ENVIRONMENTAL SUSTAINABILITY THROUGH CHEMICAL WASTES RECYCLING TECHNIQUES IN THE SOCIO-ECONOMIC CONTEXT OF SUB-SAHARAN COUNTRIES

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ABSTRACT

Sustainable socioeconomic development advocates environmental sustainability through recycling of chemical wastes. This paper captures the environmental benign processes/techniques involved in achieving these materials salvage. The basic phases in recycling are the collection, processing or manufacturing and the purchase of those products. The materials reused in recycling serve as substitutes for raw materials obtained from such increasing scarce natural resources as petroleum, natural gas, coal, mineral ores and trees. The recycling of chemical waste can serve as a channel of providing solutions to many environmental and socioeconomic problems and challenges such as increasing cost of waste disposal and depletion of natural resources. The field of chemical recycling techniques of Iron and Steel Scrap (ISS), Aluminium Cans and Glass Bottles, Polymers, Textile Wastes, Old Papers and Wood, Cement Kiln Dust (CKD), Automobile Exhaust, Animal and Fish Wastes (AFW), Domestic and Municipal Organic Waste is reviewed in this study. Highlighted also are the prospects and problems of this exercise. The study concludes that the recycling of chemical waste is of great importance especially in solving the numerous environmental problems and hence increases the nation's economy and social well-being of mankind. It recommends more serious measures at national and international levels especially developing nations of the Sub-Sahara to encourage and sensitize the government and private sector educationally on the importance of chemical waste recycling and to enhance the regulation of its practice.

Keywords: Recycling, Sustainability, Chemical Waste, Socioeconomic, Sensitization, Conservation, Sub – Sahara.

INTRODUCTION

As a result of the Brundtland Commission of 1987, the concept of the development based on conquest and wrecking of the world for increased economic productivity has been replaced with the paradigm of development based on sustaining the environment for all generations of people. Depleting the natural resources in the name of economic development that seeks to maximize economic production, only to deny the future generations the resources bequeathed to the present generation as well as the future generations of the earth's inhabitants is unacceptable (Cross, 2002).

Communities and societies are increasingly interested in minimizing the environmental vestige of human economic activities. The challenges facing the world

at large are human-related on one hand and directly or indirectly science –related on the other hand. Talk of environmental degradation, technological disasters and growing economic imbalance, all these purse concern. Innovative sustainability efforts and practices and the encouragement of sustainable behaviours are needed not only as a way of boosting nation's economy but also as a way of wisely getting rid of wastes that are desight and health hazards in our countries. Business ventures and agencies are springing up daily worldwide to tackle the problem of waste and turning them to wealth. The goals of such ventures include the following:-

- Generating economic and environmental solutions.
- Generating a proven approach for long term success.
- Creating a competitive edge by staying ahead of global trend.
- Building market opportunities.
- Incorporating personal responsibility.
- Customizing solutions that result in auxiliary income (Oloruntegbe, 2010a).

London Development Agency through recycling has achieved the following:

- Recycled over 3.2 million kg (≈ 7 million lbs) of potential landfill by collecting bags of clothing, house wares and other products.
- Promotes environmental responsibility by hosting bins for a variety of community events.
- Recycles scrap metal computers monitors and television at donation station.
- Proudly prints all brochures and publications using papers with post consumer recycled content.
- Recycles all papers and cardboard items through an in-house recycling program.
- Only uses donation bags made of bio-degradable products.

With all these efforts enumerated above, the Sub-Saharan African countries are yet to notice these, implying that we cannot afford to be watching the world making progress in this aspect without us taking the prompt action to emulate.

Recycling is also called materials salvage, recovery and reprocessing of waste materials for use in new products. The basic phases in recycling are the collection of waste materials, their processing or manufacture into new products, and the purchase of those products. Typical materials that are recycled include iron and steel scrap (ISS), aluninium cans and glass bottles, polymers, textile wastes, old papers and wood, Cement Kiln Dust (CKD), automobile exhaust, animal and fish wastes (AFW), domestic and municipal organic waste. The materials reused in recycling serve as substitutes for new materials obtained from such increasingly scarce natural resources as petroleum, natural gas, coal, mineral ores, and trees. Recycling can help reduce the quantities of solid waste deposited in landfills, which have become increasingly expensive. Recycling also reduce the pollution of air, water and land resulting from waste disposal. Recycling operations are of two broad types namely: internal and external. For the purpose of this study, external recycling operations will be considered implying the reclaiming of materials from a product that was been worn out or rendered obsolete. An example of external recycling is the collection of

old newspapers and magazines for re-pulping and their manufacture into new paper products (Encyclopedia Britannica, 2013).

Sustainable development is a mainstream recognition of a link between development and environment. It advocates meeting the economic, environmental, political, social, and cultural and health needs of the present without compromising the ability of the future generations to meet their needs. It seeks to minimize waste by maximizing recycling and discouraging the use of non-renewable resources, encourage sustainable use of finite renewable resources, discourage over-taxing the capacity of ecosystems to absorb or break down wastes, protect natural processes and climatic systems, including not overtaxing the capacity of global ecosystems to absorb or dilute wastes without adverse effects and mobilize political and institutional structures within nations and internationally to support the achievement of these goals (Eneh and Owo, 2008).

The concept of sustainability relates to the maintenance and enhancement of environmental, social and economic resources, in order to meet the needs of current and future generations. The three components of sustainability are represented in Figure 1.

