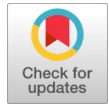


The Effect of Hydrocarbon Pollution on Niger Delta Root Crops: A Case Study of Cocoyam [Colocasia Esculenta]



P. N. Onwuachi-Iheagwara

Abstract: This paper investigates effects of re-occurring oil spillages on cocoyam, *Colocasia esculenta* (L.). It studies changes in petiole lengths, leaf blades, chlorophyll concentrations in leaves, and PAH and BTEX concentrations in tubers for three generations under diverse conditions. 8 10-gallon grow bags were used: Grow bags 5–8 were treated with a controlled quantity (4 L/cubic metre) of liquid crude hydrocarbon in June 2019–2021, with two replications, after a 2–3-day interval within a week. In grow bags 3, 4, 7, and 8, poultry manure was applied once, 2 months after small seedlings emerged from the soil surface. Grow bags 1, 2, 3, and 4 served as “controls” for non-contaminated growth. Grow bags 7 and 8 were treated with hydrocarbons and poultry manure. In the first generation, coco yams planted in grow bags 7–8 showed growth responses (average values of 1.04 m, 51 cm, 4.45 mg/g for petiole length, leaf blade length, and chlorophyll concentration, respectively) very similar to coco yams planted in pristine soil with poultry manure with average values of 1.00 m, 50 cm, 3.45 mg/g. The cocoyams planted in pristine, organic-rich soils showed a similar response with or without fertilisers (average values of 0.98 m, 48 cm, 1.83 mg/g and 1.00 m, 50 cm, 3.45 mg/g), with progressively smaller leaves as the generation increased. The cocoyams in hydrocarbon-impacted soils generally perform poorer than those in uncontaminated soil, with or without poultry manure, by the second and third generations. Poultry manure on soils with recurring hydrocarbon contamination exacerbates soil weakening. Mean PAH and mean BTEX concentrations in tubers were 0.001–0.0035 mg/kg and <0.001 mg/kg, respectively. Cocoyams are not potent BTEX bioactive scavengers, but they gradually become more concentrated in PAH.

Keywords: BTEX, Cocoyam, Hydrocarbon Pollution, Niger Delta Root Crops, PAH

I. INTRODUCTION

Cocoyam is an edible herbaceous perennial plant belonging to the family Araceae. The two common perennial aroids are the *Colocasia esculenta* (L.) Schott (Taro) and *Xanthosoma mafaffa* (Tania), but several others exist.

It is grown in Africa, the tropics and in sub-tropical areas. It is grown mainly for its roots, but all parts are edible. It is a security crop as it stores better than other common root crops, e.g. yam. Favourable growth conditions for cocoyam include a fertile, well-draining, sandy loam soil with a pH range of 4.2 to 7.5. *Colocasia esculenta* has good tolerance of a wide

variety of wetland conditions. The Nigerian government, since the first discovery of petroleum in 1956 in Oloibiri [1] has demonstrated a remarkable determination to increase the proven oil reserve. This has resulted in much growth and opportunities in the petroleum sector [2, 3]. This unfortunately, has also resulted in oil spillage over the year especially in the Niger Delta. Hydrocarbon contamination in the Niger Delta has been well documented in several articles including [4] and the negative adverse effects of hydrocarbon on the soil have been reported by such researchers as [5] and [6]. Most investigation on the effect of hydrocarbon contamination of the Niger Delta involves inoculation of a quantity of soil with hydrocarbon before or after the establishment of the crop [7] and [8]. Typically, only one crop season is considered, and the cumulative effect of recurring contamination is not taken into account. This is essential, especially in root crops. This study is a 3-year documentation of the impact(s) of recurring hydrocarbon pollution on cocoyam. Coco yams, in West Africa, are planted from March to May, mature in approximately 8 months and are harvested. The corms are planted in loamy soil 15–20 cm deep in most rural farms. Cocoyam is very important in West Africa, the primary nutrient is dietary energy provided by its carbohydrate content, with great health benefits due to its significant vitamin E content and other vitamins (B6 and C). It also contains thiamine, calcium, niacin, manganese, magnesium, copper and riboflavin. It is low in protein content (1–2 %). In studies, cocoyam has been demonstrated to lower blood sugar [9] and reduces bad cholesterol and increase good cholesterol. And can be used by diabetic patients [10].

II. MATERIALS AND METHODS

The investigation examines three generations of cocoyam products to determine the impact of recurring hydrocarbon spillage on the root crop. The investigation aims to replicate the experiences of traditional rural farmers, spanning three generations of cocoyam plant production.

