International Journal of Modern Agriculture, Volume 10, No.1, 2021
ISSN: 2305-7246

CHARACTERIZATION OF THE HEAVY METALS CONTENT OF TEIFERAOCCIDENTALIS(FLUTED PUMPKIN ORDER: VIOLALES, FAMILY: CUCURBITACEAE) GROWN IN NIGER DELTA OIL PRODUCING COMMUNITIES

Ogwu Chukwudi[1],Azonuche Juliana Ego[2]andAchuba, F. I.[3]

[1,2]Department of Vocational Education,
[3]Department of Biochemistry
Delta State University, Abraka – Nigeria

ABSTRACT

The study investigated the heavy metals content of*T. occidentalis* grown in the Niger Delta oil producing areas. The Niger Delta oil producing area was mapped into research grids and these were Kokori, Oguta,Okpai andAhoda. The research grids were mapped into research stations and five (5) research stations were randomly selected from each research grid.Edible portions of *T. occidentalis* were sampled from each research station bulked, a composite drawn, wrapped with absorbent paper, properlylabeled and taken for analysis. The analytical standards adopted were USEPA and APHA and the analytical instrument deployed for analysis is Agilent atomic absorption spectrophotometer model 240A. The aggregate mean results obtained were V, 0.83±0.70mg/kg, Fe, 51.93±29.77mg/kg, Ni, mean concentration is 0.38±0.75mg/kg, Pb, mean concentration is 0.54±0.37mg/kg and Cd mean concentration is 0.39±0.27mg/kg. The aggregate mean results of the parameters investigated were further subjected to test of significance with ANOVA with numerator 5 and denominator 15 at 0.05 level of significance. The F ratio package value is 3.34 while F-ratio crit is 2.03, thus rejecting Ho. The study recommends that *T. occidentalis* should not be cultivated and consumed by inhabitants' in the region; it also recommends that the oil exploiting companies should be made to adopt the world best practices in oil extraction and processing.It equally recommends that remediation program should be commenced in all the areas.

Keywords: oil exploitation, heavy metals, vegetable production, bioaccumulation, human health

Introduction

Vegetables are important components of human diet because they are rich sources of vitamins minerals, fibres and also have antioxidative effects in humans and animals (Mohammed and Khairia, 2013; Tukdogan, Kalicel, Kara, Tuncer, 2002; Waheed, Jafor, Masud 2003; Zahir, Nagui, Nohi, 2009; Pem and Jeeron, 2015; Slavin and Lloyd, 2012; Park and Park, 2011; Payne, Sleck, George, Steffens, 2012, Williams, 1996). They are known to prevent heart diseases, cancer and increase human immunity against diseases (Altieri and Tavani, 2001; Kaur and Kapour, 2001; Anderson, Perryman, Young, Prior, 2010; Latumer, Haub, 2010; New, 2011). Vegetables have also been associated with prevention and healing of serious health problems such as chronic obstructive pulmonary disease, mental health and blood pressure, respiratory problems, cardiovascular disease, (Schneider, Norman, Steyin, Bradshaw, 2007; Adebawo, Salau, Ezima, 2006; McMarhis, Jacka, colman, 2013; Dosil-Diaz, Raunao, Karma, Gestal, Olero, Barros-Dios, 2008). Industrial activities, effluents discharges result in contamination of vegetables grown and consumed (Chen, Bian, Hou, Yung, Liu, Tang, 2013, Adou, Bontoyan, Sweetney, 2001, Chandia, Salamanca, 2013; Neza, Lillo, Rivera, Soto, Fiquerua, 2018). Industrial environmental contaminants include: persistent organic pollutants (POP),microplastics, polychlorinated biphenyls (PCB), volatile organic compounds (VOCs), aromatic hydrocarbons, heavy metals and so on (Risato; Galhaine, Knoll, Apon, 2004; Snigh, Foster, Khan, 2004; Demirezan and Almet 2006; lake, Kirk, Lester, 2004, Meleki, Zarasvand 2008; Radwan and Salama, 2006). Nigeria is the 6th oil producing country in the world. Oil and gas account for 60 percent of Nigeria's gross domestic product (GDP). It accounts for 80 percent of the federal government's revenues and 90 percent of its export earnings (YarAdua, 2007; Osuntokun, 1999; Ruwani, 2018; Oteriba, 2018).

