Harnessing the power of nanotechnology to achieve the Sustainable Development Goals in South Africa and beyond

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Abstract

Nanotechnology has emerged as one of the disruptive innovations of the 21st century, with enormous potential to solve problems in many sectors to achieve the Sustainable Development Goals (SDGs). Since the early 1900s, nanotechnology is advancing so rapidly in many areas, including health (e.g., drug delivery system, nanodrug, vaccines formulations and point-of-care diagnostics), agriculture (e.g., nano-fertilizers), clean drinking water (e.g., treatment and purification), clean energy technologies, reducing CO2 emissions and many others. This policy brief demonstrates the power of nanotechnology in science, technology, and innovation (STI) to achieve the SDGs in developing countries, with a focus on South Africa. It will also discuss the impact and challenges of nanotechnology in several key areas and give some policy recommendations.

In 2015, UN Member States proposed about 17 Sustainable Development Goals (SDGs) that must all be met by all countries by 2030. If South Africa want to achieve the SDGs by 2030, they need to find an innovative technology that can help them, such as nanotechnology.

Nanotechnology is an emerging and rapidly developing field. It has become one of the most important scientific fields of the 21st century. According to the National Nanotechnology Initiative (NNI), nanotechnology is defined as the understanding and control of matter at the nanoscale, between 1-100 nanometres (nm), in which unique phenomena enable new applications. At the nanoscale, scientists can exploit the unique physical, chemical, mechanical and optical properties of materials to produce new structures, materials, and devices. Top-down and bottom-up approaches are two approaches used to synthesize nanomaterials. The top-down approach is the breaking down of bulk material to get nanostructures, while the bottom-up or self-assembly approach is the build-up of nanostructures employing by atom-by-atom or molecule-by-molecule.

A recent study shows that South Africa has the highest ranking (66%) in research and development (R&D) related to nanotechnology when compared to Egypt (59%) and Nigeria (38%). Most of the nanotechnology research and development in South Africa is concentrated in the fields of medicine, water, energy and so on.

Nanotechnology address health Issues

UN-SDG3 ensuring healthy lives and promoting well-being at all ages is essential to sustainable development. The aims of SDG 3 are to end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases, and to combat hepatitis and water-borne and other infectious diseases, most of which are major threats to South Africa. It also aims to reduce non-communicable diseases by one-third.

Nanomedicine is the medical application of nanotechnology that promises to provide innovative solutions to unmet medical needs, including early detection, rapid diagnosis, and targeted therapy with fewer side effects.

Rapid diagnostic

Nanomaterials such as metal nanoparticles (gold and silver nanoparticles), carbon nanotubes and quantum dots are being used for the rapid diagnosis of viruses such as COVID-19 and early detection of cancer.

Drug delivery system and vaccine development

Liposomes, lipids, and polymeric nanoparticles are among the most successful FDA-approved nanocarriers for the safe delivery of active pharmaceutical ingredients (APIs) and genetic material (i.e., mRNA and siRNA) into target host cells.

COVID-19 has been a game changer for both nanomedicine and nucleic acid-based vaccines. Without these lipid shells, there would be no mRNA vaccines for COVID-19. Nanotechnology offers vaccine developers solutions to overcome unresolved delivery challenges associated with the use of naked genetic material, such as Moderna’s COVID-19 mRNA vaccine and Pfizer’s COVID-19 mRNA vaccine.

Nanotechnology-based mRNA vaccines are easy to design and manufacture, offering advantages over conventional vaccines (e.g., inactivated, and live attenuated strains), that still require culture and are
very expensive. Nanoparticles used in the COVID-19 vaccines consists of four ingredients: 1) cationic or ionizable lipids to improve the entrapment of mRNA; 2) pegylated lipids help to prevent particle aggregation, prolong circulation lifetimes, and evade the immune system; 3) phospholipids; and 4) cholesterol molecules contribute towards the stability of lipid bilayer structure.

Case study: South Africa develop a COVID-19 mRNA vaccine

South African scientists from the Cape Town-based biotechnology company Afrigen Biologics has successfully produced a lab-scale batch of a COVID-19 vaccine that is similar to that made by pharmaceutical company Moderna. Although Afrigen Biologics developed an mRNA vaccine copied from Moderna, they used their own process. The main raw materials used in the development of Afrigen mRNA vaccines include all the raw materials used by companies such as Moderna and CureVac. The success of Afrigen's COVID-19 mRNA vaccine provides an opportunity for capacity building in low- and middle-income countries (LMICs) to manufacture their own COVID-19 vaccines and beyond.