A. Materials

Materials used in this investigation include:

- Heavy-duty fabric canvas
- Clean, pristine, organic, rich soil
- Uncontaminated cocoyam corms
- Spectrophotometer
- chromatography flame ionization detector (GC /FID)
- glass laboratory beaker
- and measuring cylinder

Manuscript received on 03 October 2023 | Revised Manuscript received on 10 October 2023 | Manuscript Accepted on 15 October 2023 | Manuscript published on 30 October 2023

*Correspondence Author(s)

P. N. Onwuachi-Iheagwara*, Department of Petroleum Engineering, Delta State University of Science and Technology Ozoro, Nigeria. E-mail: pniheagwara@gmail.com, ORCID ID: [0000-0001-6878-1817](https://orcid.org/0000-0001-6878-1817)

© The Authors. Published by Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP). This is an open access article under the CC-BY-NC-ND license <http://creativecommons.org/licenses/by-nc-nd/4.0/>

Heavy-duty fabric canvas material was purchased from the market and sewn into several 10-gallon grow bags. The grow bags were labelled “Grow bag 1” to “Grow bag 8”. Each grow bag had a bottom layer of gravel with small to medium-sized pebbles overlying a fine mesh covering the drainage holes. This is to aid in the removal of any excess water.

Clean, pristine, organic-rich soil was sourced from the neighbouring rural farmlands. Cocoyam corms were sourced from the local market.

B. Model design

Before placing the soil inside each grow bag, a representative quantity of the soil was subjected to PAH (Polycyclic Aromatic Hydrocarbon) and BTEX (Benzene, Toluene, Ethylbenzene, and Xylene) analysis to determine the presence of these chemicals in the soil.

PAH generally have a low degree of acute toxicity and non-carcinogenic effects to humans. BTEX are naturally occurring components in crude petroleum and petroleum products, such as diesel, gasoline, and aviation fuel. They are, however, deleterious to human health.

The total quantity of soil in each grow bag was approximately 1.37 cubic feet (0.037 cubic meters). Each bag was placed outside in a warm, sunny location on the university farm and watered with distilled water.

At the start of the investigation (generation 0), “uncontaminated” corms purchased from the local market were planted in the pre-prepared grow bags. This represented the zero generation preceding the “spillage” and served as the parent stock for subsequent generations. As most rural farmers do not purchase new external stock for their farms, but rather select the best from available corms for planting after an oil spill.

The produced cocoyam, sets and corms from the purchased cocoyam became the zero +1 (0+1) generation, which is the first generation.

Corms were planted, 5 days after the grow bags were prepared. The corms were planted at sunrise. Poultry manure was used as an organic fertiliser in selected bags (Grow bag 3, Grow bag 4, Grow bag 7, and Grow bag 8) every 2 months after the small seedlings emerged from the soil surface.

The changes in each grow bag were monitored and documented. Weed and water control were strictly enforced. Watering is dependent on the weather.

Upon maturity, sets and corms were randomly selected from the harvested produce and stored for the following year's planting season, which became the i+1 generation.

Where:

i = the current generation.

This was also repeated for all subsequent generations.

In each generation, the selected grow bags were subjected to 4 incidents of soil contamination with petroleum to mimic an episode of hydrocarbon spillage. “Grow bag 5” to “Grow bag 8” were treated with a controlled quantity (4 L/cubic meter) of liquid hydrocarbon. Crude oil was introduced to the soil surface in the selected grow bags using a beaker.

The treatments commenced in June each year for the selected grow bags and were replicated twice, with a 2-3 day interval within the week. The dates for the crude oil inoculation from 2019 to 2021 are shown in [Table 1](#).

Table 1: The days for the crude oil inoculation

Year	Crude Oil Inoculation Dates
2019	June 10,14,17
2020	June 17,21,24
2021	June 19,23,26

The grow bags 1, 2, 3, and 4 served as “controls” for non-contaminated growth, as no liquid hydrocarbon was introduced to these cocoyams.

Furthermore, cocoyams generally have a high demand for nitrogen and other minerals [11], thus rural farmers often use organic fertilizer. In this investigation, poultry manure was applied in selected grow bags (grow bags 3, 4, 7, and 8).

After each harvest, the following were done:

C. Collection and preparation of samples for laboratory analysis

Samples collected at the maturity of the cocoyam plants include leaves and roots from the harvested cocoyam plant.

D. Preparation of the collected leaf samples for laboratory analysis

The leaves were washed in distilled water and then dried with clean cotton material before being weighed and measured. The prepared leaves were used for chlorophyll extraction.

