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Green chemistry as the future shape of sustainability and development in Nigeria

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ABSTRACT

Sustainable development is the major discussion on the world center stage today. For instance, UNESCO declared 2005-2015 as the world decade of education for sustainable development. In addition, an intrinsic part of the United Nations millennium goals is to ensure environmental sustainability and one of the targets is integrate the principles of sustainable development into the policy of every country around the world. Nigeria as a country is not left out in the comity of nations in various use and applications of chemicals in almost all facet of life which usually have health and safety implications. The chemical and its ancillary industries contribute up to 80% of the waste released into the air water and land every day. The practice of sustainable chemistry also known as green chemistry is the only antidote to address the myriads of problems threatening the future shape of our environment. The effect of greenhouse emissions of CO_2 arising from the intensive burning of fuels in the various automobiles on the roads, the accumulation and non biodegradable nature of the various fertilizers and pesticide in use for agriculture, the direct discharge, dumping of toxic chemicals and wastes into the ecosystem and the food chain, and the non regulatory nature on the use of the various chemicals in our research, teaching and industrial laboratories.

Introduction

Sustainable development is often defined as "the development that meets the needs of the present, without compromising the ability of future generations to meet their own needs" (1).

Sustainable development is the major discussion on the world stage today. To this end, the world body, United Nations Educational Scientific and Cultural Organization (UNESCO) has declared 2005-2015 as the world decade of education for sustainable development(2).

An intrinsic part of the United Nations Millennium goals is to ensure environmental sustainability and one of the targets is to integrate the principles of sustainable development into the policy of every country around the world (3).

Chemistry is not just the central science. Every sphere of human life and development depend so much on the advances in this field. From the food we eat, the water we drink, the clothes we wear, shelter, agriculture transportation (land, rail, water and air) to our daily energy needs (fuels), the results of various researches in chemistry have impacted virtually every part of the world today.

We live in world where we cannot do without the use and applications of chemicals in its various forms. Chemicals usually have health and safety implications. In Nigeria, up to 80% of the waste released into the air, water and land every day comes from the chemical and its ancillary industries. One major objective of sustainable development is environmental sustainability. It is high time the nation keep up with the best practices of green chemistry to ensure a better future.

Green Chemistry and sustainable development

Green Chemistry has always been an intrinsic part of chemistry research. For instance, in the industrial production of soda ash, the Leblanc process developed in the 1800's results in giving up of toxic hydrogen chloride as its bye product

$2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HCl$

A much improved procedure called the Solvay process developed in 1860, employed a much cheaper and naturally starting material to give a non toxic calcium chloride as bye product

$2\ NaCl + CaCO_3 \rightarrow Na_2CO_3 + CaCl_2$

Since the publication of the book "Silent Spring" by Rachael Carson in 1962, there has been a continued interest on the subject of environmental sustainability(4). This has led to sensitization on the need to protect the environment, enactment of environmental laws, regulations, statues, enforcement as regards restrictions on chemical usage and introduction of incentives to find replacement for unsafe chemicals.

Green Chemistry gained its current standing as a scientific discipline as well as practical means to pollution prevention as the result of collaboration between the US government, industry, and academia(5).

Green Chemistry, also known as sustainable chemistry is a philosophy of chemistry aimed at usage of chemical products and processes in such a way that it eliminates the use or generation of hazardous substances from its design, manufacture and use.

Green Chemistry Research Initiatives around the World (6)

Since the advent of Green Chemistry as a research field it is pertinent to note many organizations devoted to research in this

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area have been formed around the world notable among whom are:

❖Carnegie Mellon University Institute for Green Oxidation Chemistry (USA)
❖Centre for Green Chemistry University of Monash (Australia)
❖Centre for Green Manufacturing University of Alabama (USA)
❖Center for Sustainable and Green Chemistry (Denmark)
❖Chemical Process Engineering Research Institute Centre for Research & Technology (Greece)
❖Göteborg University's Centre for Environment and Sustainability (Sweden)
❖Green Chemistry Centre of Excellence at York (UK)
❖Green Chemistry Network Centre (Delhi Univ., India)
❖Greek network of Green Chemistry (Greece)
❖Institute of Applied Catalysis A research network for catalysis (UK)
❖Institute for a Sustainable Environment University of Oregon (USA)
❖NSF Science and Technology Center for Environmentally Responsible Solvents and
❖Processes University of North Carolina; Chapel Hill (USA)
❖Queen's University Ionic Liquid Laboratories (QUILL) Queen's University of Belfast (UK)
❖The Clean Technology Research Group University of Nottingham (UK)
❖University of Leicester Leicester Green Chemistry Group (UK)
❖University of Leeds Leeds Cleaner Synthesis Group (UK)
❖University of Notre Dame Energy Centre (Indiana, USA)
❖Interuniversity National Consortium "Chemistry for the Environment" (Italy)
❖Green Chemistry Network (UK)
❖Green & Sustainable Chemistry Network (Japan)
❖Environment Protection Agency
The US EPA's Green Chemistry Program (USA)
❖Green Chemistry Institute (USA)
❖Canadian Green Chemistry Network
❖European Association for Chemical and Molecular Science (EuCheMS) WP on Green and Sustainable Chemistry