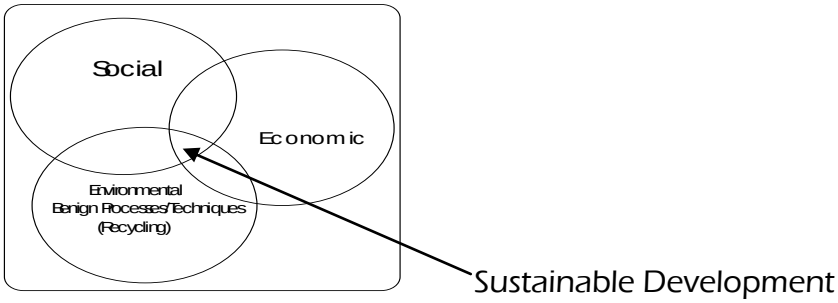

Fig. 1: Conceptual Diagram of Sustainable Development (Environmental Sustainability Report, 2011)

With sustainable development as the goal of economic, social and environmental policy (Recycling), what is needed is the redirection of economic activity in order to detach it from environmental and social degradation. Once this has been achieved, there will no longer be a conflict between economic growth and environmental protection.

The increased magnitude of human impact and the consequent deterioration of the environment have given rise to a growing concern for achieving sustainable development. The principle of precaution in dealing with complex system like the environment, safeguarding and protecting it should not be left for the educational sector alone but should be the concern of everyone. The purpose of this study is to discuss the processes/techniques of recycling of chemical wastes, its socioeconomic benefits and problems. This is aimed at educating and sensitizing the public and business agencies with these processes that could serve dual purposes of turning wastes to wealth and of lessening health problems that are as a result of careless handling of our environment.

Waste should no longer be seen as a cost and economic drains in productive resources. It has become a source of innovation like the renewable energy resource. Instead of considering waste as economic problem, desight and health hazards, means of deriving benefits from them should be looked into. The benefits of recycling, turning waste to wealth, come in many forms, the restructuring of international economy (Moray, 1999) and the development of more environmentally friendly products and processes (Clark, 1995). These wastes can be converted to a less, yet still useful materials like improved papers, polymers, candles etc. Recycling or reuse is in line with this principle that nothing should be left as waste. However, the success of large scale materials recycling depends on the economics of secondary materials recovery and the suitability of secondary materials for reuse.

The review here is centered on chemical recycling of Iron and Steel Scrap (ISS), aluminium cans, Polymers and other household plastic wastes, textile wastes, old papers, Cement Kiln Dust (CKD), automobile exhaust, domestic and municipal organic waste. The highlights of the processes involved in recycling, benefits and problems were also enumerated.

MATERIALS AND METHODS

The processes/techniques of recycling selected waste products are enumerated as follows:

Automobile Exhaust: There are four main sources of noxious gases emission from automobile that have direct effect on the environment namely; the engine exhaust, the crankcase, the fuel tank, and the carburetor. The exhaust pipe discharges burned and unburned hydrocarbons, carbon monoxides, oxides of nitrogen and sulphur, and traces of various acids, alcohols, phenols and heavy metals such as lead (Encyclopedia Britannica, 2013).

Chemical processes applied in automobile exhaust recycling include; the air-reinjection system, improved combustion system, thermal reactor, evaporative control system and catalytic converter (Adler, 1986).

To control exhaust emissions, which are responsible for two-thirds of the total engine pollutants, the air-reinjection system as a recycle process was employed. In a typical injection system, an engine-driven pump draws air through the carburetor air cleaner and pumps it into the exhaust ports of the cylinder head, in which it combines with the unburned hydrocarbons and carbon monoxides at high temperature and, in effect, continues the combustion process. In this way a large percentage of the pollutants that were formerly discharged through the exhaust system are eliminated. In some cases a specially designed exhaust manifold known as a thermal reactor is used to promote more complete combustion of the gases.

With this employed recycle process by automobile manufacturers to meet human needs while protecting the environment is an answered question on using our resources wisely to improve environmental sustainability (Barlow, 2010).

Iron and Steel Scrap: Ferrous products (i.e. iron and steel) can be recycled both by internal and external methods. Some internal recycling methods are obvious. Metal cuttings or imperfect products are recycled by remelting, recasting and redrawing entirely within the steel mill. The process is much cheaper than producing new metal from the basic ore.

In the ferrous-metal industry there are also many applications of external recycling. Scrap steel makes up a significant percentage of the feed to electric-arc and basic-oxygen furnaces. The scrap comes from a variety of manufacturing operations that use steel as a basic material and from discarded or obsolete goods made from iron and steel. The release and discard of these products have been dated 1960's in Nigeria where virtually all landfills in the country becomes piled up with scraps of old automobile bodies until recently that agencies and industrialists are showing concern in its recycling which gives rise to the collection of this scraps around the country to Iron Smelting Companies in Kano, Ajaokuta Steel Mills, Jos Steel Rolling Mill e.t.c.

One of the largest sources of scrap steel is the reprocessing of old automobile bodies. The average junked automobile contains about 62 percent iron and steel, 28 percent non-ferrous metals, and 10 percent rubber, plastics, and textiles. Salvage operations on automobile actually begin before they reach the preprocessor; parts such as carburetors and electrical components can be rebuilt and resold, and the engine block is removed and melted down for recasting. After being crushed and flattened, the automobile body is shredded into pieces by hammer mills. Ferrous metals are separated from the shredder residue by powerful magnets, while other materials are sorted out by hand or by jets of air. Only plastics, textiles and rubber from the residue are not reused. The same basic recovery procedures apply to washing machines, refrigerators, and other large bulky steel or iron items. Lighter items such as steel cans are also recycled in large numbers.

