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Nanotechnology in Water Treatment, Case Study : Egypt

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Abstract

Water shortages and lack of access to safe drinking water will continue to grow as major global problems. More than one billion people lack access to safe drinking water and 2.4 billion people lack access to proper sanitation, nearly all of them in the developing countries. Around third of the world's population live in water-stressed countries, and by 2025, this is expected to rise to two-thirds.One of the approaches being explored in many countries, including South Africa, to tackle this challenge of increasing access to clean drinking water, is the application of nanotechnologyNanotechnology could play an essential role in solving this water crisis by introducing effective and cheap wastewater treatment techniques.The main aim of this paper is assess the applicability of using Nanotechnology in water treatment in Egypt.In order to achieve this aim, the paper discusses the definition of Nanotechnology and the green Nanotechnology applications areas.Also, this paper illustrates the potential impacts and risks of Nanotechnology. Then we illustrate the case study of South Africa in using Nanotechnology to solve the problem of water scarcity.The study concluded that although Nanotechnology can help solve the water problems. There is some challenges hinder using Nanotechnology. These challenges include technology, financial, market challenges and human health risk .

Keywords: Egypt, Nanotechnology, South Africa, Water

Introduction

Scarcity of water, regarding both quantity and quality, represents a critical threat to the current and future well being of people worldwide, particularly to people in developing countries. Sustainable water management is a vital side of solving the problems of poverty, equity and connected problems.

In 2011, 768 million people still use unsafe drinking water sources. 83 percent of the population without access to an improved drinking water source (636 million) lives in rural areas. Additionally, consideration regarding the quality and safety of many improved drinking water sources persist. Accordingly, the amount of people without access to safe drinking water may be two to three times higher than official estimates. (UN,2014: 47)

Safe drinking water is very important to the protection of human wellbeing, particularly among children. Water related diseases are the most common causes of sickness and death among the poor in developing countries.

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According to the world health organization (WHO) about 6% of the worldwide disease is related to water, that infectious diarrhea being the most component (accounting for about 70% or 1.7 million deaths per year). More than 4500 children under five years of age die every day from diseases such as diarrhea.

In addition to disease and problems of malnutrition and dehydration, lack of access to safe water has numerous effects including:

- Access to safe water close to home will save amounts of time that can be devotedto productive activities and education, which lay the basis for economic growth.
- Lack of access to water reduces the amount of food available in both crops and livestock and also deteriorates the quality.
- Lack of access to water increase gender inequality and reducing the opportunities of girls and women for education, literacy and income generating activities.
- Lack of access to water can have aneffect on environmental and climate change because of landscape erosion and loss of habitat like desertification and reduces bio-diversity.

Scarcity of safe drinking water is a worldwideissue and is predicted to increase with population growth and environmental change.

Thus, there is a need to investigate and exploration of new technologies for delivering clean drinking water.

One of the methodologies being investigated in several countries to handle this challenge of expanding access to safe drinking water is the application of Nanotechnology.

Chapter 1: Definition & Application of Nanotechnology

"Nanotechnology is the science of manipulating materials at very small scales ,i.e at the atomic and molecular levels. Nanotechnology allows for the design, synthesis, and control at the length scale range of 1-100mn."(NdekeMuseeetal, 2012 :2)

Green Nanotechnology is the use of the products and devices of nanotechnology to improve sustainability. Green nanotechnology includes making green nano products and using nano products in support of sustainability.

Green Nanotechnology is the study of how nanotechnology can improve the environment. For example: using less energy during the production process, the ability to recycle products after use, and using eco-friendly materials.

Green Nanotechnology has two dimensions**: the first dimensio n**includes nano products that give solutions to environmental difficulties. These green nano products are used to prevent harm from pollutants and are incorporated into environmental technologies to remediate hazardous waste site, clean up pollutant streams, and desalinate water among other applications.

The seconddimensionof green nanotechnology includes producing nanomaterials andnano products including nanomaterials which can help in minimizing harm to human health or the environment. (Barbara karn&lynn Bergeson, 2009:1&2)

Green Nanotechnology Applications areas

Water Treatment

The procurement of safe drinking water has been a major scope for nanotechnology research and development. Nanotechnology based solutions fora water deficiency issue includes treatment, desalination and reuse.

Nano absorbents like nanoclays, zeolites, metal oxide nanoparticles, nanoporous carbon fibers and polymeric adsorbents will eliminate particulates from contaminated water. Toxic organic solutions will be regenerated into nontoxic by items through nanocatalysts and redox dymanic nanoparticles.

Carbon nanotube filters, reverse osmosis membranes using zeolite nanocomposites and carbon nanotube membranes have been utilized for water treatment and desalination. Dendrimer based ultrafiltration systems and nanofluidic systems have used low pressure membrane systems to remove ions from water solutions. (OECD, 2012:5)

Energy

Nanotechnologies give the possibility to improve energy efficiency beyond all branches of industry and to economically advantage renewable energy production through new technological solutions and optimized production technologies.

