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Review

A review on nanotechnology as a tool of change in Nigeria

M. T. Bankole[1,2], Jimoh O. Tijani[2]*, I. A. Mohammed[1,3] and A. S. Abdulkareem[1,3]

[1]Centre for Genetic Engineering and Biotechnology, Federal University of Technology, P. M. B. 65, Minna, Nigeria.
[2]Department of Chemistry, Federal University of Technology, P. M. B. 65, Minna, Nigeria.
[3]Department of Chemical Engineering, Federal University of Technology, P. M. B. 65, Minna, Nigeria.

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Nanotechnology has generated diverse awareness and attentions nowadays and stand as one of the foremost alternative modern clean technologies of the 21st century. In spite of the essential benefits of nanoscience and technology, Nigeria is yet to key into nanotechnology initiative and strategy towards improving her socio-economic development as well as transformation of important sectors. The benefits and opportunities these evolving technology offers are enormous, and have led to high expectations in the academics, industries and even government. As a consequence of the uniqueness of this technology in science and engineering, quite a vast numbers of nanomaterials are now been synthesized, characterized and fabricated to solve societal immediate problems. This is because nanoscience or nanotechnology have control over the properties of matter and therefore have the ability to create materials with specific properties that can be utilized for specific functions. Therefore, nanotechnological approach offer hopes of reshaping humanity and redefine human condition vis-a-vis reduction of pressure on the existing natural resources. Thus, this review focus on nanotechnology, its emergence, importance and perhaps its applications, most especially the significant contributions to policy makers, non-governmental organizations and the general public as a whole. This serves as one of the viable emergent technology for socio- economic growth most especially in developing countries like Nigeria.

Key words: Application, matter, nanotechnology, novel, socio-economic

INTRODUCTION

The word “Nano” means dwarf in Greek and it is exemplified as length of hydrogen atom line up in a row. A material at nano scale is one billionth of the material (10^{-9}). In nature, nanotechnology has been in existence ever since the inception of the earth, through evolution, mutation, and adaptation in which plant passed through a photosynthesis route through the aid of tiny structures called ‘chloroplasts’ which are of nanoscale (Roco, 1999). Another natural phenomenon of nanotechnology is in the area of chemical catalysis (catalysts) or bioscience (enzymes) involving catalyst or enzymes catalyse of a chemical reaction (Smith, 1997). The first to carry out an

*Corresponding author. E-mail: jimohtijani@futminna.edu.ng

experiment on a molecule using nanoscale is a man called James Clerk Maxwell in 1867. Zsigmondy in 1914 was the first to characterize particle in sizes on nanoscale using nanometer, with the advancement of Langmuir and Blodgett (1920s) through the introduction of mono layer in characterization of particle sizes.

Derjaguin (1954) also reported the first measurement of surface force and in 1959, Richard Feymann proposed a technique for the manipulation of atoms and molecules using some specific tools (Gribbin, 1997). With several improvements, Taniguchi (1974) proposed the definition of Nano-technology as a method comprises processing, separation, consolidation and deformation of a molecule by the usage of manipulating particulate matter at nanoscale. The tools used in the 1980s then were scanning tunneling microscope (STM), atomic force microscopy (AFM), scanning probe microscopes (SPMs) and molecular beam epitaxy (MBE) (Roco, 1999). Presently, with recent advancement in science and technology latest modern analytical equipment are now being used to identify, quantify the phase composition, morphological and surface structure, elemental composition as well as crystal size of a nanosample. Some of these facilities are X-ray diffraction (XRD), high resolution scanning electron microscopy-electron diffraction spectroscopy (HRSEM-EDS), high resolution transmission electron microscopy-electron diffraction spectroscopy (HRTEM-EDS), X-ray photoelectron spectroscopy (XPS), Atomic force microscopy (AFM), to mention but a few.

Nanotechnology is the engineering and art of manipulating matter at the nanoscale (1 to 100 nm), at this level, materials are characterized by difference in its chemical, physical and biological properties than its normal size equivalent (Davies, 2006). This technology can easily merge with other technology on modification based on scientific concept and that is why nanotechnology is referred to as ‘Platform’ technology (Schmidt, 2007). The application of nanotechnology as it involves environmental remediation, industrial application, reduction in energy consumption which translate to lower production cost thereby increasing the production efficiencies cannot be overemphasized. This technology might not be the total solution to our problem in the world today, but it would surely alleviate some of the social-economic challenges confronting the developing countries especially Africa. Examples of the social problems include; the need for clean water, treatment of epidemic diseases (Fleischer and Grunwald, 2008), numerous industrial applications (Theron et al., 2008), energy and several scientific innovation (Binks, 2007). While government of developed countries such as Europe, United States, China even South Africa have continued to prioritize technologies through massive investment in nanotechnology with sole aim of strengthen economic growth. Today, there is no official gazette released by the Government of Nigeria prioritizing nanotechnology applications battered toward solving any societal problems confronting over 170 million people living in the country. Thus, the potentials of nanotechnology could be explored so as to solve the immediate but critical developmental problems of the country. This paper therefore focuses on the review of nanotechnology application as it related to water treatment, nanomedicine and energy development.