Aluminium Cans: At present, manual sorting seems to be the only practical method of separating pieces of non-ferrous scraps materials such as aluminium, copper and lead. Beverage cans are another major source of recycled aluminium, in some countries, as many as two-thirds of all such cans are recycled. Because the remelting of aluminium scrap consumes only 5 percent of the energy required to make primary aluminium from bauxite, "in-process" scrap metal from fabrication sheet, forgings, and extrusions has found its way back to the melting furnace ever since production began. In addition, shortly before World War 1, "new" scrap produced during the fabrication of commercial and domestic products from aluminium was collected by entrepreneurs who began what is known today as the secondary aluminium industry. The chemical composition of new scrap is usually well defined; consequently, it is often sold back to the primary aluminium producers to be remade into same alloy. "New" scrap is now greatly supplemented by "old" scrap, which is generated by the recycling of discarded consumer products such as lawn chairs e.t.c. Because old scrap is often dirty and a mixture of many alloys, it usually ends up in casting alloys, which have higher levels of alloying elements (Encyclopedia Britannica, 2013).

Used aluminium containers constitute a unique type of old scrap. Although the bodies and lids of these cans are made from different aluminium alloys, both contain magnesium and manganese. Consequently, recycled beverage containers can be used to remake stock for either product. The energy required to produce a beverage can from scrap is about 30 percent of the energy needed to produce the can from primary metal.

Aluminium cans can be recycled and reused for cooking pots, cutleries and kitchen utensils among others. This is demonstrated in most of the Sub-Saharan African countries (e.g. Nigeria, Cameroon e.t.c.) where they are locally recycled by blacksmiths into the above mentioned products. For this reason, the recycling of used aluminium beverage containers represents an increasing source of metal for primary and secondary metal producers, hence limiting its lettering into the environment.

Polymers: High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polyethylene Terephthalate (PET), Polypropylene (PP), Polystyrene (PS), Polyvinyl Chloride (PVC) used in piping, automotive fuel tanks, bottles, toys, plastic bags, cling film, flexible containers, carpets and food packaging, battery cases, bottle crates, tape cassettes, cups and plates, window frames, flooring, cable insulation, credit cards and medical products makes up 80% of the plastics produced today called *Thermoplastics*. *Thermosets* make up the remaining 20% of plastic produced such as Polyurethane (PU), epoxy and phenolics (Vogler, 1984). Not only is plastic made from a non-renewable resource; but it is generally non-biodegradable (or the biodegradable process is very slow). This means that plastics litter is often the most objectionable kind of litter and will be visible for weeks or months and waste will sit in landfill sites for years without degrading.

Although there is also a rapid growth in plastics consumption in the developing world, plastics consumption per capita in developing countries is much lower than the industrialized countries. These plastics are, however, often produced from expensive imported raw materials. There is a much wider scope for recycling in developing countries such as the Sub-Saharan African countries due to several factors:

- Labour costs are lower.
- In many countries there is an existing culture of reuse and recycling, with the associated system of collection, sorting, cleaning and reuse of "waste" or used materials.
- There is often an 'informal sector' which is ideally suited to taking on small-scale recycling activities. Such opportunities to earn a small income are rarely missed by members of the urban poor.
- There are fewer laws to control the standards of recycled materials. (This is not to say that standards can be low – the consumer will always demand a certain level of quality).

- Transportation costs are often lower, with hand or ox carts often being used.
- Low cost raw materials give an edge in the competitive manufacturing world.
- Innovative use of scrap machinery often leads to low entry costs for processing or manufacture.

In developing countries especially the Sub-Saharan, the scope for recycling of plastics is growing as the amount of plastic being consumed increases (World Resource Foundation). Instead of throwing away soft drink containers and mineral water bottles, they can be stored and sold to brokers for added revenue.

Thermoplastics have been successfully converted to oil in direct liquefaction experiments with coal (Taghlei *et al,* 1994a), but the more attractive method is the chemical recycling of waste polymers into the corresponding monomers and/or raw chemicals (Zhang *et al,* 1995), which further might be reused for the manufacture of plastics and other plastic related materials.

Not all plastics are recyclable. There are four (4) types of plastics which are commonly recycled:

- Polyethylene (PE) – both high density and low density polyethylene.
- Polypropylene (PP)
- Polystyrene (PS)
- Polyvinyl chloride (PVC)

Chemical processes applied in polymer recycling are ***pyrolysis, methanolysis, glycolysis, hydrolysis, ammonolysis, aminolysis*** and others (Paszum and Spychaj, 1997).