Nanotechnology innovations are applied as a powerful influencefor each part of the value added chain in the energy sector.(Hessen Nanotech, 2008: 5)

- **Energy sources**: Nanotechnologies giveessential possibilities to the improvement of both conventional energy sources (fossil and nuclear fuels) and renewable energy sources like sun, geothermal energy, wind, water, tides or biomass.

For example, permit the streamlining of lifespan and effectiveness of systems for the improvement of oil and natural gas deposits or geothermal energy and thus saving of costs.

Another examples are high duty nanomaterials for lighter and more rugged rotor blades of wind and tide power plants moreover, wear and corrosion protection layers for mechanically stressed components.

- **Energy distribution:** to secure worldwide power supply, it is not justimportant to create existing energy sources effectively and environmentally friendly, but also to minimize energy losses arising during transport from source to end user, to provide and distribute energy to the particularapplication purpose as adaptably and effectively as could be expected under the circumstances.

Concerning decrease of energy losses in presenttransmission, hope exists that the extraordinary electric conductivity of nanomaterials like carbon nanotubes might be used for application in electric links and power lines.

Besides, there are nanotechnologicalmethodologies for the advancement of superconductive materials for loss less present conduction. In the long run, choices are given for wireless energy transport, e.g through laser, microwaves or electromagnetic resonance. .(Hessen Nanotech, 2008: 9)

- **Energy usage:** to accomplish sustainable energy supply, and parallel to the streamlined improvement of accessible energy sources, it is important to enhance the efficiency of energy use and to avoid unnecessary energy consumption. Nanotechnology give a number of methodologies to energy saving. like the reduction of fuel consumption in automobiles through lightweight construction materials on the basis of nanocomposites, the optimization in fuel combustion through wear resistant, lighter engine parts and nanoparticles for improved tires with low rolling resistance.
- **Energy storage:**Energy storage can be viewed in terms of the use of nanotechnology for enhancements to existing batteries and nano enabled fuel cells. Nanoparticles supplyenhancementslikefaster re-charging capability and greater shelf life.

Pollution (Pollution Prevention/ Reduction)

Decrease of waste in production processes; reduction within the utilization of harmful chemicals; reduction in the emission of greenhouse impact gases during fuel combustions; utilization of biodegradable plastics: there are just few of the numerous methodologies that could be taken to reduce the pollution of the earth.

Nanotechnology is now actively included in this segment throughthe technology to createpropelled materials that contaminate less, and as a strategy to expand the effectiveness of certain industrial processes. (Luisa Filipponi & Duncan Sutherland, 2007: 8)

Nanotechnology has the capabilities of making industrial processes more efficient regarding utilization of energy and material usage, while minimizing the creation of harmful wastes.

Overview of Global Market for Nanotechnology all Over the World

The worldwide market for nanotechnology products is estimated 11.7$ billion in 2009 and expected to grow to 26.7$ billion in 2015 with a compound annual growth rate (CAGR) of 11.1 percent. Certain segments are forecast to grow at an even faster rate.

Table (1): Growth of Market Nanotechnology Applications (2009- 2015)

	2009	2015	CAGR
Nanomaterials	9.0$ billion	19.6$ billion	14.7%
Nanotools	2.6$ billion	6.8$ billion	3.3%
Nanodevices	31.0$ million	233.7$ million	45.9%
All nanotechnology products	11.7 $ billion	26.7$ billion	11.1%

Source: Illinois Nanotechnology collaborative (2012), Illinois nanotechnology report, a road map for economic development, p.4

Investment in research on nanotechnology in developed countries like Europe and the United States are very high as governments putthe priorities for technologies that will support economic growth. There are also some intermediate countries investing heavily on nanotechnology, like China.

South Africa has created critical abilities in nanotechnology through its National Nanotechnology strategy, launched in 2006. Set up innovation centers for nanoscience in two of the country's science councils. One of these centersconcentrate on nanoscience for water.

Global Nanotechnology R&D annual investment from private and public sector reached about 15$ billion in 2009 of which about 3.5$ billion was in U.S.

The number of researchers and workers included in one area or another of nanotechnology was estimated at around 400,000 in 2009, of which around 150,000 were in the United States. It estimates to be 2 million nanotechnology workers worldwide by 2015. (MihailRoco, 2011: 429)

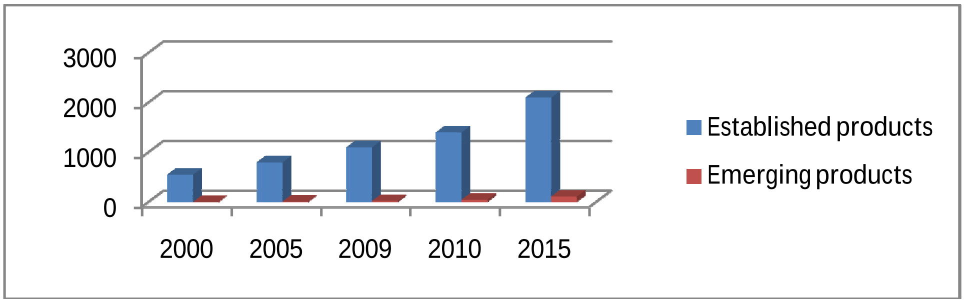
Market for Nanotechnology in Water Treatment

The worldwide market for nanotechnology products utilized in water treatment assessed at 1.4$ billion in 2010 and will grow at a compound annual growth rate (CAGR) of 9.7% to achieve anestimation of 2.2$ billion in 2015.

