Recycling of Scrap Solid (Metal) Industrial Waste in Fabrication of Tile Making Machine as a Strategy in Waste Management in Kaduna, Nigeria.

Abraham D. Morakinyo M.A.[1*] and Alkali N. Vershima, Ph.D.[2]

[1]Department of Industrial Design, Federal University of Technology, Yola, Adamawa State, Nigeria.
[2]Department of Industrial Design, Ahmadu Bello University (ABU), Zaria, Kaduna State, Nigeria.

E-mail: abrahamolushola@yahoo.com*
alkalivershima@gmail.com

ABSTRACT

In many third world or developing countries like Nigeria, there is abundant solid waste littered all over the cities. These wastes are generated without control due to lack of enforcement of existing laws to prevent waste generation or proper waste disposal. Generally, Nigerians have a poor attitude towards enacted laws. This attitude certainly leads to generation of more wastes and consequent poor management. Experts initiated and proffered strategies to reduce the volume of waste generation such as waste: reduction, prevention, recovering, repackaging, composting, recycling, reused, landfill, incineration, etc. – these are some of the major ways currently used to manage wastes generally.

There are many industries which are folding up or have folded up in Kaduna State, Nigeria. The surviving industries are retooling to meet up with current technology and market needs, while new industries are equally springing up. All of these activities to a large extent tend to generation of much Solid Industrial Waste (SIW) which are sold to the scrap metal marketers located in several parts of the state. While some are left or dumped inside and outside the industries. These waste metals were sourced from Kaduna State scrap metal markets for the fabrication of a tile making machine (TMM) as a means of waste management using recycling and reuse of scrap metals.

The design theory, consideration and calculation used in machine design were assiduously utilized and followed; for the fabrication of the TMM as a means of wastes recycling. This was discovered to be an effective procedure in waste reduction and it can impact the economy of a nation and bring about technological advancement and to a large extent, serve as a means of waste recycling leading to waste reduction when used side by side with the paradigm approach.

(Keywords: metals, TMM, recycling, waste management, fabrication, economy, technology)

INTRODUCTION

Waste management is one of the most topical issues the world over. This is because of the amount of waste that is being generated on a daily basis and the impact of such waste on both the environment and animals; especially humans as sole inhabitants and an unending pursuit especially for solutions in the management of these wastes.

Waste management, is the organized and systematic channelling of waste through pathways to ensure that they are disposed of with attention to acceptable public health management plan (Kofoworola, 2006). On the other hand, the German Waste Act (1972) defined waste as ‘‘portable objects that have been abandoned by their owner(s)’’ or ‘‘requiring orderly disposal to protect the public welfare’’ (Bilitewski et al., 1997) in (Seadon, 2006). From the Legal Information Institute, (2003) in Seadon, (2006) the United State of America (USA) defined waste in the Resource Conservation and Recovery Act (1976), as ‘‘any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities’’. The definition goes on to specifically omit ‘‘solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or

industrial discharges'' (Legal Information Institute, 2003 in Seadon, 2006). This definition broadens the scope beyond solid forms of waste, according to Seadon. The New Zealand Waste Strategy gave a concise but an all-encompassing definition of waste by the (Ministry for the Environment, 2002 in Seadon, 2006), which defines waste as ''any material, solid, liquid or gas, that is unwanted and/or unvalued, and discarded or discharged by its owner''.

The purpose of defining the term ''waste'' is to enable the demarcation of the kind of waste this article focuses on. The definitions above are encompassing because wastes were explicated from different perception by the various authors not neglecting any object term as waste. This waste generated need to be managed without an adverse effect on the environment, animals and human beings. This, if done will bring forth a positive impact on the environment, the economy, technology, social life, agriculture and other areas of human need.

Municipal Solid Waste (MSW) management systems are becoming more complex in many countries with the move from landfill-based to resource recovery-based solutions following the setting of international and national targets to divert waste from landfill and to increase recycling and recovery rates (Burnley, 2006). Establishing realistic national recycling targets requires an accurate knowledge of waste composition at the national level.