Processing of reclaimed plastics includes:

i. **Initial Upgrading**; the cleaning and sorting of the plastics.

ii. **Size Reduction Techniques**; reducing larger plastic waste to a size manageable for small machines, to make the materials denser for storage and transportation.

iii. **Extrusion and Pelleting**; the process of extrusion is employed to homogenize the reclaimed polymer and produce a material that is subsequently easy to work. The pelletization process is used to reduce the extrusion products to pellets which can than be used for the manufacture of new products.

iv. **Manufacturing Techniques** includes extrusion, Injection Moulding, Blow Moulding and Film Blowing. See figure 2 below:

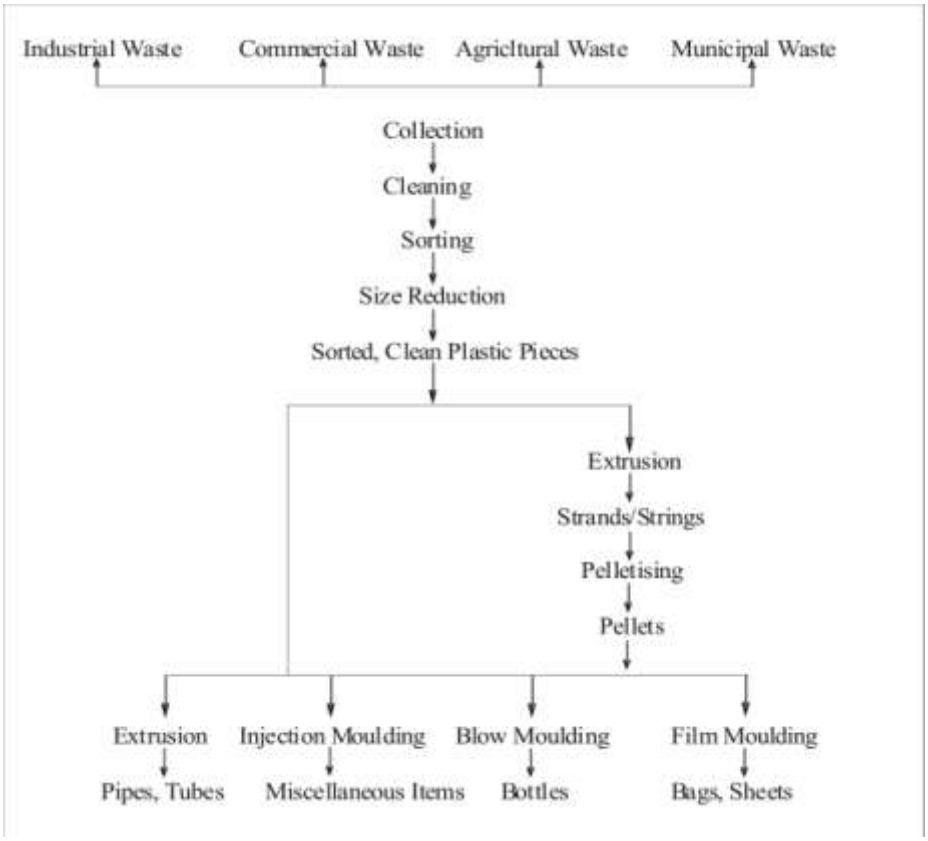

Fig. 2: Flow Chart of a Typical Waste Plastic Reprocessing Stream in a Low-Income Country (Lardinois and Van de Klundert, 1995).

Plastic waste can be used as alternative source of energy to aid the African ailing power sectors (Oloruntebge, 2010b). As in pyrolysis, this converts solids into petroleum-like substances and direct incineration, which can provide energy for power plants or industrial furnaces.

Industrialized countries had made laws for recycling of plastics. For instance, U.S.A made it that, 25% by weight of plastic materials need must be from recycled waste, Germany, 80% of plastics wastes were recycled, France recently passed a similar law (Taghlei *et al,* 1994b). It is hoped that other nations particularly the Sub-Saharan African countries can follow suit, as the benefit are enormous.

A common problem with recycling plastics is that plastics are often made up of more than one kind of polymer or there may be some sort of fibre added to the plastic (a composite) to give added strength. This can make recovery difficult. It should be noted that conventional plastic melting temperature is not high enough to eliminate all possible impurities in the waste plastics. Therefore, just like in polyvinyl chloride pellets, the products are good for non-food packaging technical applications such as pipes for sewage and electric insulators (See Table 1 for details). It will be noted that National Agencies for Food and Drug Administration (e.g. NAFDAC-Nigeria, FDA-

U.S.A e.t.c) has banned the use of recycled plastics for products that come in direct contact with food.

Table 1: Recyclable Plastics

Plastic Code	Polymer Type	Original Container Products	Recycled Products
PETE	Polyethylene Terephthalate	Bottles for soft drinks and Household products	Bottles, fibres for carpeting insulation (fibrefill)
HDPE	High-Density Polyethylene	Bottles for milk and household products, grocery bags	Trash Cans, Pails, Drainage pipes, "Lumber"
PVC	Polyvinyl Chloride	Bottles for Shampoo and Automobile Products	Additive for drainage pipes, Traffic cones
LDPE	Low-Density Polyethylene	Trash and Grocery bags	Bags, Wastes Bins
PP	Polypropylene	Bottles for food and Household products, Margarines tubes, Overwrap film, Storage-Battery cases	Automobile Battery Cases, Bottles
PS	Polystyrene	Food trays, Cups, eating Utensils, Foamed packaging (Molded and "Popcorn" style)	Trash receptacles, Foamed Packaging

Source: Encyclopedia Britannica, 2013.

Thermosetting plastics such as polyurethane and epoxy resins, by contrast, cannot be remelted; these are usually ground or shredded for use as fillers or insulating materials.

So-called biodegradable plastics include starches that degrade upon exposure to sunlight *(photodegradation)*, but a fine plastic residue remains and the degradable additives preclude recycling of these products.

