from self-assembled monolayers based on nanotechnology, which could eventually substitute for leaded solder. Leaded solder is used broadly in the electronics industry; about 3900 tons lead is used per year in the United States alone. In addition to the benefits of reduced lead use, conductive adhesives could simplify electronics manufacture by eliminating several processing steps, including the need for acid flux and cleaning with detergent and water.(2)

Nanotechnology is also used for Organic Light Emitting Diodes (OLEDs). OLEDs are a display technology substitute for Cathode Ray Tubes, which contain lead. OLEDs also do not require mercury, which is used in conventional Flat Panel Displays. The OLED displays have additional benefits of reduced energy use and overall material use through the lifecycle.(2)

2.2.4 Fuel Additives

Nanomaterial's also show potential as fuel additives and automotive catalysts and as catalysts for utility boilers and other energy-producing facilities. For example, cerium oxide nanoparticles are being employed in the United Kingdom as on- and off-road diesel fuel additives to decrease emissions These manufacturers also claim a more than 5- 10 % decrease in fuel consumption with an associated decrease in vehicle emissions. Such a reduction in fuel consumption and decrease in emissions would result in obvious environmental benefits. Limited published research and modeling have indicated that the addition of cerium oxide to fuels may increase levels of specific organic chemicals in exhaust, and result in emission of cerium oxide; the health impacts associated with such alterations in diesel exhaust were not examined.(2)

CHAPTER THREE

NANOTECHNOLOGY- BASED WATER TREATMENT TECHNOLOGIES

The following section provides an overview of the types of nanotechnology applications that are relevant to water treatment.To illustrate each type of application, this section includes specific examples of innovations using nanotechnology. It should benoted, however, that many other specific nanotechnology-based products and approaches are being developed or may alreadybe available. It should be noted that much of the information regarding these specific examples is based on public informationprovided by the manufacturers themselves. Since these products are not yet on the market or have not been on the marketlong, few independent studies exist regarding the performance of these products. Information about potential environmentalor human health risks of these technologies is not included in this section because little, if any, data about these issues isavailable in the context of specific water treatment devices.[3]

3.1 Carbon Nanotube- Based Technologies

3.1.1 Carbon Nanotube Membranes

Carbon nanotubes can be uniformly aligned to form membranes with nanoscale pores that are able to filter out contaminants.Theirnanoscale pores make these filters more selective than other filtration technologies. The carbon nanotubes also havehigh surface areas, high permeability, and good mechanical and thermal stability. Though several other methods have beenused, carbon nanotube membranes can be made by coating a silicon wafer with a metal nanoparticle catalyst that causes carbonnanotubes to grow vertically aligned and tightly packed. The spaces between the carbon

nanotubes can then be filled with aceramic material to add stability to the membrane.[3]

3.1.1.1Contaminant Removal

Laboratory studies report that carbon nanotube membranes can remove almost all kinds of water contaminants, includingturbidity, bacteria, viruses, and organic contaminants. These membranes have also been identified as promising for desalinationand as an alternative to reverse osmosis membranes.[3]

3.1.1.2Amount of Water Treated

Although their pores are significantly smaller, carbon nanotube membranes have been shown to have the same or faster flowrates as much large pores, possibly because of the smooth interior of the nanotubes.[3]

3.1.1.3Cost

The cost of producing carbon nanotube membranes continues to decrease as researchers develop new and more cost effectivemethods to mass produce carbon nanotubes. Some sources estimate that carbon nanotube membranes could becomesignificantly less expensive than other filtration membrane technologies, including reverse osmosis membranes and ceramic andpolymer membranes, as the price of carbon nanotubes falls. Desalination using carbon nanotube filters could cost less thanwith reverse osmosis due to energy savings, since carbon nanotubes exhibit fast flow rate that reduce the amount of pressureneeded to push water through. Carbon nanotube membranes are expected to be more durable and easier to clean and reusethan conventional membranes without a decrease in filtering efficiency.[3]

Carbon nanotube membranes could potentially be used in the same

way as ultra- and microfiltration membranes. Studiesindicate that they are durable, heat resistant, and easy to clean and reuse. These membranes can be cleaned through a processofultrasonification and autoclaving at about 121 degrees Celsius for 30 minutes.(3)

3.1.1.4Additional Considerations

Carbon nanotube desalination membranes are expected to reach the market in 5 to 10 years. Researchers are currently workingto overcome challenges associated with scaling up the technology.(3)

3.1.2 Nanomesh

Seldon Laboratories, a small company in the U.S., has developed several device prototypes based on its nanomesh filter media.Nanomesh is composed of carbon nanotubes that are bound together and placed on a flexible, porous substrate. The nanotubescan be placed on a flat substrate to form a paper-like filter or on a rolled substrate that can be wrapped around anyconventional cylindrical filter or other support structure. Flat nanomesh can also be pleated to maximize filter surface area.[128]Seldon currently has several portable water purification device prototypes based on this technology, most prominently a pencil-sized, straw-like filtration device known as the "waterstick.(3)