NIGERIA LINGERING PROBLEM: QUEST FOR POTABLE WATER

Water, energy and poverty are closely related, this has made access to water resources affect basic human needs. Everybody in the world depend directly on water and energy for their livelihoods (Amalu, 2011). Water, an essential resources needed in daily activities; its usability depends on the state of its cleanliness which comes as a result of sanitation of the environment. Unclean water and unsanitary practices are at the root causes of many health problems in the developing world with resultant adverse effect on international global health efforts (Tiaji, 2012a).

According to UNICEF and WHO (2013) close to one billion people do not have access to uncontaminated drinking water globally and above 2.5 billion people are without adequate sanitation facilities. The World Health Organization (WHO) estimates that 6.3% of all deaths are caused by limited access to safe drinking water, improved sanitation facilities, hygiene practices, and better water management practices. According to the United Nations (2005), more than 14,000 people die every day due to consumption of contaminated water. The bulk of these deaths were related to a number of infections, including 2 billion cases of intestinal worms, 5 million cases of lymphatic filariasis and trachoma, 1.4 million children died of diarrheal deaths; and 500,000 deaths from malaria (United Nations report, 2005).

The importance of good quality drinking water for the socio-economic benefit of any nations could not be underestimated. However inadequate access to potable water and better sanitary facilities coupled with high abject poverty ultimately affects many aspects of the society such as health, agriculture, economic growth, education, conflict etc. In health, diseases like diarrhea and several neglected tropical diseases are contracted through contact with bacteria infested water and soil and cause millions of deaths and illnesses annually (Tiaji, 2012b). Good sewerage and drainage systems can eliminate breeding grounds and water can be treated to remove bacteria found in tainted water. Effect of growth in agriculture and economic, parasitic worms afflict more than 1 billion people annually and cause a variety of ailments, like stunting, malnutrition, and anemia.

Water would be a scarce resource due to the impact of global climate change and high population growth,

Table 1. Global trend on fresh water crisis including Nigeria.

884 million people lack access to safe water supplies - approximately one in eight people
6 km is the average distance African and Asian women walk to fetch water
3.6 million people die each year from water-related diseases
98% of water-related deaths occur in the developing world
84% of water-related deaths are in children ages 0-14
43% of water-related deaths are due to diarrhoea
65 million people are at risk of arsenic poisoning in the Bangladesh, India and Nepal area
70 million Nigerians lack access to safe drinking

Source: (Pruss-Ustin et al., 2008; UNICEF/WHO, 2013)

especially in developing regions. But its availability still procure safety in the usage; often unsafe for drinking. Moreover, the current statistics shows more than three billion people globally will lack access to safe drinking water by 2050. Presently a third of the world's population lives in water-stressed countries, and by 2025, this is expected to rise to two-thirds (Amalu, 2011). The quest to ensure that all people have access to clean drinking water is now enshrined in the UN's Millennium Development Goals, which aims to halve the proportion of people without sustainable access to safe drinking water by 2015 (Belgiorno et al., 2007; UNICEF and WHO, 2012, 2013). But despite these efforts, getting the water clean is also a major challenge facing the African continent, including Nigeria.

Nigeria is blessed with abundant water resources but largely unused. In spite of the abundant water resources, the governments (Federal, State and Local) have been unsuccessful in their effort to harness these resources to sustainability and equitable scale (www.onlinenigeria.com). Nigeria, the eight most populous countries in the world, is being faced with challenge ranging from non-availability of portable water across number of its states; decay infrastructure and long term sustainability questions. The recent joint report by UNICEF/WHO, (2013) placed Nigeria as the third country with most people without access to safe water. In Nigeria, accessibility to improved water supply is prejudiced in favour of urban centres, which was originated from the colonial administration in an attempt to use improved water supply as a means of controlling the spread of diseases in urban centre. Abeokuta was the first to be supplied with pipe-borne water in 1911, followed by Lagos (1914), Enugu (1925), Kaduna (1930), Akure (1931), Jos (1935), Okene (1936), and Port Harcourt (1937). By 1953, 29 towns already has potable water and, by 1960, the number had risen to 67 which later rose to 261 by 1977 (Krebs, 2010).

