International Journal of Geology, Agriculture and Environmental Sciences
Volume – 3 Issue – 1 February 2015
Website: www.woarjournals.org/IJGAES *ISSN: 2348-0254*

Biodeterioration of plastics by weevils; an environmental and stored food product perspective

Elijah I. Ohimain[1]* Dorcas D. Bawo[1], Diepreye Ere[2] and Ekeh N. Peters [1]

[1]Bioenergy and Environmental Biotechnology Research Unit,
Department of Biological Sciences, Niger Delta University,
Wilberforce Island, Bayelsa State, Nigeria.

[2]Department of Chemical Sciences, Faculty of Science,
Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

Abstract: ***Plastics are commonly used as packaging materials especially for food, which has led to the increased generation of plastic wastes globally. Plastics generally resist degradation. A comparative biodeterioration of nylon by three species of weevils (Tribolium, Sitophilus and Oryzaephilus) was tested using 3 plastic types and 2 substrates (rice and plantain flour) for 6 weeks. The number of borings or holes was used as an index of biodeterioration. Results show that the number of borings increased from week 1 to week 6 ($P<0.05$). Amongst the 3 species of weevils tested, Oryzaephilus has the most active borings (10 – 164) holes after 6 weeks, while Sitophylus created 79 holes. Being the least active, Tribolium created 67 holes. At the end of the 6 weeks, some of the weevils died while others multiplied. Hence, out of the initial 20 weevils inoculated, 16 – 42 weevils were recorded for Oryzaephilus, 13 – 43 for Sitophilus and 15 – 47 for Tribolium. The types of plastic bags used and substrate significantly affected plastic degradation ($P<0.05$). In the 3 plastic bag types inoculated with Oryzaephilus the number of hole borings was highest in the thin black bags (164) with plantain flours followed by thick transparent bags (60) also with plantain flour. A similar pattern was observed in the plastics inoculated with Sitophilus and Tribolium though to a lesser extent. It therefore follows that the order of preference for biodeterioration is thin black > thick transparent> thin transparent plastics, plantain being the preferred substrate.***

Keywords: Biodegradation, biodeterioration, cellophane, nylon, plastics, polythene, solid wastes, weevils

1. Introduction

Solid wastes are becoming a major challenge to sustainable development globally. In Nigeria, solid wastes are disposed indiscriminately into rivers, drainage channels, streets, gutters, wetlands and other open places such as bushes. Some solid wastes are also disposed *via* open combustion. The environmental impacts of open disposal of solid wastes are many including foul odour problems, air pollution and release of greenhouse gases (GHG), blockage of canals, rivers and other drainage channels causing flooding. Improperly disposed wastes often become breeding grounds for flies, mosquitoes, pathogenic microbes and other disease vectors and pathogens [1] – [3].

Plastic and polymeric materials constitute a major proportion of municipal solid wastes (MSW) both in developed and developing countries. In Nigeria, before the oil boom of the 1970s, plastic account for only 1% of the MSW, but it now accounts for 55-65% [4]. Statistics abounds on the proportion of plastic and nylon wastes in Nigeria. In a nationwide survey, Aderogba [5] reported that plastics constitute 28% of wastes dump in Nigeria with less than 12% recycled. In Benin City, plastics account for 25.43% of the MSW [6], whereas in Kano, it accounts for 18.00% in government reserved areas, 11.36% at the city centre and 11.70% in sub-urban areas [7]. Akpu and Yusuf [8] reported that in Kaduna state, polythene/nylon accounts for 4% of the MSW in the rural areas and 14% in the urban areas, while other plastic materials accounts for 2% in the rural areas and 7% in the urban areas. In Awka, it was reported that 99% of households generate cellophane bag wastes while 59% generate other plastics and paper wastes [9]. In Akure, plastic wastes accounted for 7.5% in high income areas, 7.1% in middle income areas, 6.8% in low income areas, 10.6 in commercial centres and 6.9% in institutional areas [10]. At the hall of residence of 3 major universities in south western Nigeria (Lagos, Ibadan and Ife), nylon/polythene bags account for 13% of the solid wastes generated, while other plastics account for 5% [3], whereas at Covenant University, Ota 19.32% of the wastes generated are polythene bags, 13.64% plastic bottles, 7.24% plastic food packs and 5.67% polystyrene food packs [11]. The use of plastics is increasing globally. Plastics are now used by virtually all sectors of the economy. Bollag *et al*. [12] estimated that the worldwide plastic waste generation is about 57 million tons annually.