Today in many third world or developing countries like Nigeria there are abundant solid waste littered all over the cities. These wastes are generated without control due to lack of enforcement of existing laws that prevent waste generation or proper waste disposal. Generally, Nigerians have a poor attitude towards enacted laws, so even if the laws are there they might not be observed. This attitude will certainly lead to generation of more wastes and consequent poor management. Kofoworola, (2006) said globally, there is an increasing awareness of environmental planning and management; Nigeria also recognizes this need. Unfortunately, Nigeria has not developed and implemented environmental protection policies.

In Nigeria, wastes are generated on a daily basis. One of the ways in which these wastes are generated is in the springing up of more industries, while some industries are folding up, some are retooling and upgrading their equipment to produce and compete favourably in the market. Yet in the midst of this occurrences solid industrial waste are bred. These litter the environment, others are sold to metal scrap marketers and some are taken to refuse dumps. In the hub of all these activities more waste are still being generated.

Another way by which solid wastes are generated is through population growth or boom, as well as economic and industrial development in a country (Kofoworola, 2006). This waste management problem can be directly linked to developing countries ever-increasing population, where MSW management has become a major environmental issue as shown in Singhal and Pandey (2001) and in Kofoworola (2006). For example in Nigeria, the study by Kolawole (2000) in Kofoworola (2006) shows that the Lagos metropolis with its high level of industrial and social activities has a high rate of solid waste generation. Kolawole, (2000) also estimated that more than 10 million inhabitants of the state produce a total of 4 million tonnes of MSW annually. And how to control these wastes and hopefully recycle them has been a source of concern to the state government.

The sources of solid wastes generation are boundless with increased industrial activities, advances in technology; growing population and human activities in dare quest for development. There abound spectrums of enacted laws on waste management in the: Federal, State and Local Government levels of Nigeria. But, the enforcement of such laws has been a mirage (Nwufo, 2010). The law that deals directly with management of waste generated (in terms of recycling) in Nigeria have not been successful. But it is the goal of this paper to suggest a positive means by which this waste generated can be managed to the benefit of Nigeria economically, socially and technologically.

Because, one of the main goals of waste management world over from available literatures is to impact the economy of a nation, generate employment, reduce poverty and repackage or recycle this waste for consequential development.

Classification of Waste

Indigenous authorities require waste compositional information at the local level to

plan, implement and monitor waste management schemes that will enable them to meet their contribution to the national targets. A number of studies have been undertaken classifying and categorizing solid waste and characterizing waste accordingly, internationally. Wastes are classified as organic or inorganic. Under the inorganic are: paper/cardboard, plastics, glass, textile, metal, glass, rubber, leather, wood, etc. (Inter-Consult, 2002 in Kum et al., 2004). Metals specifically are solid wastes that come from solid industrial wastes (e.g., industrial retooling, broken or grounded equipment, etc.) construction wastes, automobile scraps, office scraps, expired spear parts, etc.

The metals we are focusing on in this article are: iron, steel, aluminium, cast iron, stainless steel and mild steel. Most machines, equipment and tools are made from these metals, which forms the major material used to produce the world infrastructure. Yet after sometimes these infrastructure or machine outlive their usefulness or breakdown. When this occurs these metals are labelled as waste in the environment and are consequently disposed.

Metals are wastes generated in Zaria and Kaduna South, Kaduna state of Nigeria. This littered and defaces parts of the city due to reasons advanced previously such as increased population, industrial activities, retooling an updating of equipment.

Management of Waste

Several initiatives in many counties have been proffered and are used for management of solid waste world over. Experts proffered that, to reduce the volume of waste generation strategies were initiated to reduced, prevent, recover, repackaged, composted, recycled, reused, landfill, incinerated, etc. These are actually the major ways currently used to manage wastes generally.