Iupac And Oecd Events Related To Green/Sustainable Chemistry

The global body on issues relating to Chemistry as a subject, International Union of Pure and Applied Chemistry (IUPAC) and an organisation that helps governments in tackling economic, social and governance challenges, Organisation for Economic Cooperation and Development (OECD) have been in the forefront in organizing workshops related to green chemistry some of which are:

❖Synthetic Pathways and Processes in Green Chemistry (Seoul, Korea, August 1996)
❖International Conference on "Challenging Perspectives on Green Chemistry", Venice, Italy, September 1997 (sponsored by IUPAC)
❖ OECD Workshop on Sustainable Chemistry (Venice, Italy, October 1998)
❖Meeting of the IUPAC Working Party on Synthetic Pathways and Processes in Green Chemistry (Venice, Italy, October 1998)
❖ OECD International Meeting on Sustainable Chemistry R&D and Education (Rome, Italy, March 2000)
❖IUPAC ICOS 13 (Mini Symposium on Green Organic Synthesis), Warsaw, Poland, July 1-5 2000
❖ Special Topic Issue and Symposium-in-Print on Green Chemistry (Pure and AppliedChemistry, July 2000)
❖ OECD Workshop on Research and Development in the Context of Sustainable Chemistry (Tokyo, Japan, October 2000)
❖Institution of the Sub-committee on Green Chemistry within the Commission III.2 of IUPAC Division III (December 2000)
❖IUPAC International Symposium on Green Chemistry, Delhi, India, January 10-13, 2001 IUPAC CHEMRAWN XIV, World Conference on Green Chemistry, Boulder, Colorado, June 9-13, 2001
❖ IUPAC 38th Congress (Environmental Chemistry and the Greening of Industry),Brisbane, Australia, July 1-6, 2001;
❖IUPAC Committee on Teaching of Chemistry, Satellite Conference, Brisbane Australia July 1st 2001
❖1st IUPAC International Conference on Green Chemistry September 10-15 2006 Dresden Germany
❖2nd IUPAC International Conference on Green Chemistry September 14-20 2008 Moscow Russia
❖3rd IUPAC International Conference on Green Chemistry August 15-18 2010

To underscore the importance of Green Chemistry, The International Union of Pure and Applied Chemistry, formed a special subcommittee on Green Chemistry. Since that time, a lot of activity has been going on in the developed world in the field of Green chemistry.

Principles of Green Chemistry

Paul Anastas and John C Warner in their book Theory and Principles of green Chemistry developed the twelve principles of green Chemistry (7

1. PREVENTION: It is better to prevent waste than to clean up waste after it is formed
2. ATOM ECONOMY: Synthetic methods should be designed wherever possible to incorporate all starting materials and intermediates into the final product
3. LESS HARZADOUS CHEMICAL SYNTHESIS: Synthetic methodology and pathways should be designed in such a way that will generate substances that is minimally or non toxic to human health and the environment
4. DESIGNING SAFER CHEMICALS: Chemical products should be designed to preserve efficiency of function and at the same time reducing toxicity
5. SAFER SOLVENTS AND AUXILLARIES: The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.
6. DESIGN FOR ENERGY EFFICIENCY: Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure
7. USE OF RENEWABLE FEEDSTOCKS:A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable
8. REDUCE DERIVATIVES- Unnecessary derivatization (blocking group, protection/ deprotection, temporary modification) should be avoided whenever possible
9. CATALYSIS:Catalytic reagents (as selective as possible) are superior to stoichiometric reagents
10. DESIGN FOR DEGRADATION: 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.

11. REAL TIME ANALYSIS FOR POLLUTION PREVENTION: Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.
12. INHERENTLY SAFER CHEMISTRY FOR ACCIDENT PREVENTION: Substances and the form of a substance used in a chemical process should be chosen to minimize potential for chemical accidents, including releases, explosions, and fires.

Green Chemistry In Africa

The first green chemistry workshop in Africa was held in Ethiopia, North Africa and was jointly organized by the Schools of Chemistry of both Addis Ababa University (AAU) and the University of Nottingham (UoN) in association with Chemical Society of Ethiopia (CSE). The objectives were firstly to create awareness among academics and professionals in the country, and, secondly to sensitize the policy makers to the role of green chemistry in environmental sustainability. Much current research is focused on the search for renewable feedstock and more environmentally acceptable solvents as replacements for petroleum-based products. This makes Green Chemistry particularly relevant to the needs of African countries such as Ethiopia, faced with an increasing demand for chemicals, little or no indigenous oil, and rapidly expanding populations (8).