Nylon is a very important fibre and its market has grown greatly since its introduction. It is a thermoplastic polymer consisting of long chains of the monomer ethylene (ethene). The high strength, elasticity, lustre, abrasion resistance, dyeability and shape-holding characteristics of nylon made it suitable for many applications [13]. Polyethylene (Polythene) is one of the world's most popular plastics. It is an enormously versatile polymer which is suited to a wide range of applications from heavy-duty damp proof membrane to light, flexible bags and films. It is currently used in Nigeria in all forms and shades ranging from wrappers of biscuits, water, food etc. They retain their physical and chemical properties over a wide range of environmental conditions such as heat, cold and chemicals. They can resist mechanical stress for a very long period of time. Despite the importance of nylons, there are both environmental and stored food preservation concerns.

Nylon or cellophane is non biodegradable but its strength while in water or soil deteriorates with time. During the deterioration period, the chemicals with which, the cellophane is composed are gradually released and thus polluting the soil or water for upward of 40 years [14]. Besides, nylon production has high GHG production protection. Bernero-Lee [15] estimated the average GHG foot print of nylon produced in Europe to be 5.40 kg CO_2/kg. Aside from the poor aesthetic view it poses at dump sites, it could sometimes cause blockage in the intestines and nostrils of fish, birds and marine mammals [16], [17].
Biodeterioration and biodegradation of plastics can either be beneficial or detrimental depending on the circumstance. For environmental purposes, it is beneficial because it helps to degrade plastic wastes thus preventing their accumulation and mitigating the negative impacts associated with the open air combustion of plastic wastes. On the other hand, biodeterioration of plastics can be detrimental especially to the food industry, where it has caused economic losses. For instance, the mere presence of insects in agricultural products decreased their value. Hence, this study was designed to assess the comparative biodeterioration of nylon by three species of weevils (*Tribolium*, *Sitophilus* and *Oryzaephilus*).

2. MATERIALS AND METHODS

Isolation of test organism
Three (3) different weevils, which are, *Oryzaephilus* sp, *Tribolium* sp and *Sitophilus* sp. were obtained from different sources (Table 1). Referenced identification keys were used to identify the organisms.

Table 1: characteristics of test organisms

Species	*Oryzaephilus surinamensis*	*Sitophilus zeamais*	*Tribolium confusun*
Food media isolated from	Corn Flour	Plantain Flour	Corn Flour
Source	NISPRI*, Port Harcourt	Rohi Biotechnologies Ltd, Port Harcourt	NISPRI, Port Harcourt
Identification keys with references	1. Length 2 3 mm long 1 longer, narrower head 2 large eyes 3 They are active, brown, slender beetle 4 (Kaplan *et al*., 2003)	1. length (2.5 – 4 mm) long 2. It has a four reddish-brown spot on the wing covers 3. It has a long, thin, snout, and elbowed antennae 4. It is able to fly Schoenherr (1838). Gen. *et al sp*.curc.4 (2):967.	1. It has a sub parallel body 2. Measuring 4.5 – 5.5 mm in length and 1.7 – 2.2 mm broad at the widest point 3. Head is heavily sclerotized 4. Cuticle is dark reddish brown 5. Antennae are of capitate type 6. Prothorax is the largest part of the thorax 7. Pronotum measures 1.63 mm at the base 8. Venation of the wings is highly reduced 9. First three sternite of the abdomen are connate. (Tuncbilok, *et al.,* 2003)

*NISPRI = Nigerian Stored Product Research Institute

Breeding of test organisms
Breeding of the three different species of weevil was carried out, using a transparent 4 L (four litre) cylindrical container (having a portion of the lid cut off and replaced with mesh to permit aeration) and fed with oat meal and yeast for a period of three (3) months, and the weevils multiplied.

Experimental set up

Twenty (20) weevils were placed in a netted transparent container and a known weight and dimension of different plastic types (transparent versus black) and thickness (thin=0.1mm versus thick =0.2 mm) was added. Plantain flour and rice grains were added to each container. The experimental set up was done in triplicates. The experiment was conducted for 6 weeks. Control samples that contained the substrates and plastic bags without insect inoculation.