E. Preparation of the collected root samples for laboratory analysis

The harvested tubers were washed to remove sand and organic debris. The cocoyam was peeled with a sharp knife and sliced into small cubes for ease of handling, and stored in a clean ceramic bowl before the PAH and BTEX investigations.

F. Chlorophyll extraction

1.0g of leaf sample was weighed and ground into a paste using a mortar and pestle. Collect the paste from the mortar using a spatula and place it in a glass jar. Add 25 mL of isopropyl alcohol to the jar and cover it. Allow to soak for 15 minutes. Decant into another glass jar with a filter paper and funnel. A spectrophotometer was used to measure the concentration of chlorophyll.

G. PAH and BTEX investigations

Determination of Polycyclic Aromatic Hydrocarbons (PAH) and Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) was realized by gas chromatography flame ionization detector (GC /FID)

The presence of PAH and BTEX was determined in the soil before the commencement of the investigation, as well as in the roots and tubers of the cocoyam in each grow bag for each generation.

i. To determine the presence of PAH and BTEX in the soil

Twenty grams of the organic-rich soil was sourced from neighbouring rural farmlands, treated by removing stones and organic debris, and then sieved. Prepared soil samples were stored in a nylon bag before GC/FID processing and analysis.



ii. To determine the presence of PAH and BTEX in the roots

Twenty grams of the prepared root sample were blended into a slurry using a laboratory blender. Two grams of the prepared tuber slurry were weighed into two clean extraction containers.

10 ml of extraction solvent (pentane) was added.

The solutions were mixed thoroughly and allowed to settle, then filtered into clean solvent extraction bottles using filter paper fitted into Buchner funnels. The extracts were concentrated to 1 mL each and injected into the GC/FID.

H. Storage of selected corms for the next planting season

Selected corms were stored from each harvest. These cobs were preserved on a raised rack, kept in a dry, calm, and well-ventilated environment for use in the next planting season. This is similar to how traditional rural Farmers preserve and use their farm products from each harvest for the next new generation. The experiment was designed to mimic actions regularly carried out by rural Farmers. It analyses a 3-year recurring seasonal spillage to capture the effect such an event would have on rural Farmers.

The timeline for the cocoyam-pollution project is shown in the appendix. Statistical Analyses were used to identify the variance among groups.

I. Error/uncertainty associated with the method

Rural farmers do not have the luxury of changing their farmland after an oil spill incident. The action taken by most farmers after a spillage is to allow the farm to “lie fallow” for some time before replanting. Thus, the soil used in the grow bags remained unchanged throughout the 3-year experiment; instead, the soil was repacked into another grow bag when the original bag became worn out, with no new soil added. This was an inadequacy in the experiment, as farm land cannot be “repacked,” but the Researcher was unwilling to contaminate actual farm land with hydrocarbons.

III. RESULT AND DISCUSSION

[Table 2](#) revealed that the cocoyams planted in hydrocarbon-contaminated soil showed growth responses (petiole length and leaf blade length) similar to those of cocoyams planted in pristine, unpolluted soils with fertiliser application. The cocoyams planted in pristine, organic-rich soils showed identical responses, regardless of whether poultry manure was added as fertiliser in the first year. It was observed that the corns planted in grow bag 1 produced smaller leaves in the third year than in the first and second years. Grow bags 3 and 4 produce much larger leaves. As both grow bags were free from contamination, this was interpreted as the effect of the addition of fertilisers in grow bags 3–4, unlike in the first two grow bags. The practice of “shifting cultivation,” as practised by rural traditional farmers, was observed to be beneficial to the land. In shifting cultivation, a piece of land is allowed to lie fallow for a specified period after the crops are harvested. This allows the land to regenerate its fertility naturally.

By the second and third generations, the differences in responses from each grow bag had become more pronounced. With recurring contamination, the hydrocarbon-impacted soil

exhibits a progressively weakening response, characterised by smaller leaves, reduced chlorophyll production, and a slight change in PAH concentration in the harvested tubers. The cocoyams planted in hydrocarbon-impacted soils generally perform poorer than those in uncontaminated soil, with or without fertilisers, in the second and third years of recurring contamination. The use of fertilisers on soils with recurring hydrocarbon pollution exacerbates soil weakening.

