Impact of Local Oil Mills *(Ebu Epo Pupa)* on the On-Site Environmental Resources Quality in a Growing Urban Center in Nigeria

Timothy O. Ogunbode[1,*], Peter O. Ogungbile[1], Iyabo V. Olatubi[2], OrevaOghene Aliku[3], Victor A. Adeniyi[4], Emmanuel A. Akintunde[5], and Janet T. Asifat[6]

[1]Environmental Management and Crop Production Unit, College of Agriculture, Engineering and Science, Bowen University, Iwo, Nigeria
[2]Pure and Applied Biology Programme, College of Agriculture, Engineering and Science, Bowen University, Iwo, Nigeria
[3]Department of Soil Resources, Faculty of Agriculture, University of Ibadan, Nigeria
[4]Department of Pure and Applied Zoology, Federal University of Agriculture, Abeokuta, Nigeria
[5]Industrial Chemistry Programme, College of Agriculture, Engineering and Science, Bowen University, Iwo, Nigeria
[6]Department of Geography, Obafemi Awolowo University, Ile-Ife, Nigeria

*Email: timothy.ogunbode@bowen.edu.ng

ABSTRACT

This study investigated the impact of local oil mills on the quality of on-site environmental resources in a growing urban center in Nigeria. Water, soil samples, dominant plant species, and macroinvertebrates were sampled and analyzed using standard procedure. Total dissolved solids, potassium, calcium, phosphate, dissolved oxygen and electrical conductivity, biochemical oxygen demand, and chemical oxygen demand of the water sampled were determined. The bulk density, soil moisture, soil organic matter, soil temperature, and soil pH of the sample collected were similarly done. Plant and invertebrate species sampled were identified using the most appropriate morphological techniques. Results of the physicochemical analysis of water samples revealed that there was no significant difference among the parameters across the sampled points at 95% level of confidence except in temperature ($p = 0.422$) while the results of soil analysis revealed that organic matter content was significantly greater ($p > 0.05$) compared to other property examined indicating that the oil mill decayed by-products contributed to the soil organic matter. The results of plant and invertebrate species showed that the upstream had the highest number of plant distribution while the source point had the highest number of macroinvertebrate species. This study therefore concluded that oil mill by-products do not pose any negative effect on the resources examined; rather, it will be more economically valuable for soil improvement.

Keywords: palm oil mill, environmental resources, environmental quality, growing town, environmental management