The experiment was monitored weekly. The number of holes and weevils were counted and used to indicate biodeterioration. Micrometer screw gauge was used to measure the thickness of the plastic bags.

In order to dry, kill and destroy the eggs or rvae of any other organism present in the food media (i.e. Rice and plantain flour), the food media were sterilized in an oven (^oC) for an hour and allowed to cool before using them in the experiment.

3. RESULTS

The comparative biodeterioration of nylon by three species of weevils (*Tribolium,* Sitophilus and *Oryzaephilus*) were tested using 3 plastic types and 2 substrates (rice and plantain flour) for 6 weeks. The number of borings (holes) was used as an index of biodeterioration. Results show that the number of borings increased from week 1 to week 6 ($P<0.05$). Amongst the 3 weevils tested, *Oryzaephilus* was most active boring 164 holes after 6 weeks, while *Sitophylus* created 23-79 holes, being the least active, *Tribolium* created 27 – 67 holes. At the end of the 6 weeks, some of the weevils died while other multiplied. Hence, out of the initial 20 weevils inoculated, 16 – 42 weevils were recorded for *Oryzaephilus*, 13 – 43 for *Sitophilus* and 15 – 47 for *Tribolium*. There was no borings in the control samples.

The types of plastic bags used and substrate significantly affected plastic degradation (P<0.05). In the 3 plastic bag types inoculated with *Oryzaephilus* the number of hole borings was highest in the thin black bags (164) with plantain flours followed by thick transparent bags (60) also with plantain flour. A similar pattern was observed in the plastics inoculated with *Sitophilus* where the highest number of holes (79) was recorded in the thin black bag containing plantain followed by 47 holes recorded for the thick transparent bags. The same trend was observed for *Tribolium*, where the highest number of holes (67) was reported for the thin black bags followed by 50 holes reported for the thick transparent bags. It therefore follows that the order or preference for biodeterioration is thin black > thick transparent> thin transparent plastics, plantain being the preferred substrate. Generally, the weevils multiplied highest in the plantain substrates, though some also multiplied in the rice substrates, but many declined in the rice substrate as well.

Table 2: Biodeterioration of plastic bags by weevils

Weevil species	plastic bag type	Substrate	No. of borings or holes on the plastic bags						No. of weevil at 6 weeks
			Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	
Oryzaephilus	thin transparent	Rice	9±6.33abcd	17±4.35ab	23±1.35a	28±14.31a	31±5.60 ab	46±7.94 abcd	26±3.66bcd
		plantain	1±0.88a	2±1.45ab	3±2.03a	6±3.76a	8±4.62ab	19±4.08ab	29±3.93cd
	Thin black	Rice	0±0.00a	0±0.00a	1±0.67a	1±0.58a	3±1.33a	10±3.79a	19±3.18abc
		plantain	44±9.24f	95±8.29c	131±4.72b	137±5.03b	141±5.03c	164±6.19e	42±2.60ef
	Thick transparent	Rice	1±0.67a	1±0.33ab	3±2.19a	4±2.85a	7±3.84ab	13±4.16a	16±4.36ab
		plantain	17±1.15cde	27±2.60b	33±3.48a	40±4.04a	45±4.33b	60±3.76bcd	41±2.03 ef
Sitophilus	thin transparent	Rice	5±3.61abc	6±1.10ab	10±4.81a	12±4.98a	14±5.77 ab	23±3.64abc	13±3.48a
		plantain	8±1.15abcd	16±1.73ab	21±2.31a	22±2.60a	25±2.03 ab	42±4.04 abcd	31±0.88cd
	Thin black	Rice	15±8.41bcde	19±5.29ab	20±8.50a	24±8.14a	30±8.50 ab	41±9.21 abcd	38±3.21def
		plantain	22±1.45e	27±0.33ab	33±1.76a	35±0.88a	42±0.58 ab	79±1.15d	43±1.45ef
	Thick transparent	Rice	3±1.53ab	8±1.62ab	11±4.67a	13±4.36a	16±5.04 ab	25±5.36abc	27±3.06 bcd
		plantain	5±1.73abc	9±0.33ab	22±5.77a	25±5.77a	29±5.77 ab	47±3.53 abcd	38±1.73def
Tribolium	thin transparent	Rice	3±0.88ab	7±2.00ab	14±4.91a	22±6.33a	24±6.36 ab	38±3.93abcd	15±2.08ab
		plantain	11±0.88abcde	15±2.03ab	31±0.88a	38±3.21a	42±2.89 ab	61±6.06bcd	44±6.35f
	Thin black	Rice	4±2.31ab	10±2.06ab	20±1.58a	22±1.22a	24±1.24 ab	32±3.17abcd	22±1.73abc
		plantain	18±3.28de	21±3.18ab	35±0.33a	39±0.88a	43±1.15 ab	67±0.33cd	47±1.73f
	Thick transparent	Rice	3±1.73ab	7±1.33ab	14±2.40a	18±2.40a	21±3.93 ab	27±4.98abcd	16±2.52ab
		plantain	4±2.31ab	8±3.18ab	16±0.00a	24±2.60a	26±2.03 ab	50±1.45 abcd	26±0.58 bcd