Textile Waste Recycling: The United State of America (U.S.A) each year records about 4 million tons of consumers after use and industrial textile related wastes in landfills. Due to the fact that recycling of textile or fibrous materials is almost not a success or still at its trial stage, this challenge purses the manufacturers, fiber and chemical supplier, recycling companies, research institutes to actively investigate the most reliable method for this product recycling. Approaches such as depolymerization, melting processing, recycling logistics, life cycle analysis, waste characterization, material component separation, composite material and reinforcement for concrete and soil among others were carried out as a broad-based research programme at Georgia Institute of Technology on Textile and Textile related materials recycling in conjunction with concerned industry. A recycling logistic tool is being developed to help the industry to make sound economic decisions regarding these operations

(Wang, 1999).The tool consists of a generic model that evaluates the economic feasibility of establishing and operating a textile recycling network.

Textile recovery facilities such as collection sites, sorting facilities and a distribution system to transport the waste separate overly worn or stained clothing into a variety of categories, some recovered textiles becomes wiping and polishing cloths. Cotton can be made into rags or form a component for new high-quality paper knitted or woven woolens and similar materials are "pulled" into fibrous state for reuse by the textile industry in low-grade applications, such as car insulation, and even building materials. The remaining natural materials, such as various grades of cotton, can be composted using *Vermicomposting* (Aishwariya and Amsamani, 2009).

Textile waste solutions provides the key that gives clothing, bedding, belts, shoes, and soft toys- virtually anything made from fabric a second lease on life. This is being achieved through:

- Simple Alteration of Use: converting clothing and textiles into industrial rags.
- More Complex Recycling: converting clothing and textiles into fibres to be used for industrial materials such as upholstery or acoustical soundproofing.
- Immediate Reuse: providing clothing for needy people in third-world countries, particularly the Sub-Saharan countries of Africa. These accounts for over 70% of the world's population who uses them and these are normally referred to as Second Hand clothes (Textile Waste Solutions). How the third-world nations get rid of the resulting waste is a thing of concern they litter them in the landscapes. No one talks about landfills nor mention recycling. This should make recycling of waste a policy issue. There is need for sensitization and reorientation (Oloruntegbe, 2010c). Textile recycling requires less energy than any other type of recycling, does not create any new hazardous waste or harmful by-products.

Old Papers and Other Cellulose Products Recycling: One of the most readily available materials for recycling is paper, which alone accounts for more than one-third by weight of all the materials deposited in landfills in most developed nations. The stream of wastepaper consists principally of newspaper, office, copying, and writing paper, computer paper, coloured paper, paper tissues and towels; boxboard (used for cereal and other small boxes); corrugated cardboard; and kraft paper (used for paper bags). The importance of recycling is increasing for the pulp and paper industry because of deteriorating forest resources, landfill problems, environmental regulations and associated legislation (Ban and Lucia, 2003).

These waste papers must usually be sorted before recycling. Newsprint and cardboard can be repulped to make the same materials, while other types of scrap paper are recycled for use in low quality papers such as boxboard, tissues, and towels. Paper intended for printing-grade products must be de-inked (often using caustic soda) after pulping; for some uses the stock is bleached before pressing into sheets.

Smaller amounts of recycled paper are made into cellulose insulation and other building products (Figure 3).

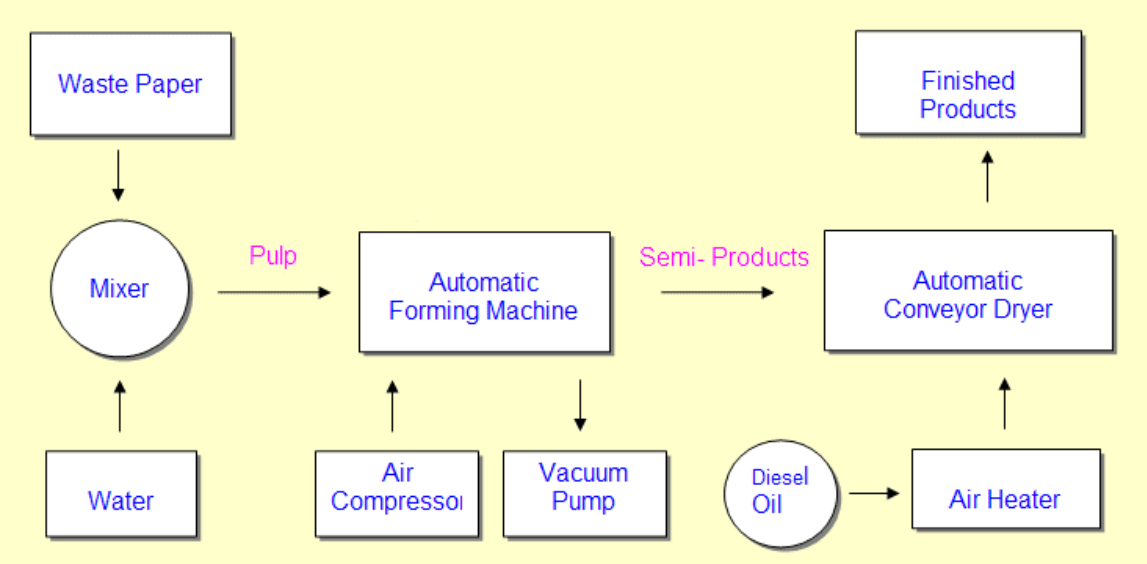

Fig. 3: Waste Paper Plant Flowchart (Environmental Sustainability Report, 2011).

