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NANOMATERIALS RESEARCH: A WONDERFUL WORLD OF GREAT OPPORTUNITIES IN AFRICA

Since "nanotechnology" was presented by Nobel laureate Richard P. Feynman during his well famous 1959 lecture "*There's Plenty of Room at the Bottom*", various revolutionary developments have been made in the field of nanotechnology. Nanotechnology produces materials of various types at the nanoscale level.

Nanomaterials research is fast becoming a wonderful world of research in science and technology. The materials bear their uses from the strongly size-related properties of nanoparticles. This has been discovered to offer uncountable and unprecedented opportunities for diverse surprising discoveries. Scientists and engineers can now examine, design, and manipulate materials at the molecular level, termed "nanoscale," between 1 and 100 billionths of a meter. A lot of governments in developed countries have hugely invested in nanotechnology. This is because the products of nanotechnology are seen to have great economic potential and offer possible solutions to national problems ranging from energy efficiency to detection of agents of biological warfare. They were generally manufactured by chemical and aerosol formation processes, with modifications being reported in literature regularly.

Due to their minute size, unexpected and unprecedented behavior of nanoparticles have been identified and this offers a great potential for innovative technological applications, but also poses great challenges to the scientists in terms of designs, syntheses, characterizations, applications and toxicity concerns. Nanoparticles (NPs) are classified into different classes usually based on their properties, shapes or sizes. The different groups include metal NPs, polymeric NPs, fullerenes and ceramic NPs. The unique physical and chemical properties of NPs have been adduced to their high surface area and nanoscale size. Their optical properties are reported to be dependent on the size. In addition, the reactivity, toughness and other properties of NPs are known to be dependent on their unique size, shape and structure. As a result of these diverse properties, NPs are suitable candidates for various commercial and domestic applications, which include catalysis, imaging, medical applications, energy-based research, and environmental applications.

The origin of nanoparticles has been traced to processes and human endeavors since ancient times. It is often observed that NPs are not necessarily produced by modern synthesis laboratories, but have obviously existed in nature for a long time, and therefore their use can be traced back to ancient times. Modern applications seem to bear resemblance to uses that have dated to antiquities. The current relevance of nanoparticles in modern era points to their unending usefulness in sustainable development for which Africa must rightly tap into. This lecture presents a general overview of the field of Nanomaterials research while specific reported applications and usefulness will be described with a view to encouraging further research that will lead to sustainable development.

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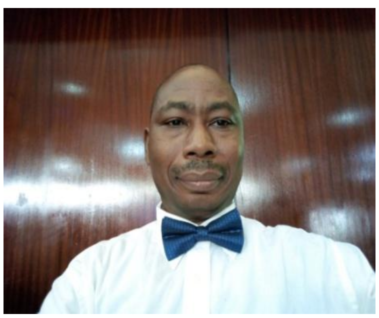
NANOTECHNOLOGY FOR SUSTAINABLE DEVELOPMENT: PROSPECTS FOR AFRICA

Nanotechnology Engineering is a multi-disciplinary engineering field, which draws from and benefits areas such as materials science and engineering, chemistry, physics, biology, and medicine. The involvement of nanotechnology in solving selected problems in engineering systems is a rapidly evolving area of research with the potential ability to bring positive impacts to an industry that is experiencing increased demand under increasingly stressed resources, particularly in developing countries of Africa. Like many previous technologies, nanotechnology could be both relevant and appropriate to sustainable development practices in developing countries of Africa. Nanotechnology applications that can benefits African countries in the near future are broadly related to energy storage, production and conversion; enhancement of agricultural productivity; water treatment and remediation; and the diagnosis and treatment of disease. In this paper a broad overview of the potential applications of various nanotechnology developments in some selected engineering fields is discussed. Another important area

highlighted is how nanotechnology provides solutions to sustainability. The review evaluates its applications in the built-environment and civil engineering, space engineering, manufacturing, water resources, energy, electronics and information technology, oil and gas, biomedical engineering and transportation engineering. It can be concluded from this review that, nanotechnology is the future solution to some obvious problems requiring engineering interventions in Africa. However, aggressive technology policies need to be adopted and broad-based strategies devised to promote partnerships which will ensure that the research and development in nanotechnology is linked to the social and economic needs of the end users. This will require that innovative researches based on indigenous problems within Africa are targeted using nanotechnology.



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NANOGENOTOXICITY IN NIGERIA: CASE STUDIES ON METAL AND METAL OXIDE NANOPARTICLES INDUCTION OF GENOMIC DISRUPTION IN EUKARYOTIC SYSTEMS