Establishment of the River Basin Development Authorities (RBDAs) in 1976 and the Directorate of Foods, Roads and Rural Infrastructure (DFRRI) in 1986 later improved the situation. In 1997, all settlements were taken into account irrespective of sizes; about 24.74% of all households in Nigeria had access to pipe-borne water. DFRRI succeeded at providing 5,054 communities in all states of the federation with potable water mainly through boreholes, and by the end of 1999 it raised the proportion of access to pipe-borne water to about 13.63% for rural households, 68.50% for urban and 42.45% for semi-urban centre (www.onlinenigeria.com). Cumulatively, the households that depended on boreholes, wells and stream/ponds were 15.41, 27.62 and 32.23%, respectively. Thus, the provisions of potable water still demands government's rapid and sustainable attention (www.onlinenigeria.com). Scarcity of potable water is considerably looking unachievable in the face of conventional technologies used in water purification due to large infrastructure requirement, high capital investment and of course high population growth where less than 30% have access to portable water (Krebs, 2010). Table 1 shows the global trend on the scarcity of clean water Nigeria inclusive. The common cleansing agent normally used is alum to get dirty water clean. Even, the normal pipe borne water popularly known as tap water did not meet up with the expectation of the teeming populace. Recently, nanotechnology has proved to be one of the best options globally among other technologies, but making this new innovation accessible and affordable to the global poor looks unattainable especially in Nigeria (Amalu, 2011). According to United Nations Industrial Development Organization (UNIDO) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), nanotechnology may offer promising solutions to water problems in developing countries, but the challenges cannot be underestimated, the two organizations have agreed to work together on a number of joint actions to search for more potential of nanotechnology in water purification and wastewater treatment (UNESCO and UNIDO, 2013).

APPLICATION OF NANOTECHNOLOGY FOR WATER TREATMENT

Because nanoparticles have a high surface area to volume ratio that could be chemically controlled, this is an indication of the technology great potential; as sorbents, materials that latch on to pollutants and pull them out of solution. For instance, multi-walled carbon nanotubes have been shown to take up lead, cadmium and copper more effectively than activated carbon, a commonly used sorbent (Savage and Mamadou, 2005). Some nanoparticles such as zero valent nano iron, titania nanoparticles also act as potent catalysts and could be used to degrade recalcitrant organic pollutants into harmless compounds. For instance, zerovalent nano iron could detoxify halogenated organic compounds, such as trichloroethylene and triclosan. Other nanoparticles that are bioactive, such as silver and magnesium oxide, can kill bacteria and might be used in place of chlorine to disinfect water (Schmidt, 2007).

Nano-engineered membranes and filtration devices could be used to detect and remove viruses and other pollutants that are difficult to trap using current technologies (Theron et al., 2008). For instance, a preliminary technique employs imprinted polymer nanospheres to detect contaminants of emerging concern, a kind of pollution recently discovered at ng/L to µg/L in various water sources posing serious public health challenges (Binks, 2007). Such nanoscale sensors might be helpful for real-time monitoring of these pollutants everything from chemicals in Prozac to hormones in birth control pills at water-treatment plants and industrial sites. Membranes with nanopores are designed to both detect and remove such pollutants. With greater ability to filter out unwanted materials, industrial wastewater and even the ocean could become available to boost the supply of clean water. One of the most promising examples is zero-valent nano-iron, which is being tested for use in removing solvents from pumped groundwater. Titanium dioxide nanoparticles could potentially be sprinkled into a contaminated body of water, where they would be activated by sunlight to degrade quite a large number of organic pollutants such as PCBs and dioxins under the influence of the generated hydroxyl radicals (Schmidt, 2007; Klavarioti et al., 2009; Chong et al., 2010; Gupta et al., 2013).

Nanotechnology is expected to have an impact on water treatment beginning with nanosorbents and bioactive nanoparticles that could be integrated into existing purification systems. These first hybrid technologies would eventually be replaced by entirely new kinds of devices that use nanotechnology to improve the efficiency of filtration, remove more kinds of contaminants and add functions, such as water-quality sensors. Research groups are currently investigating a wide variety of nanomaterials—including carbon nanotubes, zeolites, dendrimers, metal-oxide nanoparticles and immobilized semiconductor nanocomposites for use in such devices (Savage and Mamadou, 2005). Nanosorbents, nanocatalysts, smart membranes, nanosensors and other kinds of nanotechnology could serve as the basis for new, small scale water treatment systems.

Unfortunately, new kinds of pollutants are being continually discovered in water resources, even while we still deal with old problems such as lead, pesticides and *Escherichia. coli*. Nano-enhanced water filtration could be developed to target these contaminants (Liu and Yang, 2003; Schmidt, 2007; Kiran et al., 2013). Nanotechnology is being applied for water purification through a material normally referred to as nanomaterial. According to Theron et al. (2008), there are nanomaterials that serve as water filtration membrane; nanoparticles, carbon nanotubes, metal nanoparticles. These nanomaterials offer a novel potential for the treatment of surface water, groundwater and wastewater contaminated by toxic metal ions, organic and inorganic solutes and microorganisms (Cloete et al., 2010).