Bark, wood clips, and lignin from sawmills, pulp mills, and paper mills are returned to the soil as fertilizers and soil conditioners. The kraft process of papermaking produces a variety of liquid wastes that are sources of such valuable chemicals as turpentine, methyl alcohol, dimethyl sulfide, ethyl alcohol, and acetone. Sludge from pulp and paper manufacture and phosphate slime from fertilizer manufacture can be made into gypsum wallboard.

As much as 80% of the content of typical recovered paper can actually be used in the recycling process, but 2% cannot. A lot of what's is contained in bale of recovered "paper" isn't paper; Trash, such as wire, staple, paper clips, and plastic, must be removed during pulping, cleaning, and screening. This shows that recycling waste paper requires a careful effort to produce quality useable materials.

Cement Kiln Dust (CKD) Recycling: Cement Kiln Dust (CKD) is the fine-grained, solid, highly alkaline waste removed from cement kiln exhaust gas by air pollution control devices such as fabric-filter bag house and electrostatic precipitators. Because much of the CKD is actually unreacted raw materials large amounts of it can and are, recycled back into the produces. The composition of CKD varies among plants and over time at a single plant (Table 2).

This industrial by-product and waste materials must be managed responsibly to insure a clean and safe environment. Over the past several years dramatic advances have been achieved in the management and use of Cement Kiln Dust, thus reducing its dependency on landfill disposal. The majority of CKD is recycled back into the cement kiln as raw feed. In addition, new technology has allowed the use of previously land filled CKD to be used as raw feed stock. Recycling this by-product back into the kiln not only reduces the amount of CKD to be managed outside the

kiln, it also reduces the need for limestone and other raw materials, which saves natural resources and helps conserve energy (Adaska and Taubert, 2008).

Nigeria is a place where every person, poor or rich wants to build houses with nothing but cement blocks and bricks. The growing incident of cancer might not be unconnected with such release. For the purpose of health related hazard, CKD should not be released into the environment, but rather its importance and consideration in other related fields towards its recycling should be opted.

Rather than allowing such particles to fill the environment and thereby endangering lives, it finds ample use or benefits when recycled. Such beneficial uses include:

- Soil/clay stabilization/consolidation
- Waste stabilization/solidification
- Cement additive/blending
- Mine Reclamation
- Agricultural Soil Amendment
- Sanitary landfill Liner/Cover Material
- Waste Water Neutralization/Stabilization
- Pavement Manufacturing
- Concrete products among others.

Table 2: Typical Chemical Composition of Cement Kiln Dust (CKD)

Chemical Composition	Values
SiO_2	13.6
Fe_2O_3	2.1
Al_2O_3	4.5
CaO	8.1
MgO	1.3
SO_2	0.7
Na_2SO_4	1.3
K_2SO_4	5.9
Loss on Ignition (LOI)	30.24

Source: Adaska and Taubert, 2008.

Municipal and Domestic Solid Waste Recycling: Once glass, plastics, and metals have been removed from domestic and municipal refuse, what remains is essentially organic waste. These are turned out in large heap and are desight in our urban and rural areas. A typical method of treating that waste is composting, a biological process in which the organic portion of refuse is allowed to decompose under carefully controlled conditions. Microbes metabolize the organic waste material and reduce its volume by as much as 50 percent. The stabilized product is called compost or humus; it resembles potting soil in texture and odour and may be used as a soil conditioner or mulch.

The ever growing quantities of urban waste in African cities which at present amounts to 05-6kg per inhabitant per day (Korfmacher, 1997), as well as the low organic content in the soil coupled with high cost of inorganic fertilizers and their relative scarcity have increased the need to recycle organic waste materials as a

source of crop nutrients (Oloruntegbe, 2010d). As more stringent environmental rules and siting constraints limit the use of solid-waste incineration and landfill options, the application of composting is likely to increase. Organic waste recycling is almost the cheapest and easiest, that a nation can embark upon by operating a unify sewage system and establishing a recycling plant to turn the waste to organic fertilizers for soil nutrients, by so doing it will reduce the health and environmental hazards in our communities, cities and towns.

RESULTS AND DISCUSSION

Benefits of Recycling

The chemist, environmentalists and economists studies on chemical, technical and economic requirement for sustainability (Adoreno. 2003, and Cairns, 1997) revealed the need for increasing waste prevention and recycling. This is true because the collapse of renewable resources such as petroleum, coal and steel will definitely become critical, since their availability in quantity is only finite which will eventually be degraded beyond recovery if industrialized nation's consumption will continually be heavily dependant on these renewable resources. One great value of reuse and recycling is that they curtail the exhaustion and dissipation of valuable scarce resources, providing time to make the inevitable transition to alternative sustainable materials an easy one. The more benefits that can be obtained from a particular packaging material, the lesser its original inputs needed to sustain a given level of utilization. This can be viewed from the factor determining environmental sustainability of a raw material if the extent of its reuse value is justifiable and if it can be recycled see figure 4.

