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21st INAUGURAL LECTURE

Solid Waste Revolution: *The Artificial Intelligence Towards Smart, Sustainable and Safe Cities*

KOLAWOLE O. AJANAKU

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Protocol

The Chancellor, Chair, Board of Regents Sir; Vice-Chancellor, Deputy Vice-Chancellor, Registrar and other Principal Officers of Covenant University; Dean, College of Science & Technology, Deans of other Colleges present, Directors, Professors and other members of Senate; Head, Department of Chemistry, Heads of other Departments, Learned Colleagues, Administrative and Technical staff of the University, Members of my family both nuclear and extended, Beloved Kings and Queens in Hebron, Gentlemen of the Press, Distinguished ladies and Gentlemen.

"Let them shout for joy, and be glad, that favour my righteous cause: yea, let them say continually, Let the Lord be magnified, which hath pleasure in the prosperity of his servant" – Psalm 35:27 King James Version.

Chancellor Sir, my heart feels strongly delighted and my mouth shouts for joy to the Almighty God for the privilege I have today to stand before this distinguished audience to deliver the 21st Inaugural Lecture of Covenant. This is indeed the Lord's doing and it is marvelous in my eyes. This is the first inaugural from the Department of Chemistry, where I was privileged to have served as Head of Department during 2010/2011; 2013-2015 sessions. In August 2015, I was announced a full Professor which now makes me the first Professor of Industrial Chemistry of Covenant. This lecture is also the seventh from the College of Science & Technology, where by divine election I also served as the Dean from 2017-2019. I am also glad to be the first to present Inaugural Lecture after the Times Higher Education announcement of Covenant entering the 400 - 500 bracket of world University. What a privilege to also say that this is also the first in the entire history of Ajanaku's family. To God be all the glory!

In the course of this lecture, I will be sharing today, some of my contributions in the field of my chosen research endeavour, Industrial

Chemistry. I will also communicate how I was able to navigate from basic sciences to applied research that made me relevant in food chemistry and material research today. Kindly sit back and enjoy the story of my academic discoveries.

1. INTRODUCTION

My aspiration during my postgraduate study was how to solve various emanating problems in this country as they related to the then Millennium Development Goals (MDGs) in year 2002. I discovered that most of the challenging issues we had then had solutions in science, hence we needed to apply scientific knowledge for solutions to the issues. When the MDGs were reviewed and adopted in 2015 to a 17-set parameters, my interest was keen on Goal 12 - "*Responsible consumption and production*" which implies using ecofriendly production and reduction of wastes. I believe strongly that this parameter can positively affect lot of other goals in achieving a sustainable environment.

A major issue in Nigeria then and now is waste management. This has been a global issue and if other countries were able to create solutions to their waste management problems, I see no reason why we should not be able to bring solutions to ours. One major fact globally is that we all generate waste every day; and it is sad to know that we are not ready to bear the pain of managing these wastes resourcefully. I remember a Yoruba adage and illustration that goes this way "*Igbe l'owo wa*" i.e "There is much resource in waste material". This had been my motivation and set out goal during my Master's programme to create/produce valuable materials from waste materials hence my research was titled "*Extraction of valuable materials from Solid Wastes*". Distinguished listeners, the focus of my research centers on solid waste management even though there are other types that create environmental issues.

What is Waste?

Waste is any substance which is discarded after primary use, or is worthless, defective and of no use and can be seen as an act or instance of using or expending something carelessly, extravagantly, or to no purpose. The World Health Organisation describes waste as something which the owner no longer wants at a given time and place and which has no current or perceived market value (WHO, 2004).

T*he United Nations Statistics Division (UNSD)* considers wastes as materials that are not prime products (that is, products produced for the market for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose). Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded.

What then is my perspective of waste? I got my definition in the scripture (Matthew 14:14-21) on "The feeding of the Five Thousand". In verse 20, they took up the twelve baskets full of the fragments that remained. Hence, I can define waste as "*take care of these fragments and see what we can use them for*". Chancellor Sir, this will be the focus in my presentation today.

Solid Waste

Solid waste can be seen as unwanted material that is not discharged through a pipe. Thus, solid waste may include garbage, street sweepings and materials of many kinds from commercial and industrial enterprises. It also consists of particulate matter discharged into the atmosphere. The term 'solid waste' can be used to cover domestic, commercial and industrial wastes. Solid wastes are diverse in nature but could be classified as putrescible, non-hazardous and hazardous. This also includes both the non-hazardous and hazardous sludges. Hazardous waste can be toxic, infectious or carcinogenic. A number of chemical and biological solid wastes are hazardous. It is a known fact that 20 to 30 percent of about 32 million of wastes generated in Nigeria are always collected and dumped in landfill sites leading to serious concerns in waste management. If urgent actions are not taken, the entire global picture of waste generation will increase by 70% on the current level by year 2050 (Schrader-King and Liu, 2018).

Figure 1: Dumped unsorted (a) and sorted (b) solid waste collection system
Source: 2009 - 2019 SmartRanger

Sources of solid waste
Solid waste can be generated from any of the following sources:

Table 1: Sources and types of solid wastes

Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, wood, glass, metals, special wastes
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants.	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes.
Commercial/ Institutional	Stores, hotel s, restaurants, markets, office buildings, government centres etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes.
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings.	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants.	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge.
Process (manufacturing, etc.)	Heavy and light manufacturing, refineries, chemical plants, breweries, power plants, mineral extraction and processing.	Industrial process wastes, scrap materials, off-specification products, tailings.
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms.	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides).

Types of Waste

There are different types of waste depending on the source of generation.

Municipal Waste

Municipal waste is generated by households, commercial activities and other sources whose activities are similar to those of households and commercial enterprises. This does not include other wastes arising from mining, industrial or construction and demolition processes. Municipal waste is made up of residual waste, bulky waste, secondary materials from separate collection (e.g., paper and glass), household hazardous waste, street sweepings and litter collections (OECD, 2019). It is made up of materials such as paper, cardboard, metals, textiles, organics (food and garden waste) and wood. Municipal waste constitutes about 35%, while the organic material constitutes about 25% of waste fraction (Introduction to waste, 2019). Municipal waste can be biodegradable meaning they are capable of undergoing biological decomposition. Approximately 60% of municipal waste is biodegradable and a range of options are used to treat biodegradable municipal waste (Anne, 2007). The disposal means for municipal waste has usually been landfilling which is the predominant management option in most countries. However, significant steps have been taken by some countries by utilizing alternatives, such as incineration, composting and recycling apart from landfill methods. With these options, the potential impacts common with landfilling solid waste such as leachates, odours etc would have been taken care of, hence the reduction in the proportion of municipal waste consigned to landfill.

Figure 2:
Huge pile of municipal waste
Source: Shutterstock

Construction and Demolition Waste

Construction and demolition waste make up to approximately 25% of all wastes generated, with a large proportion arising from the demolition and renovation of old buildings. It is made up of numerous materials including concrete, bricks, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. They find their way into nearby bins making them heavy. They also degrade the quality of municipal waste making it difficult for further treatment of composting. About 10 – 20% of construction and demolition waste find its way into surface drains thereby choking them (Markandeya and Kameswari, 2015). Construction and demolition waste can be used as a resource for recycling and can easily be used within the construction industry. Such waste from construction and demolition source has been identified as a priority waste stream by creating measures for recycling of such materials, otherwise, it can use up valuable space in landfills due to the very large volume of the waste produced.

Packaging waste

Packaging is defined as any material which is used to contain, protect, handle, deliver and present any finished good. Items like glass bottles, plastic containers, aluminium cans, food wrappers, timber pallets and drums are all classified as packaging. Packaging waste can arise from a wide range of sources including supermarkets, retail outlets, manufacturing industries, households, hotels, hospitals, restaurants and transport companies. For some materials, such as glass, plastics and papers/cardboards, packaging waste represents a high share of the total material wastes, about 70% for glass, 60% for plastics and 40% for paper and cardboard (Adrian, 2007).

Packaging waste also has impacts in the extraction of the raw materials used for the packaging itself coupled with the treatment and disposal on the environment. The development of manufacturing companies has brought about huge generation of packaging waste. It is good to state that whenever we go out for shopping, we should be concerned about how much waste we are bringing home with us. In addition, packaging waste may contain some critical substances like polyvinylchloride and heavy metals which pose great risk to the environment. A deep look at these pictures (Figures 3 and 4) will make us to think well whenever we go out for shopping knowing the time it would take for plastic waste to degrade is about 450 years.