Nanomaterials are very effective as a separation medium for water purification: they contain a number of key physicochemical properties (Savage and Mamadou, 2005), they are also known for their high surface area to mass ratio which occurs as a result of decreasing the size of the adsorbent particle from bulk to nanoscale dimensions (Pradeep, 2009), thereby making adsorption to be considered as an efficient, effective and more economical technique for the treatment of unclean water (Jiuhui, 2008). This property of nanomaterials leads to the availability of a high number of atoms or molecules on the surface of contaminants thereby enhancing the adsorption capacities of sorbent materials (Tiwari et al., 2008; Pradeep, 2009).

Moreover, this large surface area coupled with their size, electronic and catalytic properties provide unparalleled opportunities to develop more efficient water purification catalysts and redox active media which is really gaining popularity today, especially disinfection of water using UV light mediated semiconductor photocatalyst, such as TiO_2 (Chong et al., 2010; Manoj et al., 2012). The photocatalytic activity of TiO_2 nanoparticles synthesized using hydrothermal, sol-gel, chemical precipitation etc is a well-known phenomenon in the literature. Among the heterogeneous semiconductor photocatalysts, TiO_2 has received interest in research and development to solve global water pollution problem, aside that, the treatment technique is considered to be less-expensive, environmental friendly and sustainable in the water industry without necessarily generate toxic sludge (Chong et al., 2010). Table 2 shows the photocatalytic water treatment using nano synthesised TiO_2. These advanced nanomaterials can also be immobilized with various chemical groups to increase their affinity toward a given compound.

NIGERIA PROTRACTED PROBLEM: QUEST FOR UNSEASONED ENERGY

Nigeria is blessed with energy resources; crude oil, natural gas, coal, tar sand, biomass and other renewable energy resources such as tidal and wind power, and solar

Table 2. Recent examples of pollutants photocatalytically degraded by nano heterogeneous photocatalysts (TiO_2).

Contaminant	Photocatalytic system	References
Dyes		
Reactive violet 5	UV/Anatase	Chung and Chen (2009)
Blue 9, Red 51 and Yellow 23	Solar/TiO_2 (Degussa P_{25})	Dias and Azevedo (2009)
Methyl orange	UV/TiO_2 on glass	Lopez et al. (2010)
Methyl blue	UV/TiO_2	Esparza et al. (2010)
Rhodamine B	UV/TiO_2 bilayer	Zhuang et al. (2010)
Pesticides and herbicides		
Organophosphate and Phosphonoglycine	UV/TiO_2 immobilsed on glass	Echavia et al. (2009)
Azimsulfuron Swep residues	UV/TiO_2 coated on glass rings	Pelentridou et al. (2009)
Pharmaceuticals and cosmetics	Electrocoagulation and UV/TiO_2/H_2O_2	Fabbri et al. (2009)
Benzylparaben	UV/TiO_2(Aeroxide P_{25})	Boroski et al. (2009)
	TiO_2/Fe_3O_4 and TiO_2/SiO_2/Fe_3O_4	Choina et al. (2010)
	UV/TiO_2 (Degussa P_{25})	Alvarez et al. (2010)
Drugs		Lin et al. (2011)
Oxolinic acid	UV/TiO_2 (Degussa P_{25})	Giraldo et al. (2010)
Atenolol and Propranolol	UV/TiO_2 commercial	Hapeshi et al. (2010)
Ciprofloxacin, Ofloxacin, Norfloxacin and Enrofloxacin	Solar/TiO_2 (six commercial samples)/H_2O_2	Ioannou et al. (2011)
Lamivudine	UV/TiO_2 (Degussa P_{25})	An et al. (2010)
Oxytetracycline	Simulated solar/TiO_2 P_{25}	Li et al. (2012)
	UV/TiO_2 (Degussa P_{25})	Pereira et al. (2011)
	UV/TiO_2 (Degussa P_{25})	Adams and Impellitteri (2009).
Others		
N,*N*-diethyl-*m*-toluamide	UV/TiO_2 (Degussa P_{25})	Qourzal et al. (2009)
ß-naphthol	UV/TiO_2-SiO_2	Miranda-Garcia et al. (2010)
15 emerging micropollutants	Solar UV/TiO_2 coated on glass spheres	Antoniou et al. (2008)
Grey water	UV/TiO_2 (Aeroxide P_{25})	Sharma et al. (2012)
Microcystins (Cyanotoxin)	UV/TiO_2 film	Graham et al. (2010)
	UV/Doped TiO_2	Triantis et al. (2012)
	UV/ Nitrogen doped TiO_2	Dalrymple et al. (2011)
Lipid vesicles and E.colli cells	UV/TiO_2 (Degussa P_{25})	Amarjargal et al. (2012)
Bacterial colony	UV/TiO_2 on Titanium beads	Li et al. (2011)
	UV/TiO_2-coated bio-film	Zhang et al. (2012)
Paper mill wastewater	Solar/TiO_2	Wang et al. (2011)
Endocrine disrupting compounds	UV/TiO_2 (Degussa P_{25})	Wang et al. (2009)
Municipal waste water		Montoya et al. (2009)
Contaminated soil	Solar/sol-gel $TiO_{22}$and Degussa P_{25}	Tasseroul et al. (2012)
	Plasma/TiO_2 (Degussa P_{25})	Emeline et al. (2005)

Source: Lazar et al., (2012).

energy. It has been established that crude oil reserves stand at about 40 billion barrels, and it is expected to reach about 55 million barrels in the nearest future. Natural gas resource, currently stands at about 2.7 billion cubic metre while tar sand deposits stands at about 31 billion tons, and coal resource are estimated to be between 2 and 10 billion tons (Nigeria Study Report, 2005).

