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Socioeconomic and Enviromental Sustainability Through Recycling of Chemical Wastes

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Abstract: This study examines the process of achieving socioeconomic and environmental sustainability through recycling of chemical wastes. The chemistry principle that matter is not lost or gained but remains constant is applied in here. Atom never wears out. What one laboratory or industry has no need of could be found useful in another. The recycling of chemical waste can serve as a means of providing solutions to many environmental and economic problems such as high cost of waste disposal and depletion of natural resources. The state of the art in the field of chemical recycling of polymers, textile waste and carpet, Cement Kiln Dust (CKD), Old Newspapers (ONP), domestic and municipal organic waste is reviewed in this study. The benefits and problems of this exercise are also highlighted. The conclusion drawn is that the recycling of waste is of immense benefits especially in solving the numerous environmental problems and boosting the nation's economy but that not much is done, in developing nations for example, to sensitize the schools and the general public on the importance of recycling of chemical waste.

Key words: Sustainability, recycling, chemical wastes, conservation, sensitization, science and technology

INTRODUCTION

Communities are increasingly interested in reducing the environmental footprints of human economic activities. The great challenges facing the world are human-related on one hand and directly or indirectly science-related on the other. Talk of technological disasters, environmental degradation and growing economic imbalance, these all call for concern. Innovative sustainability efforts and practices and the encouragement of sustainable behaviors are needed not only as a way of boosting nations economy but also as a way of wisely getting rid of wastes that are eyesore 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 followings:

- Generating economic and environmental solutions
- Generating a proven approach for long term success
- Building market opportunities
- Creating a competitive edge by staying ahead of global trend
- Incorporating personal responsibility
- Customizing solutions that result I auxiliary income
- Building stakeholder value with green strategies and so on (improving the bottom line starts by integrating sustainable strategies into the waste logistics model through partnership with OAKLEAF. Waste Recycling Resources for North America)

London Development Agency through recycling has achieved the followings:

- Recycled over 7 millions Ibs of potential landfill by collecting bags of clothing, house wares and other products
- Recycles all paper and cardboard items through an in-house recycling program
- Recycles scrap metal computer monitors and television at donation station
- Promotes environmental responsibility by hosting bins for a variety of community events
- Proudly prints all brochures and publications using papers with post consumer recycled content
- Only uses donation bags made of bio-degradable products (London Development Agency). But these efforts have not been noticed in most countries of Sub-Saharan Africa and Asia, meaning that we cannot afford to be watching the world making progress in this are without our taking action.

Environmental sustainability is the long-term maintenance of ecosystem components and functions for generations. Sustainability is related to the quality of life in a community-whether the economic, social and environmental systems that make up the community are providing a health, productive, meaningful life for all community residents, present and future.

The UNESCO's Division of Ethics of Science and Technology is one division that is active in the field of

applied ethics such as bioethics, ethics of the environment, ethics of outer space, ethics of science and teaching of ethics (UNESCO International Science, Technology and Environmental Education Newsletter, Vol XXIX, No 3-4, 2004). Implications of these fields revolve around the concern for the environment. 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 school alone but should be the concern of everyone. There is also a moral view to this argument. Every organism in the surrounding has hundred percent right of continual existence like human. Such right must be protected and safeguarded. The purpose of this study is to discuss the processes of recycling of chemical wastes, its benefits and problems. This is meant to educate and familiarize the entire 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. Rather than considering waste as economic pipe drains, sight sores 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 the international economy (Moray, 1999) and the development of more environmentally friendly products and processes (Clark, 1995). What one laboratory of industry has no need of, another finds use for it. And of course, recycling of waste would appear to be a possible alternative solution and more attractive option than seeking a safe disposal in landfills (Taghiei *et al*., 1994). There is also the shortage of land everywhere. This poses additional problem for waste disposal.