Figure 3: Analysis of waste generation in UK
Source: Composite: Suzanne Lemon/Guardian Design Team

Figure 4: Plastica waste pollution in Ocean
Source: Christian Thompson/EPA showing the extent of plastic waste in Accra, Ghana

Agricultural waste

Agricultural waste is composed of organic wastes and wastes such as plastic, scrap machinery, pesticides, waste oils and veterinary medicines. There are issues of negative environmental impact of unmanaged agricultural waste and all these issues can be solved by strict conditional spreading of the waste on land; utilization of anaerobic digestion and composting just to mention few. If all these steps are not properly followed, there will be tendency to experience a run-off of nutrients to surface waters which can cause over enrichment of the water body (Figure 5). Farming activities can also lead to emission of methane and ammonia gases with high level of acidification and contribution to greenhouse gases emissions.

Figure 5: Dumped Agro-Industry seed waste
Source: FAO of the United Nations

Agricultural waste comprises of animal waste (manure, animal carcasses), food processing waste (only 20% of maize is canned and 80% is waste), crop waste (corn stalks, sugarcane bagasse, drops and culls from fruits and vegetables, prunings) and hazardous and toxic agricultural waste (pesticides, insecticides and herbicides, etc) (Obi *et al.,* 2016).

Industrial waste

Industrial waste comprises many different waste streams arising from a wide range of industrial processes. Some of the largest waste generating industrial sectors include the production of basic metals, food, beverage and tobacco products, wood and wood products, paper and paper products. Wastes from the manufacturing sector continue to rise, despite national and international declarations to reduce waste from manufacturing industry, to introduce cleaner technologies and other waste minimization initiatives and to work towards manufacturing practices that are sustainable in the long term (Greg O'Connor, 2007).

The manufacturing industry has a central role to play in the prevention and reduction of waste as the products that they manufacture today become the wastes of tomorrow. Manufacturers can achieve this by:

considering the impacts of their products throughout their life at the design stage of the product;

using manufacturing processes that minimize material and energy usage;

eliminating or reducing, where possible, the use of substances or materials hazardous to health or the environment; and

manufacturing products in such a way that they last longer and may be recycled or reused at the end-of-life stage.

Hazardous solid waste

A waste is defined as hazardous if it is corrosive, ignitable, reactive or explosive. Furthermore, a waste is defined as toxic if it contributes to death or serious illness or if it poses a substantial hazard to human health or the environment when it is improperly managed. The physical and chemical nature of toxic and hazardous waste vary from one industry to another and even within industry from one establishment to another.

With increasing manufacturing processes, solid, liquid, and/or gaseous emissions generate by-products. Some of these wastes are potentially harmful to human health and environment and thus need special techniques of management (United Nations, 1989). A list of some hazardous characteristics is provided by the United Nations (1989). This was part of the recommendations and codes of identification to follow when transporting dangerous goods as illustrated in Table 2.

Table 2: UN Class number hazardous characteristics

UN Class Number	Hazardous Characteristics
1	Explosive
3, 4	Flammable
5	Oxidizing
6	Poisonous/infectious
7	Radioactive
8	Corrosive
9	Toxic (delayed or chronic)/ecotoxic

Source: United Nations (1989)

2. SOLID WASTE PROBLEMS IN SOME NIGERIAN STATES

The management of waste in Nigeria has become one of the most pressing environmental issues with our growing population exceeding 170 million; it has made the country to be among the most significant waste generators in Africa. The effect of huge waste generation is seen in almost every facet of the system with blockage of drainages thereby leading to flood, erosion, bad roads, holdups and accident, high prices of commodity because there are no good road channels to bring the items to the market place (Figures 6 a-f).

Figure 6a-f: Effects of waste generation to environmental sustainability

Lagos State

The population of Lagos is estimated at about 22 million and is still growing due to ceaseless migration from the inland and the West African suburbs. Lagos is a strong commercial hub with several industrial complexes and ventures by virtue of population with high purchasing power. Over 80 percent of Nigeria's industrial activities on 12 industrial estates are located in Lagos. The major polluters in the city are textile, food processing, electroplating, rubber and plastic, pharmaceutical and chemical and paint facilities. Four of the industrial estates, Ilupeju, Ikeja, Iganmu and Oshodi, contain the majority of large and medium-sized industries. The Apapa industrial estate contains petrochemical, detergent, textile, paper, printing, steel and brewing facilities as well as vehicle workshops, naval shipyards, thermal power plants and a sewage depot. Metal concentrations are lower in the lightly industrialized

Victoria Island area and lowest in shipping quays area.
Various factors have been adjudged as the cause of the crippled performance of local government in waste management. The local government structures are unstable because of the setup, financial allocation, administrative machinery and composition. All these lead to urban management problem. The problems became an international embarrassment during the peak of hosting an International festival of Art and Culture named FESTAC 77 and also during the bidding for hosting of the 2010 world cup. Then, Lagos, the then Federal Capital city, was described as the most dirty capital city in the world. This embarrassment led to the emergency of the first waste management agency in Nigeria established by the Lagos State Military Government on 1st April, 1977. Refuse Disposal Board was formed and it started as a centralized body with stated duties while the state government was wholly responsible for its sustenance. The board commenced operations with Powell Duferen Pollution Control of United Kingdom as managers. The organisation was re-named Lagos State Waste Management Authority (LAWMA), with the mandate to collect and dispose municipal and industrial wastes in the state.

LAWMA operates five landfills for municipal and industrial solid waste disposal. It is a pity to note that none of these landfills is in operation presently. Infact, solid wastes packed from Lagos are usually brought to Ogun State here (Ota precisely) for dumping. There is no sanitary landfill in this country. What a shame! The bulk of the industrial wastes dumped are cotton fibres from textile plants, packing cardboard, tyres and process sludges containing asbestos. In 1991, LAWMA unloaded approximately 105,000 tons of industrial wastes into its landfills. Unlike most developing countries, scientific data are very scanty in Nigeria. The data on waste generation in Lagos is scanty, only estimated data exist. As at 2009, estimation of 9,810,160 tonnes was proposed by Ugwuh (2009).

Rivers State

The petroleum industry is the major industry and the largest polluter in

Rivers State. The medium and large-scale industries are concentrated on the Trans Amadi industrial estate with plastics and rubber, food, manufacturing, metallurgical, pharmaceutical and chemical companies making up the bulk of industries. Oil spills and leakages occur so often resulting in both chronic and acute environmental degradation of surface water and adjacent wetland and mangrove ecosystems. Through road building and site preparation, oil exploration has caused extensive deforestation. The petroleum industry generates most of the heavy tonnages of hazardous waste produced per year in the State (Osae-Addo, 1992).

Localized air pollution problems of particular concern in River State are cement kiln dust, SO_2 from the fertilizer plant, pollutants from the NNPC refinery and gas flaring which emits greenhouse gases leading to increase in global warming. According to the Port Harcourt Environmental Sanitation Authority, neither hazardous nor industrial wastes are separated from municipal solid wastes before disposal in the two municipal waste dumps. Waste management in Port Harcourt is unsatisfactory as there are no proper techniques in place to ensure the orderly executions of the basic principles of waste management. Hence, garbage often litters the streets in some suburbs of the city.

Kano State

The contribution of Kano's very low rainfall, growing population, advancing desertification and industrial pollution seriously threatens Kano's water resources. With about 80 tanneries in the city, Kano is the centre of Nigeria's tanning industry which also contains a large number of rubber and plastics, food, metallurgical and manufacturing industries. Solid wastes from the tanneries emit odours and are an excellent breeding ground for disease vectors. Kano has a low amount of hazardous waste compared to other industrialized states in Nigeria.