Despite the large quantity of oil and gas and high potential for electricity, Nigeria still depends to a large extent on traditional energy sources such as fuel wood, bagasse and crop residue for its domestic energy needs while the fuel wood consumption is about 80 million cubic meters (about 25 million tonnes) mainly used for cooking, heating, cottage industrial applications and food processing industries (Nigeria Study Report, 2005). Harnessing these resources is one of the major challenges in the country; only 20% of the nation's hydro-power potential is tapped for use and the amount of solar radiation in the country is about 5.5 KW-h/m^2-day, but not fully used, making the country to lose huge prospect for energy generation ((ECNUNDP, 2005). With the country's four refineries which produce about 30% of installed capacity of 445,000 bpd and lost, so many away through bunkering and pipeline vandalism affecting not only the consumption but has also paralysed the country's industrial and socio-economic development, according to the National Bureau of Statistics (NBS) who revealed that "electricity and oil production challenges have slowed down the growth of Nigeria's Gross Domestic Product, GDP" (Adeola, 2013).

The Nigerian government has currently implemented public sector reform plans geared towards reducing poverty, corruption eradication, and empowering the private sector to become the engine for economic growth in the country. This reform initiative called the National Economic Empowerment and Development Strategy (NEEDS) has identified the deregulation of the downstream oil sector as a key aspect of the reform plan. The major work of NEEDS is the commercialisation and privatisation of the energy sector. This will make energy products more readily available to all, although at a higher price (Nigeria Study Report, 2005). Although, this energy sector reforms would lead to improve access to clean and affordable energy but the consequence of this could be detrimental to the poor masses since income per day is less than one US dollar. Therefore, a scientific innovation would be needed to raise people's awareness about the comparative advantages of more efficient energy sources through nanotechnology than previously used options.

APPLICATION OF NANOTECHNOLOGY FOR ENERGY DEVELOPMENT

Energy is around us all, though not accessible, therefore there will be a need to convert it into a usable form. Currently, we extract chemical energy from coal, oil and natural gas because these energy-rich materials come in convenient forms. These are also relatively easy to transform into a range of products, including formulated fuels, and into electricity which can be widely distributed by power lines. As fossil fuels grow scarce and increase in value, nanotechnology could be used to reduce losses during energy conversion. For instance, nano-engineered catalysts could improve the conversion of crude oil into various petroleum products, as well as the conversion of coal into clean fuels for generating electricity (Schmidt, 2007). In oil and gas applications, nanotechnology is used to increase opportunities to develop geothermal resources by enhancing thermal conductivity, improving down hole separation, and aiding in the development of non-corrosive materials that could be used for geothermal-energy production. Nanomaterials that are metallic in nature can be used to delineate ore deposits for geochemical exploration. Nanotechnology can also be used to improve the drilling process. Some specialized petroleum laboratory has developed an advanced fluid mixed with nanoparticles and superfine powder that significantly improve drilling speed. This blend eliminates damage to the reservoir rock in the well, making it possible to extract more oil (Abdollah, 2009).

Nanotechnology is used to enhance the development of unconventional and stranded gas resources. Near-term challenges focus on liquefied-natural-gas (LNG) infrastructure and efficiency, LNG quality, and developing gas-to-liquids (GTL) technology. Nanotechnology can address the problems associated with accessing stranded natural-gas resources by developing nanocatalysts and nanomembranes for GTL production and creating nanomaterials for compressed-natural-gas transport or long-distance electricity transmission (Abdollah, 2009).

Another application is in terms of electricity, novel electrical generating method includes electrokinetic power generation where fluids with charged ions are forced through a nanosized channel creating current. This process is similar to the electro-chemical process of action potential generation in animal neurons (nerve cells). Though not useful for large volumes of power production, the technology is still useful in powering other nano applications such as Lab-on-a-Chip. For energy conversion, the increased surface area to volume ratio of nanoparticles enhances solar energy collection and efficiency by exposing more conducting surfaces to the sunlight. The research and development of solar cells using nanotechnology is probably the most promising for alternative energy production (Gardner, 2008).