Reuse or recycling has been interchangeably used when discussing waste management. One of the solid wastes like metal can be reused, through the fabrication of machines and equipment. Fabrications of machines using metal waste can go a long way to reduced waste generation and at the same time bring to bear useful equipment that can serve a nation technologically, economically and enhance development that has direct bearing on the populace. It is a systematic way of bringing out of a substance a better product again after recycling. Dijkema et al., (2000) in a paradigm said substance, however, is a waste only when it is experienced as or labelled as waste. A producer according to Dijkema, for example, may consider unwanted by-products `prompt scrap' or `production waste', whilst others regard these a potential resource. Waste is a subjective concept, or rather a qualification of a particular substance or object, which does not vanish after disposal. The qualification, however, may change: what is considered waste today can be a resource in the future. A more strategic notion, therefore, is that a substance or object is qualified as waste when it is not used to its full potential.

Under the paradigm, Dijkema et al., (2000) said any production process can be used for the transformation of waste, which vastly increases the alternatives for system design. In networks of industrial plants the waste of one plant can be the feedstock of another. Normally, in a transaction that concerns by-products neither of the two parties involved considers the substance a waste. If, however, the receiving party terminates its activity, the producer would immediately experience problems in disposing its by-products, and the substance would then be qualified as a waste product. Waste, therefore, is an emerged quality of a substance or object. Subsequent processing of any waste material causes the emerged quality to submerge again.

This paper draws together the findings of a research carried out in fabricating a tile making machine by reuse or recycling of metal wastes generated basically from the industries in Zaria and Kaduna South, Kaduna State of Nigeria, West Africa. Metal Fabrication is believe to be one of the means by which waste can be recycled, reused, and consequently impacts the economy and technology of a developing nation such as Nigeria.

MATERIALS AND METHOD

The population for this study is Zaria and Kaduna South Local Governments Areas of Kaduna state, Nigeria. Kaduna generally is the commercial, industrial, political and educational nave centre of northern Nigeria. Kaduna has many industries which are folding or have folded up. The surviving industries are retooling to meet up with current

technology and market needs, while new industries are equally springing up. All of these activities to a large extend lead to generation of much MSW which are sold to the scrap metal marketers located in several parts of the state. While some are left or dumped inside and outside the industries.

Metals were sourced from Kaduna State scrap metal markets for the fabrication of a tile making machine (TMM) Metals collected from these markets for both the major and minor components of the machine were mild steel, stainless steel and cast iron. The collection of these scraps was done component by component as required. These were used for components like the pulleys, sprockets, pins, keys, shaft, auger blade, gears, spring, the lever steel stand, angular metal footings, milling chamber, plates, cone-nose end, rollers big and small, flange, blind flange, clamp, motor bed and connecting plate, etc.

Mild steel has been the best and most widely used, in building the world's infrastructure and industries (Britannica, 2009 in Morakinyo, 2012). Mild steel is available, cheaper and easy to machine, it possesses all the properties of metals - physical, mechanical, magnetic, thermal, electrical and chemical which makes it usable as mentioned by (Khurmi and Gupta 2004) and (Nagpal, 2002). The scraps were identified, collected-purchased, transported, treated, refashioned, grounded and finished.

It is good to note that in the spectrum of the recycled metals: there were some few new components bought directly from the stock shop. These are components that have material standards: bearings (big and small), bolt and nuts, pins, washers, light metal sheets for the covers, switches, thermostat and some angle bars

Equipment/Tools and Facilities for Fabrication

The processing of these metals was done in a metal fabrication shop utilizing the under-listed equipment/tools and facilities: the angle and bench grinders, industrial cutting machine, the hand and industrial drilling machine, industrial folding machine, the milling and lathe machine and a hack saw. Others are measuring tape, square, Vernier and normal calliper, oxyacetylene (oxygen and gas) cylinder and nozzle, slotting/shaping machine, chain pulley machine, hammer, grip pliers, vice, welding machines, spray gun, spanners, screw drivers, etc.