A large portion of the current market is made up of established treatment products, reverse Osmosis, nanofiltration, and ultrafiltration membrance modules, which may be arranged as nanotech- based. The market for established products was nearly 1.4$ billion in 2010 and is expected to reach 2.1$ billion in 2015, with a compound annual growth rate (CAGR) of 9.2%.

Numerous emerging products, like nanofiber filters, carbon nanotubes, and a range of nanoparticles are in the pre- marketablephase. The market for emerging products was 45$ million in 2010 and expected to reach 112$ million in 2015 at a compound annual growth rate of 20%. (BCC, 2011:7)

Figure (1):Market for Nanotechnology in Water Treatment 2000-2015($ Millions)



Source: BCC, (2011), Nanotechnology in water treatment, report by BCC Research, p.7

Chapter 2 :The impact of Green Nanotechnology

In the process of producing and utilizing green nanotechnology products, additionally to direct impacts, there are also indirect impacts, like spillovers to third parties and various impacts on supply chains, impacts on the environment and energy utilization.

The costs connected with the application of green nanotechnologies need to be balanced against their valuable effects , considering such variables as the timing and appropriation of different costs and benefits, interest rates, opportunity costs, and the relative advantages of green nanotechnologies compared with conventional applications. (OECD, 2011: 11)

More efforts are continuously made to discover methods for evaluating the full scope of potential impacts economic, environmental and societal implications.

Challenges in Assessing the Impact of Green Nanotechnology

Some of the various issues which make evaluating the impact of green nanotechnology challenges including:

- Assessing the impact of nanotechnology is formed a lot of complicated by its multipurpose nature. Nanotechnology could be central to a product and provide its key usefulness, or it might be subordinate to the value chain and constitute a small portion of a final product; or it might not even be present in the final product, just influencing the methodology promoting its creation. So, to assess the impact of green nanotechnology it is important to look at the final product containing nanotechnology as well as the potential impact of nanotechnology all over the value chain. (OECD, 2013: 25)
- Some impacts like health, environmental impacts and safety may not apparent until years after utilization of nanotechnology items.
- Nanotechnology is stand out of numerous areas of interventions and is progressively interconnected with other innovations. So, extracting the exact role of nanotechnology will be difficult. (OECD, 2013: 16)

Methodology for Nanotechnology Valuation

1) The UK Defra Comparative Methodology Model

The 2010 Defra project, introduced a comparative methodology for estimating the economic value of innovation in nanotechnologies, including a method for performing a comparative valuation between a nano- enabled product and an product that is currently on the market.

The Deframethodology calculates the value of this nanoenabled product over a set time frame, exploring the benefits to the consumer and producers and also assesses the benefits to society.

The Defra Valuation Model

	Consumer valuation – sales price	consumer surplus
∈ =	+	+
	Sales price – production costs	producer surplus
	+	+
	External Factors	Externalities

2) The Star Metrics programme

(science and Technology for America's Reinvestment: estimating the effect of Research on Innovation, competitiveness and Science) programme.

The programmedivided to two implementation phases

Phase (I) measures the initial impact of S& T funding on job creation.

Phase (II) aim to measure the impacts seen by science investment in four majorscope

- Economic growth measured through patent numbers and business start up figures.
- Workforce outcomes measured by indicators like researcher mobility into the workforce.
- Scientific knowledge as measured through publications and citations.
- Social outcomes measured through the impacts of funding on health and environmental factors.

The STAR METRICS model uses an input- output (I/O) modeling framework, a concept originally developed by Leontief. The main purpose of using this methodology is to model the interdependence among industrial sectors in an economic system. The models produce a multiplier index that measures the total impact of an increase in demand on employment or income. (OECD, 2012: 9-12)

Analysis of Existing Methodologies

Model Inputs

- The Defra model cannot assess new products because of its comparative methodology; it can justassess products in relation to an incumbent. The inputs require learning of existing technologies to which the nano- enabled product is to be compared.

Utilization of Valuation Methodologies

- STAR METRICs and other I/O methodologies depend on specialists to get output data, and are regularly complex resulting in an absence of transparency. However, this kind of model is viewed as the most broadly accepted when determining the economic outputs within an industry.
- The Deframethodology is best used within an extensively defined market, in that it is planned for utilization at a product or application level opposed to supplying sectoral outcomes or examining aggregate product groups. This is opposite to the inter- industry approach of STAR METRICS which is more accurate and relevant on a macro scale.