INTRODUCTION

Natural environment is always influenced by different kinds of modifications as a result of various anthropogenic activities (Okanlawon *et al.*, 2015; Okueso, 2008). Thus, it is being subjected to a lot of changes due to various human influences such as agricultural, industrial, and construction activities and so on. Humans change the environment through soil tillage, application of chemicals to boost agricultural production, and construction activities such as roads, buildings, deforestation, dam building, and mining, among others (Nwankwoala, 2015; Shende *et al.*, 2015; Tilman & Lehman, 2000). As a result of this influence, most natural endowments have been modified or changed from what they are in their natural states, and this happens from time to time. For instance, the application of chemicals such as fertilizers, when washed by runoff, could find their ways into the underground water thereby changing the quality status of the groundwater. The same scenario applies to soil quality and air quality, among others. However, there is no doubt that many of such human activities impact not only negatively on the environment and the resources therein but also positively. For instance, through human movement, especially transborder boundary migration, many plant and animal species have been transferred to another location from their natural environment. Such lives have become acclimatized to a new environment. However, the processing of agricultural products for added value is prominent among humans right from the creation. For instance, Ater *et al.* (2018) and Nelson *et al.* (2018) revealed that maize could be grinded to powdery form to make pap or cooked among other ways of adding value to the product. Similarly, Kehinde and Aboaba (2016) as well as Adeyemo and Okoruwa (2018) reported on various ways man could improve on the value of cassava. The processing of oil palm fruits is not new as many people in the zones where the plant is dominantly grown and found always extract red oil from the fruit among other by-products (Nwankwo & Nwosu, 2018; Sarku & Appiah, 2017). The milling of oil palm has advanced from manual method to mechanical method. Despite this improvement in the technology in oil milling, both the manual and mechanical methods are still being combined in many localities. One of the major businesses of tropical women is the palm oil milling among other small- and medium-scale enterprises being engaged in and also being promoted by government policies to checkmate the scourge in the rate of unemployment and to ensure food security among other reasons. Palm fruits are obtained and then taken to the sites already designated for the purpose, most of which are often located close to dependable water sources such as rivers/streams or close to a borehole or dug-out well. The reason for their proximity to water source is that the resource forms a major input into the activity after the palm fruit. The location of these mills has however posed a lot of damages to other natural resources attached to the sites such as soils, plants, water, and also the aquatic invertebrates. At times, most of the wastes from processing activities such as effluents are often washed into the stream or, as solid wastes, dumped on top of the adjacent soils. Such indiscriminate dumps may have implied consequences on the natural resources on and around the mill such as water, either surface or subsurface, soil resources, and plant composition. Air quality is also perceived to bear the brunch of the oil mill activities. Invertebrate communities have been used widely to monitor environmental impacts of several nutrient-enhanced industrial outputs into aquatic ecosystems, such as aquaculture (Sutherland *et al.*, 2007), pulp and paper (Kilgour *et al.*, 2004), fish processing plants (Lalonde & Ernst, 2012), and sewage-treatment plants (Saunders *et al.*, 2007), but the effects of oil milling plants effluent/waste on invertebrates are yet to be established especially for a community that generates part of its revenue from oil milling activities. On this note, this study has been embarked upon to investigate the impact of local oil mills on the in situ environmental resources within the site so as to evaluate the fitness of such resources for human use. Specific objectives are to assess the effect of local oil mills on the on-site surface water quality, to determine the effect of the mills on the on-site plants and soil resources, and to determine the effect of oil palm effluents on the composition of vertebrates in the adjacent flowing stream.

MATERIALS AND METHODS

Study Area

This research was carried out in Iwo, the headquarters of Iwo Local Government Area of Osun State, Nigeria. Iwo is located in Osun State in Southwestern Nigeria (Figure 1). The region has an area of 245 km^2 with a population of 191,348 according to the 2006 population census. The prevailing climatic condition is tropical with about eight months of rainfall (March to October) and about four months of dry season (November to February). Iwo is an agrarian economy depending on primary activities as a major source of livelihood. Such activities include crop farming, animal slaughtering, lumbering, fishing, and oil palm milling, among others. There are other secondary and tertiary activities in the town, but this is a negligible proportion among the populace. Among small and medium enterprises in the town is oil palm milling. One of the invasive plants in Iwo and its environment is the palm tree. The palm tree is dominantly found in the tropical environment, of which Iwo is one. Plantation of oil palm is found in most cocoa farms apart from other modern plantations being raised by both indigenes and nonindigenes. The prevalence of oil palm processing has been further encouraged by government policies through soft loans for the establishment of local mills, mechanization of the processing activities, and improved pricing system, among others. Thus, local oil mills are found in the nooks and crannies of Iwo, most especially along flowing streams and rivers like the Aiba and Yanyanhun streams, among others. Most of these local mills have names given to them by the operators at each site whether as a family or as other groups of individuals, after which they are known. For instance, there are several of these oil palm mills along Aiba downstream, namely, Aiba Oil Mills (*Ebu Aiba*), Alawe Mills (*Ebu Alawe*), and Ayewa Oil Mills (*Ebu Ayewa*), among others. Aiba Oil Mills (Figure 1) was specifically chosen for this investigation. Aiba Oil Mills is located along the Aiba River channel within the township of Iwo.