Theoretically all materials are recyclable. Dalton affirmed that matter cannot be created nor destroyed. Kelter *et al*. (1975) stated that behind this theory, there is a simpler concept that atoms never wear out. Take a process that converts ethene, formed from carbon and hydrogen, to polythene materials (plastics), many of these materials are thrown away after use as wastes. They litter the landscape in some towns and cities.

These wastes can be converted to a less, yet still useful materials like candle. Recycling or reuse is in line with this principle that nothing should be left to waste. However, the success of large scale materials recycling depends on the economics of secondary material recovery and the suitability of secondary materials for reuse.

The review here is focused on chemical recycling of polymers and other household plastic wastes, textile wastes and carpet, Cement Kiln Dust (CDK), lead contaminant, Old Newspaper (ONP) waste, domestic and human organic waste. Highlights of the processes involved in recycling, the benefits and problems were also mentioned.

MATERIALS AND METHODS

Chemical recycling of specific products

Polymers: Polyethylene, Polyethylene Terephthalate (PET), Polypropylene (PPE), Polyvinyl Chloride (PVC) and actual plastic waste from such items as water sachet, yogurt and milk jugs or bottles, soft drink food beverage bottles, plastic wraps, plastic flat ware and so and so forth, have been successfully converted to oil in direct liquefaction experiments with coal (Taghlei *et al*., 1994). The more attractive method is the chemical recycling of waste polymers into the corresponding monomers and/or raw chemicals (Zhang *et al*., 1995), which might be reused for the production of further plastics and other advanced materials.

Chemical processes applied in polymer recycling are divided into six groups (Paszum and Spychai, 1997). These methods include mathanolysis, glycolysis, hydrolysis, ammonolysis, aminolysis and others.

The hydrolysis reaction of PET waste powder in trioxonitrate (v) acid was undertaken in batch process at 88-120°C temperature and 1 atmospheric pressure. Particle size ranging from 50-512.5 pm and reaction time of 30-200 min required for hydrolysis of PET were optimized. Terephlathalic Acid (TPA) and Ethylene Glycol (EG) remain in liquid phase and were separated out by using NaOH solution and then acidification of EG was recovered during hydrolysis by salting out technique. Oxidation of EG was avoided by introduction of sodium sulphate into reaction mixture. TPA and EG produced by this process were analyzed qualitatively and quantitatively. The products were almost equal to PET conversion. From the processes for example, post consumer PET containers are recycled into new products such as fiber carpet, sleeping bags and jackets, fabric for clothing and windbreakers, athletic and casual shoes, cassette tapes, car upholstery and bumper and containers for shampoo and cosmetics. Manufacturers are finding more and more practical end uses for the recyclable PET everyday (Adoreno, 2003). Instead of throwing away soft drink containers and mineral water bottles, they can be stored and sold to brokers for added revenue (Fig. 1).