The synthesis and utilization of metal [silver (Ag)] and metal oxide [copper oxide (CuO), titanium dioxide (TiO_2) and zinc oxide (ZnO)] nanoparticles (NPs) in personal care products are exponentially increasing worldwide. Their release and co-existence in the environment may have long term genotoxic effects on the biota. Information is scarce on *in vivo* interactive effects of these NPs on the genetic material. We investigated the potential DNA damaging effect of the individual NPs (Ag, CuO, TiO_2 and ZnO) and their mixtures (1:1) (Ag + CuO and TiO_2 + ZnO) using the *Allium cepa* chromosome aberration (CA) assay, micronucleus (MN) assay in the peripheral blood of juvenile *Clarias gariepinus* (catfish), and mouse bone marrow MN and sperm morphology assays. The sperm motility, count and concentration of testosterone were also evaluated. The shapes and sizes of the individual NPs were characterized using the Transmission Electron Microscopy. The mechanism of DNA damage was evaluated through oxidative stress parameters [superoxide dismutase (SOD), catalase (CAT), reduced glutathione (GSH) and malondialdehyde (MDA)] in the liver of exposed catfish and mice. The histopathology of the gills, liver and testis was done using standard protocols. The interaction factors of the mixtures

were calculated. Ag, CuO and TiO_2 NPs were spherical in shape while ZnONPs were rod-like in shape; and were all less than 100 nm. In *Allium cepa*, the frequency of dividing cells was significantly ($p < 0.05$) reduced across tested groups except AgNPs that showed a significant ($p < 0.05$) increase. The NPs except CuO induced a concentration-dependent increase in chromosomal aberration in *A. cepa* root cells. Micronuclei and other nuclear anomalies significantly ($p < 0.05$) increased with the NPs in catfish. Ag, CuO, Ag + CuO and TiO_2 NPs induced a significant ($p < 0.05$) increase in micronucleated polychromatic erythrocytes (MNPCE) in mice at tested concentrations. The frequencies of sperm motility and count significantly ($p < 0.001$) decreased, while the sperm abnormalities significantly ($p < 0.01$) increased at tested concentrations with the NPs. Likewise, serum testosterone level was significantly ($p < 0.05$) increased at tested concentrations. Activities of SOD and CAT, and levels of GSH and MDA were significantly ($p < 0.05$) altered in the liver of catfish and mice exposed to individual NPs and their mixtures. Gill lamella hyperplasia, and hepatocellular and spermatogenic cell necrosis were observed in catfish and mice, respectively. Interaction analysis of data indicated antagonistic effects in *A. cepa* assay, MN induction in catfish and mice; and synergism in sperm count and abnormalities in mice. The individual and mixture of the NPs induced genomic instability in *Allium cepa*, *Clarias gariepinus* and *Mus musculus* through generation of intracellular reactive oxygen species. These are of public health importance as their interactions in the body may initiate the process of mutagenesis, carcinogenesis and reproductive abnormalities over time.

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NANOTECHNOLOGY: ECONOMICS AND MANAGEMENT SCIENCE PERSPECTIVES

The research phenomenon of *Nanotechnology* which cuts across all fields of science, engineering and technology has no doubt raised critical challenges of intellectual discourse also for research in the field of social and management sciences especially Nanoeconomics so much that it portends a redefinition and reinvention of new economic order paradigm in order to capture and cope with the pace of speed and new horizons of nanotechnology. The strategy to synthesize, manipulate, and restructure to reduce molecular particles to the smallest ranging from 1 to 100 nm in size creates new discourse for resource and challenge of resource utilization optimization and distinguishing countries along economic divide and industry along competition of effectiveness, efficiency and ultimately profitability.

These discussions rekindle a new dimension in welfare economics, health, accounting actuarial sciences, environmental economics, labour economics and overhauling the existing theories both in classical and neo-classical literatures. As it is difficult to separate Men, Resource and Power, so it is difficult to separate nanotechnology and the political economy of the future. However, the unimpeded search into nanotechnology has left with a critical factor of reduction of size of molecular particles, the movement of value chain from the previous to current result, the production cost of the additional value viz-a-vis the utility derivable by the consumer and the price for which a consumer is ready and willing to pay all interplay with nanomaterials as well as and the products and services so produced.

On the other hand, the following challenges and limitations stand to mitigate the progress and development of Nanotechnology in Africa:

I. Lack of research investments.
II. Intellectual property right.
III. Lack of clear cut national policy articulation on nanotechnology.
IV. Lack of nexus or fusion of local and indigenous knowledge into nanotechnology.
V. In effective curriculum that lack components of new ideas, such as nanotechnology.
VI. Lack of Industry-based research and collaboration with research institutes.

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PLANT MEDIATED SYNTHESIZED METAL NANOPARTICLES: INTERROGATION OF THEIR ELECTROCHEMICAL BEHAVIOUR TOWARDS THE DETECTION OF ENVIRONMENTAL AND BIOLOGICALLY IMPORTANT MOLECULES

Hazards and toxicity associated with the physical and chemical synthesis protocol of metal nanoparticles has recently led researchers to look for alternative routes that is eco-friendly, cheap and fast; the green chemistry approach where plant extracts and microorganism are used in the bioreduction of the metal salt is fast gaining popularity in the field of nanobiotechnology. In this presentation, the metal salts are reduced to their "nanoform" through a one-step synthesis protocol using leaves extract of a plethora of plants. Optical property, Plasmon resonance, phytochemical activity for the reduction as well as the particle size of the metal nanoparticles presented was determined using advanced spectroscopic and microscopic techniques, such as UV-visible spectroscopy, ATR-FTIR spectroscopy and scanning electron microscopy. In addition to these techniques, electrochemical techniques such as cyclic voltammetry and impedance spectroscopy was used to interrogated the behaviour of the metal nanoparticles towards a 1-electron transfer redox probe with a view to establish their viability for use in was investigated using cyclic voltammetry and electrochemical impedance spectroscopy.