Ibadan, Oyo State

Ibadan is much more than a base for companies with multinational interests as many of the incentives that draw large multinational manufacturing companies like British American Tobacco, Coca - Cola, 7up, Nigerian Breweries, Xingda Technical Plastic Company Limited amongst others are equally appealing to local firms, both large and small. There are also Industrial Estates which can support the establishment of small and medium scale enterprises such as textiles, paint, chemicals, food processing, electrical, electronics and plastic industries. The environmental agency was initially using only one landfill site situated in Ring Road area of the city where all the solid waste generated within the city is usually dumped for landfilling. By year 1999, the landfill was closed and a new dumping site was opened at Aba-Eku. This site was turned to an open dumping site, with complaints from the residents. The Oyo State government in December 2008, decided to convert the old Ring Road refuse disposal site in Ibadan to a commercial centre. This is where Shoprite is standing today. Imagine that kind of structure being erected on a landfill.

Enormous quantities of solid waste are generated in Ibadan daily, even though the exact figures are not known, probably owing to the use of diverse methods of calculation. Maclaren International Ltd. found that the average per capita quantity of solid waste generated was 0.37–0.5 kg/day for the traditional areas of the city and 0.53 kg/day for the newer areas. Oluwande (1983) estimated the average solid waste generated and its mean production rates per head for three distinguished areas of Ibadan: 0.420 kg/day in the GRA; 0.377 kg/day in outlying areas; and 0.35 kg/day in the old city.

According to Egunjobi (1986), 38 million kg of solid waste was collected in the suburbs of Ibadan in 1986. The suburbs constitute about 21% of the city. On this basis, it can be estimated that 181 million kg of solid waste was generated in the city as a whole in 1986. This gives a per capita waste-generation rate of 0.31 kg/day, using the 1986 estimated population of 1.6 million for the city. PAI Associates recorded the volume and weight of solid waste generated per household per day in Ibadan. The study revealed that waste generation varied according to land use, with residential land use taking the bulk of the share.

Benin, Edo State

Benin City in Edo State is the site for numerous industrial companies: soft drinks factories, two large breweries (including one of the largest breweries for Guinness Stout), wood and timber processing industries, textile mills, carpet manufacturers, floor tile producers, animal feeds industries, printing and publishing firms and pharmaceutical firms. There is also a State-owned cement company located at Okpella; a marble chip production company at Akoko-Edo while garri mills are also part of the numerous industrial outfits. All of these generate a lot of solid waste which affect the settlement.

The then Nigeria Military Government promulgated a decree stipulating that all small-scale industries be moved out of the city centres to designated locations in the more remote areas or villages. In line with that decree, the then Edo State Government decided to create the small-scale industrial village at Ogbesan, near Benin City, Nigeria. The situation that led to the establishment of a typical small-scale industrial site (Ogbesan), its failure and the current state of the abandoned site clearly indicate that the activities and wastes dumped at the sites adversely affected the ability of soils from the site to support plant growth.

3. WASTE MANAGEMENT STRATEGIES IN SOME CITIES

The waste management techniques in most countries differ. Several indices such as waste type, waste characteristics, economy and available technology influence the choice of waste management technique. Let us have a view of some of the waste management techniques in some cities.

Castellon de la Plana, Spain (Ezechi *et al.,* 2017)

The waste management technique in Castellon de la Plana, Spain is summarized by Bovea *et al.* (2010). The waste composition in Castellon de la Plana, Spain is mainly organic (57%). The household waste collection is carried out through selective collection of waste at materials banks (glass, paper/cardboard and packaging) and street-side collection of the remaining waste. At the sorting plants (glass sorting plant, paper sorting plant and packaging separating plant), the collected waste is separated before recycling. The other waste categories are compacted at a transfer station (TS) and transported to the material recovery facility (MRF). The organic portion of the waste is composted whereas the remaining waste is recycled. The non-recyclables are then compacted in bales and disposed in a landfill without energy recovery.

Chennai, India

The MSW generation and management in Chennai, India is summarized by Jha *et al.* (2008). The common management technique in India is landfilling (70–90% open dumpsites). Composting of a small fraction of the waste has been conducted in Delhi and Mumbai. The MSW generated from Chennai originates from residential, commercial, restaurant and industrial activities in the following proportion: 68%, 14%, 12% and 2%, respectively. Healthcare wastes are disposed separately. There are two landfills in Chennai which are Kodungaiyur (KDG) and Perungudi (PGD) landfills and these were utilized in disposing the waste of the city by zoning.

Palm Beach County, FL

The MSW management in Palm Beach County, FL is summarized by Weitz *et al.* (2002). In the United States, MSW collection, transportation, recycling, composting, combustion and landfilling are well organized through sound technological advancements. In Palm Beach County, FL, several waste management facilities such as refuse derived fuel processing facility, ferrous processing facility, a material recovery facility and a co-composting facility are available to manage and convert the waste into useful end products. The sequence of waste management is recycling, composting and landfilling.

Berlin, Germany

The MSW management in Berlin, Germany is summarized by Zhang *et al.* (2010). In Berlin, the waste management techniques are incineration and landfilling. The implementations of the 3Rs (reduce, reuse and recycle) significantly contributed to the success of MSW management in Germany. The improvement in the sorting and recycling of recyclable waste positively impacted the waste management sector. Some waste categories were prohibited from disposal into landfills. For instance, landfilling of untreated waste with high organic content was prohibited since June 2001 by the waste disposal act which specifically refers to domestic waste in Germany. As a consequence, several landfill sites were closed in Germany. The number of landfills reduced from 50,000 in 1970s to 333 in 2000. At present, there are only about 160 landfill sites still in operation nationwide and in Berlin, there are currently three landfill sites. This is because methane emissions from landfills in Germany have previously accounted for about 25% of total methane emissions. However, incineration of waste have increased in Germany from 7 incinerators with a capacity of 718,000 tonnes/y in 1965 to 72 incinerators with a capacity of 17,800,000 tonnes/y in 2007.

4. THE PROBLEM OF SOLID WASTE DISPOSAL

The problem of waste disposal is not unique. In many parts of the world, people are facing a serious solid waste disposal problem. The problem results because we are producing too much waste, and there is too little acceptable space for permanent disposal. Land used for landfills is minute compared to the land area in the settlement. Rather, existing sites are being filled and it is difficult to site new landfills. Another major limiting factor is the cost of disposal.

To some people, a perfect system for waste disposal would be a technology that is capable of accepting an unlimited amount of waste and safely containing it forever outside the sphere of human life. This is an impossible dream and is not environmentally comprehensive. The environmentally preferable concept with respect to waste management is to consider waste as resources out of place. Although we may not be able to reuse and recycle all wastes, it seems apparent that the increasing cost of raw materials, energy, transportation, and land will make it financially feasible to reuse and recycle more of the resources. Moving toward this objective is moving toward a view that there is really no such thing as waste, they are only resources. Under this concept, waste would not exist, because it would not be produced or, if produced, would be a resource to be used again. This is sometimes termed industrial ecology in

which our industrial society would function more like an ecological system where waste from one part of the system would be a resource for another part.
There is the growing awareness in many of our waste management programmes which simply involve moving waste from one site to another and not really managing it. For example, waste from urban areas may be placed in landfills, but eventually these may cause new problems if they produce methane gas or noxious liquids that leak from the site and contaminate the surrounding areas but if managed properly, however, methane produced from landfills is a resource that may be burned as a fuel. This gives a typical example of what takes place in industrial ecology. A concept of this emerging development is known as Integrated Waste Management (IWM), which is best defined as a set of management alternatives including reuse, source reduction, recycling, composting, landfill, and incineration in order to combat the waste disposal problem globally (Ibimilua and Ibimilua, 2014).

5. CASE STUDY OF INDUSTRIES

Several manufacturing industries generate a lot of by-products which are either not properly treated or neutralized. In Nigeria, some of the industries generating solid wastes are pulp and paper, food, breweries and pharmaceuticals.

Brewery Wastes

In brewery industries, a number of by-products are obtained from their manufacturing processes, amongst which are spent grains, surplus yeast, malt sprouts, broken bottles/cullet, effluent, carbon dioxide and wastewater. Table 3 shows a typical solid waste generation at brewery (Henry and Richard, 2009).

Table 3: Solid waste generation in Breweries

S/N	Solid output/waste	Mode of disposal
1.	Sweeping waste e. g cobs, stones and other foreign material	Solid disposal

S/N	Solid output/waste	Mode of disposal
2.	Spent grains /Spent yeast/Trub	Conveyed to silo for wet sale to the public. Dried and sold in bags. Added to the spent grains.
3.	Treatment sludge	Effluent.
4.	Broken bottles/Cullet	Collection by waste Board on contract/sales to glass factory.
5.	Kieselguhr	Effluent.
6.	Crown corks	Waste disposal.
7.	Paper pulp	Waste disposal.
8.	Cartoon rejects	Burning/Sales.
9.	Paper trays	Sales

Beer production process consists of the key stages of malting, milling, mashing, extract separation, hop addition and removal, fermentation, separation of the yeast from the beer, maturing, filtration and packaging (Figure 7).