Carbon nanotubes (CNT), fullerenes and quantum dots are used to make solar cells lighter, cheaper, and more efficient. For example, constructing photovoltaics with vertical laying CNTs greatly increases the amount of light that can be collected. Notre Dame Researchers are utilizing quantum dots with the ability to absorb different wavelengths of light that result in dynamic solar cells in the near future. Another arena that nanotechnology will impact is increasing photovoltaic efficiency through the use of materials like lead-selenide. These materials cause more electrons (and therefore more electricity) to be released when hit by a photon of light. Additionally, structural properties of photovoltaics can be modified using nanotechnology.

The ASTAR Institute of Microelectronics has constructed photovoltaics out of nanowires that give solar cells extreme enhanced flexibility not seen in many silicon-based cells. In terms of energy storage, it must be stored so that it can be used as needed. In the near term, nanotechnology could be used to create appliances and other products that can store energy more efficiently, that is, take up charge and hold it over time. Many research groups are working on better batteries, often using engineered nanomaterials (Schmidt, 2007). When batteries are constructed with nanoscale materials, this property will increase power density to battery size (Gardner, 2008). The efficiency of battery power is partially dependent on the diffusion distance between oppositely charged nodes. Nanomaterials can reduce this diffusion distance, coupled with hydrophilic electrolyte polymers, and battery efficiency is poised to increase dramatically. Altair Technologies has developed a prototype battery that has three times the capacity of existing batteries and can be fully charged in six minutes. Presently, scientists are trying to address the final two concerns in lithium-ion batteries. They have created batteries that prevent electrode contact prior to battery activation. This gives the product an almost limitless shelf life and an active life of 25 years (as opposed to two years).

In addition, reserve cells within the battery release chemicals during disposal that neutralize the normally toxic output from typical batteries (Baxter et al., 2009). Nanotechnology in battery production should revolutionize the industry of hybrid cars. The Micro-Vett Fiat Doblo powered by an AltairNano lithium ion NanoSafe battery has travelled 186 miles between chargings (that can take less than 10 min). Phoenix Motorcars will sell about 500 nano-powered Sports Utility Trucks featuring Altair technology in the coming years as well. Interesting areas being explored to assist battery technology is using CNTs to produce “printable” sheets of batteries and using viruses to self-assemble battery components (Gardner, 2008).

Similarly, nanotechnology will offer exciting advances in hydrogen energy production, storage, and distribution. In hydrogen production, similar processes to the photovoltaics are being utilized. Splitting water with light could get rid of the reliance on fossil fuels and other hydrocarbons. This process requires precision, and at the moment, research into this production method is in the early stages. One of the most exciting areas for nanotechnology to impact hydrogen energy is efficient hydrogen storage (Abdollah, 2009). There is currently no viable technology to store large volumes of hydrogen fuel because it is either too bulky or expensive. This is a severe limitation to implementing hydrogen as an alternative energy source (Baxter et al., 2009).

Researchers at Rensselaer have developed “nanoblades” that are extremely thin, uniform, and have high surface areas. Also, scientists have found that fullerenes can hold large volumes of hydrogen (equivalent to the density of hydrogen at the center of Jupiter). The efficiency of hydrogen transport could be further enhanced by the use of carbon nanotube wiring in place of traditional pipelines. These lines would have increased strength, conductivity, and stability at high temperatures. Researchers at Rice University are examining CNT wiring for just this purpose. Nanoparticle monitors are also being developed at New Mexico Tech to be placed in hydrogen transport pathways to detect potential impurities (Gardner, 2008).

For efficient energy transmission, nanotechnology could be used to create new kinds of conductive materials that lose very little energy as electricity moves down the line. Many research groups are investigating whether nanowires and nanocoatings could reduce losses in electrical-transmission lines. And for efficient energy use, nanotechnology could lead to breakthroughs that indirectly conserve large amounts of fossil fuels. Nanomanufacturing might also enable us to make all kinds of products using less energy. For instance, nanosensors might be used to track energy use and help minimize waste (Schmidt, 2007).

NIGERIA PROLONGED MENACE: SEARCH FOR INNOVATIVE MEDICINE

In Nigeria, the health condition of the populace is highly deplorable. Common diseases plaguing the country are malaria, guinea worm, pneumonia, measles, gonorrhea, schistosomiasis, typhoid, tuberculosis, chicken pox, diarrhea, HIV/AIDS (Oyebanji, 2013). The Federal and State Governments are the major providers of basic health facilities and services in Nigeria, providing significant funding to various aspects of the health sector in the country. WHO, UNICEF, UNDP, and the Carter Foundation have aided also in the control and eradication of communicable/infectious diseases like guinea worm, tuberculosis, cholera, river blindness, schistosomiasis and HIV/AIDS (Oyebanji, 2013).