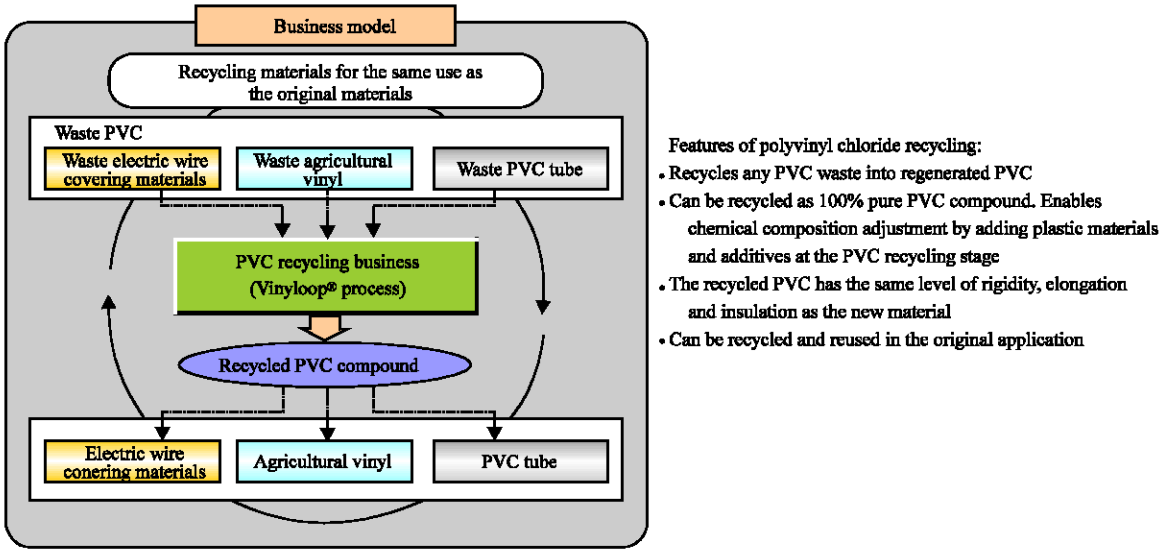

Fig. 1: Business circle of polyvinylchloride recycling (Environmental Sustainability Report)

Plastic waste can also be used as alternative source of energy to aid the African ailing power sectors.

Some industrialized countries had made laws for recycling of plastics. For instance, in the United States of America, laws are in effects in some states that 25% by weight of plastic materials need must be from recycled waste. In Germany, 80% of plastic wastes were recycled by 1995 (Taghlei *et al*., 1994). By now it would have been nearing 100%. France recently passed a similar law. Other nations particularly the third world can follow suit. The benefits are enormous.

Conventional plastic recycling is facing a number of problems. There are nearly a hundred classes of plastic polymers with a thousand specifications. Therefore an advanced technology is required for sorting and separating post consumer waste plastic for high quality recycling. Moreover, the potential exists for impurities to diffuse into products packaged in recycling containers. Conventional plastic melting temperature is not high enough to eliminate all possible contaminants in waste plastics. Therefore, just like in polyvinyl chloride secondary seeds, the products are good for non-food packaging technical applications like pipes for sewage and electric insulators. It will be noted that United States (of America), Food and Drug Administration (FDA) has banned the use of recycled plastics for products that come in direct contact with food.

Carpet and textile materials: About 4 million tons of post consumer and industrial fibrous textile and carpet waste is landfilled each year in the US. Many carpet and textile manufacturers, fiber and chemical suppliers, recycling companies and academic institutions are actively pursuing various methods to recycle fibrous waste. In the past decade a broad-based research programme has been carried out at the Georgia Institute of Technology on Carpet and textile recycling in close cooperation with the industry. These approaches include depolymerizatiion, melt processing, recycling logistics, life cycle analysis, waste characterization, material component separation, composite material and reinforcement for concrete and soil. A recycling logistic tool is being developed (Wang, 1999) to help the industry to make sound economic decisions regarding these operations. The tool consists a generic model that evaluates the economic feasibility of establishing and operating a carpet recycling network. This in consists of strategically located collection sites, sorting facilities and a distribution system to transport the waste.

Although, a sustantial parts of the textile waste from the Western world find great and important use in the third world countries, particularly Africa. The clothes are referred to as second hand clothing. They like other used products, vehicles, electronics are like new ones in the hand of the poor and the rich as well. These poor nations are like landfills for waste from the developed natiions. It is not surprising too that some toxic radioactive wastes find their ways to many of these third world countries through similar sources. Koko village in Sapele, Delta State in Nigeria was an example where toxic radioactive waste from an Italian industry was dumped in 1987. The Nigerian government had to evacuate and rehabilitate the natives far away from the sire because of the serious health implications.

How the third world nations get rid of the resulting waste is a thing of concern. They litter then the landscapes. No one talks about lanfills not to mention recycling. This should make recycling of waste a policy issue. There is need for sensitization and reorientation.

Cement Kiln Dust (CKD): Cement kiln dust is a waste product generated by the cement industry. It is in powder form composing mainly of micro-sized particles collected from electrostatic precipitators. The chemical composition of CDK is shown in Table 1.