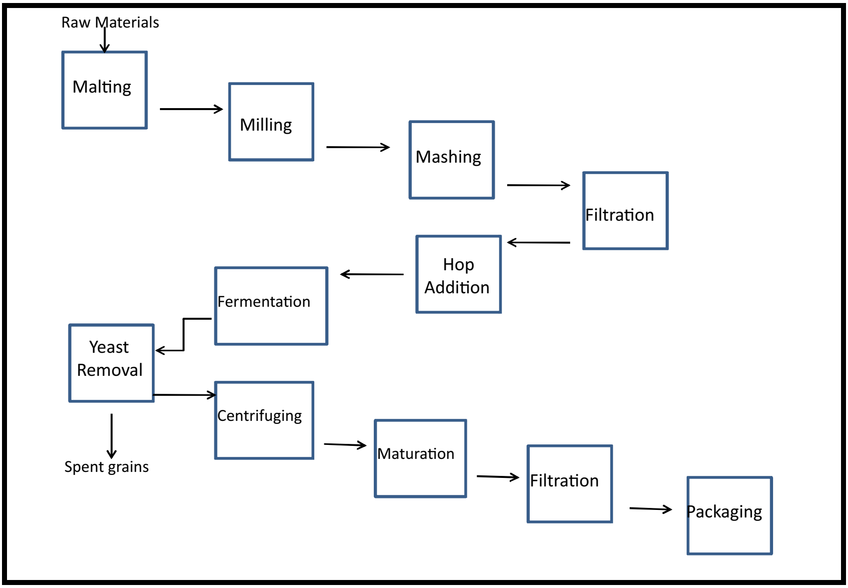

Figure 7: Process Flow Chart for Spent Grains Generation
Source: Ajanaku, 2009

In the mashing stage of brewing, the cereals are mixed with water to facilitate enzymatic conversion of starch to fermentable sugar. The major constituents of the brew are malt and a carbohydrate adjunct such as corn grit or rice. After filtering the mash, the residue obtained contains mainly husk, bran and embryo of malted barley kernels. It also contains corn bran in a case where corn is used as adjunct and the residue is called Brewery Spent Grains (BSG). Brewery Spent Grains can also include yeast and trub which is the precipitate extracted during the hop boiling and is added to the grains. It contains proteins, phenolic compounds and lipids that are precipitated during the boiling process in brewing. The spent grains, after washing are pressed to remove some of the water and soluble solids and are then dried in a grain dryer.

The effects of brewery effluents disposal on public water bodies in Nigeria has been described (Dawodu and Ajanaku, 2008). Although BSG is the main byproduct of the brewing industry, it has received little attention as a marketable commodity. Its disposal is often a problem and it is used primarily as an animal feed; it may be more profitable, however, as an ingredient in human food products because of its protein and high dietary fibre content. The work, therefore, forms part of continuous study to explore the blending of BSG into food ingredient as potential source of protein and fibre enrichment applications in food and other confectioneries. It is also to examine acceptable blends with a threshold limit that is not harmful to humans thereby handling the problem of protein deficiency in humans.

My academic contribution in solving brewery waste

Chancellor Sir, as shown in Table 3, I already highlighted two by-products from the process of the company which awakened my keen interest of conversion, namely spent grain obtained after the process and the waste glasses called cullet. With a broad view of solid waste generation in industries and the accompanying negative effects of un-utilization of these generated wastes on the environment and potential health risks to both humans and animals, there is need to explore the conversion methods, which I refer to as “revolution”, taking brewery as a case study, through which these solid wastes, Brewery Spent Grain (BSG) and Cullet (broken glass) could be effectively utilized. An environmental friendly approach is required to achieve this goal which will eventually be in accordance with the zero emission goals that utilize a scientific approach to a useful product.

What then do we use these spent grains for?
Brewery spent grain is the main byproduct of the brewing industry and has received little attention as a marketable commodity. It is a barley fibre source with high dietary fibre content (Robert, 1996). It consists mainly of husk, bran and embryo residual of the barley kernel. Our thinking then was that BSG could be useful for increasing both dietary fibre and protein in human nutrition through the use of this material in some formulated foods. Dietary fibre has been a popular subject with nutritionists in recent years and now having BSG as a source of dietary fibre for humans, and its effects on serum lipids and fecal sterol excretion in ileostomy subjects became the interest. The waste product is usually dumped at landfills and this always results in environmental issue if not properly managed. It is also used as high protein supplements in farms and mainly used as an animal feed because it contains 26-30% protein, hence it can hardly be considered as spent.

Sir, the growing interest in the use of Brewery Spent Grains in human foods and meat products, was initiated by Ozturk *et al.* (2002) by using it with soy lecithin as a surfactant and conditioner in doughing process. This type of modified dough system accommodated up to 40% of Brewery Spent Grains in blends and the panel acceptability of the products was limited to a maximum of 15% BSG, because of an undesirable flavour imparted by the supplement.
Valentina and Paul (2008) studied a number of nutritional and textural properties of bread by incorporating spent grains into wheat flour together with a range of different enzymes and evaluated the bread quality.

My academic contributions in human foods

Chancellor Sir, the effect and performance of using brewery spent grain in formulating diet for Donryu rats was investigated in our published articles (Dawodu and Ajanaku, 2008; Ajanaku *et al.,* 2011). We used rats because they also have the same digestive system as humans. The rats were allocated into 6 dietary treatment groups of 6 rats each and fed with diet containing graded levels of BSG 0, 3, 6, 9, 12 and 100%. The experimental feeding lasted for fifteen days. The BSG formulated diet was found to have a positive effect on the growth performance of the rats up to levels of 12% including the control. This study established that 3 and 6% BSG could be used as protein supplement in human foods with 9% BSG as the maximum limit. In the light of the above, BSG formulated diet in the 3-9% is a good supplement to human foods as well as to animal feed. Therefore, BSG disposal as industrial wastes into the Nigerian ecosystems, would be reduced to the minimum bearable if not completely eliminated; an important advantage in developing economies. The histopathological evaluation showed that 3–9% BSG could be used as protein supplement in human foods. The use of BSG as food supplement would also help to reduce the number of people suffering from micronutrient deficiency related diseases in developing nations.

Afterwards, the inclusion of the spent grains was carried out by blending with flour in cookies and bread making process. This increased the protein content of the product hence producing protein cookies/bread from the waste materials. The microbial load and toxicology level were also determined. The amino acid content of the spent grains was compared with wheat flour. The overall result showed that fine grain size (0.61 mm) of BSG had the same total amino content with the golden penny flour which was employed for the blending as at the time of the research. This justifies the surface area principle that is needed for quality blending of the materials. The physical and sensory evaluation values of the supplemented product were adjudged acceptable. The spread ratio of supplemented product decreased significantly ($p \leq 0.05$) with increasing incorporation levels. The sensory evaluation of the product signified that supplements with 3% spent grains had higher

overall sensory evaluation than those supplemented with 6 to 15% BSG. The 6% value (67.5%) can still be tolerated by virtue of acceptability by the panelist; hence 3-6% BSG acceptance level based on organoleptic evaluation is suitable. However, above 6% addition level the values decreased significantly ($p \leq 0.05$). Brewery spent grain addition affected changes in colour, the intensity of which increased with increasing addition of BSG. These changes were from golden yellow (control) to yellow (3% BSG); brown (6% BSG); dark brown colouration (9-15% BSG). Summarily, the lightness of the cookies decreased as the percentage of BSG addition increased (see Figures 6, 7 and 8). The thickness and the width increased with increased level of BSG blending. The spread ratio decreased in all blends in comparison with the control.
An acceptable limit of 3% inclusion was proposed to enhance quality product. Some trace metals present in the local and imported cookies were compared with BSG supplemented cookies and the results contributed to increase in the Packed Cell Volume (PCV) of the body since iron content has direct relationship with PCV and the haemoglobin content of the body system.