Model Outputs

- The STAR METRICS model gives a wide perspective of the science and technology (S&T) industry overall although the Defra model takes a more product or process orientated methodology.
- The Defra model is comparative;consequently the output of the model represents the benefits of the nano- enabled product assessed against an incumbent, instead of its absolute value.

The Economic Impacts of Nanotechnology

The Impact on Labor Market

The opening of new companies or the expansion of existing ones towards business that join nanotechnology will in the endinfluence the labor market.

One methodology to evaluate the impact on labor market is to predict the number of laborsneeded in the future from the current users of key instrumentation. The national science foundation (NSF) forecast that the demand for new nanotechnology workers worldwide to around 2 million by 2015, of which 0.8-0.9 million in United States, 0.5-0.6 million in Japan, 0.3-0.4 million in Europe, about 0.2 million in the Asia pacific region and 0.1 million in other regions.This projection will increase to six million jobs worldwide by 2020. (BCC, 2010:5)

Revenues

Overall worldwide sales revenues for nanotechnology were 11,671.3$ million in 2009 and are predicted to increase to more than 26000$ million in 2015, with a compound annual growth rate of 11.1%

The largest portions of nanotechnology in 2009 were Nanomaterials. All nanomaterials estimate to increase from 9,027.2$ million in 2009 to around 19,621.7$ million in 2015, with a compound annual growth rate of 14.7%.

The Sales of nanotools expected to increase from 2,613.1$ million in 2009 to around 6,812.5$ million in 2015, with a compound annual growth rate of 3.3%.

Sales of nanodevicesestimate to encounter moderate growth. This market portionexpectedto increase from 31$ million in 2009 to around 233.7$ million in 2015, with a compound annual growth rate of 45.9% (BCC , 2010:6)

Nanotechnology and Intellectual Property Right

The economic impact of nanotechnology may likewise be measured through intellectual property activity because of the vital importance of securing innovations and technological interests.

Although there is several types of Intellectual property protection can govern innovations related to Nanotechnology, the most important Intellectual property right will be patents. (Kate seearetal, 2009 :67)

A total of 21,379 patents related to nanotechnology scope have been granted by USPTO in 2013, and around 31,350 nanotechnology patents have been published. In comparison with 2012, the number of nanotechnology patents in USPTO increased by 60% growth rate.

The USA positioned first by having 57% of all nanotechnology patents in USPTO in 2013.(MC Derost, 2014: 6)

Application of Green Nanotechnology in Water and Wastewater Treatment

sustainable access to clean and reasonable water is viewedas the most fundamentalgoal for human being , and remains a significant worldwide challenges because of increasing demand, due to population growth , global climate change and water quality deterioration.

Water treatment: deficiency of water threatens the improvement and the human security of many countries all over the world, it is predicted that this problem could solved by emerge of nanotechnology in water treatment like water reusing, sea water desalination and water remediation more efficient and effective.

Waste water treatment: wastewater is any water that has been unfavorablypolluted by organic toxins , bacteria and microorganisms, industrial effluent or any component that deteriorated its natural quality.

Wastewater can divided to two types: i) Municipal wastewater which include liquid waste discharged by domestic residences and commercial properties and ii)industrial waste water like liquid waste discharged by industrial and agricultural activities(I.J. Elsalibyetal, 2013: 4&5)

Nanotechnology for water and wastewater treatment can play a vital role in water security.

The Nanotechnology for water treatment can be classified into 3 categories

Nanofiltration membranes: these consider as a physical boundary and selectively dismiss substances smaller than their pores, thus remove harmful pollutants and retain useful nutrients present in water.

The filters and membranes are produced using some nanomaterials including carbon nanotubes, nanoporous ceramics (clays), dendrimers, zeolites, nanofibres and nanosponges.(NFR, 2009: 4)

Nanocatalysts and magnetic nanoparticles :nanocatalysts and magnetic nanoparticles may allow the utilization of heavily polluted water for drinking, sanitation and irrigation.

Catalytic particles not only remove pollutants but also can chemically degrade them. Magnetic nanoparticles could be used to remove pollutants from water, when coated with compounds that have a selective equivalence for different contaminating substances.

Magnetic Nanoparticles technologies appearsuitable for decomposing organic pollutants and removing salts and heavy metals from water. (AymanBatisha, 2013:18)

Nanosensors for the Detection of contaminats: detection innovation for water purification would permit individuals to more quickly discover what the contaminants are, without having to send samples to laboratories for testing. Nanosensors can detect single cells or even atoms, making them much more sensitive than with larger components.Nanosensors for the detection of contaminants and pathogens can improve health; maintain a safe food and water supply.