Fabrication Procedure

Prior to the fabrication of the equipment, preliminary drawings right from the conception of the idea (tile making machine) to the end product were made. This led to various gradations of drawings of the entire machine from manual to computer aided design (CAD) with software like AutoCAD and Sketchup. The drawings were broken into various component parts to ease fabrication of parts. From these sketched diagrams, workable designs were selected to work on (Figure 1).

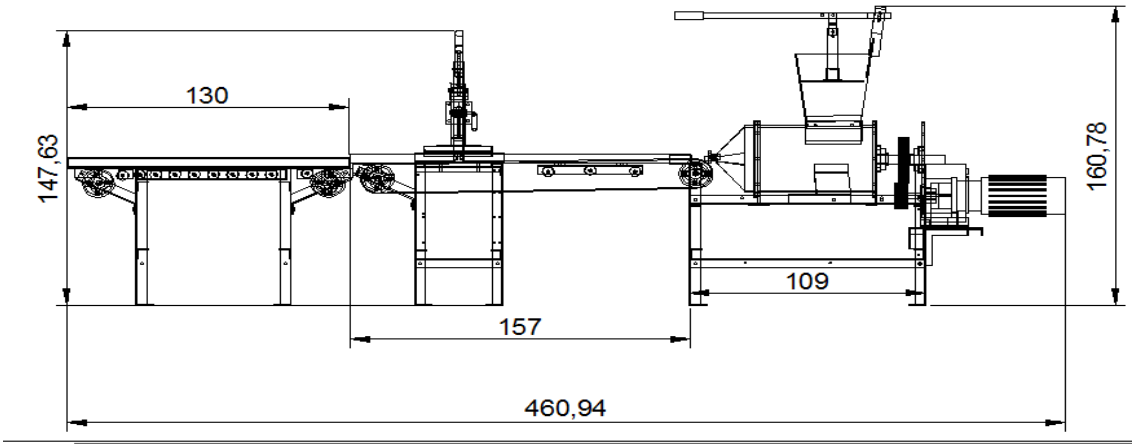


Figure 1: Front View of the Tile Making Machine (Source: Morakinyo, 2012 and Morakinyo, et al. 2013).

In the preliminary pilot study, 3D models of some component parts became imperative. Apart from the engineering drawing that serves as a blue print, the 3D modelling is a mathematical model used to view a project prospect; this is in form of a physical model produced. In the case of this research, only the complicated and nerve-racking geometric shapes of the major component parts were produced using cardboard paper and strawboard which helped in obtaining triangulation of shapes, feedback and decision making. This paper models were later transferred or copied unto the key steel materials. Morakinyo, (2012) states that this helped to achieve:

a. Accuracy of shape and dimension.

b. Prevent wastage of material or generation of more waste and time.

c. Failure of component function.

d. Possibility of component parts as designed.

e. Ease in cutting and forming out shapes.

Generally speaking the fabrication procedure is as presented in Figure 2.

Design Theories, Considerations and Calculations

The design theory, consideration and calculation of the major component parts were assiduously utilized and followed as used in machine design and fabrication (MDF). This was done component by component and with the calculation of the various forces acting on each components of the machine. The result of the machine fabricated as a means of waste reduction is handy in the next heading.

RESULTS AND DISCUSSIONS

The result of the fabricated Tile Making Machine (TMM) through recycling of solid metal wastes is presented pictorially to allow visual communication on the kind of components fabricated from the industrial solid waste –to an emerge product the TMM. The plates presented below shows a lot that can be done in the recycling of solid waste through fabrication as a means of treating waste for effective management.

In plates I to XII if they are closely examine one will discovered that each metal has its original colour as purchased from the scrap markets. Some were just machined (use of power driven tools to cut, shape and finish metals) some join as a component, and others assembled components that made up the TMM as recycled metals. These figures are shown for authenticating the fabrication of the TMM. It is a fact now that functional and multifaceted machines or equipment can be realised from the recycling of solid wastes.