Cookies supplementation using Brewery Spent Grains was suggested in order to improve the dietary nutrition especially in developing countries. Cookies supplemented with 3 and 6% BSG could be seen to possess better cookies properties compared with those supplemented with 9 to 15% BSG. The overall sensory evaluation indicated 3-6% supplementation as the optimum value rated on a par with the control. The trace metals analysis in the BSG supplements further compared favourably with that of locally baked and imported cookies.
Behold the cookies and the bread samples from the so-called wastes from brewery process (Figures 8-10). Indeed, Waste to Protein Cookies.

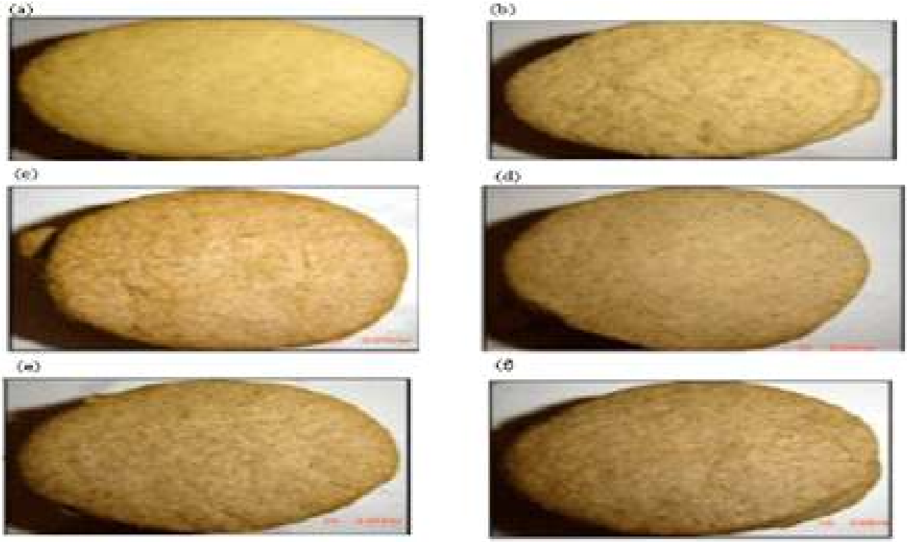

Figure 8: Spent Grains blended cookies (a) Control cookies, (b) 3% BSG blended cookies, (c) 6% BSG blended cookies, (d) 9% BSG blended cookies, (e) 12% BSG blended cookies and (f) 15% blended cookies

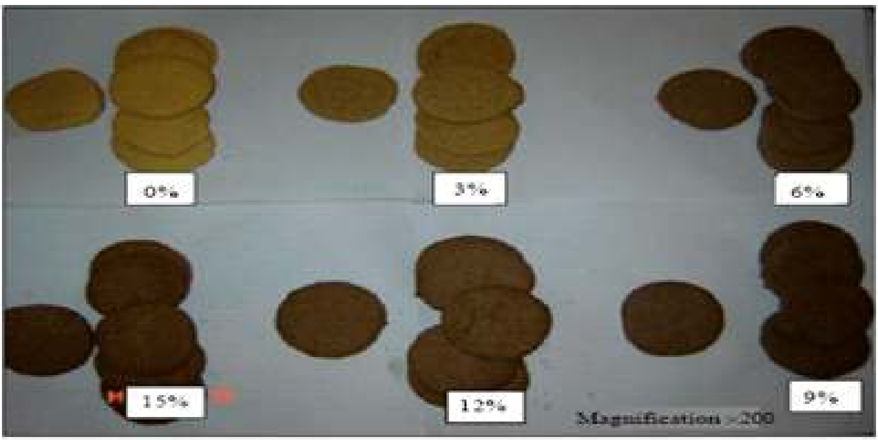

Figure 9: Collective plate of Spent Grains blended cookies

Figure 10: Spent Grains Blended Breads (a) Control, (b) 3% BSG blend, (c) 6% BSG blend, (d) 9% BSG blend, (e) 12% BSG blend, (f) 15% blend

Other contributions in the field of food chemistry

Malnutrition is one of the major concerns to most countries in Africa, and other developing countries where there are shortages in nutritious foods for the young ones. Unexplainably and naturally as the new born baby grows older, the demand for nutrient increases and breast milk alone becomes inadequate to sustain the baby's demand. The deficiency in affordable foods for neonates after weaning has contributed to increased malnutrition rate, illnesses and children's mortality rate. Sequel to this, many mothers began the introduction of other foods such as imported cereal food, for those that can afford while some with financial inadequacy employed fermented cereal food porridge made from the staple. In as much that this watery porridge has very little nutritive value, there is need to improve the nutritive content to help solve two issues: malnutrition and poverty.

In Nigeria, 10% of the world's maternal and mortality rates of children within age of five are attributed to high level of malnutrition. Infants under six months of age suffer most from severe acute malnutrition and this is often associated with higher mortality in infants than older adults. A recent report in Bauchi signposted that mothers are battling to save their severely malnourished kids because of the exhaustion of the stock of Ready to Use Therapeutic Food that is usually administered on children suffering from Severe Acute Malnutrition. Stunting has become one of the diseases that happen to a child's brain when they do not get the right kind of food or nutrients in their first one thousand days of life (Sunday Tribune, August 2019).

Breast feeding a new born baby for a minimum of six months before introduction of supplementary foods to bridge vitamins, iron, protein and energy deficiency is essential since breast milk offers systemic immunity and antigen handling for neonates. As babies grow older, the demand for additional nutrients increases and breast milk alone becomes insufficient. In Nigeria, the first weaning food introduced to children of low-income group is 'Ogi' also known as pap or akamu which is derived from the fermentation of maize, sorghum or millet. This is seen as one of the cheapest and popular foods for weaning neonates and also serves as common breakfast food for adults when taken hot with bean balls (Akara). However, Ogi contains only 1.8% protein, less than 1% fat and 310 kcal/100 g as compared to about 9% of protein and 4% fat in maize. The loss in nutrient is due to the fermentation and sieving processes during the processing technique from maize to Ogi.

Chancellor Sir, I then began the investigation on what to add to Ogi for enrichment to meet the needs of common nursing mothers from homes that cannot afford the cost of prepared Cereals, such as SMA, Cerelac etc as weaning food. This led to introduction of groundnut (fried, roasted and boiled), *Carica papaya*, crayfish at various weight to weight concentrations into Ogi for fortification. Quite a number of tests were carried out after batching process to have the products. Chemical analyses that cover proximate content of the products, functional properties that involve pH, water absorption, titratable acidity, ascorbic content were carried out. Pasting characteristics that involved peak viscosity, setback value, pasting temperature, relative value unit and organolopetic/sensory analysis was used to ascertain the viability of the products. In fact, most of the findings of the research work after being published in Scopus outlets, have become a source of living for two of my students. One (Bisola) has a brand name of her food product as "Abegbes Kitchen" in Lagos and also Theresa, that did her M.Sc with me has seven (7) products (oat flour, beans flour, plantain flour, dried ponmo, stone free ofada rice, fruits and veggies and gizdodo) currently in stores at Ibadan, Ota and Lagos. Food chemistry is the bomb, Sir. Some of the findings are shown below:

Sorghum ogi pawpaw product
Preparation of slurries and the meal
The sorghum grain was cleaned and steeped in 5 litres of tap water for 2 days at room temperature (28 ± 2°C). This was recovered by draining off the steeping water and then wet-milled on a premier mill after which a slurry was prepared. This was soured for 12 hrs and decantation of the supernatant was carried out to obtain sorghum-ogi (a fermented sorghum meal) slurry. In the cause of preparing the pawpaw slurry, the fruits were peeled and blended. The entire mixture was prepared based on already prepared batch composition of 100 g of sorghum-ogi (dry basis) being mixed with 0, 20, 40, 60, 80 and 100 g of pawpaw slurries (dry basis). The slurries were then blended and were allowed to ferment for 2 days at room temperature, after which the supernatant was discarded and the slurry pressed to dryness.

Table 4: Nutrient content of ripe *Carica papaya* L.