Nigeria produces 800m standard cubic feet of gas daily and flares 76 percent (Ogbonaya, 2019; Emefiele, 2019; Adeosun, 2017; Nigeria Society for Environmental Management, 2018). Crude oil contains varying chemical compounds including heavy metals (Susu, Abowei and Onyema, 2012; Petterson and Gold, 2016; Jane and Bell, 2005). The sources of petroleum contamination in the environment include oil spillages, equipment failure, tank wash, ballast water, flash floods, erosion, gas flaring and so on (Naghipour, Chenari, Tahari, Naghipour, Mehrabian, Atharehi, Jaafari&Roubakhsh, 2018; Anyakora, Ogbeche, Palmer, Coker, Ukpo&Ogah, 2005; Allowayv& Ayres, 2008; Dursun, Gezgin&Demiban, 2007; Greenpeace, 2008; Hjorenkrans, 2003; El-Gamal, 2004).

*Teiferaoccidentalis*is a tropical perennial vine grown in West Africa as a vegetable and mainly cultivated in the Niger Delta (Igbargbor, 2015; Ozum, 2018; Odia, 2016).Being a perennial vegetable predisposes *T. occidentalis* to toxicants bioaccumulation and biomagnification (Umo, 2018; Ufot and Useni, 2015; Okoniro and Ojei, 2014). The Niger Delta is the oil-bearing belt of Nigeria, 90 percent of the oil produced in Nigeria is mined in the Niger Delta (Ruwani, 2019; National Bureau of Statistics (NBS) 2020; Adeosun, 2018) Several studies have been carried out in the Niger Delta on the socio-economic impact of oil exploitation, but studies on the impact of oil activities on toxicants bioaccumulation and biomagnification on crops remain scanty or inexistent and this has made this study imperative.

The purpose of this study is to determine the concentrations of heavy metals in *T. occidentalis*grown in the Niger Delta oil producing areas. The heavy metals investigated are: V, Fe, Ni, Pb and Cd.

The study is guided by the research questions below;

1. What are the concentrations of V, Fe, Ni, Pb and Cd in T. occidentalis grown in the Niger Delta oil producing area?

2. are the concentrations of the heavy metals in *T. occidentalis*grown in the Niger Delta within the limits stipulated by WHO 2014?

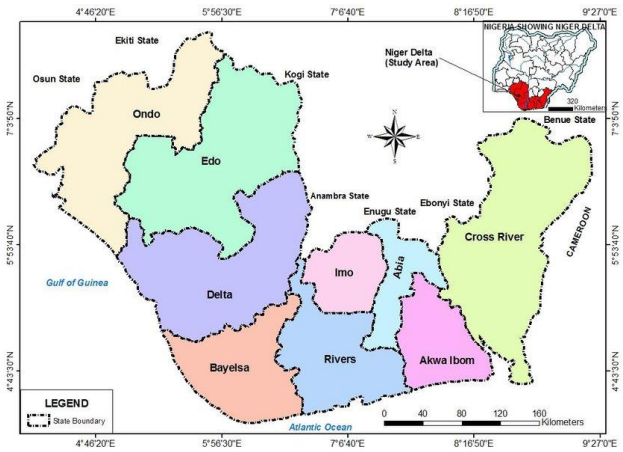
3. Can students, youths and farmers continue to cultivate and consume *T. occidentalis* grown in the Niger Delta oil producing area?

The study is guided by a hypothesis below:

Ho: There is no significant difference between the heavy metals concentration in *T. occidentalis* cultivated in the Niger Delta and world Health Organisation maximum allowable concentration for V, Fe, Ni, Pb and Cd in leafy vegetables.

Study Area

Figure 1: Map of Niger Delta Showing States.



The Niger Delta is the oil-bearing region of Nigeria. The Niger Delta covers an area of 70,000 square kilometres extending eastwards to latitude 4300^{E} to the Nigeria Cameroon border and bounded by the Atlantic Ocean (Anyaegbuna, 2000; Osuntokun, 2000).The Niger Delta people are mainly farmers and fishermen with some engage in petty trading and others work as artisans. Oil and gas companies are the onlyvisible industries in this region.

Materials and Methods

The research area Niger Delta was mapped into research grids randomly selected from oil producing communities and these are Okpai oil producing community research grid, Kokori research gride, Oguta and Ahoda research grids. From each of the research grides, five (5) research stations were randomly selected and these are as follows;Okpai research grid comprisedOluchi, Umuagwulu, OkpaiAshaka, Anieze and OkpaiObeze. Kokori research grid is made up of Alaka research station, Urhuokpokpo, Umiawha, Okarorho and Samongidi research stations. The Oguta research gride comprised Nkwesi, Nneukwu, Mgbele research station, Osu-Obodo and Egbuoma research stations while Ahoda research grid comprised Akaramiri, Akinima, Akoh research station. Alaahoda research station and Anamkpa research station. *T. occidentalis* were randomly selected from each sampling station adopting Herringbone sampling design. The samples from each research station were bulked, composite drawn, wrapped with absorbent paper, labelled and taken to the laboratory for analysis.