Overview of nanotechnology, biosynthesis and its applications

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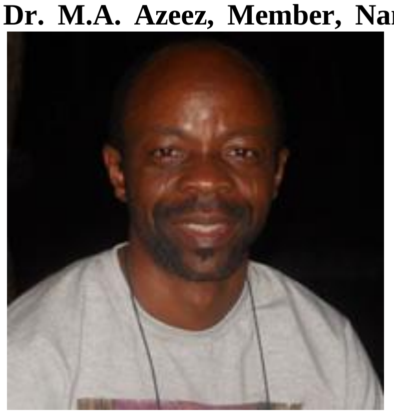

Many decades of human existence have witnessed tremendous activities in knowledge based research of material science, which has resulted in the development of physical world and its components in bigger than the biggest, and smaller than the smallest dimensions of mass, length and time. During this period, man has devised several means of creating smallest particles (nanoparticles) in an innovative manner and engineered them for intended purpose – 'this is otherwise known as nanotechnology'. The novelty of nanoparticles or nanomaterials resides in the uniqueness of their properties which are often different from that of corresponding bulk materials of the same kind and are usually influenced by the particle size. Metallic nanoparticles and their alloys such as gold, silver, iron, cadmium, zinc, platinum etc., exhibit unique optical, thermal, electrical, chemical and mechanical properties which are primarily based on their small size and high surface to volume ratio. As such, they have been employed in various aspects of human endeavours including biomedical (drug delivery and pharmaceutics), energy storage (capacitance, solar cells), water treatment, catalysis, sensors, food and agriculture (nanofertilizer, nanopesticides).

Nanoparticles can be synthesized by several techniques which may be physical, chemical and biological. The physical and chemical methods include laser ablation, lithography, radiolysis, aerosol techniques and photochemical reduction. These methods are known to be cumbersome, time and energy demanding, expensive and sometimes involve the use of high pressure, hazardous chemicals such as Sodium borohydride and hydrazine, making the biological method the most preferred. Biosynthesis of nanoparticles, an emerging highlight of intersection between nanotechnology and biotechnology otherwise known as nanobiotechnology has become the major focus of the scientific community due to its simple, fast, cost effectiveness and eco-friendliness. The nature's ability to reduce metal salts to their corresponding nanoparticles has led to discovery of new natural sources of microbial, fungal, animal and plant origin that can synthesize nanoparticles.

Of all the natural sources, plant materials have been given special attention due to their eco-friendliness, non-involvement of the elaborate process of maintaining cell structures and opportunity for large scale synthesis of nanoparticles. In green chemistry, extracts and metabolites from these novel sources have been used either as reducing agents i.e. to reduce various metal salts to their corresponding nanoparticles or as stabilizing or capping agents to prevent agglomeration of nanoparticles. For the purpose of this workshop, the green methods of nanoparticle synthesis will be explored with particular emphasis on roles of plant extracts and other metabolites of natural origin. An attempt will be made to discuss the chemistry of action involved in the eventual synthesis of nanoparticles and their various applications.

Physical and chemical synthesis of nanoparticles and characterization techniques

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This presentation focuses on characterization techniques employed for understanding physical and chemical properties of synthesized nanoparticles for various applications. The precise analysis of nanoparticles stability, size, size distribution, morphology, elemental identification, crystal structure, functional groups, thermal variation at nano level for various applications require sophisticated characterization techniques, such as particle size analyzer, electron microscopy, atomic force microscopy, x-ray diffraction, various spectroscopic and thermal analysis. Some of the challenges lie in finding the right characterization techniques that have the optimum capabilities for studying the characteristics of nanoparticles.

The properties and stability of dispersed nanoparticles can be analyzed by using dynamic light scattering (DLS) and zeta potential. An electron microscope (SEM/TEM/HRTEM) uses a beam of electrons to illuminate a sample and produce a magnified image. The morphology and size, as well as selected area electron diffraction (SAED) of the nanoparticles are commonly analyzed by transmission electron microscope (TEM). The atomic force microscopy (AFM) provides a precise three-dimensional surface profile of nanoparticle films deposited on the substrate, while X-ray diffraction analysis provides information about the structural arrangement of atoms and molecules of the nanoparticle materials. The spectroscopic techniques (XPS, EDS, FTIR, UV-Vis absorption) are good characterization tools to understand the physicochemical properties of nanoparticles. The temperature dependent measurements and glass transition temperature of the nanoparticles are analyzed by thermogravimetry analysis (TGA) and differential scanning calorimetry (DSC). Other techniques like electrical, magnetic and mechanical characterization are very essential also for proper understanding of nanoparticle behaviour. The physicochemical properties of nanoparticles always exert influences over their interactions with any given system and consequently play an important role in selection of the appropriate application. The aim of the presentation is to expose the participants to range of characterization techniques in nanotechnology.