Mean ± SE (n=3), N =20, same alphabets along the column are not significantly different (P>0.05) according to the Duncan Multiple Range Test.

4. DISCUSSION

Nylons have been known to protect food products from insects, rodents etc. This may be due to the ability of the containers to keep their microclimate shielded from the influence of the surrounding environment [18]. However, insects have been a problem associated with stored food products [19]. There is a need to protect stored food from attack by insects because they can destroy large quantities, particularly during long-term storage [20]. In developed countries even the mere presence of a few insects in a bulk, at densities of considerably less than one insect per kg grain can cause a serious loss in its market value. Food losses are at its greatest in tropical and subtropical climates due to high temperatures and also poorer control and storage techniques. Hence, based on the findings from this study, food should be packed with thin transparent nylons, which the weevils attacked the least.

Tribolium sp is a beetle mainly found in cereal products and flour [21] but can also attack a range of other foods which include stored grain products such as flour, cereals, meal, crackers, beans, spices, pasta, cake mix, dried pet food, dried flowers, chocolate, nuts, seeds, and even dried museum specimens [22], [23]. These weevils have chewing mouthparts, but do not bite or sting and can elicit an allergic response [24], but is not known to spread disease and does not feed on or damage the structure of a home or furniture. The life cycle takes from 40 to 90 days, and the adult can live for three years.

Synthetic polymers including nylon are a growing environmental concern because they are generally non biodegradable, and recent research has been focused on the biological treatment of plastic wastes and the development of biodegradable plastics. The amide bond (CONH) which occurs widely in natural polymers, like polyamino acids is easily hydrolyzed by proteolytic enzymes. However, very little is actually known about the biodegradation of amide bonds present in the main polymer chain of nylon [25]. Furthermore, recently the biochemical studies on the biodegradation of nylon by a lignin-degraded fungus were reported [26], [27]. From the nuclear magnetic resonance (NMR) analysis of the degradation products, it was proposed that the methylene group adjacent to the nitrogen atom in the polymer chain was attacked by the enzyme and subsequently the reaction proceeded auto-oxidatively [27]. Flavobacteria sp. K172, have been reported to possess the enzyme nylonase for the biodegradation of nylon 6 [28]. Other microbes that have been reported to be able to degrade nylon include Acinetobacter, *Pseudomonas putida* and *P. fluorescence, Aspergillus fumigates, A. niger, and A. sydowii, Phanerochaete chrysosporium, Sphingomonas, Brevibacillus borstelensis, Norcadia, Geotrichum candidum.* But the challenge of most of these microbes in the degradation of plastic is the initiation of the attack, which is prevented by the polymerization of the plastics. Based on the findings of this study, it appears that the weevils are able to initiate the biodegradation of the nylon polymer by creating borings which could form attachment sites for microbes for subsequent attack and degradation of the polymer. Biodegradation or biodeteroration of xenobiotic compounds has been recognized as a useful way to eliminate environmental pollutants. However the efficiency of removal is dependent on the specific enzymes that can catalyze the desired degradation reactions [13].

5. CONCLUSION

Due to low cost, stability and convenience, plastics are now commonly used for packaging food, beverages and water under different environmental conditions at different states including solid, semi-solid/paste, and liquid and to a lesser extent gas. Plastics have long half lives and are generally non-biodegradable. Hence, they accumulate in the environment over time causing flooding, and becomes breeding sites for insects and other disease vectors, while occupying important spaces in landfill. Synthetic plastics resist biodegradation because microbes do not generally possess enzymes for the degradation of xenobiotics due to lack of attachment sites caused by extensive polymerization. Hence, this study presenting biodeterioration of plastics by weevils could create avenue for attachment and initiation of attacks by microbes, which could ultimately lead to biodegradation and mineralization of plastics in the future. We conclude by suggesting more research using different types, colour, thickness and texture of plastics.