Sample Preparation

The *T. occidentalis* samples were oven dried at 40 degrees Celsius to constant weight. After cooling, 5g was weighed and 25 ml aqua Regia (3HCl: $1HNO_3$) was added and digested on a hot plate till sample volume was about 1ml. The solution was then cooled and filtered into 50 ml standard flask and made up to mark with distilled water.

Instrumentation

Quantitative determination of the heavy metals was carried out using an Agilent atomic absorption spectrophotometer model 240A equipped with an acetylene burner after digestion of plants samples. Hallow cathode lamps of metals of interest were used and background correction was done using deuterium lamp.

Results

The results of the heavy metals concentration in *T. occidentalis*grown in the Niger Delta are shown in tables 1 to 5.

The results of the heavy metals concentration in *T.occidentalis* investigated in Okpai oil producing area are as follows in table 1.

Table 1: Showing the result of heavy metals concentration in *T. occidentalis* in mg/kg

	Research Stations						
Parameters	**A**	**B**	**C**	**D**	**E**	**Mean**	**Std. Deviation**
V	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fe	47.65	48.00	45.75	47.62	48.61	47.53	1.07
Ni	0.84	0.75	0.69	0.74	0.95	0.79	0.12
Pb	0.62	0.65	0.60	0.62	0.66	0.64	0.03
Cd	0.58	0.61	0.55	0.53	0.60	0.58	0.03

The mean results of the metals in *T. occidentalis* determined in Okpai were further presented graphically in a bar chart as shown in figure 2.

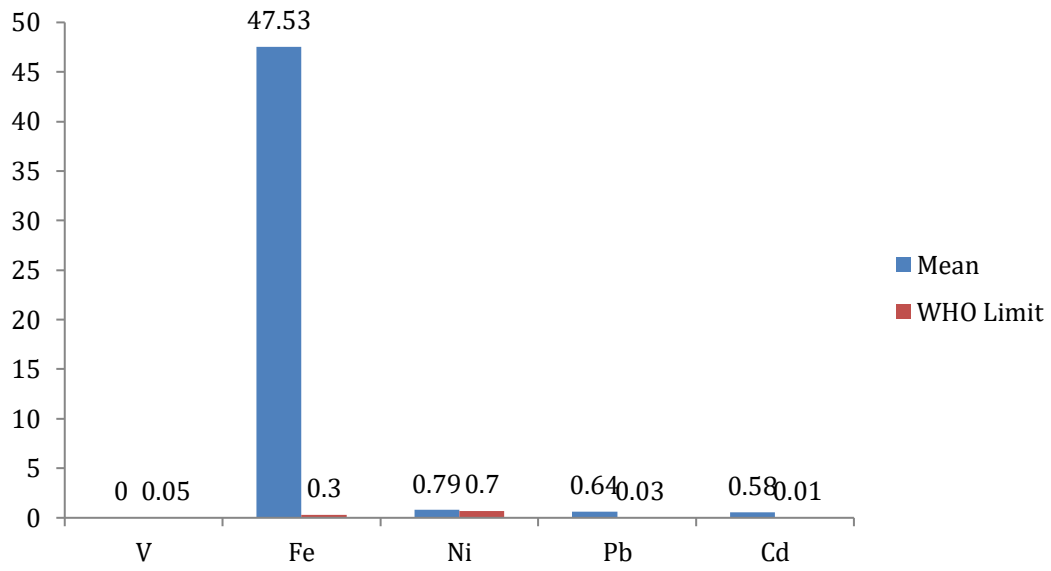


Figure 2: Mean of the heavy metals concentrations*T. occidentalis* in Okpai in bar chart

The aggregate analysis of heavy metals content of *T. occidentalis* grown in Niger Delta oil producing area are as shown below.

Table 2: Heavy metals content of *T. occidentalis*grown in Kokori oil producing area research stations.