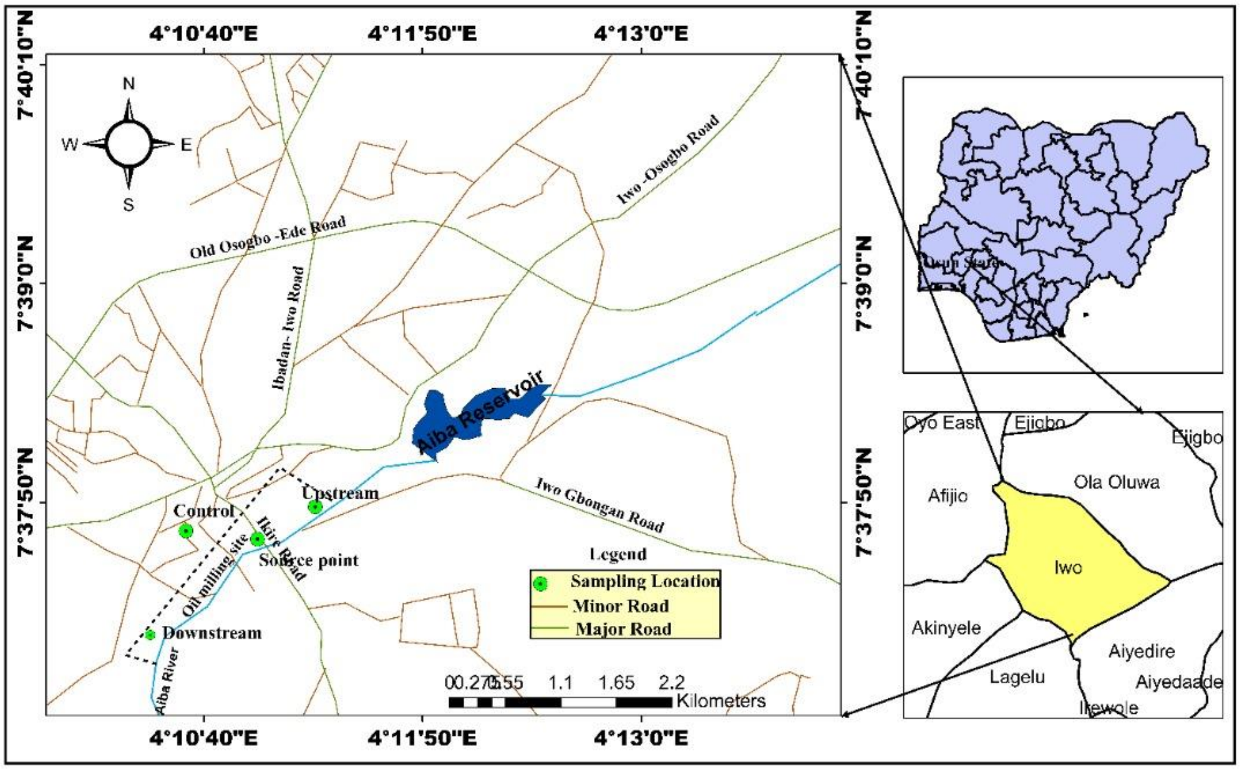

Figure 1. Map showing the study site (Aiba Oil Mills) in Iwo, Osun State, Nigeria.

Methods of Data Collection and Analysis

The data required for this study are water samples, dominant samples of plants, and invertebrate samples. The sampling was done in January, which falls within the dry season in the area. The following terms were used to describe the sampling points in the study:

i. **Source:** This describes the point where mill wastes are deposited and where effluents gain entry into the river channel. This is located on the riverbed for water samples but on land area for other terrestrial parameters such as soil and plant samples;

ii. **Upstream**: some distance away from the "source." This is on the riverbed for water-associated samples and on land area for terrestrial parameters; and

electrical conductivity, biochemical oxygen demand, and chemical oxygen demand. On-site measurement of relevant parameters was also taken appropriately. The data were subjected to both descriptive and inferential analysis (ANOVA) using SPSS version 16.0.