ACKNOWLEDGEMENT

This manuscript was based on the undergraduate research project carried out at the Biological Science Laboratory, Niger Delta University by Ekeh N. Peters under the supervision of the other authors. The authors wish to thank Mr Adesola Ojesanmi, who developed the initial proposal for the research and Mr Daabo Offurugbo who assisted in the collection of samples and identification and breeding of the insects used for the study.

REFERENCES

[1] S.O. Abah, E.I. Ohimain, "Assessment Of Dumpsite Rehabilitation Potential Using The Integrated Risk Based Approach: A Case Study Of Eneka, Nigeria," World Applied Sciences Journal, VIII (4), pp. 436-442, 2010.

[2] S.O. Abah, E.I. Ohimain, "Healthcare waste management in Nigeria: a case study, "Journal of Public Health and Epidemiology, III (3), pp. 99-110, 2011.

[3] A.A. Amori, B.O. Fatile, S.O Ihuoma, H.O. Omoregbee, "Waste Generation and Management Practices in Residential Areas of Nigerian Tertiary Institutions," Journal of Educational and Social Research, III (4), pp. 45-51, 2013.

[4] N.E. Urama, R.E. Ukwueze, G.C. Aneke, "Minimizing the Negative Externality from Sachet Water Consumption in Nigeria," European Journal of Business and Management, IV (15), pp. 118-126, 2012.

[5] K.A. Aderogba," Polymer wastes and management in cities and towns of Nigeria and sustainable environment". Peak Journal of Physical and Environmental Science Research, II (1), pp. 1-12, 2014.

[6] D.I. Igbinomwanhia, "Characterization of Commercial Solid Waste in Benin Metropolis, Nigeria," Journal of Emerging Trends in Engineering and Applied Sciences, III (5), pp. 834-838, 2012.

[7] A.B. Nabegu, "An Analysis of Municipal Solid Waste in Kano Metropolis, Nigeria," J. Hum. Ecol., XXXI (2), pp. 111 – 119, 2010.

[8] B. Akpu, R.O. Yusuf, "A rural-urban analysis of the composition of waste dumpsites and their use for sustainable agriculture in Zaria," Nigerian Journal of Scientific Research, IX & X, 1 – 8, 2011.

[9] I.A. Modebe, U.U. Onyeonoro, N.N. Ezeama, C.N. Ogbuagu, N.E. Agam, "Public Health Implication Of Household Solid Waste Management In Awka South East Nigeria," The Internet Journal of Public Health, I (1), no page number, 2009.

[10] A. J. Oloruntade, P.A. Adeoye, F. Alao, "Municipal solid waste collection and management strategies in Akure, South-Western Nigeria," Caspian J. Env. Sci., XI (1), pp. 1~10, 2011.

[11] J.O. Okeniyi, E.U. Anwan, "Solid Wastes Generation in Covenant University, Ota, Nigeria: Characterisation and Implication for Sustainable Waste Management" J. Mater. Environ. Sci., III (2), pp. 419-424, 2012.

[12] W.B. Bollag, J. Dec, J.M. Bollag. Biodegradation & Encylopedia of microbiology. In: J. Lederberg (ed.). Academic, New York. p. 461-471, 2000.

[13] S. Negoro, "Biodegradation of nylon and other synthetic polyamides". In Biopolymers Online. John Wiley, New York, 2005.

[14] F.I. Aziegbe, "Seasonality and Environmental Impact Status of Polyethylene (Cellophane) Generation and Disposal in Benin City, Nigeria," Journal of Human Ecology, XXII (2), pp. 141 – 147, 2007.

[15] M. Berners-Lee, "How Bad are Bananas? The Carbon Footprint of Everything,: Profile Books Ltd, London, 239pp, 2010.

[16] L.B. Spear, D.G. Ainley, C.A. Ribic, "Incidence of plastic in seabirds from the tropical Pacific l984-91: Relation with distribution of species, sex, age, season, year and body weight," Mar. Environment. Res., XL, pp. 123- 141, 1995.