The 1st PACN Green Chemistry congress also held in 2010 in Ethiopia

A pan African Green Chemistry workshop was later held in South Africa in 2007. As a result of this, a group of researchers in South Africa have studied the chemistry of coordination compounds in solvent free medium and ionic liquids in order to avoid the traditional volatile organic solvents which are considered as carcinogens. (9-11)

The first workshop on green chemistry in Nigeria was held in 2008 and in 2009 the chemical Society of Nigeria held its annual conference in Abeokuta Nigeria with Green Chemistry as the major theme. Consequent upon this, application of green chemistry is already being explored though at its infancy stage (12-13)

Case For A Strong Green Chemistry Initiative In Nigeria

Compared to developed nations of the world and other parts of the Africa and judging from the fact that Nigeria is a large market for chemicals and toxic technology in the continent, it is sad to note that there is yet to be a strong initiative and infrastructure in place to develop green chemistry in Nigeria.

Though the country may not yet be strong in the manufacturing sector yet there is no gainsaying the fact as end users and major consumers of various state of the art and moribund technologies made from chemicals, there is an urgent need to put up measures for a sustainable environment after the usage and consumption of all our chemically related technologies.

The "dirty dozen" and the "nasty nine"

The Stockholm Convention initiated in 2004 is a global treaty to protect human health and the environment from highly toxic Persistent Organic Pollutants (POPs). POPs circulate for years and sometimes decades before degrading and have been known to cause cancers, birth defects and impact immune development, and reproductive systems, etc amongst animals and humans (14).

The goal of the convention is to restrict and eventually phase out the production, use, trade, release and storage of these toxic chemicals.

The dirty dozen (Aldrin, Chlordane, Dichlor-Diphenyl-Trichloroethane (DDT), Dieldrin, Dioxins, Endrin, Furans, Heptachlor, Hexachlorobenzene, Mirex, Polychlorinated Biphenyls, Toxaphene) and the nasty nine(Pentabromodiphenyl ether, Octabromodiphenyl ether, Chlordecone, Lindane, Alpha-hexachlorocyclohexane, Beta-hexachlorocyclohexane, Perflourooctane sulfonic acid, Hexabromobiphenyl and Pentachlorobenzene) are terms coined for agricultural chemicals found to have serious environmental and health implications.
Most of the aforementioned chemicals are still in wide use in Nigeria.

Green Chemistry and Agriculture

It is becoming clearer by the day that a lot of chemicals routinely used in agriculture are associated with alarming health and environmental implications. Traditional farming practices leave unwanted chemicals as pollutants in the air, soil, water and air arising from pesticides and pesticide residues.
Green Chemists are tackling the challenge of removing pollutants without, in the process, creating more toxic waste. For example, Green Chemists at Carnegie Mellon University have developed TAML® catalysts that can be safely used to remove specific chemicals, and pesticide residues (including atrazine and alachlor), from water(15).

Green chemistry alternatives are vital to sustainably producing agricultural goods without continued dependence on toxic pesticides and chemicals of concern in the soil. New pesticides are being designed and produced that can be more benign and/or more targeted. Biopesticides- derived from plant or microbial "pesticides" - is an area in which there is a lot of movement and potential for Green Chemistry to supplant certain chemicals of concern (15).

In Nigeria, there is the need to reduce or totally remove non biodegradable pesticides residues from the environment.

Green Chemistry and Environmental waste

The huge volume and potential value of e-waste trade has created opportunities for abuse. Attempts to address the export of hazardous waste have been on the books for decades. The most significant initiative is the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal. Negotiated in 1989, the agreement came into effect in 1992. It aims to stop the illegal export and trade of hazardous waste, often shipped from wealthy nations to less developed ones(16)

Nigeria, in the world today, is one the highest consumer of electronic products especially computer and all its accessories. The country is reputed to be one of the biggest markets of mobile cell phones. As a result of this, most electronic products eventually get imported to the country most as second hand products, which are almost reaching the end of their life span, gets discarded and end up in landfills and incinerators across the country (17,18). The production of electronics involves the use of heavy metals and certain chemicals that do not easily break down. As a result, they can persist or remain in both the environment and our bodies for a long time. About 40% of the heavy metals, including lead, mercury and cadmium, in landfills come from electronic equipment discards.

Recycling and reusing e-waste poses special challenges. For instance, when toxic materials are attached to non-toxic materials it's more difficult to safely disassemble and recycle these items. Despite attempts to legislate a solution, there is a large, illegal trade in shipments of e-waste to developing countries like China, India, Pakistan and parts of Africa

including Nigeria. This is driven in part by the valuable metals found in many electronics. For instance, almost 20 per cent of the weight of a cell phone consists of copper, a metal in great demand and selling at record prices.