Table II: Measure Values from Each Generation

S/N	Grow bag status	Grow bag	petiole length, meter	Leaf blade length, cm	Chlorophyll I, mg/g
Generation-1					
1.	Un-contaminated	1	0.98	48	1.89
2.	Un-contaminated	2	0.98	48	1.76
3.	Un-contaminated + fertilizers	3	1.00	50	3.3
4.	Un-contaminated + fertilizers	4	1.00	50	3.6
5.	Contaminated	5	1.01	52	4.44
6.	Contaminated	6	1.06	50	4.46
7.	Contaminated+ fertilizers	7	0.96	46	1.35
8.	Contaminated+ fertilizers	8	0.96	44	1.30
Generation-2					
9.	Un-contaminated	1	0.98	48	1.66
10.	Un-contaminated	2	1.00	48	1.56
11.	Un-contaminated + fertilizers	3	1.00	50	0.96
12.	Un-contaminated + fertilizers	4	1.00	50	0.98
13.	Contaminated	5	0.96	46	3.33
14.	Contaminated	6	0.97	44	2.5
15.	Contaminated+ fertilizers	7	0.95	44	0.94
16.	Contaminated+ fertilizers	8	0.95	44	0.96
Generation-3					
17.	Un-contaminated	1	0.95	47	1.66
18.	Un-contaminated	2	0.99	50	1.66
19.	Un-contaminated + fertilizers	3	0.95	47	4.44
20.	Un-contaminated + fertilizers	4	0.94	44	4.46
21.	Contaminated	5	0.85	43	3.2
22.	Contaminated	6	0.87	43	3.2
23.	Contaminated+ fertilizers	7	0.80	41	0.98
27	Contaminated+ fertilizers	8	0.86	43	0.96

Soil analysis reveals a gradual buildup of PAHs with successive generations when soils are routinely contaminated with hydrocarbons ([Table 3](#)). The cocoyam tuber, although not a potent bioactive scavenger, gradually became more concentrated in PAH, but the BTEX concentration is approximately constant ([Table 4](#))

Table III: Soil Analysis

Sample	PAH (mg/g)	BTEX (mg/g)
Uncontaminated Soil (start of experiment):	1.00E-06	<0.000001
Uncontaminated Soil (end of experiment):	1.33E-06	<0.000001
Contaminated Soil (start of experiment):	1.00E-06	<0.000001
Contaminated Soil (end of experiment):	3.50E-05	<0.000001

Analysis: uncontaminated soil= 50% uncontaminated with fertilizers + 50% without fertilizers
contaminated soil= 50% contaminated with fertilizers + 50% without fertilizers

IV. CONCLUSION

Often, when speaking of pollution, air, water, and land contamination come to mind. Food pollution is usually discounted. Although the rate of absorption of Polycyclic Aromatic Hydrocarbons (PAH) and Benzene, Toluene, Ethylbenzene, and Xylene (BTEX) into the soil is slow, the study suggests that the bioactive scavenger constituents of tubers should be monitored to prevent secondary contamination of rural populations living off the land.

Table IV: Tuber PAH BTEX Analysis

	PAH	BTEX
Generation-1; Coco yams harvested		
Grow bag	mg/g (x 10 ⁻⁶)	mg/g (x 10 ⁻⁶)
1 Un-contaminated	1.00	< 1.00
2 Un-contaminated	1.00	< 1.00
3 Un-contaminated + Fertilizer	1.00	< 1.00
4 Un-contaminated + Fertilizer	1.00	< 1.00
5 Contaminated	1.05	< 1.00
6 Contaminated	1.05	< 1.00
7 Contaminated+ Fertilizer	1.08	< 1.00
8 Contaminated+ Fertilizer	1.08	< 1.00
Generation-2; Coco yams harvested		
1 Un-contaminated	1.00	< 1.00
2 Un-contaminated	1.00	< 1.00
3 Un-contaminated + Fertilizer	1.10	< 1.00
4 Un-contaminated + Fertilizer	1.10	< 1.00
5 Contaminated	1.00	< 1.00
6 Contaminated	2.00	< 1.00
7 Contaminated+ Fertilizer	2.30	< 1.00
8 Contaminated+ Fertilizer	2.30	< 1.00
Generation-3; Coco yams harvested		
1 Un-contaminated	1.00	< 1.00
2 Un-contaminated	1.00	< 1.00
3 Un-contaminated + Fertilizer	1.20	< 1.00
4 Un-contaminated + Fertilizer	1.30	< 1.00
5 Contaminated	5.00	< 1.00
6 Contaminated	5.00	< 1.00
7 Contaminated+ Fertilizer	5.10	< 1.00
8 Contaminated+ Fertilizer	5.10	< 1.00

DECLARATION

Funding/ Grants/ Financial Support	No financial support or any kind of funds, grants, or financial assistance received.
Conflicts of Interest/ Competing Interests	There are no conflicts of interest to the best of my knowledge.
Ethical Approval and Consent to Participate	The article does not require ethical approval or consent to participate.
Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	I am the sole author of the article.