Table (2): Water Treatment Technologies

Conventional technology based water treatment	Nanotechnology based water treatment
Membrance filtration including Integrated systems Bioreactors Turbidity removal	**Membrance filtration including** Integrated systems Nanobioreactors Turbidity removal Nanofiltration
Chemical treatment including Coagulation and flocculation Disinfection	**Chemical treatment including** Disinfection e.g using nanometallic particles
Heat and UV disinfection	**Catalysis enhanced heat and UV disinfection**
Dendrimer Filtering	**Dendrimer filtering**
	Integrated treatment and monitoring systems

Source: OECD (2011), fostering Nanotechnology to address global challenges :water, p.16

Benefits of using Nanotechnology in Water and Wastewater Treatment

Increased effectiveness: contaminants could be more effectively removed , contaminants that were previously impossible to remove could now be removed, because of the expand specificity of nanotechnology and the advancement of smart filters tailored for particular utilization.

Simplification :nanotechnology could radically reduce the number of steps , materials and energy required for water treatment , making it simpler to implement widely in rural areas.

Reduced cost: significant introductory investment would be required to incorporate or switch to nanotechnology based water treatments. On the other hand, once adopted these innovations could considerably lower water treatment costs over the long term. (NRF, 2009: 3&4)

Chapter 3: Case Study of using Nanotechnology in water Treatment: South Africa

The National Nanotechnology strategy (NNS) was launched in 2006 in South Africa.In spite of the fact , that Nanotechnology has been installed in national strategy and policy since the publication of the white paper on science and technology in 1996. Water is one of six focus areas highlighted in the NNS where nanotechnology can offer the most significant benefits for South Africa. (NedekeMuseeetal, 2010 :2)

In South Africa, various research and development are carrying out exploration on nanomaterials and their utilization in water treatment.

South Africa has created international cooperations with other developing countries which concentrate on the field of nanotechnology. like, the India- brazil- south Africa (IBSA).

The IBSA nanotechnology initiative, a cooperative innovation programmes between the departments of research and development in India, Brazil and South Africa, indicate how south- south cooperation can advertise the utilization of nanotechnology for clean water and focuses to advancement being made in these countries.

IBSA gives the high priority for three scope of research. Nanofiltration and ultrafiltration membrances ,nano based water purification systems for remote and rural areas; and carbon nano gels, nanotubes and nano fibers. (TARA, 2011: 11)

An alternate cooperation initiative is between the South African and European Union under the EU's framework programme six (FP6). Under FP6 , south Africa scientists can join in mutual projects in all activity, and seperate National contact points (NCPs) have been set up in South Africa to maximize mutual benefits for all parties included in this initiative. Also, the European – south African science and technology Advancement programme (ESASTAP) is a devoted stage for the progression of European and south African scientific and innovations collaboration containing projects in nanotechnology. (council of the European Union, 2007: 6)

Nanotechnology Indicators in South Africa

1) Funding and Investment

One of the most significant indicators of a country's potential for innovation and development is Gross domestic expenditure on R&D (GERD) as a percentage of GDP. This indicator indicates the intensity of R&D performance in a country.

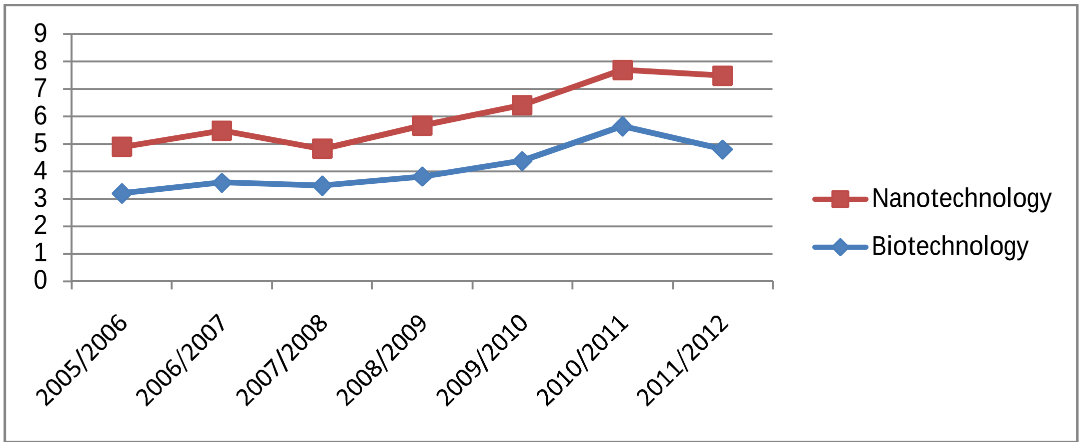
Table (3): R&D Expenditures (% of GDP)

2003	2005	2007	2009	2012
0.79	0.90	0.92	0.92	0.76

Source: South African National survey of Research and experimental development, statistical report 2012the government of South Africa has invested over 170 R million in 2010 for different areas of nanotechnology research and development (R&D)

South Africa's National Development plan calls for higher research and development investment, the plan put target for R&D spending to reach 1.5% of GDP by 2019.