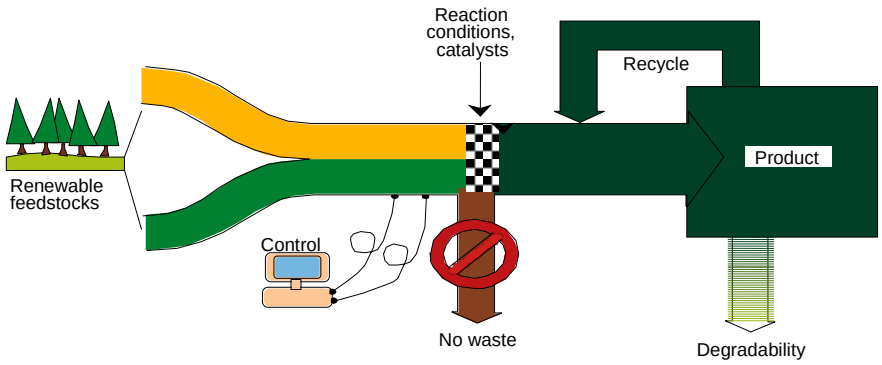

Fig. 4: Raw Material's Environmental Sustainability Cycle (Stanley, 2006).

Among others, the benefits of recycling includes: -

- It reduces the amount of wastes requiring disposal in our communities, cities and towns as such, materials like plastics, metal objects, papers and others will definitely be prevented from littering.

- It solves the problem of health hazard. Recycling of certain particulates such as CKD, asbestos fibres and automobile exhaust which are carcinogens (cancer-causing agents) will help reduce their effects on human health.

- Recycling is a good business. Most people know that recycling plays an important role in managing the garbage generated in homes and businesses,

and that it reduces the need for landfills and incinerators. Recycling is a growth industry with many kinds of business opportunities ranging from collection, and processing to manufacturing to inventing new technologies. With people getting involved will create jobs and improve the national economy. A typical example; is the "yan bola strategy" in Nigeria.

- Recycling helps the national economy when fewer raw materials have to be imported. It is a well known fact that the extraction of aluninium from its ores using electrolysis, concentration of low-grade metallic irons demands high cost, high energy and more resources. Based on these, it makes their recycling very economical, cheaper and viable.

- Petroleum, ores and natural gas are finite raw-materials which will not last forever. Therefore, recycling causes their reservation, which are already in place and could be left for many years unexploited or unexplored. Nigeria's petroleum deposit of yesterday is not the same as today.

- It saves natural resources. Environmental space is the sustainable rate at which we can use environmental resources without causing irreversible environmental damage; depriving the future generation of the earth's inhabitants of the resources they will need (Elijah *et al,* 2007). This can result from digging up fewer metals, mining less coal and drilling less for oil. Fluorides emission produced during electrolysis which pollutes lands, kills grasses and causes lameness in cattle (Harwood, 1999) too will be reduced. The environment will free from harmful substances like acids, cadmium, nickel and mercury when batteries are recycled. Therefore, recycling will to a certain level eliminate these contaminants from our environments causing less pollution.

- Refuse Derived Fuel: recycling produces refuse derived fuel, and natural fertilizers to be used by farmers.

Problems with Recycling:

- **Highest Value:** Some proponents of recycling suggest that everything should, could and ought to be recycled. While recycling often provides the highest value return for an item, this is not always the case. Many items that are recyclable are not profitable to recycle. Without guaranteed quantity and quality, the highly volatile recycling markets are not always open for certain materials.

- **Lack of Technology:** Recycling plastics presents a particular problem because of the difficulty in identifying the types of polymer used. It must be noted that the use of polymers in producing materials used daily in the society is relatively new, hence lack the technology to carry out operation.

- **Contamination:** Paper in the household and commercial refuse system is often easily recycled. But when newspapers are thrown together with garbage, they become wet and contaminated and probably cannot economically be

recycled. Consumers still view recycled paper as "inferior" paper and choose not to buy recycled paper stock, which drives the production down and the cost up, making recycled paper a cost prohibitive item. Glass contamination continues to be a problem in recycling as is plastic waste.

- **Resource Costs:** Recycled materials are a resource for industry. As such, the cost of the recycled material is one factor in deciding whether or not to use recycled materials. The collection of recyclable items, sorting (labour intense effort), cleaning and other "extra" costs are included in the use of post consumer material recovery. Some recycling efforts are also energy intensive. Most recycling projects are labour intensive. Every recyclable material has some problems. The overriding issue however is demand for recycled materials. Recycling as an industry is demand driven. Only those materials for which there is a great demand at any given time are economical to recycle.

- **Pollution:** One of the old arguments against recycling is that recycling often requires the use of chemicals to clean and reprocess materials for use. One example is bleaching paper slurry to create a cleaner, whiter paper. Recycled paper slurry often includes inks that create a muddy and speckled tone in the paper. The bleaching required to whiten paper is significantly more than is required to whiten wood pulp. As with incineration and waste of air pollution, recycling and water pollution must be compared to land disposal and land pollution potentials (OSUFS, 2014).

- To improve the amount and quality of recycling not considering other initiatives, source recycling is a must and recycling facilities should be constructed. Recycling centre, preferably matched with refuse transfer stations, include an unloading area, a storage space and a transfer trailer loading equipment. Next to the transfer area is a recycling facility, where waste pickers sort recyclable wastes.

CONCLUSION

The study showcased that, the numerous environmental problems facing our communities, cities can be solved through chemical waste recycling and also as a means of socioeconomic and environmental sustainability. Developing countries such as Nigeria in the Sub-Saharan Africa can not only focus on human development, boosting its economy, but also to protect its healthy environment through recycling.