CDK contains high alkali content causing the fearful alkali aggregate reaction. A large quantity is produced every year. In United State alone, about 4-12 million tons are released annually (Adaska and Taubert, 2008). The quantities and the consequences of the release of CDK are of little or no concern to agencies and industrialists. If there is any concern shown in Nigeria for instance there is no available research evidence. This is yet a minus and lack of concern for citizenry of a country that produce and use billions of tonnes of cement yearly. 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 attendance health hazard, CDK ought not to be released into the environment. The possibility of its recycling in other fields is thus increasing in importance and consideration.

CDK can be recycled and reused for agricultural soil treatment, pavement base layer and for blended cement among others. The last use absorbs CDK in large quantities. Rather than allowing such particles to fill the environment and thereby endangering lives, CDK finds ample use when recycled.

Lead recycling: Lead is yet another contaminants of soil and water (in any ecosystem) that endangers lives, flora and fauna, of which man is an ultimate recipient. Lead gets to the penultimate destination through air, surface water or ground water. It is released from lead mines; primary and secondary lead smelters and battery recycling plants. A particularly important pathway for human exposure occurs when fugitive particles deposited on the surrounding soils. The stability of lead in soils is such that elevated concentration can persist for many years, even after the closure of the facility (Small *et al*., 1995). In the residential areas, exposure of lead in soil occurs directly through inhalation or drinking lead borne pipe water or ingestion associated with gardening activities, childhood play or indirectly through the soils. Lead contributed to the home dust which is subsequently inhaled or ingested and absorbed into the blood or body issue. Car batteries and dry cells are used in large

Table 1: The chemical composition of CDK

Chemical composition	Values
SiO_2	14.65
Fe_2O_3	2.15
Al_2O_3	4.75
CaO	41.72
MgO	1.12
SO_2	0.72
Na_2O	0.90
K_2O	0.60
IOI	32.30

Adaska and Taubert (2008). Sustainable waste management and recycling: challenges and opportunities

abundance in the third world in electrical appliances like radio, phones and in lighting purpose where electricity supplies are non-existent. The spent ones are thrown carelessly everywhere. These have great health consequences as lead poisons body organs such as kidney, liver and heart.

Apart from this, there are other sources of the release of lead contaminants to the urban environment. These include vehicular emissions, fuel and thrash burning and disposal. Contribution from lead based paint especially where repainting of older houses is preceded by aggressive scraping, sanding and/or burning is significant. Incidentally there is no law guiding such activities, neither are governments of the third world nations interested in reducing volume of traffic and automotive lead emissions. Not only that everybody wants to own car but also an average citizen wants to own many cars.

Lead recycling processes especially operations of automotive lead-acid batteries consist of battery cracking and draining of spent acid, separating the electrode lead from the battery casing and in some cases smelting the recovered lead. Unfortunately, many plants were historically operated without the necessary care to ensure full capture and containment of the lead.

Old Newspaper recycling (ONP): The importance of recycling is increasing for the pulp and paper industry because of decreasing forest resources, landfill problems, environmental regulations and associated legislation (Ban and Lucia, 2003). One of the main drawbacks of recycled fiber is the loss of mechanical strength of study made from recycled fibers. The origin of the strength loss has been a source of debate. The recycling potential depends on many factors, fiber furnish, pulp chemical compositions, pulp beating, sheet drying, etc., the effect of recycling on nonwood pulp fibers are not well documented yet.

Pulp produced from mechanical pulping (ground wood pulp) produces a weak paper and usually requires the addition of some chemicals to hold the paper together as it travels through cutting process. Ground wood pulp