	Research Stations						Std.
Parameters	**A**	**B**	**C**	**D**	**E**	**Mean**	**Deviation**
V	0.68	0.05	0.66	0.63	0.64	0.53	0.27
Fe	62.64	62.64	62.58	62.58	62.63	62.62	0.04
Ni	0.96	0.97	0.93	0.99	0.97	0.97	0.02
Pb	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00

The heavy metals concentration of *T occidentalis*grown in Kokori oil producing area was presented graphically with bar chart in figure 3.

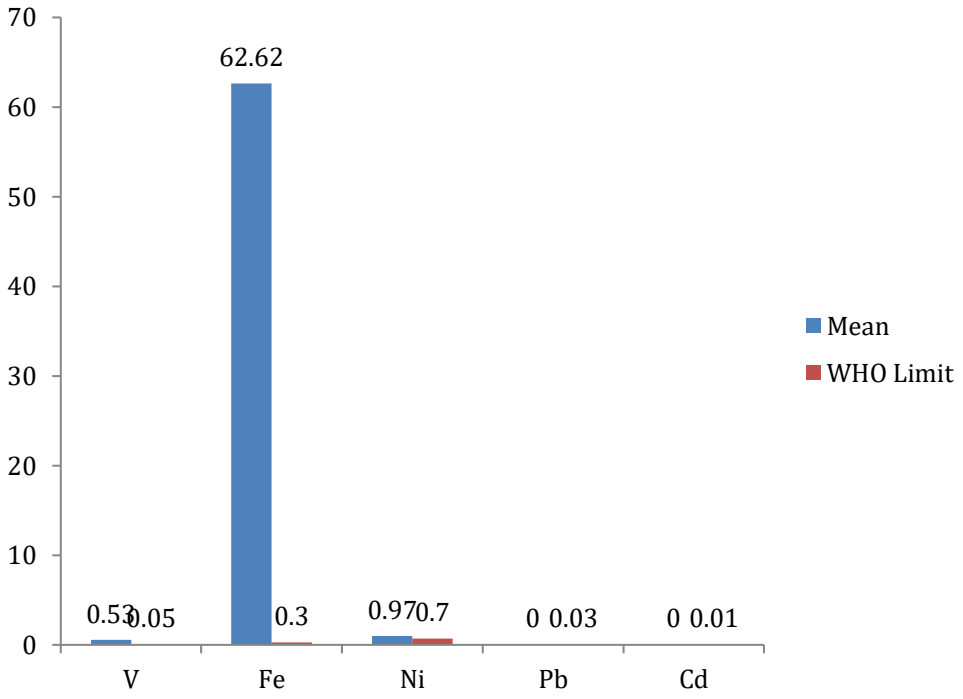


Figure 3: Mean of the heavy metals concentrations *T. occidentalis* in Kokori in bar chart

Table 3: heavy metals content of *T. occidentlais*grown in Oguta oil producing area research stations.

	Research Stations						
Parameters	**A**	**B**	**C**	**D**	**E**	**Mean**	**Std. Deviation**
V	0.79	0.72	0.74	0.77	0.69	0.74	0.04
Fe	84.31	83.29	84.32	84.58	84.36	84.17	0.51
Ni	1.25	1.32	1.36	1.33	1.27	1.29	0.04
Pb	0.64	0.63	0.67	0.66	0.64	0.65	0.02
Cd	0.41	0.40	0.43	0.44	0.43	0.42	0.02

