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SUSTAINABLE DEVELOPMENT: THE ROLE OF CHEMICAL TECHNOLOGY IN THE INDUSTRIALIZATION OF NIGERIA

E. M. Okonkwo, O. J. Okunola and C. S. Ezeanyanaso
National Research Institute for Chemical Technology, Basawa, Zaria, Nigeria

ABSTRACT

Like any nation in the world, the challenges facing the sustainability of technological advancement of chemical industry in Nigeria today are re-inventing the use of materials. To address this challenge, chemistry is actually central to many of the environmental and resource use issues at the heart of sustainable development. Also, collaboration from an interdisciplinary group of stakeholders will be necessary. An emerging approach to this challenge seeks to embed the diverse set of environmental perspectives and interests in the everyday practice of the people most responsible for using and creating new materials—chemists. The approach, which has come to be known as Green Chemistry, intends to eliminate the intrinsic hazard itself, rather than focusing on reducing risk by minimizing exposure. This addresses the stake of chemists, stakeholders, and policymakers in everyday practices that are re-inventing chemistry and its material inputs, products, and wastes in a developing economy, otherwise known as Nigeria.

Keywords: Sustainability; Chemical; Technology; Nigeria

SUSTAINABLE DEVELOPMENT

The Brundland Commission (World Commission on Environment and Development, 1987) defined sustainable development as the process in which the exploitation of natural resources, the allocation of investments, and the process of technological development and organizational change are in harmony with each other for both current and future generations.

Based on this context, “sustainability” is a path forward that allows humanity to meet current environmental and human health, economic, and societal needs without compromising the progress and success of future generations World Commission on Environment and Development, 1987; Graedel & Allenby, 1995). Sustainable practices refer to products, processes, and systems that support this path. For example, such processes might involve developing new energy resources to meet societal needs; but to be sustainable, they must also be economically competitive and not cause harm to the environment or human health. Addressing sustainability necessarily cuts across all disciplinary boundaries and requires a broad system view to integrate the different and competing factors involved. This includes “strategic connections between scientific research, technological development, and societies’ efforts to achieve environmentally sustainable improvements in human well-beings” (National Research Council, 1999) and involves the creative “design of products, processes, systems, and organizations, and the implementation of smart management strategies that effectively harness technology and ideas to avoid environmental problems before they arise” (National Academy of Engineering, 1997). In this paper, progress in the chemical industry is considered within these broader efforts to address sustainability.

According to the American Chemistry Council (Graedel & Allenby, 1995), “the business of chemistry (in the United States) is a $450 billion enterprise (about 26 percent of the global chemical production) and is a key element of the nation’s economy. It is the nation’s largest exporter, accounting for ten cents out of every dollar in U.S. exports).

Going forward, the chemical industry is faced with a major conundrum — the need to be sustainable (balanced economically, environmentally, and socially in order to not undermine the natural systems on which it depends) — and a lack of a more coordinated effort to generate the science and technology to make it all possible. As the feedstock industry for modern society, the chemical industry plays a major role in the sustainability effort—to advance the science and technology to support the design, creation, processing, use, and disposal of chemical substances that provide a foundation for sustainability.

SUSTAINABLE DEVELOPMENT AND CHEMISTRY

In a world with a continuously increasing population and limited resources, the idea of a sustainable development is of major importance is it for the future. Only research and innovation will allow the development of economic and social networks and processes that fulfill the requirements of sustainability. The future has to be planned with visions, creativity, and fantasy, including brand new approaches and the exploration of the unknown. Sustainability, in science and technology, begins when we start thinking of how to solve a problem or how to turn science into technology. Chemistry, as the science of matter and its transformation, plays a central role in this process. It is the bridge between physics, material sciences, and life sciences. Only chemical processes, which have reached – after careful optimization – a maximum in efficiency, will lead to more sustainable products and production. Scientists and engineers, who invent, develop, and optimize such processes, play a key role. Their awareness, creativity, and looking ahead is needed to bring reactions and chemical processes to maximum efficiency. The term "Green Chemistry" has been coined for efforts towards this goal.