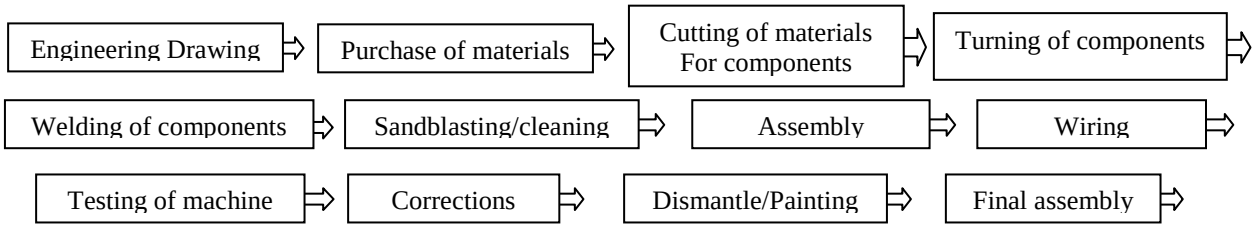


Figure 2: Fabrication Procedure

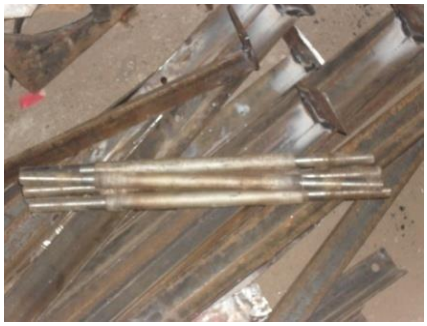
(Source: Morakinyo, 2012 and Morakinyo et al., 2013)

First Cell of Six Plates I-IV

I:- fabricated processing section comprising the Hopper, milling chamber, nose-cone, electric motor, driven gear and the rigid stand. All these are from the scrap market

II: - Fabricated Shaft auger with milling paddles and blades.

III: - Receiving Section, comprising the Rollers, Rollers' Rail, roller Hanger and the Jaw Joint Connector (link of the Second and the Third Sections).



IV**:-** Four stepped Roller's Shafts and Footings.

V:- Four cut Padded Cylindrical Pipes for the big conveyor rollers.

VI:- Cone-nose.

(Source: *Original Research Photographs Morakinyo, 2012)*

Second Cell of Six Plates VII - XII

VI :- Cut And bended Auger Plates

VIII:- Corrected and expanded Milling Chamber.

IX:- Two Templates' Tray

X:- cross section of stamping and cutting mechanism

XI:- Progressive Assembly as the Fabrication Progressed and The Entire Machine Coupled.

XII:- pieces of metal cut in the process of fabrication

(***Source:*** *Original Research Photograph Morakinyo, 2012)*

Plates I to XII are illustrations of the major components fabricated from metal got from the scrap marketers. These were sorted, purchased, transported, fabricated, finished, tested and made ready as offshoot of recycling through fabrication. Each of these components was fabricated based on the engineering drawings in line with design considerations, theories and calculations earlier stated.

The steps that were used in the fabrication of this components and eventual emergence of the TMM are similar to the steps used in the recycling of waste by Kofoworola (2006). These steps are: (1) source, collection and transport of waste; (2) sorting and clean-up of waste; (3) processing of marketable materials; and (4) marketing and sale of the product. This fourth step is part of the process because, when a product has been finished, assembled and is functional; it is ready for the market based on its potential.

The interrelation of these activities exerts a strong influence on the economics of the recyclable waste scheme. Therefore, these basic steps should be considered and practiced more efficiently. This to a greater extent has been attained because with the TMM the economy of the nation will be impacted once the machine is put into use to produce tiles that can be sold within and exported as a means of foreign exchange.

Waste recycling can help eliminate and thus minimize wastes. It is possible to minimize waste through the fabrication of machines from the used of disposed metals from the industries and metal scrap markets. From the components fabricated, it is apparent that these metals have become feeds stocks. This waste, therefore, is an emerged quality of a substance or object as in Figure 3.