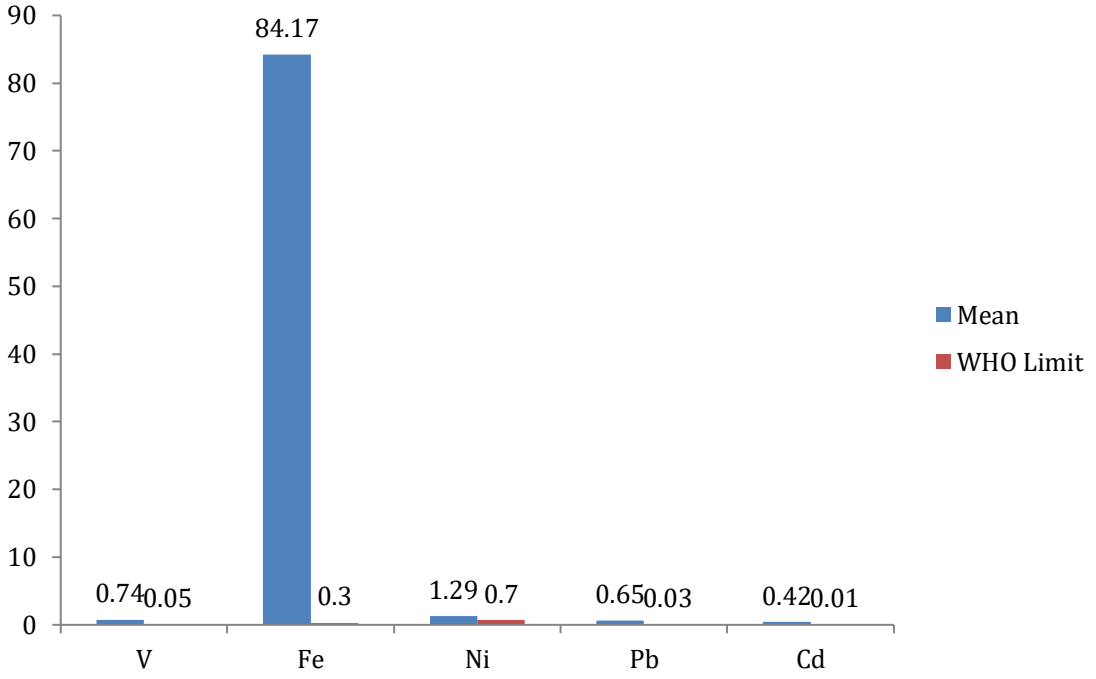


Figure 4: Mean of the heavy metals concentrations *T. occidentalis* in Oguta in bar chart

Table 4: Heavy metals of *T. occidentalis* grown in Ahoda and producing area research stations.

	Research Stations						
Parameters	**A**	B	C	**D**	**E**	**Mean**	**Std. Deviation**
V	1.72	1.66	1.73	1.72	1.77	1.71	0.05
Fe	13.24	13.33	13.62	13.30	13.35	13.38	0.13
Ni	2.45	2.50	2.44	2.45	2.42	2.44	0.03
Pb	0.86	0.88	0.86	0.85	0.84	0.87	0.02
Cd	0.54	0.55	0.54	0.53	0.53	0.34	0.01

The heavy metals concentration of *T. occidentalis* grown in Ahoda oil producing area was presented graphically in bar chart in figure 5.

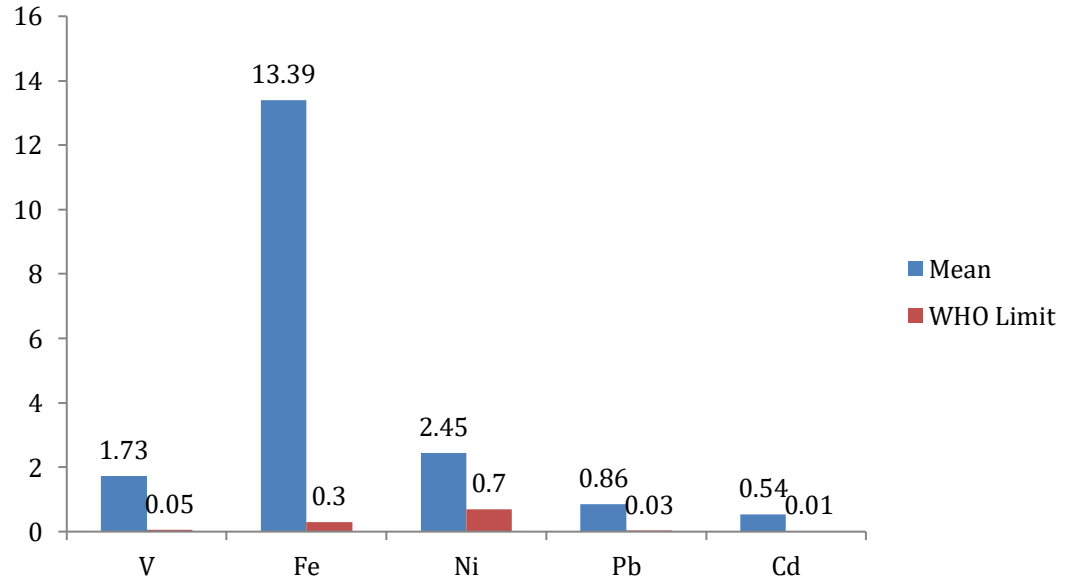


Figure 5: Heavy metals concentration of *T.occidentalis*grown in Ahoda

Table 5: Mean of the heavy metals content of *T. occidentalis* grown in the Niger Delta oil producing area.