Figure(2): Expenditure on Multi Disciplinary areas of R&D – R'000 (2005/2006- 2011/2012)



2) Human Capital

Highly skilled human resources are the vital component with regards to building a country's capacity for a knowledge based economy.

Table (4): Researchers in R&D (Per Million People)

2003	2005	2007	2009	2012
303	362	396	405	423

Source: South Africa Yearbook 2012/2013

In 2010, South Africa had a total of 22340 Researchers full time equivalent representing 1.8 researchers per 1000 employees.

The number of business researchers has increased at an average annual rate of 20% during the period (2000-2010).and women represented 40% of total researchers in 2010 in South Africa. (South Africa department of science & technology, 2013:6)

3) Science

Table (5): Nanotechnology Articles in South Africa

year	**2005**	**2007**	**2010**	**2012**
Number of nano articles per million people	1.91	2.36	5.08	7.40
Number .of nano articles per GDP (PPP)	0.22	0.24	0.48	0.65

Source: world bank. The world bank web of knowledge (ISI)

The distribution of publications related to nanotechnology versus all publications. wefound that United States ranked first with (22%), then China (11%), Japan (10%), Germany (8%), France (6%) and the United Kingdom (5%). These six countries represent 63% of all publications related to nanotechnology. (OECD, 2009:34)

Publications related to nanotechnology are expanding because of increasing attention on nanotechnology in the National strategy.

4) Technology

Table (6): Nanotechnology Patents in South Africa

year	2002	2005	2010	2013
Nanotechnology patents in EPO	2	3	5	6
Nanotechnology patents in USPTO	2	1	7	14
Ratio of nanotechnology patents to nano articles	4.35	10.00	2.88	6.06

Source: centre for science, technology and innovation indicators.(CesTII)

United States ranked first in nanotechnology patents. It has a 48% share of all nanotechnology patents followed by japan (14%) and Germany (10%)

As for Nanotechnology patents, south Africa ranked 28th out of all countries in EPO Classification.

The Success Factors of south Africa's Experience in Nanotechnology

Institutional Framework

- South Africa has created an institutional framework for the improvement of nanotechnology and this puts the innovation at the vanguard of its development initiatives.
- South Africa facilitated research at national level by the department of science and technology.

Infrastructure

Although most African countries suffer from poor infrastructure. But dissimilar to African countries South Africa has a stronger physical infrastructure to support Nanotechnology.

Additionally, South Africa has financial and physical resources and also created research base which empowers it to conduct rigorous tests and adjustments of the technology to meet the needs of the poor people. (Trust Saidi, 2009: 25)

Nanotechnology Strategy

The fundamental goals of the South Africa's Nanotechnology strategy are:

- Support long term nanoscience research.
- Support the development of new devices for application in different areas.
- Develop the resources human needed and supporting infrastructure to permit the development. (Republic of south Africa, 2006: 11)

Types of nanomaterials used in water treatment in south Africa

The nanomaterials utilized for water treatment are within 3 categories:

1) **Nanosorbents:** nanosorbents are nansized particles onto which some inorganic and organic molecules could be absorbed. In south Africa, several nano have been synthesized tested for their application in water treatment. These include carbon nanotubes, metal nanoparticles ,nanosponges and zeolites.
2) **Nanocatalysts:** these are mostly zero- valent metallic nanoparticles that have solid catalytic properties. These nanocatalysts can also be bimetallic to enhance the catalytic properties. Nanocatalysts catalyse basically the reduction of metal ions in solution and can catalyse dechlorination of chlorinated organic pollutants. Some south African scientists are working in the immobilization of nanocatalysts onto sand filters and polymeric nanostructured membrances. (NRF, 2012:2)
3) **Nanostructured filtration membrances:** nanostructures filtration membrances are polymeric permeable membrances that have nanosizedproes.(Thembela Hillieetal, 2012: 35)

Since south Africa has been announced as water scarce country, nanofiltration promises to provide water through the desalination of brackish water that does not meet health standards.

Benefits of using Nanotechnology in water Treatment in South Africa

Nanotechnology offers several of benefits to the water sector by enabling more effective removal of contaminates at lower concentrations because of increased specificity. Additionally, the number of treatment steps, the quantity of materials, as well as the cost and energy required to purify water could be radically reduced using nanotechnology.

The operating costs for producing a kiloliter of water using nanofiltration in south Africa range from 0.16$ to 0.25$ while the operating costs using reverse osmosis membrance are about 0.36$ per kiloliter. These reasonable costs make nanofiltration technique available to rural areas in South Africa. (Meridian Institute, 2013: 39)

Regarding the quality, some studies indicate that nanofiltration has the ability to remove almost all water contaminants including bacteria and heavy metals.

Chapter 4: Nanotechnology &water treatment in Egypt

Water Resources in Egypt

Water resources in Egypt are restricted to the Nile River, rainfall and flash floods, groundwater in the deserts and Sinai.

Each resource has its constraints on utilization. These constraints identify with quantity, quality, time or utilization cost.