GREEN TECHNOLOGY

Green is the way to go. In order to go with green technology, you need to fully understand what green technology is. Basically, green technology is that in which the technology is environmentally friendly and is created and used in a way that conserves natural resources and the environment. You may hear green technology being referred to as environmental technology and clean technology.

Green technology is a field of new, innovative ways to make changes in daily life. Currently, this clean technology is in the beginning stages of its development. The future will only bring bigger and better things for this field.

GOALS OF GREEN TECHNOLOGY

Green technology is the future of this society. Its main goal is to find ways to produce technology in ways that do not damage or deplete the Earth's natural resources. In addition to not depleting the natural resources, green technology is meant as an alternative source of technology that reduces fossil fuels and demonstrates less damage to the human, animal, and plant health, as well as damage to the world. Next, green technology is used so that products can be re- used and recycled. The use of green technology is supposed to reduce the amount of waste and pollution that is created during production and consumption.

TYPES OF GREEN TECHNOLOGY

In field of green chemistry, there are many green technologies out there among which are;

Energy: The most important and urgent concern and want for green technology is for energy purposes. We need better, more efficient process to produce energy without burning the entire world's coal and using all the world's fossil fuels and natural resources.

Building: Green building is an innovative way to build buildings and houses by using the tools and materials most efficiently towards the environment.

Preferred purchasing: Green preferred purchasing is a new way of finding products and methods of production that has the smallest impact on the environment. This searching and re-searching yields products that are deemed to be environmentally preferred purchases.

Chemistry: Green chemistry is the application of chemical products that eliminate harm to the environment.

Nanotechnology: Because nanotechnology involves manipulating materials to the smallest nanometer, it can be best to implement the green nanotechnology using the green principles.

GREEN CHEMISTRY

The term green chemistry, as adopted by the Working Party, is defined as, “The design, development, and implementation of chemical processes and manufactured products to reduce or eliminate substances hazardous to human health and the environment” (Anastas & Warner, 1998). Looking at the definition of green chemistry, the first thing one sees is the concept of *invention* and *design*. By requiring that the *impacts* of chemical products and chemical processes are included as design criteria, the definition of green chemistry inextricably links hazard considerations to performance criteria.

Therefore, green chemistry is a tool not only for minimizing the negative impact of those procedures aimed at optimizing efficiency, although both impact minimization and process optimization are legitimate and complementary objectives of the subject. Green chemistry, however, also recognizes that there are significant consequences to the use of hazardous substances, ranging from regulatory, handling and transport to liability issues. To limit the definition to deal with waste only would be to address only part of the problem. Finally, the definition of green chemistry includes the term “hazardous”. It is important to note that green chemistry is a way of dealing with risk reduction and pollution prevention by addressing the intrinsic hazards of the substances rather than those circumstances and conditions of their use that might increase their risk.

Therefore, green chemistry offers a viable path for achieving sustainability goals across the chemical industry. That is, there is the potential to develop industrial technologies that could provide goods, products, and services in a way that does not reduce the supply chain of resources, harm the environment and human health, or limit the opportunities and choices for future generations.

SOME RECENT DEVELOPMENTS AND EXAMPLES OF GREEN CHEMISTRY

Chemists from all over the world are using their creative and innovative skills to develop new processes, synthetic methods, analytical tools, reaction conditions, catalysts, etc. under the new green chemistry cover. Some of these are:

1. A continuous process and apparatus converts waste biomass into industrial chemicals, fuels, and animal feed. Another process converts waste biomass, such as municipal solid waste, sewage sludge, plastic, tires, and agricultural residues, to useful products, including hydrogen, ethanol, and acetic acid.
2. A method for mass producing taxol by semi continuous culture of the Taxus genus plant.
3. A fermentation method for the production of carboxylic acids.
4. A method of partially oxidizing alcohol, such as methanol to ethers, aldehydes, esters or acids, by using a supercritical fluid mobile.
5. A process for producing a fluoropolymer by using supercritical carbon dioxide.
6. A cost-effective method of producing ethyl lactate, a non-toxic solvent derived from corn.
7. A range of ‘organic solvents’, for example, bioethanol, that are worker friendly and environmentally sound.
8. A new environmentally friendly technology in mixed metals recovery from spent acid wastes has been used to recover zinc and ferrous chloride from pickle liquor.
9. The demand for non-ionic surfactants is growing. A new example of this is alkly glycoside, which is made from saccharide. This product can be used as a replacement for alkylaryl sulphonate anionic surfactants in shampoos. Sodium silicate can be used as a more environmentally benign replacement for phosphorus-containing additives in washing powder. Three coconut oil soap bases for liquid cleansing applications have been developed. One of these products has a very light color and low odor, making it suitable for introducing dyes and fragrances.
10. Feedstock recycling of plastic wastes into valuable chemicals useful as fuels or raw materials.
11. The first bio-pesticide for sugarcane, called BioCane, has recently been launched in Australia. The product is based on a naturally-occurring fungus that has been cultured on broken rice grains to provide a medium for distribution. Biocane granules are claimed to be particularly effective against greyback cane grub.

PRINCIPLES OF GREEN CHEMISTRY

In adopting green chemistry, the following principles must be ensured;

1. It is better to prevent waste, than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

3. Practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficiency of function while reducing toxicity.
5. The use of auxiliary substances (for example solvents, or separation agents) should be made unnecessary wherever possible and innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at an ambient temperature and pressure.
7. Unnecessary derivitization (blocking group, protection/deprotection, and temporary modification of physical/chemical processes) should be avoided whenever possible.
8. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
9. Chemical products should be designed so that at the end of their function, they do not persist in the environment and break down into innocuous degradation products.
10. Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
11. Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

REASONS FOR GREEN CHEMISTRY PRINCIPLES

Green chemistry is aimed to help practitioners involved in the invention, design, and application of chemical products and processes to reduce or eliminate the use and generation of hazardous substances (Pietro, Anastas, Black, Breen, *et al*. Tumas, 2000). The principles promote environmental chemistry at all levels: research, reduction to practice, education, national and international policy, and public perception. They help chemists and chemical engineers design more environmentally, benign products and processes through the selection of feedstock, reagents, alternative synthetic transformations, solvents, reaction conditions, and end products, as well as the design of safer chemicals. For instance, when considering what feedstock to use in generating a particular compound, the green chemist will explore renewable feedstock whenever practical. There is no guarantee that such renewable feedstock is possible for a given reaction nor, if they are, that they will provide a net environmental benefit. Nonetheless, the principles of green chemistry provide a set of design criteria and goals that can help improve the environmental performance of new products and processes. As they begin to apply the principles of green chemistry, chemists are discovering many pathways toward environmentally greener designs. For instance, synthetic catalysts and biocatalysts, such as enzymes, offer a variety of alternative synthetic pathways that are consistent with the principles of green chemistry. These catalysts also enable the use of alternative reagents and feedstock previously impractical with conventional chemistries. The two crosscutting enabling technologies hold much promise in fulfilling the expectations for green chemistry.

DEVELOPING COUNTRIES AND GREEN CHEMISTRY

In developing countries, the introduction of green chemistry is still in a stage of infancy, despite the significant need and the significant role green chemistry can play. Many of the practices in developing countries are still far from the concepts of safety, pollution prevention, and design of energy efficiency. Environmental pollution and waste generation are some of the aching problems many developing countries are suffering from. Many of the reasons behind these problems lie in policies and strategies adopted that are based on end-of pipe treatment. Most frequently, income generation activities are dependent on an efficient use of energy and other resources, such as water, which may pose some serious problems to future generations.