Nanotechnology in water solution

UN-SDG6 aims to ensure everyone has access to clean water and sanitation, and to improve water quality by reducing contamination of wastewater with harmful chemicals such as heavy metals and pharmaceutical pollutants. The increasing number of emerging pharmaceutical contaminants in the environment is a global problem that affects human health, the environment, and aquatic life. Innovative technologies such as nanotechnology has demonstrated its potential to address the challenges posed by heavy metals, pathogens, and emerging pharmaceutical contaminants in the wastewater. Nanotechnology-based adsorbents, sensors, filters, membranes, composites, catalysts, and metal nanoparticles have been reported to have the ability to detect, adsorb, and remove harmful chemical and pharmaceutical pollutants from wastewater. Emerging pharmaceutical pollutants in wastewater includes antiretrovirals, antibiotics, steroid hormones, non-steroidal anti-inflammatory drugs, and analgesics (NSAIDs), beta-blockers and lipid regulators. Nanotechnology can provide cheaper water treatment products, environmentally friendly, portable, and user-friendly devices for cleaning, purifying, and removing pollutants. South African research institutions such as the Council for Scientific and Industrial Research (CSIR), MINTEK and a number of other private companies have developed several types of nanotechnology-based prototypes for water purification and treatment.

Nanotechnology in agriculture solution

UN-SDG2 aims to end hunger, achieve food security and improved nutrition, and promote sustainable agriculture. It is estimated that around 63% of the population in Sub-Saharan Africa (SSA) is heavily dependent on agriculture as a source of income and employment. Agricultural production in developing countries has a greater impact on reducing poverty (SDG 1) and improving food quality and contribution to food security (SDG 2). The application of nanotechnology in agriculture promises to help small farmers monitor and optimize agricultural production in response to environmental conditions and challenges. Nanotechnology-based biosensors offer innovative solutions to unmet needs in the food industry and agriculture, such as early detection of plant pathogens and food spoilage. For sustainable agriculture, nano-fertilizers are helping to improve agricultural production and food quality with high nutritional value. A recent study conducted in the Northern Cape Province of South Africa reported the success of using pheroid® technologies combined with nanotechnology (e.g., FePO4) as foliar iron fertilizers and iron bio-fortification of the soybean.

Nanotechnology in energy solution

UN-SDG 7, it ensures access to affordable, reliable, sustainable, and modern energy for all. Unlike the rest of the world, African countries' energy sectors rely heavily on fossil fuel-based energy production, such as coal, gas, and oil. Eskom Holdings SOC Ltd is a state-owned company and the largest electricity supplier to South Africa and the Southern African Development Community (SADC) region. However, Eskom uses coal to generate electricity, making it the largest emitter of greenhouse gases in Africa and the 14th largest emitter of carbon dioxide globally in 2021. The application of nanotechnology in energy helps to reduce energy consumption through the development of cleaner energy, cheap, more efficient, and reliable. In solar cells, nanotechnology such as silicon (Si) nanoparticles, nanocrystalline quantum dots, graphene, and carbon
nanotubes (CNTs) can improve efficiency and energy storage. South African energy companies such as ESKOM, SASOL, and many other private energy companies need nanotechnology to remain competitive and improve energy production and services.

Nanotechnology impact areas

Scientists, private sector leaders and policymakers around the world have recognized nanotechnology as a key technology that will boost economic growth and foster sustainable development in the 21st century. African countries (including South Africa) face several challenges that nanotechnology can solve, so they cannot afford to miss the nanotechnology revolution.

In South Africa, nanotechnology can impact on several key sectors such as:

• Health sector: nanomaterials improve the diagnosis and treatment of the infectious diseases (HIV, TB, and malaria), neglected tropical diseases, and non-communicable diseases (Diabetes, cancer, and cardiovascular diseases).
• Water sector: nanomaterials can improve the detection and treatment of water pollutants and provide humans with pollution-free water.
• Agricultural sector: nanomaterials can improve the use efficiency of agrochemicals, soil integrity and resilient agricultural system, while promoting food security.
• Energy sector: nanomaterials can boost the use of renewable energies e.g., solar energy storage.

Although nanotechnology promises enormous opportunities in several key areas, we cannot ignore the potential unintended impacts of this emerging technology on human health (Health – SDG3) and the environment (life below water – SDG14 and life on land – SDG15).

Key recommendations

• There is a huge gap between the development of nanotechnology and nanoethics. Therefore, an ethical risk assessment needs to be implemented to determine the risks and life cycle analysis of nano-enabled products.
• Governments and regulatory agencies need to develop clear regulatory guidelines for nanotechnology applications and nanotechnology-enabled products to protect and improve human health, safety, and the environment.
• Policymakers, industry, and researchers need to work together to implement specific technologies to assess validation and standardization protocols for nanotechnology and nano-enabled product.
• In order to attract the private sector and businesses, policymakers must create a predictable, stable, and effective regulatory environment that encourages investment in nanotechnology innovation.
• Governments and policymakers need to set a code of conduct for nanotechnology research to ensure the safety of staff, researchers, and the community at large.
• Government and scientists need increase public awareness and educate the public about the benefits and risks of nanotechnology innovations to enable them to make an informed decision.

Only a few countries in Africa have national nanotechnology strategies in place, so there is an urgent need to invest in nanotechnology to harness the power of nanotechnology to achieve their SDGs.

References