3.1.2.1Contaminant Removal

Seldon indicates that nanomesh can be engineered to remove a wide range of biological, organic, and inorganic contaminants.The filter media can be constructed of several layers of carbon nanotubes, with each layer functionalized to remove a differenttype of contaminant. Seldon says that the nanomesh currently used in the waterstick can be used to remove more than 99.99percent of bacteria, viruses, cysts, spores, molds, coliform, parasites, and fungi and also significantly

reduces lead and arsenic.Functionalized versions of nanomesh can remove organic contaminants such as pesticides and herbicides, as well as inorganiccontaminants such as heavy metals, fertilizers, industrial effluents, and others. The filter media can also be coated with anantibacterial agent to prevent bio-film formation. Seldon is currently working to enhance this technology so that it can beused to desalinate seawater.[3]

3.1.2.2Amount of Water Treated

Seldon says that unlike other media with comparable pore size, nanomesh provides adequate flow rates without the applicationof pressure due to the fast mass transport properties of carbon nanotubes. A prototype filtration device with a 5 centimeterdiameter has been shown to have a flow rate of 6 liters per hour. The waterstick is designed to treat a liter of contaminatedwater within 90 seconds. It produces 200 to 30o liters of water during its useful life, though this can be extended by regularlychanging the pre-filter.[3]

3.1.2.3Cost

Seldon is planning to price the watersick competitively with other similar technologies so that it will be affordable for peoplein developing countries, assuming aid organizations assist with distribution.[3]

3.1.2.4Ease of Use

The waterstick is designed for individual use and is used like a drinking straw, producing clean water as the user drinks.Thewaterstick is currently designed to be disposable, though Seldon indicates that, in time, it may develop a unit with replaceablefilter cartridges. Additionally, the waterstick is designed to automatically stop flowing

when its useful life is over. Loosenanomesh media can be incorporated into existing filtration devices.[3]

3.1.2.5 Additional Considerations

Seldon has reportedly developed a cost-effective mass production system for manufacturing nanomesh media. Seldon'smassproduction system has a production capacity of 276 square meters of material per month, with each square meter providingenough material for 395 devices. A water stick prototype is currently being used by doctors in Africa.[3]

3.2 Other Nanofiltration Approaches

3.2.1Nanofiltration Membranes and Devices

A number of nanofiltration membranes are available as alternatives to reverse osmosis and ultra- and microfiltration. Forinstance, Korean company Saehan Industries offers a line of nanofiltration membranes for use in a wide range of scales, includinghousehold POU. Additionally, Saehan has developed a device that incorporates nanofiltration with pre- and post-treatmentfilters for household water purification without the use of a storage tank. Storage water tanks are required for most reverseosmosis systems, but Saehan says that they can increase the risk of water recontamination if water is stored too long or withimproper sanitation.[3]

3.2.1.1 Contaminants Removed

Saehan indicates that its nanofiltration device can be used to remove almost all water contaminants, including bacteria andheavy metals. Saehan says that the device is also effective for desalination because it removes 90 percent of ion contaminantsand salts.[3]

3.2.1.2Amount of Water Treated

The nanofiltration device can treat between ' and 3.5 liters of water per minute. Amounts less than ' liter are insufficient forthe device to operate properly, and amounts in excess of 3.5 liters require the use of a larger pump to provide sufficientpressure.(3)

3.2.1.3 Cost

Saehan's smallest-scale nanofiltration membrane operates at 5 bars of pressure, while its smallest-scale reverse osmosismembrane produces 36 percent less water, but requires 55 bars of pressure. Consequently, Saehan suggests that nanofiltrationmay be significantly less expensive than reverse osmosis because of its lower energy input needs.(3)

3.2.1.4 Ease of Use

Use of the nanofiltration device involves pouring water into the entry spout and retrieving it from the exit spout when needed.Details on maintaining this system have not yet been released. Nanofiltration membranes are used in the same way as othersimilar membranes. These membranes must be stored in dry, room temperature conditions. They should not be exposed toexcessive cold or heat. The membranes are sold in air tight bags to prevent bacterial growth, and, in the event that the bag ispunctured, they should be placed in a replacement air tight cover. After initially used, the membrane should be kept wet at alltimes.(3)

3.2.1.5 Additional Information

Saehan's technology has been field tested in a variety of applications and locations, including drinking water treatment in China,desalination in Iran, and others.(3)