The United Nations, reporting on the millennium development goals at a country level, indicated a high level of energy consumption and limited energy resources in most of the developing countries. The report strongly recommends the imperative need to ration the use of energy resources in these countries and to implement energy conservation policies. The same trend of difficulties developing countries face has been illustrated in the series of country reports produced by the rural development at the water and environment department of the World Bank.

Sustainable chemistry could play a pivotal role in salvaging many of the ailing conditions that many of the developing countries are subjected to. The use of solar energy, introduction of sustainable farming, recycling, and the implementation of lifecycle thinking and lifecycle analysis as a management tool for some of the chronic issues, such as municipal waste management, are a few examples of how green chemistry can benefit developing communities.

Green chemistry can also have a very strong impact on water sufficiency issues in that part of the developing world where water resources are polluted.. It is through the implementation of a cleaner production and the use of safe and biodegradable chemicals that a huge volume of wastewater could be re-used to quench the emerging, critical need of water in many of these countries.

DEVELOPING GREEN TECHNOLOGY IN NIGERIA

Nigeria is confronted with several peculiar challenges which make a green agenda appear unattainable. The top of these include the solutions that have been adopted because of the inefficiencies in the energy and transportation systems, as well as waste management. The building industry also has its peculiar handicaps.

ENERGY SUPPLY

It is reported that Nigerians burn an average of 40 million liters of petrol/diesel per day for the private generation of electricity (The Vanguard Newspaper, 2008). Keeping the efficient supply of energy in the hands of licensed providers appears to be a long way away, so the government through its agency Nigeria Energy Commission is seeking alternative clean power (such as from wind, solar, and waste). The Nigeria Energy Commission, whose mandate includes to "guarantee adequate, sustainable and optimal supply of energy at appropriate cost and in an environmentally responsible manner to the various sectors of the economy, by utilizing all viable energy resources in an optimal mix – appears incapable of championing initiatives in alternative clean energy (Nigeria Energy Commission).

Industry operators can play a significant role in the development and use of clean energy. "Simple" solutions, such as the use of modular solar-powered generating plants (particularly for domestic use), will make a big difference in a country which is reported to have 60 million petrol/diesel powered generating sets (The Vanguard Newspaper, 2009). What appears to be lacking is a concise government agenda, translating into strategies, the top of which are the policies and incentives required to encourage private sector participation.

Several years ago, the Government of Rwanda entered into a 25 year partnership with a German state for the provision of alternative clean power. The Kigali project is one of several initiatives being undertaken under this arrangement. The solar plant will, upon completion, generate 325 kilowatts of electricity. The government-led initiative has generated sufficient interest within the private sector, which is expected to play a prominent role in future projects under the partnership.

TRANSPORTATION

The poor state of infrastructures and the lack of impactful investments mean that most of the Nigerian cities lack efficient transportation systems. Other more recent problems, such as petrol pricing and carbon dioxide emissions, should be forcing governments to consider implementing better public transportation initiatives.

Vehicles using clean energy technologies are relatively expensive. A hydrogen powered bus developed in 2009, and whose only emission is water, is priced at US $1.5 million (Sustainable Public Transport Systems – Alternative Energy News. April, 2010). However, varieties of cost efficient hybrids have been developed over the past decade and are in use in many developing countries.

A growing range of global environment funds, such as the Global Environment Facility (GEF), are available specifically for the funding of sustainable public transport and less polluting energy supplies. It is reported that in Africa, only Tanzania has taken advantage of the GEF (Sustainable Public Transport Systems – Alternative Energy News. April, 2010).

WASTE MANAGEMENT

There has been very little done by successive governments or relevant agencies with regards to environmentally sustainable waste disposal. Indiscriminate dumping of waste by individuals and government agencies is rife. Only in the past couple of years has the Lagos State Government developed (and is implementing) a waste management strategy.