Constituents	Approximate value
Water	89%
Calories	39 kcal
Protein	0.61 g
Fat	0.14 g
Carbohydrates	9.8 g
Calcium	24 mg
Iron	0.1 mg

Constituents	Approximate value
Phosphorous	5 mg
Potassium	257 mg
Magnesium	10 g
Sodium	3 mg
Vitamin A	1094 IU
Vitamin E	0.73 mg

Source: USDA Nutrient Database for Standard Reference, Release 18 (2005).

Table 5: Batch composition of the Sorghum ogi pawpaw blends

Sample	A	B	C	D	E	F
Pawpaw (g)	0	20	40	60	80	100
Sorghum (g)	100	100	100	100	100	100

Sir, our findings depict that the addition of pawpaw significantly increased the vitamin C content of ogi. Hence, it could be inferred that the incorporation of pawpaw to sorghum-ogi could improve the vitamin C content of the ogi. The total sugar, the summation of both the reducing and non-reducing sugar, increased with an increase in the level of added pawpaw having highest value of 1.25 ± 0.04 mg/100 g in 100% blend.

The pH and titratable acidity of ogi samples were found to range between 3.52 and 4.25, and 3.02 and 3.72 mg NaOH/100 mL of filtrate, respectively. There was no apparent effect of pawpaw addition on the pH and titratable acidity of ogi. Changes in diastatic activity of ogi samples were observed with increasing level of pawpaw addition, with values of 21.8 ± 2.02 to 110.8 ± 2.04 mg maltose/100 g respectively for sorghum ogi at 0% level of substitution and sorghum pawpaw-ogi at 100% level of blending. The bulk densities of the samples obtained were near one another in the range of 0.698 and 0.950 g/mL, with 0% blend having the smallest bulk density, implying that it would occupy the smallest space. The water absorption capacity of pawpaw-ogi blends also decreased with increasing additional level of pawpaw.

Table 6 Results of analysis of taste panel scores.

Quality attributes	A	B	C	D	E	F	LSD	"F" Value
Taste	4.7 a	4.0 d	4.1 c	4.6 b	4.7 b	5.6 a	1.57	3.52
Colour	6.2 a	6.0 a	5.4 a	5.7 a	5.7 a	5.8 a	0.80	0.67
Texture	4.7 a	4.1 b	3.2 bc	4.2 c	3.2 d	3.4 e	2.28	2.50
Flavour	3.5 d	4.1 c	4.4 c	5.2 b	5.6 a	5.9 a	1.87	8.55
Sourness	4.0 a	5.0 b	5.8 ab	4.4 c	3.5 d	3.3 e	1.31	6.50
Appearance (dry sample)	5.2 a	5.3 a	5.3 a	5.2 a	5.2 a	5.3 a	0.63	2.10

Table 7 Amylograph pasting characteristics of pawpaw-ogi blends.

Sample	Tp (min)	Mg (min)	Tvp (°C)	Vp (B.U)	Mn (min)	Vi (B.U)	Vr (B.U)	Ve (B.U)	Mn-Mg (B.U)	Vp-Vr (B.U)	Ve-Vp (B.U)	Ve-Vr (B.U)
A	81	32	89	320	36	280	210	830	4	110	510	620
B	84	33	93	290	34	265	210	840	1	80	550	630
C	86	32	96	285	34	340	230	810	2	55	525	580
D	85	34	96	310	36	270	200	910	2	110	600	710
E	83	30	93	315	32	255	220	890	2	95	575	670
F	82	29	91	270	36	210	190	700	7	80	430	510

Tp = Pasting Temperature; Mg = Gelatinazation time; Tvp = Temperature at peak viscosity; Vp = Peak viscosity during heading; Mn = Time to reach peak viscosity; Vi = viscosity at 95°C; Vr = viscosity after 30min holding at 95°C; Ve = Viscosity on cooling to 50°C; Mn – Mg = Ease of cooling; Vp – Vr = Stability of the starch; Ve – Vp = Set back value; Ve – Vr = Galetinization index; B.U = Bradender unit

Organoleptic assessment of the sorghum ogi blends

The taste panel assessment of the blends is shown in Table 6 for quality attributes of all the samples. The results were treated with the analysis of variance method. For sourness, 0% and 20% blends were found to be significantly different from the other samples at 5% confidence level and 0% only was significantly different from other samples for texture. Also, 0 and 100% blends were significantly different from the other samples for taste while 100 and 80% blends were significantly different for flavour. For colour and appearance, there was no significant difference in all the samples.

Table 8: Softening point of few types of glass

Glasses	Softening Points (°C)
Soda lime	696
Alkali zinc borosilicate	720
Lime alumino-silicate	910

Glasses	Softening Points (^oC)
Barium alumini-silicate	872
Alkali borosilicate	820

Source: *Bolz and George (2002).*

Brewery cullet

Cullet creates a serious environmental problem, mainly because of the inconsistency of the waste glass streams. Cullet generated in Brewery is usually sold to glass manufacturers, for example Beta Glass, Agbara, Ogun State. They are then added to new raw materials for glass production. Glass manufacturers typically use cullet of 33% along with raw materials to make new glasses. The use of cullet reduces energy consumption because it consumes less energy for melting than other raw materials. Cullet re-entering a furnace is composed of waste glass from two sources namely factory cullet and external cullet. Factory cullet arises from rejects in the manufacturing process. External cullet consists of industrial cullet from downstream processing plants (e.g. beverage and food packers) and domestic cullet from public collection schemes (e.g. bottle banks). The latter is by far the biggest source of external cullet.

My contributions

The use of waste glass in production of porcelain tiles

Porcelain, a family of ceramic materials, is composed essentially of clay, feldspar and quartz, hence, the name triaxial whitewares (Kamseu *et al.,* 2007). The triaxial composition usually consists of 50 wt% fine-grained clay called kaolin ($Al_2O_3.2SiO_2.2H_2O$); 25 wt% flux, feldspar ($K_2O.Al_2O_3.6SiO_2$) and 25 wt% filler, quartz (SiO_2). The progression of the microstructure of porcelain to their final state is identified in that the clay provides plasticity, allowing easy shape formation as well as a binder for other components when in the green state (Iqbal and Lee, 1999). Kaolin clay is very elastic and strong that it holds the shape of the object during firing. The quartz is to provide the mechanical strength while the feldspar is the fluxing material for porcelain (Carty and Senapati, 1998). A key advantage of porcelain is its chemical stability, providing excellent aesthetics that do not deteriorate with time as well as high compressive strength with good electrical insulating property (Sedghi *et al.,* 2012). Since glass is a unique inert material that could be recycled many times without changing its chemical properties, this property can be maximized in construction. The efficiency of utilization may depend on the method of collecting and sorting glass waste of different colours of clear, green, and amber (Park, 2000). This process, being one of the concepts of zero emissions research and initiatives, has not been fully exploited (Ajanaku, 2013).

Our study was then directed towards the utilization of recurrently generated soda-lime scrap glass and abundantly available river sand, in a porcelain ceramic mix by replacing K-feldspar and quartz from standard triaxial porcelain body (kaolin-quartz-feldspar). Four batch compositions were prepared utilizing scrap glass in the range of 13-25 wt%, kaolin 50 wt%, feldspar 12-25 wt%, and sand 20-25 wt%; the respective oxide composition in them was analysed (Tables 9 and 10). The compact green samples were heated in the temperature range of 1050°C – 1250°C. The physico-mechanical properties i.e., linear shrinkage, bulk density, water absorption, apparent porosity and flexural strength of the heated samples were determined using standard techniques (Figures 11 and 12). The various phases developed in the vitrified samples and crystal morphology were analysed by X-ray diffractometry and Scanning Electron Microscopy, respectively (Figures 13 and 14). Results showed that partial replacement of K-feldspar by soda-lime glass scrap in triaxial porcelain mix body was more beneficial than its complete replacement because the samples were vitrified at lower temperature (~1200°C) in comparison to standard K-feldspar containing porcelain (~1250°C) with the presence of well-developed niddle shaped mullite crystals that support higher strength.

Chancellor Sir, this investigation widens the scope of utilizing soda-lime waste and usage of the abundantly available river sand as a fluxing agent in kaolin-quartz-feldspar bound triaxial porcelain. The densification was not detrimentally affected rather the introduction of the waste glass led to the formation of new phases in the nonequilibrium microstructure of porcelain stoneware. The products from the study are shown in Figures 15 and 16 of this presentation.