Soil samples

Soil samples were taken from the topsoil (0–15 cm) using soil auger at the upstream (Lat. 7.35°N, 4.31°E), midstream (Lat. 7.62°N, 4.23°E), and downstream (Lat. 7.30°N, 4.28°E) and control points (Lat. 7.25°N, 4.18°E) some meters away from the mill as recommended by the United States Environmental Protection Agency (2020). Similarly, samples were taken within the dump sections of the mill location. These samples were collected in order to assess the influence of oil mill activities on the soil characteristics and properties. The samples were taken to the

iii. **Downstream:** some distance away from the "source." This is on the riverbed for water-associated samples and on land area for terrestrial parameters.

Water quality

Samples of water are required to determine the variations in the quality status of water in the stream so as to know the impact of milling activities on it and its fitness for human consumption. As a result of the shallowness of the water, samples were taken from the surface of each sampling point such as the upstream (7.37°N, 4.48°E), midstream (7.28°N, 4.38°E), and downstream (7.26°N, 4.09°E). A 2-L keg rinsed with distilled water was used to take the samples. This was done in three replicates. These were then taken to the laboratory for analysis to determine their total dissolved solids, potassium, calcium, phosphate, dissolved oxygen and laboratory and analyzed for bulk density, soil moisture, soil organic matter, soil temperature, and soil pH.

Plant samples

Samples of plants invasive to the oil mills were taken and compared with the other plants in the neighborhood (control site). The characterization of the plants was carried out at the Plant Taxonomy Laboratory of Obafemi Awolowo University, Ile-Ife. The plants were collected using a clean shovel into labelled polythene bags and kept in a cooler in order to retain their respective characteristics and/or properties and subsequently transported to the laboratory for analysis.

Macroinvertebrate abundance and distribution

A 3-minute kick method with a D-frame net (700- to 800-micron mesh) was used for sampling invertebrates along the streams. The net was placed on the stream bottom and upstream substrate disturbed by movement through the environment. As substrate was disturbed, the operator and net moved upstream for the required time. Samples collected from the net were preserved in 70% alcohol and transported to the laboratory. In the laboratory, samples were washed in a 600-micron mesh sieve to remove alcohol, invertebrates were then picked from the substrate with the aid of a magnifying glass, and the entire specimens were counted and identified under a binocular dissecting microscope using the available keys. Sampling was done at three points, namely, source point, upstream, and downstream.

RESULTS AND DISCUSSION

Impact of Oil Palm Mill Activities on On-Site Surface Water Quality

Table 1 shows the result of the mean variations in the physicochemical parameters across the sampling points.

One-way ANOVA statistic (completely randomized design) using Duncan's post corroborate the results of Awotoye *et al.* (2011) and Izah *et al.* (2016). Izah *et al.* in 2016 recommended biotechnological application as an option for waste management.

Table 2 shows the results of soil property analysis.

hoc test showed that there was no significant difference between the physicochemical parameters across the three points at 95% level of significance except temperature ($p = 0.422$). Thus, it can be concluded that the results of physicochemical analysis are not sufficient to infer that the palm oil milling activities had any noticeable impacts on the quality of surface water during the period of the investigation.

The water samples showed that the effluents from the milling activities have negligible impact on the water samples. This is not surprising as milling activities during this investigation were limited to the land area (some distance from the sample points) and the volume of work was low during the period of investigation to impact on water quality. These findings

Impact of Oil Palm Mill Activities on On-Site Soil Resources

The results of soil property analysis are presented in Table 2. The results revealed that there is no significant difference in the

soil property except in organic matter ($p > 0.05$). This could be attributed to the accumulated decayed oil mill by-products.

This observation corroborates the findings of Okwute and Isu (2007).

Impact of Oil Palm Mill Activities on Macroinvertebrate Abundance and Distribution

The results of the abundance and distribution of macroinvertebrates are presented in Table 3.