Design and building innovation

Building better communities through environmental innovation should top the agenda of any government and influence the actions to actualize the dream of sustainable green environment. The government needs to lead by example in this regard, rather than passing laws that determine what the private sector can do. Government agencies must incorporate sustainable strategies into their own projects. Policies on greening construction or buildings should be introduced with the government championing implementation. Such policies could include energy and water efficiency, environmental quality of building materials and resources, indoor environmental quality, and innovation in design. A certification process, such as the Leadership in Energy and Environmental Design (LEED) ratings, could be introduced with attractive incentives for compliance by the private sector.

Professionals in the industry must educate themselves and their clients about the benefits of incorporating green initiatives as an upfront investment in construction projects. This is with a view to significantly reduce operating cost over the lifetime of a building, while contributing positively to the environment and the people who use the building. There is sufficient proof to show that “green” sustainable building projects do not have to be cost-prohibitive. There are many cost effective steps that can be taken to make a community a better place to live and work.

WHAT CHEMISTS CAN DO TO PROMOTE SUSTAINABLE DEVELOPMENT?

Sustainable development is an inherently political issue. There are limits to what can be achieved at a global level, unless the Governments give a firm lead by tackling difficult issues and, if necessary, providing the incentives to change people’s behavior (Hazell *et al*., 2000). For example, if approached in the right way, more efficient processes using less material and producing less waste can often go hand in hand with economic growth and improve the social well-being. However, this is not always the case and it may be unrealistic to expect commercial organizations to adopt the more sustainable practices unless the financial and other frameworks within which they operate make this advantageous to their ‘bottom line’. Individual chemists can still achieve a great deal within existing frameworks by the application of sound chemical science, common sense, and good management. Some examples are summarized in Table 1, below.

Table 1: Examples of what Chemist can do to Promote Sustainable Development

Area of work	Examples of how chemists can promote sustainable development
RESEARCH AND DEVELOPMENT (in industry, government agencies, academia, etc.)	Developing new, more environmentally friendly products and processes Improving energy production and energy use systems Improving our understanding and knowledge of relevant environmental processes Identifying and anticipating problems Helping to refine techniques to assess environmental impact
Production	Considering environmental impact Good product management (for example: optimizing raw materials) Minimizing waste Carrying out sustainability auditing and reporting
Analytical and Monitoring	Developing improved methods Interpreting results Advising where caution is necessary (for example: just because sensitive modern techniques can detect a material at very low levels, doesn't mean its presence is significant)
All areas of work	Following management principles Considering whether there are better ways to 'meet the need' Being aware of relevant legislation, codes of practice, standards, and guidance Leading by personal example Assessing, as far as possible, the environmental, social, and economic impacts of activities and taking appropriate decisions or given appropriate advice Using appropriate tools and techniques.

Adapted from Hazell *et al*. (2000). (http://www.rsc.org/lap/rsccom/ehsc/ehscnotes.htm)

THE WAY FORWARD FOR NIGERIA GREENERS

Nigeria is said to be endowed with an abundance of renewable energy resources. According to the Nigeria Energy Commission, there is a lack of technologies, a dearth of professionals and an absence of appropriate policies and regulations to stimulate the demand and attract investors.

Under the Kyoto Protocol on climate change, developed countries can offset some of their emissions through renewable energy projects in the developing countries via the Clean Development Mechanism (CDM). It is estimated that projects under the CDM could (over the long-term) generate up to $100 billion worth of funds for developing countries. Unfortunately, Africa's share of such projects remains low. Of the over 300 projects currently approved, only six are in Africa, none of these are in Nigeria.

What would be a practical way forward? The short answer is "take small steps". Government agencies must lead by example. Professionals in the industry need to educate themselves and their clients and commit to introducing environmental sustainability in design and building. Just like rebranding Nigeria, the government needs to embark on environmental initiatives to develop a green consciousness amongst Nigerians. To actualize Vision 20:20:20, there is a need to develop green technologies that are relevant to the needs of the country. R & D is the needed catalyst for the historical milestone in scientific, technological, and economic advancement of any nation. There cannot be sustainable industrialization without research and development.