Table 9: Batch Composition (wt%)

Raw Materials / Blend	AK-1 (Standard)	AK-2	AK-3	AK-4
Kaolin	50	50	50	50
River Sand	25	25	25	20
Feldspar	25	Nil	12	15
Scrap Glass	Nil	25	13	15

Table 10: Oxide composition of the experimental bodies

Constituents(wt%)	AK-1	AK-2	AK-3	AK-4
SiO_2	67.03	67.72	67.28	66.30
Al_2O_3	20.74	16.57	18.57	18.93
Fe_2O_3	0.99	0.98	0.98	0.88
TiO_2	0.48	0.51	0.49	0.49
(CaO + MgO)	0.72	3.93	2.38	2.64
(K_2O + Na_2O)	3.67	4.06	3.87	4.47
LOI	5.93	5.79	5.85	5.84

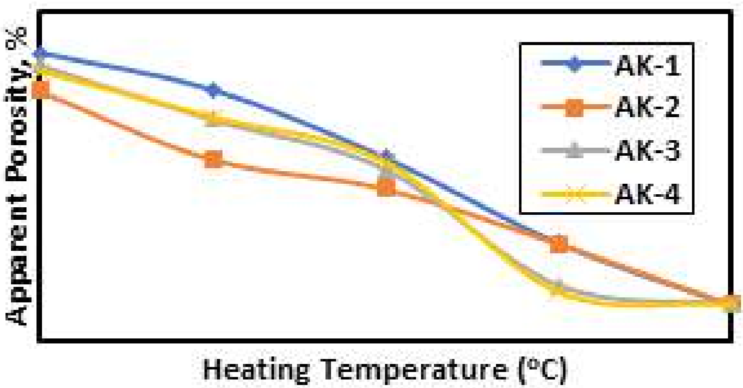

Figure 11:
Variation in Apparent Porosity of experimental samples in relation to heating Temperature

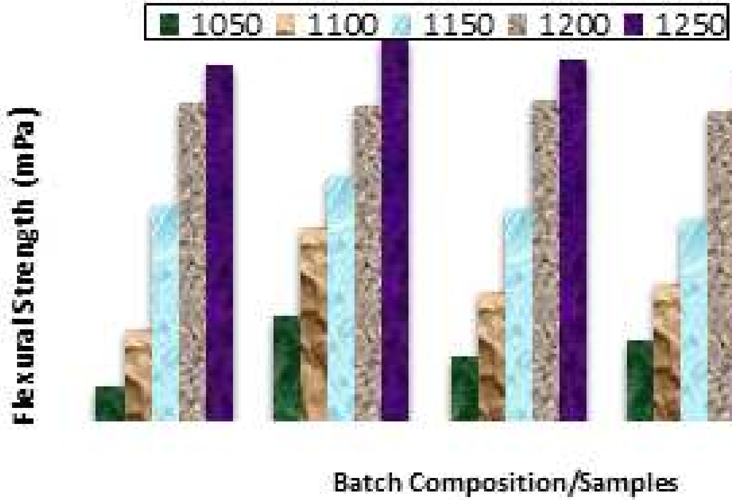

Figure 12: Variation in Flexural Strength of experimental samples in relation to heating Temperature

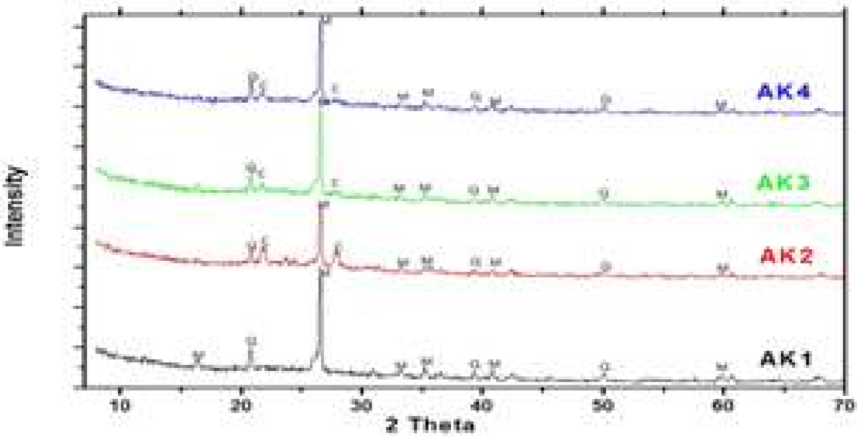

Figure 13: XRD patterns of the samples (AK-1, AK-2, AK-3 & AK-4) fired at 1250°C

Key: M=Mullite; Q=Quartz and C=Cristobalite

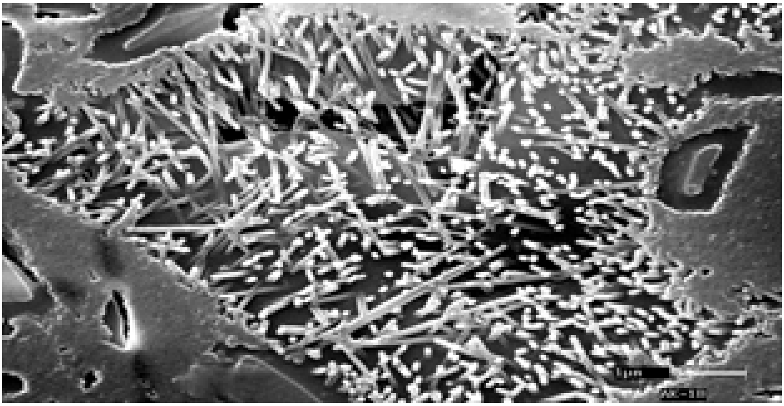

Figure 14: Microstructure from the same sample showing mullite crystal formed in the matrix mixture

The revolutionary findings from the usage of waste glass gave inspiration to many ideas that we had to explore the usage of different types of kaolin clay from two countries (Nigeria and India). We discovered that Nigerian kaolin clay has better potential and of good quality than Indian clay by the amount of Alumina Silica ratio with performance in every area (Ajanaku *et al.,* 2018). Quite a number of products came from this study under the mentorship of Professor Das (my host) in India. I was able to produce tiles from glass wastes, ceramic wastes etc. with good strength by the simple concept of porcelain triaxial mixture using Nigerian kaolin (Ajanaku *et al.,* 2013b; Ajanaku *et al.,* 2014; Ajanaku *et al.,* 2015; Ajanaku *et al.,* 2016).

Figure 15: Some of the products produced from waste materials

Figure 16: Discussing the output of one of the products in India

Sir, one of my recent graduated Ph.D students (Dr. Aladesuyi) went to the extent of producing mullite structure from the Nigerian sourced Kaolin with good results. Quite a number of published articles in Scopus indexed journals came out of this research (Aladesuyi *et al.,* 2017a; Aladesuyi *et al.,* 2017b; Aladesuyi *et al.,* 2018).

What then is happening to us in the country that God has enriched with many resources? Are we just allowing these resources to lie waste without utilization? We need to take steps as a nation and put the resources God has blessed us with together to get the desired products for the development of this nation. What we think is working today becomes obsolete tomorrow and that is the next phase the global world is working towards. It will soon be a world of artificial intelligence when all things will be controlled by a touch of buttons. We need to wake up to meet up. If it can work in Canaan Land, then it is possible in Nigeria.

6. THE ARTIFICIAL INTELLIGENCE FOR WASTE PROCESSING

It has been observed that many do not have proper consideration of what could happen if we do not manage the planet well. Our major problem is that we live in a world of convenience; we order everything online and we use plastic for everything because it is easier. I believe that people could do more by change of attitude and habits in order to inspire us more in our area of expertise to solve waste issue to a much better process of utilization than just generation and accumulation.

The recycling process

It is important to state here that the recycling process should commence with all of us by putting the right trash in the right bins. This always does not happen with everyone, hence it creates a general problem with compounded issues to solve. The first issue is that when people do not put the right trash in the right bin, it creates trash contamination and the next way to solve the problem is to have employees sorting out trash. This job is not usually classified as well-paid, and since it is a dirty and repetitive job, employees tend to leave after a few months of engagement thereby creating a personnel challenge for waste managers.

Another challenge is the high cost involved in recycling wastes. With the high cost of recycling materials, for example in separating the recyclable waste from the non-disposable, it becomes cheaper for the waste management companies to take options like landfilling and incineration where they can take profits up to 70% rather than taking small profits when they opt to recycling process.