This is consequent to the fact that processing of any waste material brings about the emerged quality to submerge again. Kofoworla (2006) believed that a product or material is recycled when it is reintroduced into the original production process and used to form a new product. Fabrication is an original production processes used in production of the TMM. Fabrication can go a long way to reduced waste if there is an encouragement by the government and the Nigeria public on this sort of recycling of metal scraps by patronage of made in Nigeria products such like the TMM . Kofoworola ibid, cautioned that the availability of markets and favourable price structures for recyclable materials may encourage the continued production of waste items, while ignoring options that could eliminate wastes in the first place.

Figure 3: The Developed Tile Making Machine. (*Source: Morakinyo, 2012 and Morakinyo et al., 2013).*

In order to prevent continuous generation of waste while ignoring options that could eliminate wastes items as stated above, the researchers will like to suggest that the paradigm approach be utilized. The paradigm suggests that in the same place where wastes are generated there can be plants for the recycling and transformation of the same into a valuable product from the same resource. The paradigm advocated that the material cycle should continue as an integrated waste management system.

Dijkema et al., (2000) advanced that this paradigm is not an entirely new one, as in many industries some processing of a waste becomes economically and ecologically feasible, and the substance or object previously labelled `waste' changes into a `resource'. He gave an example in the development of the petrochemical industry; as an on-going process. The production of ethylene out of naphtha, for example, can only be profitable if the other products of this cracking operation, notably propylene, C4s, and aromatics, can also be sold at a reasonable price. The design and optimisation of naphtha crackers therefore is aimed at maximisation the yield of valuable products, while at the same time minimising the production of waste-gases that can only be used as fuel.

He added that, once this paradigm is accepted, the necessity of an integrated resource system is obvious. It immediately follows that under this paradigm, waste management and production form a single system. If decisions are made on either of them, the consequences for the complete system must be visualized and taken into account. The new paradigm thus forms the foundation of a movement towards a cyclic economy that resembles the way nature's ecosystems are built up: a network of integrated processes that form cycles. Ayres and Ayres (1996) and Graedel and Allenby (1995) in Dijkema et al. (2000) deduced that the holistic approach towards industrial ecosystems and industrial ecology use this analogy to capture and build upon a strategy for sustainable development. The concept of material cycles is used to effectuate this strategy for a waste infrastructure.

In order to stimulate a more symbiotic realisation of industrial activities and waste treatment, the waste management infrastructure must not be treated in isolation from the systems that generate waste. Rather, the two must be combined in the concept of material cycles, (Reuter, 1998) and (Dijkema and Reuter 1999) in Dijkema, et al. (2000). Materials flow through production and waste management systems alike, cycles back and forth and forms the connection between industrial and waste management activities.

While advocating the paradigm for the industries, this would be feasible if the design and engineering sections of such industries in Kaduna are encouraged to design and fabricate machine or other valuable equipment within the same plant. Further, if the beneficiaries of the ‘about to’ dispose wastes, the engineers and the designers will be honest to inform the company on several potentials of this waste that can be recycled within the industry. This will facilitate the advocated paradigm within an industry.

Some of the fabricated components were actually reused or repackaged as one of the strategies stated for in management of waste. Plate IV is a steering shafts turn to roller shafts; plate V was an industrials roller cut to size and repackaged into medium size roller that supports the belt conveyor in conveying the extruded slabs from the orifice, latter cut as tiles. Plate VIII was municipal water transporting pipe, cut and turned to a processing chamber of the TMM. Many others were one component or the other recycled into a better and functional component.

RECOMMENDATION AND BENEFIT OF RECYCLING

Recycling of solid metal industrial waste (SMIW) in the fabrication of the TMM to a greater extent has reduced waste and a new product emerged as a means of technological advancement. The production of the TMM has listed Kaduna state and Nigeria in general as technology developers. This has in a clear term listed Nigeria as a contributory nation when it comes to technology. Wastes if properly managed can enlist a nation among the technologically developed nations. That means solid metal waste if combined with high intellectual ability, with design skills can bring about human infrastructure, mechanical and institutional resources, to the economy of Kaduna state and Nigeria. This is an option which should be promoted in any municipal solid waste management program of the Government. Waste management through fabrication is a great tool towards technologically advancement of any nation.