The release of waste into our environment has a great cost. One of the far reaching implications is the health hazard it poses to the populace.

Harmful chemicals released from incinerators and leached from landfills contaminate air and groundwater. The burning of plastics at the waste stage releases dioxins and furans, known developmental and reproductive toxins which persist in the environment and concentrate up the food-chain.

The dumping of toxic waste in 1987 in Koko,a Nigerian community by some Italian business with active connivance of their Nigeria accomplices left in its wake casualty with chemical burns, nausea, paralysis, premature births due to toxicity of the dumpsite led to the promulgation of the Harmful Waste Decree 42 of 1988 which facilitated the establishment of the Federal Environmental Protection Agency (FEPA) through Federal Government Decree 58 of 1988. This was the first major attempt on the part of the government to develop an institutional capacity and legislations to address the issue of a sustainable environment. In 1999, another agency, National Environmental Standards and Regulations Enforcement Agency (NESREA) was also established to enforce environmental laws, standard and regulations.

The handling and use and disposal of chemicals in our teaching and industrial laboratories and other places without a recourse to material safety and data sheet (MSDS) is tantamount to abuse and misuse of chemicals which of course leave untold and unmitigated effect on the environment. Also there is no regulation and enforcement guiding transportation of dangerous goods and chemicals in the country.

Green Chemistry and Global Climate Change

Ozone layer depletion is a major environmental issue of global significance today. It has been suggested that ozone depleting substances should be guarded against in Nigeria to limit the production of ground ozone which is the bad ozone (19). The ozone depletion process begins when CFCs (used in refrigerator and air conditioners) and other ozone-depleting substances (ODS) are emitted into the atmosphere. The ozone layer, in the stratosphere acts as an efficient filter for harmful solar Ultraviolet B (UV-B) rays. Winds efficiently mix and evenly distribute the ODS in the troposphere. These ODS compounds do not dissolve in rain, are extremely stable, and have a long life span. After several years, they reach the stratosphere by diffusion and so destroying the ozone. This forms an ordinary oxygen molecule (O_2) and a chlorine monoxide (ClO) molecule. Then a free oxygen** atom breaks up the chlorine monoxide. The chlorine is free to repeat the process of destroying more ozone molecules. A single CFC molecule can destroy 100,000 ozone molecules!

$CFCl_3 + UV\ Light \Longrightarrow CFCl_2 + Cl$

$Cl + O_3 \Longrightarrow ClO + O_2$

$ClO + O \Longrightarrow Cl + O_2$

The free chlorine atom is then free to attack another ozone molecule

$Cl + O_3 \Longrightarrow ClO + O_2$

$ClO + O \Longrightarrow Cl + O_2$

and again ...

$Cl + O_3 \Longrightarrow ClO + O_2$

$ClO + O \Longrightarrow Cl + O_2$

and again... for thousands of times.

It is hoped that by the year 2015, the use of ozone depleting gases, such as CFCs, will be phased out in developing countries. What arrangement is being made in Nigeria to deal with this problem?

The fact that the concentration of greenhouse gases in the atmosphere are increasing has elicited global concern and some preliminary research is being done in Nigeria (20).The key greenhouse gases (GHG) causing global warming is carbon dioxide. CFC's, even though they exist in very small quantities, are significant contributors to global warming. Carbon dioxide, one of the most prevalent greenhouse gases in the atmosphere is released to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), and wood and wood products are burned. Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from the decomposition of organic wastes in municipal solid waste landfills, and the raising of livestock. Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of solid waste and fossil fuels.

Very powerful greenhouse gases that are not naturally occurring include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6), which are generated in a variety of industrial processes.

n June 1992, the "United Nations Framework Convention on Climate Change" (UNFCCC) was signed in Rio de Janeiro by over 150 nations. The climate convention is the base for international co-operation within the climate change area. In the convention the climate problem's seriousness is stressed. There is a concern that human activities are enhancing the natural greenhouse effect, which can have serious consequences on human settlements and ecosystems.

Conclusion

It is imperative a strong green chemistry initiative is inaugurated which will link the academia with the industry with a view of curtailing the effect of dangerous chemicals on the environment and future sustainability.

Apart from various legislations already in place, emphasis should also be placed on regulation of chemicals, safe usage, hazard evaluation, handling, transportation of dangerous chemicals, health and safety education of the various chemicals in use in the laboratory, industry and in the marketplace.

The Government at various levels as well as local interest groups must ensure that we keep up with the best practices of green chemistry obtainable in other parts of the world. The use of toxic chemicals and adoption of toxic technology should be discouraged by all means.

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