How to solve these problems?

Since it is very difficult to change people's habits and it is so glaring that most people do not want this kind of job then; we can deploy robots to carry out the task. It may not be an easy task to programme a robot to sort different materials in a waste contamination system. How can you programme a robot to know the difference between plastic and paper? It means we will have to generate a large list of waste materials for identification for the robot to differentiate, hence the need for machine learning.

Figure 17:
AI or Robots for waste sorting and processing
Source:https://www.wiswm.com/2018/10/22/waste-management-robots/

By artificial intelligence method, it is possible to create an autonomous robot that can sort materials and can keep learning and improving over time. The problem with machine learning models is that just a few samples of each material are not enough because the robot will always be finding new objects and it may not be able to know its material. For them to have good accuracy there will be need for millions of different images for programing the waste sorting process. This is the general thinking of developed countries and the pace of change is becoming too fast that if nothing is done, we will have to be faced with the real consequences because the fourth industrial revolution is just behind the corner and disruption is the keyword.

There are household robotic waste bins to separate materials at source thereby reducing the cost of sorting. There are already robotic kitchens that minimize food waste and there are robots for stimulating reuse and repair for selected products. It should be pointed out that the real transformation is already here and it is more radical than we think, and maybe, less radical than required. In reality, the dominance of robots in recycling will create new business models and industrial patterns that will be based on the robotic evolution.

7. MY ACADEMIC CONTRIBUTION AT COVENANT

Chancellor Sir, I came on board the Covenant flight in February 2007 by prophetic dictate. Interviewed by Late Professor Aize Obayan and Pastor Yemi Nathaniel, I made myself available to be trained by the then HOD Chemistry, Professor M. Adediran Mesubi. The journey began and I was out to add value. I was privileged to be in the Waste to Wealth (W2W) committee and from there the initiative of waste revolution for Covenant began. We were able to bring on board two Memoranda of Understanding for waste recycling – *Belpapyrus Nigeria limited* for waste paper recycling to tissues and *Alkem Nigeria limited* for PET bottles bailing and recycling. Sir, we appreciate the Board and Management of the University for the financial commitment that commenced the project a few years back. Quite a number of funds have been generated and it is good to state that the W2W initiative is self-sustaining in the University today. Special thanks to the Chancellor for the approval of funds for the purchase of the W2W truck and also for the provision of available space yard where the wastes materials are being sorted and processed. Some of the pictures for the process are hereby

Figures 17 a-j: Activities of W2W at Covenant University

Sir, there is need to mention that the W2W committee also partnered with the Enactors team of Covenant in some projects. We gave the students ideas of what can be done with some of the wastes around and these have really helped in some of the projects going on in the campus today under the Enactors team, especially the PET bottle revolutionary approach to products.

Ladies and gentlemen, apart from the contributions I was able to discuss above, I have also worked with my Ph.D students in the area of nanotechnology as it covers: (1) the synthesis of nano-modified polymeric materials from seed oil as a means of replacing the petrochemicals used in the preparation of most polymeric materials. We had publication on this concept as well (Siyanbola *et al.,* 2017). (2) Green synthesis of nanoparticles for optical properties with many publications as well (Akinsiku *et al.,* 2019; Akinsiku *et al.,* 2018a; Akinsiku *et al.,* 2018b; Akinsiku *et al.,* 2016 and Akinsiku *et al.,* 2013). (3) Synthesis and Characterisation of Mixed-valence Manganites, taking a view at the effects of Doping on A- and B- Sites (Edobor-Osoh *et al.,* 2019) and (4) Corrosion study and prevention using the green and safe approach (Ajanaku *et al.,* 2015; Ajanaku *et al.,* 2014; Omotoso *et al.,* 2015; Omotoso *et al.,* 2012; Ajayi *et al.,* 2011a; Ajayi *et al.,* 2011b; Olusola *et al.,* 2011 and Olusola *et al.,* 2009).

Sir, all these contributions in the area of nanotechnology have distinguished me as a Chemist cutting across two areas of studies, Sciences & Engineering, hence my specialization: Industrial Chemistry (Materials). To God be all the Glory!

8. RECOMMENDATIONS AND CONCLUDING REMARKS

Considering the valuable resources coming out of waste materials from most of our daily activities, it has become very imperative for us to agree on the terms of tackling the waste management challenge. Individuals, communities and government need to come to terms and solve the problems in line with United Nations Sustainable Development Goals (SDG) to have a sustainable environment. There is need to set up SDG index of measurement. This will promote healthy competition among states by evaluating the progress of implementation as it concerns the social, economic and environmental terms that will help us to achieve the SDGs by 2030.

There is need for us to imbibe the 3Rs approach of Reduce, Reuse and Recycling of wastes as a means of sustainable drive. Let there be waste transfer stations in every state in Nigeria. It is a known fact that waste transfer station is not common in Nigeria and the only State that has a waste transfer station is Lagos State. Let there be appropriate and applicable approach by the government in getting rid of the solid waste instead of the dumping in landfill approach currently in place. The world is moving and we cannot afford to stay at a place in our country.

Composting plant can be developed; a waste-to-energy process can become operational as the biogas generated can be used to power electricity. Digesters can also be used to generate biogas. The use of thermal conversion can also be employed as carried out at Addis-Ababa, Ethiopia. Until this period, the country has been dumping rubbish on a vast, ever growing landfill site that cover an area of a size of 36 football pitches. This is coupled with the fact that the country is having a challenge of power supply. A *Reppie* plant was then set up in order to solve the two issues by synchronizing the waste management and energy generation. The plant burns the waste generated and uses it to boil water. The steam then drives turbine generators. This is one of the modern gas treatment technologies with a great reduction in the release of toxins during the degradation process at dumpsites.

We should commence recycling processes for some selected waste materials with the focus of transforming them to valuable materials. Apart from teaching waste management as part of the curricula, recycling clubs can be introduced in schools in order to instill the waste management culture in youths. There is need to sell the 3Rs concept to all and sundry as these will help in cutting down the amount of waste generation and promote utilization. The people will obviously support a system that conserves natural resources. The principle of sorting and bagging waste for recycling purposes should be emphasized rather than the indiscriminate dumping of waste. Plastic recycling by conversion of waste sachet into garbage bags for packing and sorting materials can be developed. There is need to have a smart recycling approach to capture materials after the point of consumption and bring them back into sourcing and production ecosystem.

The need to have a selective, progressive plan for a smart waste collection process is inevitable as we drive towards the attainment of a smart city. Some of these strategies include using technology for operational analytics and route optimization as these can considerably lead to achieving sustainability goals in this wise and reducing the operational costs. This is where the artificial intelligence comes into play by having electronic sensors, digitalization and coding of goods with recyclable properties and gradually automating materials and processes towards collection, sorting and recycling them into valuable products.

This is the way to go in order to achieve smart solutions for the management of waste in the city. This will enable us to solve waste management issues even as a master plan is made available for a most suitable system of transportation, storage, and disposal of solid waste.
Finally, let companies using PET as their packaging process come up with strategies to reduce plastic pollution, which has become a social and environmental concern. Creating a sustainable collection and recycling method would be a good idea. A buy-back approach through partnership can be used to achieve this process which makes it possible for treatment and reuse strategy. Another means is developing plant-based resins via research and development that will reduce the amount of PET usage in the system thereby enhancing biodegradation if found in oceans and dumpsites.

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Now unto God eternal, invincible and the only wise God; my help and the lifter of my head. Permit me to express my heart unto God from this composed song by Brooklyn Tabernacle Choir from Psalm 121 verses 1-8

"I will lift up mine eyes to the hills
from whence cometh my help.
My help cometh from the Lord,
The Lord which made heaven and earth.
He said, He would not suffer thy foot,
thy foot to be moved.
The Lord which keepeth thee,
He will not slumber nor sleep.
Oh the Lord is thy keeper the Lord is thy shade
Upon thy right hand, upon thy right hand.
No the sun shall not spite thee by day,
nor the moon by night.
He shall preserve thy soul, even forevermore.

My help, my help, my help,
all of my help cometh from the Lord……..”

Dear Chancellor Sir, It is a great privilege indeed to deliver the 21st Inaugural Lecture of Covenant University.

Ajanaku Kolawole Oluseyi

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