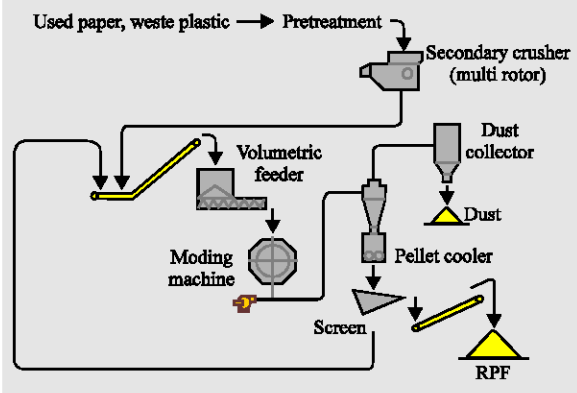

Fig. 2: Refuse Paper and Plastic Fuel (RPF) Plant Flowchart (Environmental Sustainability Report)

contains lignin, which provides high bulk and opacity, as well as smoothness and ink absorbency. This makes ground wood pulp only ideal in the manufacturing of newspaper. Incidentally it is the lignin that turns yellow when a newspaper is turned to light.

Chemical pulping removes the lignin during a cooking process and as a result produced a strong pulp that can be bleached to high level of brightness. Bleached chemical pulp, known as Kraft pulp, is used in the production of white writing paper. Unbleached chemical pulps are used in the production of brown paper bags and corrugated boxes (Fig. 2).

Old Negwspaper (ONP) is the most visible form of waste paper found in the household. It is by both weiht and volume one of the highest percentage (10%) of the most residential waste streams. Commercial establishments also generate large volumes.

ONP is a new, cheap and major raw material for paper industry. It is however, not without its own problem of contamination by insect pest, whether the material is wet or dry, bailed or unbailed. These are the criteria by which the ONP is judged.

Bailed ONP should contain <5% other paper, prohibitive materials may not exceed 0.5% of out throws ONP and contaminant materials such as glass, plastic, metal or other non paper materials may not exceed 2% (Rogoff and Williams, 1994). This guidelines show that recycling ONP requires a careful effort to produce quality useable materials.

Recycling of solid organic matter: Soil organic matter is an important raw material for soil conditioning. These are turned out in large heap and they are eyesore in our cities. Smith gave the composition of municipal solid waste in selected African countries (Table 2).

Table 2: Composition of municipal solid waste in selected African cities (tones)

Composition/Cities	Kumasi	Acrra	Ibadan	Kampala	Kingali
Organic	84.0	85.0	55.0	75.0	94.0
Plastic	-	3.4	8.3	-	-
Glass	-	1.9	1.8	-	-
Metal	-	2.8	-	-	-
Paper	-	4.9	12.9	-	-
Cloth	-	3.0	-	-	-

Korfmacher (1997); Solid waste collection system in developing urban areas of South Africa: An overview and case study

The ever growing quantities of urban waste in African cities which at present amounts to 0.5-6 kg 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. There is an inexhaustible and readily available supply of this. Its removal will reduce the health and environmental hazards in our own and cities. Recycling organic waste is about the cheapest and least sophisticated. What a nation needs to do is to operate a central sewage system and establish a recycling plant to turn the waste to organic fertilizers for soil nutrients.

RESULTS AND DISCUSSION

Benefits: It is worthwhile to dwell on the far-off prospects of material use for an environmentally sustainable economy. The motivation for waste and pollution prevention through recycling can only be fully appreciated when related to long-run goal of material conservation. Let us assume that recycling may or may not save money on disposal costs, create jobs, save energy, or reduce litter but reality will tell us that many conceive the thought of recycling because they believe that materials are getting scarce and that conserving them is the best thing to do. True to this, the society we live in today is without a doubt not sustainable because industrialized countries' consumption depends heavily on renewable resources, particularly fossil fuels and metals and targeted economic development of the world's developing majority will hasten the exhaustion of these scarce resources. The collapse of renewable resources such as steel, oil and coal will definitely become critical. Because they are available only in finite quantities, they will eventually be degraded beyond recovery.

The economists and environmentalists studies on technical and economic requirement for sustainability (Adoreno, 2003; Barrera-Roldan and Saldivar-Valdes, 2002; Cairns, 1997; Hill, 1983) revealed the need for increasing waste prevention and recycling. One great value of reuse and recycling is that they postpone the

exhaustion and dissipation of valuable scarce resources, providing time to make the inevitable transition to alternative sustainable materials an easy one.