Consequently, the fabrication of the TMM when put to use in the production of tiles will serve as a means of wealth generation thereby impacting the economy of the state positively. The tiles produce would be sold within and also serve as an article of trade to other African countries. In the long run the needed economic transformation can be realised.

Solid wastes like metals are not suitable for landfills or incineration, but for recovery, reuse, or repackaging and to a greater extent fabrication of the TMM fit this option in terms of management of waste through recycling. Internationally, there is a move from landfill-based to resource recovery-based solutions following the setting of international and national targets to divert waste from landfill and to increase recycling and recovery rates (Burnley, 2006). This study will strongly advocate that fabrication of new products from the disposed waste can bring about this move or shift from landfills. To attain this goal effectively the Federal and State Governments should establish realistic national recycling centres and targets which require an accurate knowledge of waste composition at the national level.

On a final note fabrication of metal waste is actually rigorous, in order to conquer this adequately, equipped fabrication shops or plants are required for effective recycling of this

municipal solid waste. After all said and done, fabrication is a great tool in waste reduction, prevention and generation of feedstock.

CONCLUSION

This study has been able to establish that one of the ways for effective management of solid waste is metal fabrication. This, if used will go a long way in reducing the metal waste that littered and defaced the city of Kaduna. It also established that newer product can emerge as quality equipment from the recycling of metal wastes.

Subsequently, the state and Federal Government with the entire Nigeria populace need to play a strategic role if metal fabrication will achieve the desire result as stated by this study in eliminating or reducing wastes that are generated on a daily basis. The defacing of Kaduna city can be managed successfully if fabrication is exploited in recycling of waste.

Technology and economic issues in waste recycling show that most economies are impacted positively by waste reused. It is evident that the economy and technological advancement of Nigeria can be impacted positively through metal fabrication by utilising metal from the scrap markets.

The concept or paradigm of material cycles offers a convenient method of abstraction to model the broad spectrum of technologies involved, as the material cycle's concept enables a shift in focus-from single linear technologies to interconnected systems. It is obvious that this material (scrap metals) labelled waste have now become a potential resource in the production of a valuable product in terms of the TMM.

A more strategic notion therefore, is that a substance or object is qualified as waste when it is not used to its full potential. Waste is an inevitable end product that has to be disposed of in such a manner that the effect on the environment is minimized.

REFERENCES

1. Ayres, R.U. and L.W. Ayres. 1996. *Industrial Ecology*. Edward Elgar: Cheltenham, U.K.
2. Bilitewski, B., G. Ha¨rdtle, K. Marek, A. Weissbach, and H. Boeddicker. 1997. *Waste Management*. Springer-Verlag: Heidelberg, Germany.
3. Burnley, J.S. 2006. "A review of Municipal Solid Waste Composition in the United Kingdom". *Waste Management*. doi:10.1016/j.wasman.2006.06.018
4. Dijkema, G.P.J. and M.A. Reuter. 1999. "Dealing with Complexity in Material Cycle Simulation and Design". *Comp Chem Eng* 1999; 23:S795-8.
5. Dijkema, G.P.J.,M.A. Reuter, and E.V. Verhoef. 2000. "A New Paradigm for Waste Management". *Waste Management*. 20:633 – 638.
6. Graedel, T.E. and B.R. Allenby. 1995. *Industrial Ecology*. Prentice Hall: Englewood Cliffs.
7. Inter-Consult. 2002. "Assessment Report of the Community based Solid Waste Collection System in Phnom Penh". Unpublished Report. Phnom Penh, Cambodia.
8. Khurmi, R.S. and J.K. Gupta. 2004. *Theory of Machines.* Eurasia Publishing House (pvt) Ltd.: New Delhi, India.
9. Kofoworola, O.F. 2006. "Recovery and Recycling Practices in Municipal Solid Waste Management in Lagos, Nigeria". *Waste Management*. doi:10.1016/j.wasman.2006.05.006.
10. Kolawole, A. 2000. "Waste Management in Lagos State with Oshodi-Isolo as Case Study". Unpublished B.Sc. Thesis. Mechanical Engineering Department, University of Lagos, Nigeria. 1–19.
11. Kum, V., A. Sharp, and N. Harnpornchai. 2004. "Improving the Solid Waste Management in Phnom Penh City: A Strategic Approach". *Waste Management*. 25:101–109.
12. Legal Information Institute. 2003 (August 15). "Title 42 – Chapter 82 – Solid Wastes (Legal Information Institute)". Available from: http://www4.law.cornell.edu/uscode/42/ch82.html (Accessed: 2003, September 22).
13. Ministry for the Environment. 2002. "The New Zealand Waste Strategy". New Zealand.
14. Morakinyo, A.D. 2012. "Design and Fabrication of a Tile Making Machine (TMM)". Unpublished Master's Thesis. Submitted to the Department of Industrial Design ABU: Zaria, Nigeria.
15. Morakinyo, A.D., U.A.A. Sullayman, and D.S. Yawas. 2013. "The Design and Development of a