[17] E.R. Secchi, S. Zarzur, "Plastic debris ingested by a Blainville's beaked whale, Mesoplodon densirostris, Washed ashore in Brazil," Aquat. Mammal. XXV(1), pp. 21-24, 1999.

[18] J.E. Amadi, M.O. Adebola, "Effect of moisture content and storage conditions on the storability of garri," African Journal of Biotechnology, VII (24), pp. 4591-4594, 2008.

[19] P.C. Buckland, "The early dispersal of insect pests of stored products as indicated by archaeological records," J. Stored Prod. Res., XVII, 1-12, 1981.

[20] D. Pimentel, "World Resource and Food Losses to Pests. In: Ecology and Management of Food-industry Pests," Gorham, J.R. (Ed.). AOAC, USA. Pp. 5-11, 1991.
[21] D. Allsopp, J.K. Seal, "Introduction to biodeterioration" 2nd Edition. Cambridge University Press, UK, 2004.
[22] S.Via, "Cannibalism facilitates the use of a novel environment in the flour beetle, *Tribolium castaneum*," Heredity, 82, pp. 267-275, 1999
[23] P.A. Weston, P.L. Rattlingourd, "Progeny production by *Tribolium castaneum* (Coleoptera: *Tenebrionidae*) and *Oryzaephilus surinamensis* (Coleoptera: *Silvanidae*) on maize previously infested by *Sitotroga cerealla* (Lepidoptera: *Gelechiidae*)," J. Econ. Entomol., 93, pp. 533-536, 2000.
[24] K. Alanko, T. Tuomi, M. Vanhanen, M. Pajari-Backas, L. Kanerva, K. Havu, K. Saarinen, D.P. Bruynzeel, "Occupational IgE-mediated allergy to *Tribolium confusum* (confused flour beetle)," Allergy, 55, pp. 879-882, 2000.
[25] A.D. Tetsugar, K. Masaaki, N. Tomoaki, "Biodegradation by lignin degrading fungi," Applied and Environmental Microbiology, 63, pp. 329 – 331, 1996
[26] T. Deguchi, Y. Kitaoka, M. Kakezawa, T. Nishida, "Purification and characterization of a nylon-degrading enzyme," Appl. Environ. Microbiol., 64,pp. 1366–1371, 1998.
[27] T. Nomura, K.W. Myers, C.M. Kondzela, J.M. Murphy, H. Honma, H.R. Carlson, "Variation in lipid content in the muscle of chum and pink salmon in the Gulf of Alaska in May 1999," Bull. Nat. Salmon esources Center, IV, pp. 13–18, 2001.
[28] Wikipedia 2014, http://en.wikipedia.org/wiki/Plastic. Accessed: June 12, 2014.

Elijah I. Ohimain is an Associate Professor of Bioenergy, Agricultural and Environmental Microbiology and formerly the Head of Department of Biological Sciences, Niger Delta University, Wilberforce Island. Dr. Ohimain has a Ph.D. degree in Environmental Microbiology from the University of Benin, Nigeria and Post graduate diploma in Sustainable Development from Staffordshire University, UK. His research is focused on geomicrobiology, agricultural microbiology, environmental science and bioenergy. Dr Ohimain has authored over 140 publications.

Dorcas D. Dorcas is senior lecturer in the Department of Biological Sciences, Niger Delta University, Wilberforce Island. She was the pioneer Head of that Department. She was also the Ag. Dean of Students Affairs for four years. Dr. Bawo is the currently the Ag. Director of General Studies of the University. She has a Ph.D in Applied Entomology from ICIPE/RSUST. Dr. Bawo's research interest is on insect behaviour, morphology and physiology. She is a member of the Entomological Society of Nigeria, Nigerian Society of Plant Protection among others.

Diepreye Ere is a senior lecturer in organic chemistry at Niger Delta University, Wilberforce Island, Bayelsa State. He obtained his PhD in Organic Chemistry from the University of Hull, UK His research interest is in bioorganic chemistry with special interest in heterocyclic compounds. He is a member of the Nigerian Chemical Society.

Ekeh N. Peters is a Bachelor of Science degree holder (B.sc) in Environmental Biology from Niger Delta University, Wilberforce Island. His research works are focused on the Environmental impacts of plastic waste.