A critical factor determining a raw material's environmental sustainability is the extent of its reuse value and if it could be recycled. The more uses that can be derived from a particular packaging material, the smaller the original inputs that are needed to sustain a given level of utilization. Today's recycling programs are valuably contributing in this direction but the sustainable environment of the future will need to advance much further.

From the sub mission, the benefits of recycling can be summarized as follows:

- It saves money. For example, the high cost of extracting aluminium by electrolysis and concentrating low-grade iron or makes the recycling of these two metals very economical. The high energy demand makes it much cheaper to recycle than to manufacture the metals
- It saves the environments. This can result from digging up fewer metals, mining less coal and drilling less for oil. The red mud waste from purifying bauxite causes worry about alkali getting into the water supply; fluoride emission produced in complicated reactions during electrolysis too will be reduced. Fluoride emission pollutes agricultural lands, kills grass and causes lameness in cattle (Harwood, 1999; Hill and Holman, 2001). Recycling will remove these contaminants from the environments
- It leads to reservation of materials, which are already in place and could be left untouched for a number of years. Ores, oil and natural gas are finite materials. They will not last forever. A nation that once has oil deposit today may not have tomorrow. Hill and Holman (2001) gave a picture of how long the reserve of different materials will last
- It solves the problem of waste disposal. Recycling of metal articles, plastics and others will prevent them causing litter

Possible problems: Sometimes recycling is not economical because of the cost of sorting, collecting and processing the waste material. The higher the value of the material the more economical it is to recycle. While gold is totally or hundred percent recyclable, aluminium and steel are only 40% recycled. Others go into junking, dumping and uncovered corrosion.

Recycling plastics presents a particular problem because of the difficulty in identifying the types of polymer used. It is easy to separate iron from copper and be recycled but polyvinyl chloride and polythene are much more difficult to distinguish and separate. It must be noted that the uses of polymers in producing materials used daily in the society is relatively new. They came into limelight within the last two decades. Ironically they present more environmental problems because they occupy more space being very light.

To improve the amount and quality of recycling not considering other initiatives, source recycling is a must and recycling facilities should be constructed. Recycling centers, 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.

Source recycling improvement depends heavily on citizen participation and will only be successful if there is a serious commitment from waste producers to store recyclable and non-recyclable wastes in separate containers. An intensive and effective awareness campaign must be conducted in order to mobilize and motivate everyone to practice this separation of wastes. Here is where responsible citizens, manufacturers and companies come in. If we wish to do what is right for the society and the environment, recycling is one of the most accessible and tangible commitments. Practicing recycling adds to its more literal purpose of participating in an environmental ritual. It then becomes more valuable to belong to one of the few rites that are extensively shared throughout an increasingly disjointed society.

CONCLUSION

Literatures have revealed that the recycling of chemical waste is not only an important means of solving the numerous environmental problems but also a means of socioeconomic and environmental sustainability. A nation willing to boost its economy and conscious of healthy environment for its citizenry cannot but pay due attention to recycling. The school and science classrooms could be starting points of achieving these developments Course on recycling can be introduced as core curriculum. This is with a view of extending its importance to the general public. Major stakeholders in environmental education on one hand, industries and research institutes on the other, must come out with policy on how best to make maximum exploitation and utilization of this untapped resource.

The earth minerals are finite materials which will not last forever. More so that natural resources are no longer considered a source of wealth but science and technology. If this is the case, there should be no stone left unturned in achieving sustainable development through science and technology of recycling.

RECOMMENDATIONS

It is suggested that before the present generation passes, we must recycle partly to avoid new landfills. Much more than hating disposal facilities, many times, recycling earns money and it can be cost-effective. Advocate even push to extend recycling to a point where it pays for itself. Ultimately, recycling lessens the need for virgin materials, reduces pollution from material extraction and production, prevents litter, reduces landfill emissions, provides a basis for new businesses to use recovered materials and creates local jobs and incomes. Wastes must no longer be looked at as woes but rather a source of wealth.

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