Tile Making Machine (TMM)". *International Journal of Engineering Research & Technology (IJERT), India*. Online: www.ijert.org, IJERTV2IS80525 (accessed: 2013August, 30th). 2(8) 2013.

16. Nagpal, G.R. 2002. *Machine Design. (3rd ed.).* Khana Publishers: Delhi, India.

17. Nwufo, C.C. 2010. "Legal Framework for the Regulation of Waste in Nigeria". *African Research Review: An International Multi-Disciplinary Journal, Ethiopia*. African Journals Online: www.ajol.info (accessed: 2013 August, 21) Vol. 4 (2) 2010 Pp. 491-501.

18. Reuter, M.A. 1998. "The Simulation of Industrial Ecosystems". *Min. Eng.* 11(10):891--918.

19. Singhal, S. and S. Pandey. 2001. "Solid Waste Management in India: Status and Future Directions". *TIMES*. 6(1): 1–4.

20. Steel. 2009. *Encyclopaedia Britannica 2007*. *Ultimate Reference Suite*. Encyclopedia Britannica: Chicago, IL.

ABOUT THE AUTHORS

Abraham David Morakinyo, is a Lecturer at the Department of Industrial Design, Federal University of Technology, Yola, Adamawa Sate, Nigeria. He is a member of Ceramic Researchers Association of Nigeria (CeRAN) and member of International Journal of Design (IJD). He holds a Master of Arts (MA) and BA (Hons.) in Industrial Design from Ahmadu Bello University (ABU) Zaria. He also had a Nigeria Certificate in Education (NCE) in fine and applied arts from Federal College of Education Pankshin. His research interests are in ceramic and creative design, ceramic materials, machine design, modelling, fabrication and production, interior design, etc.

Alkali N. Vershima, is a Senior Lecturer, and an academician par excellence in the Department of Industrial Design, Ahmadu Bello University (ABU) Zaria, Kaduna State, Nigeria. He holds a Ph.D., M.A., and B.A.(Hons) in Industrial Design from Ahmadu Bello University (ABU) Zaria. His research interests are in waste management, advance ceramic science and materials, fabrication, product development, interior decoration, anthropology, body and glaze composition, etc. He is a member of Ceramic Researchers Association of Nigeria (CeRAN) and member of Craft Potters Association of Nigeria (CPan).

SUGGESTED CITATION

Morakinyo A.D. and A.N. Vershima. 2014. "Recycling of Scrap Solid (Metal) Industrial Waste in Fabrication of Tile Making Machine as a Strategy in Waste Management in Kaduna, Nigeria". *Pacific Journal of Science and Technology*. 15(1):47-57.

Pacific Journal of Science and Technology