Parameters	Okpai	Kokori	Oguta	Ahoda	Mean	Std. Deviation
V	.00	.83	.74	1.73	0.83	0.71
Fe	47.53	62.62	84.17	13.39	51.93	29.77
Ni	.79	.97	1.29	2.45	1.38	0.75
Pb	.64	.00	.65	.86	0.54	0.37
Cd	.58	.00	.42	.54	0.39	0.27

Heavy metals content of *T. occidentalis* grown in the Niger Delta were presented graphically in bar chart as shown in table 5 in standard deviation and WHO MPC in mg/kg.

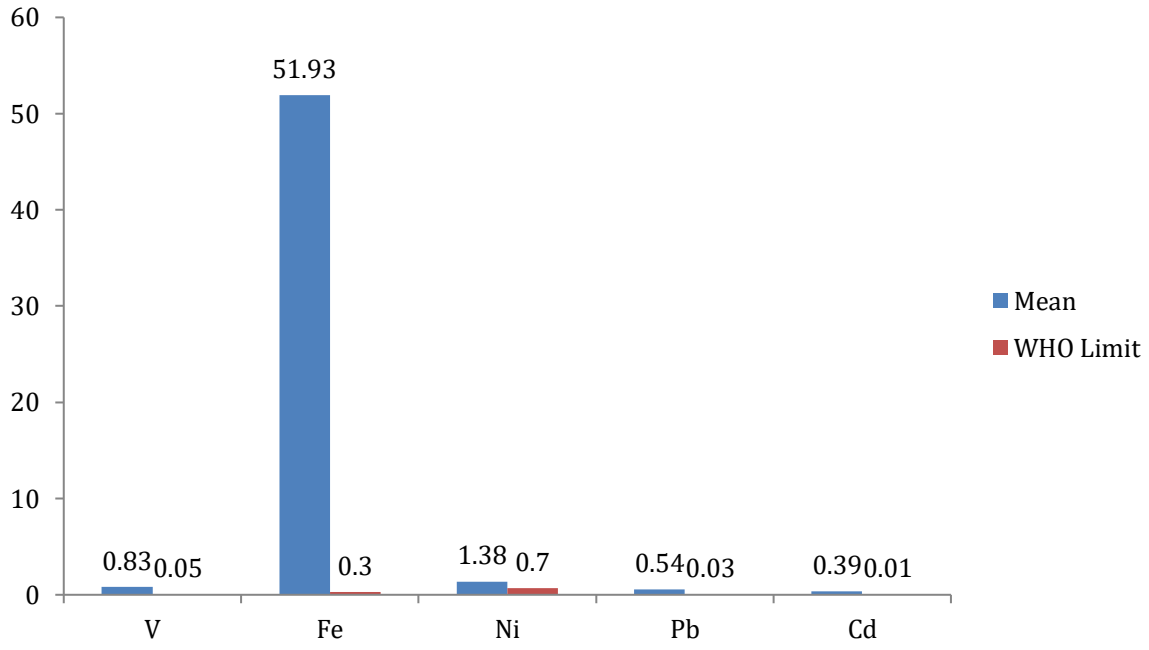


Figure 6: heavy metal content of *T. occidentalis* grown in the Niger Delta oil producing areas.

The aggregate mean of the heavy metals investigated in *T. occidentalis* in Niger Delta was subjected to test of significance with analysis of variance (ANOVA) with numerator 4 and denominator 15 at 0.05 level of significance the F ratio package value is 3.34 while F-ratio crit is 2.03. This reveals that Ho is rejected, that there is significant difference between the concentration of the heavy metals investigated and World Health Organisation maximum allowable concentrations for the heavy metals determined in leafy vegetables.

Discussion

Vegetables are consumed in virtually every in part of the world due to their dietary and medicinal importance. *Teiferaoccidentalis* is the most cherished vegetable in the Niger Delta oil mining zone of Nigeria.

Contamination of crops and vegetables by industrial effluents has been widely reported (Yang, Lu, Lang, Bao, Yang, 2011; Denti, Cocucci, Givalamo, 2009; McBride, Shayler, Spliethoff, Mitchell, Marqerez Bravo, Ferenz, Russel-Anelli, Casey, Bachman, 2014). The analyses of the *T. occidentalis* grown in the Niger Delta oil producing areas revealed differential concentrations.