Table 2. Results of Soil Property Analysis

Sampled Site	Field Capacity (g/kg)	Bulk Density (g/cm^3)	Particle Size Distribution			Organic Matter (g/kg)
			Sand (%)	Clay (%)	Silt (%)	
Upstream	0.94 ± 0.01	0.88 ± 0.01	56.07 ± 0.01	25.00 ± 0.58	18.93 ± 0.01	0.29 ± 0.01
Source	0.70 ± 0.01	0.95 ± 0.01	61.11 ± 0.01	17.80 ± 0.01	21.09 ± 0.01	0.59 ± 0.01
Downstream	0.88 ± 0.01	0.86 ± 0.01	50.45 ± 0.01	20.00 ± 0.15	29.55 ± 0.01	0.21 ± 0.01
Control Point	0.69 ± 0.01	0.84 ± 0.01	49.80 ± 0.17	9.55 ± 0.01	40.65 ± 0.01	0.18 ± 0.21

Table 1. Variations in the Physicochemical Parameters Across the Sampling Points

S/N	Desc.	pH	EC	T°C	BOD (mg/L)	COD (mg/L)	Alkalinity (mg/L)	Turbidity	NO_3 (mg/L)	PO4 (mg/L)	SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)	TH	Oil and Grease	TS (mg/L)
A	US	6.3 ± 0.58	688 ± 1.00	38 ± 0.58	8.21 ± 0.01	134 ± 0.00	120 ± 0.58	0.3 ± 0.03	0.031 ± 0.00	0.011 ± 0.00	0.024 ± 0.00	10.60 ± 0.01	60.40 ± 0.00	273.0 ± 0.58	0.95 ± 0.01	41.00 ± 0.88
B	S	11.2 ± 0.0	632 ± 1.15	38 ± 0.58	7.66 ± 0.01	110 ± 0.58	225 ± 0.00	0.2 ± 0.03	0.029 ± 0.00	0.030 ± 0.00	0.046 ± 0.00	24.40 ± 0.01	13.60 ± 0.01	268.0 ± 0.58	0.69 ± 0.01	38.00 ± 0.58
C	D	9.6 ± 0.058	673 ± 0.58	37 ± 0.58	8.01 ± 0.00	150 ± 0.58	160 ± 1.15	0.3 ± 0.02	0.058 ± 0.00	0.014 ± 0.00	0.050 ± 0.00	16.10 ± 0.00	31.10 ± 0.00	300.0 ± 0.00	1.03 ± 0.01	47.20 ± 0.00

Note. $N = 3$, where N is the number of replicates; US = upstream, S = source, DS = downstream, EC = electrical conductivity, BOD = biochemical oxygen demand, COD = chemical oxygen demand, TDS = total dissolved solids, T°C = temperature, TSS = total suspended solids, TH = total hardness, TS = total solids in milligram per liter (mg/L).

Table 3. Distribution of Aquatic Macroinvertebrate Species from Three Different Points of an Oil Milling Site

Invertebrate Species	Source	Upstream	Downstream
ODONATA			
Aeshna grandis	5	0	0
Sympetrum fonscolombii	7	0	0
Anax junius	3	0	0
Libellula saturata	5	0	0
Ladona deplanata	2	0	0
ORTHOPTERA			
Gryllotalpa **sp**	6	0	2
DIPTERA			
Mosquito larvae	12	18	0
EPHEROMEPTERA			
Adult mayfly	11	0	0
Larvae mayfly	24	64	10
Unidentified larvae	64	0	0

The result shows the abundance of macroinvertebrates collected from an oil milling site. Samples were collected from three points on the Aiba Stream; namely, the first point is the source point for the deposition of the milling effluent, the second point is the upstream, and the third point is the downstream. Among the three points of collection, the source point had the highest number of macroinvertebrate species while the downstream had the lowest. The source point also had the highest varieties of the insect species (Table 3). Mayfly larvae were the most abundant in all the sites sampled while mosquito larvae were abundant at the source point as well as the upstream.

The invertebrates collected in this study were all insects; some were terrestrial while others were aquatic. Majority of these insects have what is called amphilife. This is because they spent a certain part of their life cycle (usually the immature stages) in water and others on land (Dolný *et al*., 2014; Resh & Carde, 2009).