There are three major public health diseases that are of great challenge in Nigeria; tuberculosis, malaria and HIV/AIDS. Tuberculosis (TB) as a major public health problem in the country is an air-borne infectious disease caused by bacteria, which primarily affects the lungs. WHO declared TB a global emergency in 1993 and it remains one of the world’s major causes of illness and death (United States Embassy in Nigeria, 2012). According to WHO, the country is ranked 5th among the 22 high TB burden countries, bearing 80% of the global burden of TB (WHO, 2013). The number of TB cases in 2002 increased from 31,264 to 90,307 in 2008 in the country. Though, more than 450,000 TB cases have been successfully treated in the past 5 years in Nigeria, the challenge is still on the emergence of multi-drug resistant tuberculosis (MDR-TB) (WHO, 2013).

In Nigeria, malaria is the most prevalent public health problem. Malaria is a risk for 97% of country's populace while the remaining 3% live in the malaria-free environment. The disease is a major cause of maternal mortality and poor child development (United States Embassy in Nigeria, 2011). It is estimated that there exist about 100 million malaria cases with over 300,000 deaths annually in Nigeria. It account for about 11% of maternal mortality and about 50% death in children aged 6 to 59 months (South West, North Central, and North West regions) with least occurrence of 27.6%, in children of same age in the South East region of the country (United States Embassy in Nigeria, 2011). The new malaria treatment is Artemisinin-based combination therapies (ACTs) which have replaced chloroquine but has not still met the requirement needed for malaria total eradication (Nigeria MDG, 2013). Roll Back Malaria is a new means of preventing malaria in Nigeria (global strategies for malaria control) which includes the use of insecticide-treated nets, indoor residual spraying and environmental management, but it faces two main challenges; ability to meet up the demands of the huge population and geographical area of the country, and the gap in funding.

AIDS is an acronym for acquired immune deficiency syndrome, a disease caused by the human immunodeficiency virus (HIV). When this virus attacks the immune system, there will be no more defenses against diseases and infections in the body (Oyebanji, 2013). About 3.1 million people are living with HIV in Nigeria. HIV occurrence among the general population is 3.6% while its prevalence among pregnant women is 4.1%. About 300,000 new infections occur yearly with people under the age 15 to 24 (UNAIDS, 2013). About 1.5 million people living with HIV require antiretroviral (ARVs) using the new WHO guidelines but only 30% of these people have access to it (UNAIDS, 2013). All these challenges in the health sector will need a new and compliment means of tackling it. Nanotechnology will be of great aid in the face of this particular lingering problem in the country.

APPLICATION OF NANOTECHNOLOGY IN MEDICINE

In medicine, nanotechnology helps predict the major diseases that are likely to develop by an individual. The goal would be to routinely and cheaply analyze several hundred substances in a patient's blood and estimate disease risks with a relatively high degree of accuracy (Schmidt, 2007). This would also provide a window on a person's overall state of health. Several research groups are in fact working on developing a "labon-a-chip" device, using nanotechnology to perform a comprehensive analysis of a drop of blood. This analysis would alert the doctor to early precursors of disease that reflect both genetic predispositions and environmental factors, such as diet, exercise, stress and exposure to air pollution. In pre-emptive medicine, it focuses on early intervention, but it also requires early diagnosis. It is to help detect treatable diseases earlier so that they can help patients preempt the full-blown development of illness or at least manage it effectively over a lifetime. Nanotechnology can enhance the development of sensitive diagnostic tests, as well as devices for health monitoring and disease management (Schavan, 2011).

Diabetes care is one important area that would stand to benefit, nanobased diagnostic tests could detect the earliest stages of insulin resistance, and similarly, preemptive medicine might be used to help a large portion of the population more effectively deal with cardiovascular disease and hypertension. This model could be expanded and used to manage many chronic diseases, e.g. lupus or arthritis. Likewise in personalized medicine, the vision is to make medicine more personalized comes from the notion that information about an individual can be used to monitor treatment. A doctor has a much greater chance of coming up with an effective medical strategy if he or she knows something about a patient's disease subtype, metabolism (particularly as it relates to drugs), liver status and risk for other diseases. Nanotechnology could provide new tools for gathering detailed information about variations in disease states and about unique parameters of treatment. More importantly, nanotechnology could spur the personalized medicine revolution by helping bring about real-time, sensitive monitoring of drug therapies. With more frequent feedback, a doctor could easily adjust drugs and dosages to personalize a patient's therapy. Indeed, treatments are expected to become more complex (Schmidt, 2007).

Nevertheless, in participatory (regenerative) medicine, the excitement about the potential for regenerative medicine has generally focused on stem cells, but nanotechnology could also lead to radically new treatments for spinal cord injury, macular degeneration, Type 1 diabetes and other dysfunctions. The goal, in all these cases, is to regenerate a part of the body that has been injured or has deteriorated as the result of disease, genetic defects or normal aging. Whether stem cells can be coaxed to rebuild tissues and restore function remains to be seen, but an equally promising approach is to employ nanostructured artificial tissues. It is still early, but many laboratories are experimenting with a wide variety of nanomaterial scaffolds that can be infused with cells to form artificial tissues, such as bone and liver. It appears possible to repair damaged nerves by injecting them with nanomaterials that form bridge-like lattices (Schavan, 2011). Other nanostructures show promise as foundations for growing three-dimensional networks of blood vessels. Regenerating damaged tissues is one approach, but lost function might also be restored using nanoenhanced replacement parts for the body devices that hook right into the nervous system.