The concentrations of V in the research areasranged from low to high. The concentration of V is higher than the WHO maximum recommended in Kokori, Oguta and Ahoda but was undetected in Okpai. The increased concentration of V in the three research stations is attributable to the decades of oil exploitation activities going on in these areas of study. Increased V in leafy vegetables have been reported by (Ko& Su, 2012; Liu, Hong & Wing, 2016). The health implications of high exposure to vanadium are pulmonary odema, inflammation of the trachea and bronchi, irritation of the skin and upper respiratory tract (Samuel, Kotsyuk et al., 2012; Golge&Kabak, 2015). Vanadium also causes cancer (Department of Health and Human Services (DHHS), 2005; International Agency for Research on Cancer (IARC), 2006). It also causes damage to lungs, throat, and causes nausea (Agency for Toxic Substances and Disease (ATSDR), 2002). The concentration of Fe in *T. occidentalis* in the Niger Delta are higher than the allowable concentrations for leafy vegetables. The highest concentration of Fe was recorded in Oguta research stations;Kokoriconcentration was moderate while in Okpai research stations recorded the least concentration. The mean of aggregate concentration of Fe is higher and the WHO maximum allowable concentration for Fe the leafy vegetable. These elevated concentrations of Fe in all the research areas are consequences of oil mining activities. High concentration of Fe a leafy vegetables has been reported; (Danish, Moshen, Navid, Fatemah, Fardin, Mi-Saeed, Kahlil&Esmsil 2018; Raltan, Dalta, Chlonka,Suribabu& Singh, 2005). Health effects of high Fe exposure or intake of Fe causes nausea, vomiting, building of Fe in the liver, stomach, pains, heartburns, headaches, hypotension and so on (ATSDR, 2002). The result of the analyses also revealed that the concentrations of Ni in the *T. occidentalis* grown in the niger Delta oil producing areas ishigh. The highest concentration was recorded in Ahoda research station followed byOguta station, Kokoriand then Okpai. The aggregate mean concentrations in the study areas are higher than the WHO maximum allowable concentration of Ni in leafy vegetables. Oil activities are responsible for the increased Ni concentration in theseNiger Delta oil producing areas. Increased level of Ni the leafy vegetables have been reported, (Deboradaran et al., 2007; Pirsaheb, Fatali, Sharaffi&Bohlovli, 2005). Human exposures to Ni give rise to chronic bronchitis, cancer of the lungs, nasal sinus, allergic reactions such as dematitis (Pruvot, Douay &Herve, 2006; Qadir, Ghafoor&Murfeiza, 2000). It also causes severe itching, rash and bumps on the skin, blisters and draining fluid in severe cases pneumonitis (Sharma, Agrawal& Marshall, 2007; Sifter, Rozsa, Gruiz, Tatrac&Marval, 2008). The concentration of Pb in the *T. occidentalis* in the area of has varying concentrations. The highest concentration was recorded in Ahoda research station, followed byOguta research station and then Okpai.Pb was not detected in Kokori oil producing community. The aggregate mean concentration of Pb in *T. occidentalis* in the Niger Delta is higher than the WHO maximum allowable concentration for Pb in leafy vegetables. The elevated Pb concentration in the three research stations except Kokori is the concomitant effect of oil exploitation in the areas. High concentration of Pb in leafy vegetables has been reported (Shahhen, Rfan, Khan, Islam & Ahmed, 2016; McBride et al., 2014). Lead poisoning results in loss of appetite, abdominal pains, neurological changes, gastroenteritis, neusea, it results in slow development in children and causes damageto their nervous system (Mielke& Reagan, 2005). The results of the analysis of Cd concentration in *T. occidentalis* grown in the Niger Delta revealed that Cd concentration is high. The highest concentration of was reported in Okpai, closely followed byAhoda, then Oguta.Cd was not detected in Kokori. The aggregate mean concentration of Cd of the study area is higher than World Health Organisation maximum allowable concentration for Cd in leafy vegetables. This increased concentration of Cd in *T. occidentalis* in the Niger Delta is associated with oil mining activities in the region. Elevated concentration of Cd the leafy vegetables have been the subject of reports in several researches (Sadeghe, Muhammed&Shorati, 2016; Stores, Kiran, Pani, Rani, Kaur&Nital, 2008). Exposure to Cd causes damage to lungs, kidney, brain and lung disease (ATSDR, 2002). It produces flu-like symptoms such as chills, fever and muscle pains and headaches. It also affects the liver and the lungs (Charlesworth, Miquel& Ordonez, 2010). It causes bone demineralization, renal dysfunction and hallucination (Murray, Pinchin& Mac, 2011)

Conclusion

Industrial activities leave in their trails most often environmental degradationsbecause pristine ecosystems are impacted upon. Economic growth is a welcome development but becomes deleterious when the health is compromised. Oil exploitation in the Niger Delta has contaminated the soil of the

area with its attendant health implications. It is pertinent that oil exploitation should be carried with strict adherence to the laid down rules to reduce environmental bastardization and health complications on the host communities. Sequel to the results of the study, it is recommended that:

1. *T. occidentalis* should not be cultivated and consumed by students and inhabitants of the Niger Delta study areas.