Members of the order Odonata were the most abundant insect species at the source point with different species among which the red-veined darter *Sympetrum fonscolombii* was the most abundant. This is surprising as the green darner is known to be the most common and abundant species throughout North America (Dunkle, 2000), although they breed in a wide range of habitats including streams and occasional rivers (Paulson, 2009). The blue corporal *Ladona deplanata* sampled in this study was just two in number; this is not unexpected as these insects have been known to breed less frequently in streams (Dunkle, 2010). The presence of *Ladona deplanata* in this water body is indicative as they are known to be associated with infertile waters, but on the contrary, mayfly larvae, which were the most abundant in this study, are known to indicate an unpolluted environment. This means that to a large extent the water body is still a safe environment provided the number of *L. deplanata* is maintained or reduced. The mayfly larvae were present in large numbers in all the sites sampled, which indicates that the water body assessed in this study is environmentally healthy as opined by Stokstad (2014). Similarly, Suter and Cormiery (2014) revealed that mayflies cannot be present in a water body contaminated with heavy metals as they are too sensitive to water quality and they are a major source of food for most aquatic vertebrates that humans also use as food (Grant, 2001; Parker, 1994).

Impact of Oil Palm Mill Activities on On-Site Plant Composition

Table 4 reveals the distribution and diversity of plants in the oil mill site.

Table 4. Plant Distribution and Diversity in an Oil Milling Site Along Aiba River

Plant Species	Source	Upstream	Downstream
Amaranthaceae			
Alternanthera sessilis	+		
Gomphrena globosa		+	+
Acanthaceae			
Nelsonia canescens	+		
Ruellia tuberosa		+	
Poacea			
Panicum brevifolium	+		
Malvaceae			
Sida acuta		+	
Capparidaceae			
Cleome gynandra		+	
Solanaceae			
Physalis angulata		+	+
Aizoaceae			

Trianthema portulacastrum	+	+
Poaceae		
Panicum maximum	+	
Asteraceae		
Synedrella nodiflora	+	
Ageratum conyzoides	+	
Synedrella nodiflora		+
Convolvulaceae		
Ipomoea asarifolia	+	
Caesalpiniaceae		
Senna hirsuta	+	
Boraginaceae		
Heliotropium indicum		+
Urticaceae		
Laportea aestuans		+
Cyperaceae		
Cyperus iria		+
Paspalum vaginatum		+
Commelinaceae		
Commelina benghalensis		+
Rubiaceae		+
Pentodon pentandrus		

Plant species distribution in the oil milling site along the Aiba River is shown in Table 4. The upstream had the highest number of plant distribution with 12 different species while the source point had the lowest. *Gomphrena globosa, Physalis angulata,* and *Trianthema portulacastrum* were the species present both at the upstream and at the downstream. None of the plant species was on all the sites. The plants collected from this study are all lower plants, and majority are weeds as well as herbs; for instance, *Gomphrena globosa*, which was among the most abundant plants sampled in this study, is a weed and known worldwide for its medicinal properties (Lans, 2007; Roriz *et al*., 2014; Silva *et al*., 2012). *Physalis angulata* too is a widely distributed weed of tropical, subtropical, and warmer temperate regions; it is frequently found near rivers, and it grows best in moist, fertile soils at very high densities (Travlos *et al*., 2010). This discovery implied that the soil resources in the oil milling site are rich in plant nutrients. *Trianthema portulacastrum* in addition is a weed that is widely distributed across Africa and America, and it is also known as a medicinal herb in the cure of certain common diseases (Shivhare *et al*., 2012).

CONCLUSION AND RECOMMENDATION

The physicochemical analysis showed that the oil milling activities had no significant impact on the quality of the water body studied. Similarly, the results of soil analysis revealed that the by-products of the oil milling activities contributed to the organic matter content of the soil. The results of plant analysis indicated the presence of plant species that are globally known for their medicinal values and a sign of soil richness in fertility. The implication of this analysis is that the oil mill by-products add nutrients to soils, which may be valuable for farming purposes if found in farmland areas.
The presence of macroinvertebrates in the surface water body implies that the oil palm milling wastes do not pose any threat to aqua life abundance and distribution, and being filter feeders, the effluents from the mills serve as good source of food to them.