Water Supply

The main supply of water in Egypt is the Nile River. The Nile allocates 55.5 BCM/year to Egypt.

Rainfall:the average annual quantity of successfully used rainfall water is about 1.3 BCM/year. This sum cannot be viewed as a reliable source of water because of high spatial and temporal variability.

Ground water: the total amount of ground water has been estimated at around 40,000 BCM. Although, current abstraction is estimated to be 2.0 BCM/year. The fundamental constraints in using this source are the great depths (up to 1500 m in some areas) of these aquifers and deteriorating water quality at the increasing depth.

Desalination: desalination of seawater in Egypt has been given low priority as a water supply source because the high cost of treatment compared with other sources.

Shallow groundwater: in the Nile aquifer cannot be viewed as an absolute source of water supply. The aquifer is recharged just by seepage losses from the Nile, the irrigation canals and drains and percolation losses from irrigated lands. Subsequently, its yields should not be added to Egypt's total water supply. The current abstraction from this aquifer is estimated at 6,5 BCM in 2013.

Treated domestic sewage: is being reused for irrigation with or without mixing with fresh water. It is assessed that the aggregate amount of reused treated waste water in Egypt is about 0.3 BCM in 2013.

Reuse of nonconventional water sources like Agricultural drainage water and treated sewage water cannot be added to Egypt's Fresh water supplysources.

The aggregate amount of reused water is estimated to be 13 BCM in 2013. (Ministry of water resources and irrigation, 2014: 3)

Table (7):Water Resources of Egypt

Nile River	55.5
Rainfall	1.3
Groundwater	2.0
Water supply in Egypt	**58.8**

Water Demand

Water demand in Egypt are continuously expanding because of population growth and increasing standards of living.

Agriculture: the agriculture sector consumes more than 85% of Egypt's share of Nile water annually.

Municipal water requirements: Municipal water demand was estimated to be 10 BCM in 2013. Wherever around 97% of urban population and 70% of rural population of Egypt dependsr on piped water supply.

Industrial sector:the estimated value of the water requirement for the industrial sector was 2.5 BCM/ year in 2013. A small portion of that water is consumed through evaporation during industrial processes (only 0.7 BCM) whereversthe vast majority of that water comes back to the system in a contaminated form. (Ministry of water resources and irrigation, 2014: 5)

Table (8):Water Demand in Egypt

Municipal	10
Industrial	2.5
Agricultural	67
Water Demand in Egypt	**79.5**

From the previous analysis, it is obvious that Egypt suffers from a serious problem of water scarcity. The actual resources currently available for use in Egypt are 58.8 BCM/year, while water requirements for different sectors are about 79.5 BCM/year. The gap of 20 BCM/year occurs between the needs and availability .This gap must be overcome by wastewater treatment.

Water Treatment in Egypt

The water sector in Egypt is facing several difficulties in both quantity and quality. Egypt suffers from water shortage and deterioration of water quality.

The per capita water share is below 1,000 m3/ year and expected to reach 600m3/year in 2025. Which indicate water deficiency.

Egypt practices the utilization of different types of marginal quality water, like agricultural drainage water, treated domestic wastewater and estimated brackish water.

Wastewater is estimated at 4,930 Mm/year in 2010, with 121 operational wastewater treatment plants and around 150 plants under construction. The whole capacity of the installed treatment plants accounts to around 1.752 billion m/year. (Naglaa Mohamed, 2010 :20)

Wastewater Treatment Technologies

There are several parameters that affect when comparing one technology to others; the main dominant parameters are:

- Availability of land

- Availability of highly skilled workers
- Availability of operation & Maintenance finance
- Availability of energy
- Performance efficiency
- Capital and operational costs.

Technologies Applied

- Up flow Anaerobic sludge Blanket (UASB)
- Septic tank (modified septic tank)
- Stabilization ponds
- In Steam wetland system
- RBC (Rotating Biological Contactor) (Mohy El Din &Rifaat, 2010: 4)

Main Constraints Facing use of Wastewater Are

a) Technical Challenges

- Poor infrastructure to collecting and treating wastewater.
- Insufficient infrastructures to treat the whole amounts of wastewater produce.
- Most wastewater treatment plants are not operating efficiently and often over loaded.

b) **Financial challenges:**there are several financial obstacles facing utilization of wastewater in Egypt like high costs of treatment systems, high operational costs and low prices of freshwater.

c) Quality Challenges

- The differences in the quality of treated wastewater from one treatment project to another, according to inflow quality, treatment level and plant operation efficiency.
- A significant amount of wastewater enters without any treatment into freshwater. (Naglaa Mohamed, 2010: 21)

The applicability of using Nanotechnology in Water Treatment in Egypt

Nanomembrance plants can be built as portable units, which can be assembled in the urban centers and then transported to the demand areas where they are needed. So, Nanofiltration technologies are suitable for Egypt especially in rural areas.

The initial construction costs can be reduced, through building the plants as portable units.