REFERENCES

- Charles Udosen, Abasi-Ifreke S. Etok and I. N. George (2009). Fifty years of oil exploration in Nigeria: the paradox of plenty, *Global journal of social sciences* vol. 8, NO. 2, 2009: 37-47 ISSN 1596-6216 <https://doi.org/10.4314/gjss.v8i2.51579>
- Idigbe Koso I and Onwuachi-Iheagwara P.N. (2014); Driving sustainable growth through natural gas assets in Nigeria, Vol. 5(2) pp. 145-147. Scholar link Research Institute Journals, ISSN: 2141-7016, UK
- Koso I Idigbe, P.N. Onwuachi-Iheagwara (2013), Growing Local Content in the Energy Industry in Nigeria: A Sustainable Development Opportunity, *International Journal of Research and Advancement in Engineering Science* Vol. 3(1), pp. 124-131, ISSN: 2276 – 8149
- Onwuachi-Iheagwara NP and Iheagwara I B (2020). *Indian Journal of Science and Technology*, Vol.3(31): 3141-3149, ISSN / eISSN: 0974-6846 / 0974-564. Available online at: <https://doi.org/10.17485/IJST/v13i31.713>
- Ekundayo, EO ; Obuekwe, CO (1997). Effects of an Oil Spill on the Soil's Physicochemical Properties at a Typical Udipsamm Site in Midwestern Nigeria. *Environmental Monitoring Assessment* 45 209-221 <https://doi.org/10.1023/A:1005776514235>
- Daniel-Kalio, LA and Pepple, SF (2006). Effect of Bonny light crude oil pollution of soil on the growth of dayflower (*Commelina benghalensis* L.) in the Niger Delta, Nigeria. *Journal of Applied Science and Environmental Management*, 10 (2), 111-114. <https://doi.org/10.4314/jasem.v10i2.43681>
- Bamidele, J F and Sijuade Esan (2012); Growth response of Taro (*Colocasia esculenta* L.) in soil polluted with Abura petroleum oil, *J. Appl. Sci. Environ. Manage. March*, 2012 Vol. 16 (1) 17 - 20
- Odjegba, VJ; Sadiq and AO (2002). Effect of spent engine oil on the growth parameters, chlorophyll and protein levels of *Amaranthus hybridus* L. *The Environmentalist*. 22: 23 –28. <https://doi.org/10.1023/A:1014515924037>
- Owusu-Darko P. G., Paterson A. and Omenyo E. L. (2014), Cocoyam (corms and cormels)—An underexploited food and feed resource, *Journal of Agricultural Chemistry and Environment*, Vol . 3, No.1, 22-24. <https://doi.org/10.4236/jacen.2014.31004>
- Eleazu CO, Iroaganachi M, Eleazu KC.(2013) Ameliorative potentials of cocoyam (*Colocasia esculenta* L.) and unripe plantain (*Musa paradisiaca* L.) on the relative tissue weights of streptozotocin-induced diabetic rats. *J Diabetes Res*. 2013;2013:160964. doi: 10.1155/2013/160964. Epub 2013 Jul 22. PMID: 23971053; PMCID: PMC3736419. <https://doi.org/10.1155/2013/160964>
- Udounang, P.I., Ekwere, O. J. and Akpainyang, F. E. (2022) Comparative effect of fertilisers on cocoyam and component crops on cocoyam-based intercropping system in Uyo, Southeastern Nigeria. *International Journal of Agricultural Policy and Research*, Vol . 10(1), pp. 16-25, January 2022. Available online at: <https://www.journalissues.org/IJAPR/https://doi.org/10.15739/IJAPR.22.003>

AUTHOR'S PROFILE



P. N. Onwuachi-Iheagwara is a lecturer at the Delta State University of Science and Technology, Ozoro. Her research interests include petrophysics, environmental studies, pollution studies, and remediation. She is registered with the Council for the Regulation of Engineering Practices in Nigeria (COREN), the Council of Mining Engineers and Geoscientists (COMEG), and is a registered educator with the Teachers Registration Council of Nigeria (TRCN). She is a member of several professional associations. She has several publications that can be viewed on Academia.edu, ResearchGate, Publons, Semantic Scholar, her Google Scholar page, and her ORCID profile. Her online profile is on LinkedIn.



APPENDIX

The Gantt chart for the various activities undertaken is shown in [Table 5](#)

Table- V: Gantt chart for Investigation

[illegible]

The Effect of Hydrocarbon Pollution on Niger Delta Root Crops: A Case Study of Cocoyam [*Colocasia Esculenta*]

[illegible]

[illegible]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)/ journal and/or the editor(s). The Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP) and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.