This investigation therefore concludes that oil mill by-products do not pose any negative effect on the resources examined but rather contributed to the organic content of the soil. Further studies are therefore recommended to see the possibility of using the oil palm by-products in the formulation of biofertilizer.

REFERENCES

Adeyemo, T. A., & Okoruwa, V. O. (2018). Value addition and productivity differentials in the Nigerian cassava system. *Sustainability*, *10*(12), 4770. https://doi.org/10.3390/su10124770

Ater, P. I., Aye, G. C., & Daniel, A. (2018). Analysis of maize value addition among entrepreneurs in Taraba State, Nigeria. *International Journal of Environment, Agriculture and Biotechnology*, *3*(6), 2011–2019. https://doi.org/10.22161/ijeab/3.6.8

Awotoye, O. O., Dada, A. C., & Arawomo, G. A. O. (2011). Impact of palm oil processing effluents discharge on the quality of receiving soil and river in South Western Nigeria. *Journal of Applied Sciences Research*, *7*(2), 111–118.

Dolný, A., Harabiš, F., & Mižičová, H. (2014). Home range, movement, and distribution patterns of the threatened dragonfly *Sympetrum depressiusculum* (Odonata: Libellulidae): A thousand times greater territory to protect? *PLoS ONE*, *9*(7), e100408. https://doi.org/10.1371/journal.pone.0100408

Dunkle, S. W. (2000). *Dragonflies through binoculars: A field guide to dragonflies of North America*. New York, NY: Oxford University Press.

Dunkle, S. W. (2010). *Dragonflies through binoculars*. New York, NY: Oxford University Press.

Grant, P. M. (2001). Mayflies as food. In E. Dominguez (Ed.), *Trends in research in ephemeroptera and plecoptera* (pp. 107–124). New York, NY: Kluwer Academic/Plenum Publishers.

Izah, S. C., Angaye, T. C. N., & Ohimain, E. I. (2016). Environmental impacts of oil palm processing in Nigeria. *Biotechnological Research*, *2*(3), 132–141.

Kehinde, A. I., & Aboaba, K. O. (2016, Sept. 23–26). *Analysis of value addition in the processing of cassava tubers to "garri" among cottage level processors in Southwestern Nigeria* [Paper presentation]. 5th International Conference of AAAE, United Nations Conference Centre, Addis Ababa, Ethiopia.

Kilgour, B. W., Somers, K. M., & Barton, D. R. (2004). A comparison of the sensitivity of stream benthic community indices to effects associated with mines, pulp and paper mills and urbanization. *Environmental Toxicology and Chemistry*, *23*(1), 212–221.

Lalonde, B. A., & Ernst, W. (2012). Analysis of benthic invertebrate communities as a function of distance from two fish-processing plant effluent discharges in New Brunswick, Canada. *Archives of Environmental Contamination and Toxicology*, *63*, 45–53.

Lans, C. (2007). Ethnomedicines used in Trinidad and Tobago for reproductive problems. *Journal of Ethnobiology and Ethnomedicine*, *3,* 13. https://doi.org/10.1186/1746-4269-3-13

Nelson, M., Lawrence, M., Hardwick, T., Clifton, M., Nothando, D., & Mark L. (2018). Maize value chain analysis: A case of smallholder maize production and marketing in selected areas of Malawi and Mozambique. *Cogent Business Management*, *5*(1). https://doi.org/10.1080/23311975.2018.1503220

Nwankwo, O. O., & Nwosu, U. L. (2018). Marketing cost and value chain analysis of oil palm fruit processing in Imo State, Nigeria. *Journal of Agriculture and Food Sciences, 16*(1), 107–125.

Nwankwoala, H. N. I. (2015). Causes of climate and environmental changes: The need for environmental-friendly education policy in Nigeria. *Journal of Education and Practice*, *6*(30), 224–234.

Okanlawon, S. A., Odunjo, O. O., & Soyebo, O. O. (2015). Challenges of sustainable management. *Journal of Economic and Sustainable Development*, *6*(5), 244–252.