3.2.2Nanofibrous Alumina Filters

U.S.-based Argonide Corporation offers nanofibrous adsorbent technology with its line of NanoCeram filter media andcartridge filters, which are made with electropositive alumina nanofibers on a glass filter substrate. The alumina nanofibershave more available surface area than conventional filter fibers and exhibit a higher electropositive charge, which Argonideindicates allows them to adsorb significantly more negatively charged contaminants such as viruses, bacteria, and organic andinorganic colloids at a faster rate.[3]

3.2.2.1 Contaminant Removal

Argonide indicates that NanoCeram filters remove and retain over 99.99 percent of viruses, bacteria, parasites, naturalorganic matter, DNA, and turbidity.['46]The filters have also been shown to adsorb 99.9 percent of salt, radioactive metals, andheavy metals such as chromium, arsenic, and lead, even the particles are nanoscale or dissolved. NanoCeram filters functionbest between pH 5 and 9. Argonide offers a granular version of NanoCeram that reportedly removes over 99 percent ofsalt, heavy metals, viruses, bacteria, and turbidity.[3]

3.2.2.2 Amount of Water Treated

Without the application of pressure, NanoCeram filters have a flow rate of about ' to '.5 liters per hour per squarecentimeter of media. The maximum of 4 bars of pressure can be added, resulting in a flow rate of 9 to 'o liters per hour persquare centimeter of media. NanoCeram cartridge filters have a pleated design that increases surface area, which givesthem greater holding capacity. The filter medium is also reported to be more clog resistant than

ultra porous membranes.[3]

3.2.2.3 Cost

Argonide says that NanoCeram filters are cheap to produce because they can be manufactured using papermakingtechnology. The filter media currently cost US$3 per square meter, but may cost US$3 per square meter once massproduced. Cartridge filters cost US$75 per 20 to 200 filters, depending on diameter. Filter media sheets can be wrappedaround a metal tube, placed between two conventional filters, or held in a screened container, minimizing the cost of acquiringa filter device. Because NanoCeram filters adsorb ultra-fine particles instead of collecting them on their surfaces, theyhave a relatively long useful life.[3]

3.2.2.4 Ease of Use

According to Argonide, NanoCeram filters do not require pre- or post-treatment, cleaning, frequent filter changes, or hazardous waste disposal. Most set ups have a pour-through design. The filters have been shown to simultaneously remove biological and chemical contaminants, even in salty of highly turbid water, without chemical disinfectants or coagulant-flocculants.[3]

3.2.2.5 Additional Considerations

Argonide indicates that coolants and ultra-fine metal powders removed by NanoCeram filters can be recovered and recycled for industry applications.[3]

3.2.3 Nanofiber Gravity-Flow Devices

U.S.-based KX Industries has developed World Filters, a line of gravity-flow filtration devices containing nanofibers specifically for use in developing countries. The filter medium consists of a prefiltration layer that removes dirt, an adsorption layer that removes chemical contaminants, and a nanofiber layer that removes colloidal-sized particles and contaminants. The nanofiber medium is made from a variety of

hydrophilic polymers, resins, and ceramics, cellulose, alumina, and other materials. The technology is available in household and community-level scales.[3]

3.2.3.1 Contaminant Removal

World Filters reportedly remove over 99 percent of bacteria, viruses, parasites, organic contaminants, and other chemical contaminants.[3]

3.2.3.2 Amount of Water Treated

KX Industries indicates that the household scale World Filter device can produce 378 liters of water per filter at a rate of 4 to 6 liters per hour. The village-scale device produces more than 7,500 liters per day at a rate of 5.6 liters per minute. Each village scale filter is effective for up to 95,000 liters of water.[3]

3.2.3.3 Cost

The household device is expected to retail for US$6.00 to US$11.00, with replacement filters costing US$0.80 to US$0.90 each, translating to US$0.002 per liter of water. The village-scale device is expected to cost US$100 to US$150, which is approximately US$0.0003 per liter.[3]

3.2.2.4 Ease of Use

KX Industries indicates that World Filters are designed to be easy to use without training or extensive instructions. Both the household and village-level devices require no maintenance and have no moving parts.[3]

3.2.2.5 Additional Considerations

KX Industries plans to establish local facilities in developing countries for the production of the device hardware, as well as local distribution systems similar to those used by the beverage bottling industry. KX is also contracting NGOs to distribute the devices in some regions.andThereare many other .[3]

CHAPTER FOUR

Conclusions:

1- Nano-technology could potentially lead to more effective means of filtration that not only remove more impurities than current methods but do so faster, more economically and more selectively.

2-nanoscale raise awareness about the implications of nanotechnology for the poor

3-close thegaps within and between sectors of society to catalyze actions that address specific opportunities and risks related tonanotechnology, especially those of most ;significance to developing countries.

4-identify ways that science and technology can play an appropriate role in the development process.

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