APPLICATION OF NANOTECHNOLOGY IN OTHER AREAS

Aside from the three major application of nanotechnology discussed above, the technology has been established to be useful and functional in many other areas. Nanotechnological developments are related in different ways to positive effects on the protection of environment and resources. For instance, in the chemical industry, new nanocatalysts are the basis for alternative reaction paths, it save more energy at lower temperatures and allow optimal material usage due to their selectivity (low amounts of by-products). As environmentally friendly materials, completely new raw material sources, as for example new bioplastics, have the potential to replace conventional polymers or even metals, e.g. in car manufacturing. They are made of renewables and are not only characterized by an almost neutral CO_2 balance, but also lead to increasing independence from petroleum-based raw materials. It has been reported also that Carbon Nanotubes (CNT) play an increasingly important role in the development of new materials (www.technologyreview.com). As for example, the substitution or the reduction of indium in indium tin oxide (ITO) for the production of transparent electrodes, e.g. in liquid crystal screens or organic light-emitting diodes, the use of conductive substances (e.g. conductive silver) or the utilization as catalyst (substitution of platinum or other catalyst metals) and the reinforcement of materials through CNT for lightweight-construction applications (reduction of material usage with same load capacity).

Literature also reveal that concept of nanotechnology can be applied in the development of low friction material, stab and bullet-proof nanoscale material, environmental protective material, nanomaterial for intelligent street and identification of counterfeiting products (www.inno-cnt.de). Other areas of application of nanotechnology include; nutrition and agriculture, communication, electronics, etc.

BENEFITS OF NANOTECHNOLOGY

The benefits of nanotechnology for sustainable development are enormous, but summarized below (Savage and Wentsel, 2008):

i. Cost effective use of renewable energy,
ii. Early environmental treatment and remediation,
iii. Low energy requirement and waste generations devices,
iv. Lighter and stronger nanomaterial,
v. Early disease detectors for preventive treatment,
vi. Smaller, accurate and sensitive sensing and monitoring devices.

Lack of natural and clean water threatens the security and economic growth of many communities in the world today, hence nanotechnology stand as a good substitute or supplement compared to other available water remediation technologies. The treatment of the unclean water and recycling of the purified water would bring significant reductions in cost, time, and labor to industry which later result into greater economic sustainability and overall system development (Savage and Mamadou, 2005). The design of nanotechnology enhanced greater benefits as regards renewable energy including an increased efficiency of lighting and heating, increased electrical storage capacity, a decrease in the amount of pollution from the use of energy (www.technologyreview.com). Nanotechnology provides an efficient energy conversion and energy storage (Baxter et al., 2009). This overall benefit deriving from nanotechnology will revive the economy of any nation because a balance in energy production will improve and sustain the economic growth through job creation.

Another area of benefit is nanomedicine. Nanotechnology stands a good chance of revolutionizing the practice of medicine. The control and synthesis of atoms and molecules into a nanoscale, offer a wide range of products for medical purposes that are yet to be harness. These novel nanostructures drugs act faster on target delivery for treating common conditions such as cancer, Parkinson's and cardiovascular disease compared to normal drugs (www.technologyreview.com). The engineering of nanomaterials as an artificial tissue would help replace diseased kidneys and livers, and even repair nerve damage (Schavan, 2011). Nanotechnology is also used in tissue engineering, to provide a better bioscaffold and a surface to grow tissues (Kingsley et al., 2013). Moreover, nanodevices could be integrated with the nervous system to create implants that restore vision and hearing and eventually build prosthetic limbs that better serve the disabled. It is clear that advances in nanomedicine could help vast numbers of people maintain their health, their independence and their participation in society (Schmidt, 2007). Other benefits are found in agriculture such as food security and soil analysis, cosmetics industry, communication industry, sanitation and environmental remediation e.t.c. There is no doubt that nanotechnology is a tool for sustainable development.

Conclusion

This review has clearly demonstrated that nanotechnology is not an industry nor will it produces new industries. However, it offers new competitive dimension to existing industries. The concept of nanotechnology therefore promised to deliver numerous benefits to the society and it will have tremendous potential if it can be developed. There is no doubts that nanotechnology is a promising tool of change in this our world today. In USA, Japan, Germany, South Africa, nanotechnology has been invested on by their scientists, engineers, investors and even policy makers for sustainable development in different sector of their economy. Therefore, it will be of great importance if this tool of change; Nanotechnology is harness in this country, Nigeria.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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