Okueso, S. A. (2008). Improving environmental management for sustainable development in Nigeria. *International Journal of Environmental Science, 4*(1), 35–39.

Okwute, L. O., & Isu, N. R. (2007). Environmental impact of palm oil effluents (POME) on some physico-chemical parameters and total aerobic bioload of soil at a dump site in Anyigba, Kogi State, Nigeria. *African Journal of Agricultural Research*, *2*(12), 656–662.

Parker, M. S. (1994). Feeding ecology of stream-dwelling pacific giant salamander larvae (*Dicamptodon tenebrosus*). *Copeia, 1994*, 705.

Paulson, D. R. (2009). *Dragonflies and damselflies of the West*. Princeton: Princeton University Press.

Resh, V. H., & Carde, R. T. (Eds.). (2009). *Encyclopedia of insects*. Amsterdam, The Netherlands: Academic Press.

Roriz, C. L., Barros, L., Carvalho, A. M., Santos-Buelga, C., & Ferreira, I. C. F. R. (2014). *Pterospartum tridentatum*, *Gomphrena globosa* and *Cymbopogon citratus*: A phytochemical study focused on antioxidant compounds. *Food Research International*, *62*, 684–693. https://doi.org/10.1016/j.foodres.2014.04.036

Sarku, R., & Appiah, D. O. (2017). Analysis of palm fruit value addition for socio-economic development in the Kwaebibirem District, Ghana. *International Journal of Development and Sustainability*, *6*(4), 149–167.

Saunders, J. E., Al Zahed, K. M., & Paterson, D. M. (2007). The impacts of organic pollution on the macrobenthic fauna of Dubai Creek (UAE). *Marine Pollution Bulletin, 54*, 1715–1723.

Shende, V. A., Janbandhu, K. S., & Patil, K. (2015). Impact of human beings on environment. *International Journal of Researches in Biosciences, Agriculture and Technology* [Special Issue], *3*, 23–28.

Shivhare, M. K., Singour, P. K., Chaurasiya, P. K., & Pawar, R. S. (2012). *Trianthema portulacastrum* Linn. (Bishkhapra). *Pharmacognosy Reviews*, *6*(12), 132–140. https://doi.org/10.4103/0973-7847.99947

Silva, L. R., Valentão, P., Faria, J., Ferreres, F., Sousa, C., Gil-Izquierdo, A., Pinho, B. R., & Andrade, P. B. (2012). Phytochemical investigations and biological potential screening with cellular and non-cellular models of globe amaranth (*Gomphrena globosa* L.) inflorescences. *Food Chemistry*, *135*(2), 756–763. https://doi.org/10.1016/j.foodchem.2012.05.015

Stokstad, E. (2014). The mountain top witness. *Science*, *343*, 592–595.

Suter, G. W., & Cormiery, S. M. (2014). Why care about aquatic insects: Uses, benefits, and services. *Integrated Environmental Assessment and Management*, *11*(2), 188–194.

Sutherland, T. F., Levings, C. D., Petersen, S. A., Poon, P., & Piercey, B. (2007). The use of meiofauna as an indicator of benthic organic enrichment associated with salmonid aquaculture. *Marine Pollution Bulletin*, *54*, 1249–1261.

Tilman, D., & Lehman, C. (2001). *Human-caused environmental change: Impacts* *of plant diversity and evolution being* [Paper presentation]. National Academy of Sciences Colloquium on Future of Evolution, Arnold and Mabel Beckman Centre, Irvine, CA. *PNAS, 98*(10), 5433–5440. https://www.pnas.org/cgi/doi/10.1073/pnas.091093198

Travlos, I., Travlos, S., Economou, G., & Lyberopoulou, S. (2010). The weed *Physalis angulata* in western Greece. In *Proceedings of 16th Conference of the Greek Weed Science Society, Karditsa. 1-2 December* (p. 41).

United States Environmental Protection Agency. (2020). *Soil sampling: Operation procedure*. Athens, GA: United States Environmental Protection Agency, Laboratory Services and Applied Sciences Division, 300-Region 4.