Special research grants should be awarded to universities, research institutes, and polytechnics with specific projects geared towards green technology development. Some scholars should also be sent abroad to acquire more training in areas relevant to green technology development.

FUTURE CHALLENGES AND OPPORTUNITIES FOR THE CHEMICAL PROFESSION AND THE SCIENCE OF CHEMISTRY

The principles of green chemistry are also a substantial beginning for the chemical profession in trying to deal with the novel ethical context in which humanity has been placed by the unprecedented power afforded to it in the 20th century by science and technology (Jonas, 1984).

Generally, green chemistry has major contributions to make to the quality of life, human welfare, and sustainable development. However, before green chemistry can contribute fully to these areas, it must be integrated into the discipline of chemistry, itself. This requirement presents a number of major challenges to the chemical profession.

Chemists will need to integrate into pure chemistry the questions of why or why not a particular technology should be abandoned, improved, or adopted on environmental protection grounds. These questions must become as important in research and education and made as concrete as the ubiquitous questions associated with what comprises chemical technology and how it actually works.

Nowadays, green chemistry has become a preference, in which chemistry that is not really "green" gets paraded as such before the scientific community and the world. Such fraud will inevitably bring the type of disenchantment and confusion that might simply discredit the field and would deny future generations the experience of the chemical dimension essential to a sustainable, technologically advanced civilization.

Certainly the largest sustainability issues, where chemists have so much to offer, will require new approaches that can only be built with long-term commitment. For example, finding an efficient way of converting solar to chemical energy is a large sustainability issue. The culture of present-day chemistry places too many short-term obstacles in the path of research problems of this type. But chemists must solve such problems to achieve sustainability. Thus, the culture must adapt to recognize that certain sustainability problems will require novel approaches with inherently longer incubation times. Chemists must learn how to better evaluate and sustain research programs that, instead of rapid publication of incomplete research work. do offer reasonable promise of bringing within, the fullness of time, those critical advances that will genuinely promote the cause of sustainability.

The very difficult issue of achieving a wholeness of scientific intelligence were more than the current specialized and professionalized expertise has paid due homage to. The science of chemistry cannot escape this growth and remain meaningful and important to humanity. Chemistry exerts an enormous influence on human action and is thus inextricably intertwined with the forces that guide human action, especially ethics and certain forms of passion. As such wholeness is achieved, the power of scientific objectivity will be more openly directed by the action orienting insights and passions that make us all human, such as our love of life and our desire to protect it. Such passions are neither vacuous nor disorienting. Rather, they are forces that are fully capable of directing chemists toward research that really matters to each and every human being living and to come.

Finally, Chemistry will have much more to offer by becoming more meaningful to humanity, increasing in attractiveness as a career choice, growing to be more worthy of support, spawning new, large economic developments, and progressing to be more interesting and compelling if chemists work to define and follow their natural and unique role in achieving a virtuous civilization that sees broad validity within the community of living things for the claim to continuity of existence in an environment of natural genesis.

CONCLUSION

With the ever-growing human population in Nigeria, environmental pollution, depletion in supply of non-renewable energy sources, high cost of living, and incessant power failures, the country needs an alternative energy source, more environmental friendly products, and processes that are more reliable, safer, secure, and affordable. Research and development in green chemistry is the only key to an industrialized, technologically advanced, economically vibrant, less polluted, and a safer Nigeria. If Nigeria can provide leadership in this vital field, we shall play a dominant role in the future as far as power generation is concerned and our Vision 20:20:20 will be achieved, if not surpassed. Then, we would have secured not only ourselves, but the future generations.

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ABOUT THE AUTHORS:

E. M. Okonkwo is the Director General/CEO of National Research Institute of Chemical Technology (NARICT) Nigeria.

O. J. Okunola is a research officer in petrochemical/polymer division of National Research Institute of Chemical Technology (NARICT) Nigeria.

C. S. Ezeanyanaso Okunola is a research officer in petrochemical/polymer division of National Research Institute of Chemical Technology (NARICT) Nigeria.