Ensuring environmental sustainability and socioeconomic development through chemical waste recycling requires to begin with, a radical change in the "environmental behavior", "thinking recycling", and "thinking environment" of individuals, groups, institutions, industry, social organizations, politicians, and governments.

Therefore, chemical waste recycling learning and practice constitutes a prerequisite. Thus, it requires a high level participation of scientists, engineers, economists, policy makers, and mostly, evaluative thinkers in the public at large. The question is how to contribute to this end in the socioeconomic context of environmental sustainability through chemical waste recycling techniques.

RECOMMENDATIONS

The roles of chemical waste recycling in environmental sustainability are as crucial as they are diverse. This paper has attempted to review them, but not exhaustively, especially as new recycling processes and techniques/methods are being exploited by the day. It is recommended that more serious measures should be taken at national and international levels to encourage the learning and practice of recycling and to enhance the regulation of its practice in order to maximize the services, lessens the need for virgin materials, reduce pollution from material extraction and production, prevent litter, reduce landfill emissions and create local jobs and incomes in environmental sustainability, which is a milestone in the new global paradigm of sustainable development.

REFERENCES

Adaska, W.S. and Tuubert, D.H, (2008) Beneficial Uses of Cement Kiln Dust. Proceedings of IEEE/PCA 50th Cement Industry technical Conference, May 19-22nd, Miami, Florida, Pp. 1- 19

Adler, U, (1986) Automotive Handbook, 2nd English Edition, German Publication, U.S.A

Adoreno, H.S., (2003) Environmental Sustainability through Recycling. http://www.sunstar.com.ph/static/pan/2003/12/01/fact/environmental.sustainability.through.recycling.html.

Aishwariya, S. and Amsamani, S., (2009) Recycling Textile Waste – Newer Dimensions. AUW, Coimbatore, India. Pp.1 – 22.

Ban, W. and Lucia, L.A., (2003) Enhancing Kraft Pulping through Unconventional High Sulphide Containing Pretreatment Liqour. A Review. Tappi J., 5. Pp. 75 – 87.

Barlow, D., (2010) Improving Environmental Sustainability, Why Renewable Energy, Pollution Control and Population Matter

Cairns, J., (1997) Defining Goals and Conditions for a Sustainable World. Environmental Health Perspective, 105. Pp. 1164 – 1170.

Clark, J.H., (1995) Chemistry of Waste Minimization. 1st Edition, Blackie Academic and Professional Publication. U.K.

Cross, Nigel (2002). "Sustainable Development," Developments, The International Magazine, 18, 3+.

Elijah, I.R., Adejuyigbe, I., Olorunnishola, A.A.G and Ige, S.I., (2007). "Characterization of Exhaust Pollutants Emitted from a Two – Stroke Spark Ignition Engine." Programme and Book of Abstract of the First International Conference on Sustainable Development, held 14 – 15 November at the University of Abuja, Nigeria, Pp. 83.

Encyclopedia Britannica, (2013) "Ultimate Reference Suite." Chicago, Encyclopedia Britannica Article.

Eneh, O.C and Owo, N.J., (2008) "Sustainable Development-A Review." *International Journal of Development Studies,* 3(3), Pp. 100 – 103

Harwood, R., (1999). "Chemistry" Cambridge University Press, Cambridge, MA.

Korfmacher, K.S., (1997). "Solid Waste Collection System in Developing Urban Areas of South Africa; An Overview and Case Study." Waste Management and Research, 15: Pp. 377 – 499

Lardinois, I. and Van de Klundert, A., (1995). "TOOL, Plastic Waste, Option for Small – Scale Resource Recovery in Developing Countries." A Publication in the Urban Solid Waste Series, Gouda, Netherlands.

Moray, R., (1999). "Creating Wealth from Waste, Grassroots Recycling Network." 1st Edition, Thomas Nelson and Sons, London.

Oloruntegbe, K.O., (2010), "Socioeconomic and Environmental Sustainability through Recycling of Chemical Wastes." *Research Journal of Applied Sciences* 5(1): Pp. 13 – 19

OSUFS (2014), "Community Development." http://ohioline.osu.edu/ed-fact/0108.html, [accessed 15/05/2014].

Paszum, D. and Spychaj, T., (1997). "Chemical Recycling of Poly (Ethylene terephthalate); American Chemical Society, 36: Pp. 1373 – 1382.

Stanley, E.M., (2006). "Green Chemistry and the Ten Commandments of Sustainability." Chemchar Research, Inc, U.S.A.

Taghlei, M.M., Feng. Z., Huggins, F.E. and Daily, D.A., (1994), "Co liquefaction of Waste Plastics with Coal." Energy Fuel, 8: Pp. 1228 – 1232.

Vogler, J., (1984), "Small – Scale Recycling of Plastics in Developing Countries." Intermediate Technology Publication.

Wang, Y., (1999), "An Overview of Activities on Recycling of Fibrous Textile and Carpets Waste at Georgia Institute of Technology." Proceedings of the 4th World Congress on Recovery, Recycling and Re-integration, 2-5th February, Geneva, Switzerland, Pp. 126 – 131.

Zhang, Z.T., Hirose, S., Nishio, Y., Morioka and Azuma, N. *et al* (1995). "Chemical Recycling of Waste Polystyrene into Styrene over Solid Acids and Bases." Industrial Engineering Chemical Research, 34; Pp. 4514 – 4519.

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