Table (9):Nanotechnology Indicators in Egypt

	2005	2007	2009	2012	2013
1) Funding & Investment Research and development expenditures (% of GDP)	0.24	0.26	0.21	0.23	----
2) Human capital: Researchers in R& D (per million people)	---	642	420	530	---
3) Science: a) Number of nano articles per GDP (PPP) b) Number of Nano articles per million people	0.22 0.97	0.41 2.14	0.65 3.83	1.22 8.18	1.07 ---
4) Technology: a) Nanotechnology patents in EPO b) Nanotechnology patents in USPTO c) Ratio of nanotechnology patents to nano articles	0 3 4.17	0 2 1.21	0 1 0.33	0 5 0.76	0 4 0.47

Source: world bank. The world bank web of knowledge (ISI)

SWOT analysis of Nanotechnology in Egypt

Strengths	Weaknesses
- Institutional structure: Egypt's Academy of scientific research and technology (ASRT) has been largely responsible for shaping the country's science and innovation system. Royal scientific society well established and nature infrastructure for scientific testing and consulting services. - Qualified skilled graduates with competitive wages.	- Lack of awareness of applications and benefits of nanotechnology. - Low expenditures on R&D : between 2004 and 2010 governmental R&D expenditure averaged around 0.25% of GDP - High level of Bureaucracy - Lack of communication between R&D and the market.
Opportunities - International nanotechnology trends. - Nanotechnologies could provide a solution to such problems as wat	**Threats** - The political instability - Brain Drain: a large number of talented Egyptians leave the country. - International competitiveness: the high speed of technology development worldwide make it hard for local companies to keep pace with and develo completive contributions.

Cost- Benefit analysis of Nanfiltration Membrances

Cost of Nanofiltration Membrances

a) Capital Cost

Capital costs vary from 400$ to 600$/ m3/d depending on various factors including size, materials of construction, and site location.

b) Running costs (of a 100,000 m3/d water treatment)

Item	description	calculation	Cost monthly/US $
Water resource fee	0.07/m3	0.07*100,000*30	210,000
Electricity fee	For 50 m head efficiency 0.8	0.17 kwh*0.10 *100,000* 30	51,000
staff	20 staff average 2500$/ month salary	20#2500	50,000
Administration cost	50% of staff cost	50,000* 50%	25,000
Maintenance and replacement cost	Yearly 1% of total construction cost	400* 1% /12 * 100,000	33,333
Total monthly cost			369,333
Cost/m3			0.12

Benefits

- Energy use: nanofiltration requires less energy than equivalent reverse osmosis based systems for a similar feed water quality.
- Lower discharge and less wastewater than reverse osmosis.
- Nanofiltration removes almost all water contaminants including bacteria and heavy metals. (Meridian Institute, 2006: 21)
- Nanomembrance plants can be constructed as portable units.

Challenges in using Nanotechnology to Access to Safe Water

1) Technology Challenges

Nanotechnology for water treatment is a beginning science. There is a requirement for a considerable measure of innovative work before it might be mainstreamed in products.

There is a lack of investment in both research and exploration of innovations. There is disengaging between academic researchers and corporate financing.

Absence of scientific document for safety could be a major gap behind the research and development of these products. (TARA, 2011: 16&17)

Most research in the nanotechnology sector is in the lab stage which means testing the innovation. Just a few have been prototyped and tested. The current capacity of advances to scale up is extremely restricted.

There is a lack of stress on the incubation stage that enables research and proven technologies to end up to be marketable products.

2) Product Challenges (Human Health Risk)

A significant concern when appraisal sustainability of water supply based on nanotechnology is human health and environmental risks.

How nanomaterials cooperate with cells and biological organisms should be explored extensively. The risks associated with nanomaterials may not be the same as the risk associated with the mass versions of the same materials. Once a particle decreases in size, a larger ratio of atoms is found at the surface compared to the inside.

In this way, the impacts of these materials on biological systems should be seriously addressed.

3) Financial Challenges

Water is seen as a free product. It is generally nature provides.Subsequently, the willingness to pay for water is extremely restricted.

4) Market Challenges

A vast greater part of the target group is illiterate or functionally literate. Absence of sufficient and appropriate communication tools is one of amongst the main causes for low awareness. They keep away from new products that do not have much social evidence.Also, there is a problem of delivery as target group are concentrated in rural areas, where infrastructure is not well established.

Conclusion

The study revealed the existence of a growing scarcity of fresh water resources in Egypt. Nanotechnology revolution can play an essential role in solving the problem of rising demands of clean water and decreasing of the available supplies of freshwater.

But any assessment of future markets for Nanotechnology based water treatments must take account of both the risks and opportunities.

So, we conclude that nanotechnology is a promising solution to the water crisis ; but this solution faces some challenges. The most important one is the risks associated with nanomaterials on human health, other challenges are the cost of getting the nanotechnology and transfer the nanotechnology from lab scale to fabrication scale.

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