2. The environment should be protected by the exploiting companies to reduce impact on the settlers and this can only be achieved by adopting the world best practices.

3. Remediationsof the soil of the Niger Delta oil producing communities are highly recommended to bring back the soils to their original healthy status.

REFERENCES

1. Adouk, Bontoyan W. and Sweeney, P. J. (2001) Multiresidue methods for analysis of pesticides residues in fruits and vegetables by accelerated solvent extraction and capillary gas chromatography.*Journal ofAgricultural and Food Chemistry, 49, 4153-4160.*
2. Rissato, S. R., Galthaine, A. S., Knoll, F. R. and Apon, P. M. (2004). Supercritical fluid extraction for pesticide multi residue analysis in honey: determination by gas chromatography with electron capture and thus spectrophotometric detection. *Journal of chromatography.*1048, *153-159.*
3. Sing, S. B., Foster, G. D. and Khan, S. U. (2004). Microwave assisted extraction for the simultaneous determination of thiamethoxanimidacloprid and carbendaxin residue in fresh and cooked vegetables samples. *Journal of Agricultural and Food Chemistry, 52,* 105-109.
4. Chem, X., Bian, Z., Hou, H., Yang, F., Lu, S., and Tang, 0. Development and validation of a method for the determination of organochlorine pesticide residues in two buses by gas chromatography tandem mass spectrometry, *Journal of Agricultural and Food Chemistry,* 61, *5746--5757.*
5. Radwan, W. A., Salama, A. K. (2006). Market basket tosses for some heavy metals in Egyptian fruits and vegetables. *Food and Chemical Toxicology.*44, 1273-1278.
6. Maleki, A. Zaraswand, M. H. (2008). heavy metals in selected edible vegetables and estimation of their daily intake in Savandaj, Iran. *The Southwest Asian Journal of Tropical Medicine and Public Health,* 39(2), *335-340.*
7. Lake, D. L., Kirk, P. W. W., Lester, J. N. (2004). the fractionation characterization and speciation of heavy metals in sewage sludge and sewage sludge amended soil. *Journal of Environmental Quality,* 13, 175-183.
8. Kaur, C., Kapoor, H. C. (2001). Antioxidants in fruits and vegetables the millennium health.*International Journal Of Food Science Technology,* 36, *703-725.*
9. Anderson, J., Perryman, S., Young, L., Prior, S. (2010). Dietary fibre fact sheet, No: 9033 Colorado State University, Fort Collins Co, USA.
10. Latimer, J. M., Haub, M. D. (2010). Effects of dietary fibre and its components on metabolic health.*Nutrients,* 2, 1266-1289.
11. McMartins, C. E., Jacka, F. N., Colman, I. (2014). The association between fruits and vegetables consumption and mental health disorders evidence from five waves of national survey of canadians. *Prey. Med, 56,* 225-230.
12. Dosil-Diaz, 0.,Ruanao-Ravina, H., Gestal-Ofero, J. J. Barros-Dios, J. M. (2008). Consumption of fruits and vegetables and risk of lung cancer. Gear control study in Galicia Spain. *J Nut.,*24, 407-413.
13. Chandia, C., Salamanca, M. (2012). Long-term monitoring of heavy metals in Chileon coastal sediments in the eastern South Pacific ocean. *Mar., Poll., Bull., 64,* 2254-2260.
14. Meza, V., Lillo, C., Rivera, D., Soto, E., Fiqueror, R. (2018).*Sarcocarnianeel*as an indicator of Environmental pollution soil on a comparative studies in coastal wetlands of Central Chile, *Plants,* 7, 66-74.
15. Friends of the Earth (2014). Gas flaring and Nigeria environment: an annual world environment day publications. Vol 12.
16. Oteriba, S. (2018).The danger of oil bare economy. http//:dangerofoilbareeconomy.com. Retrieved November 12, 2019.
17. Niger Delta Environmental Survey (2002). The oil spills in Nigeria 1970-2011. Bulletin.

18. Aworawo, D. (2006). Oil exploitation environmental degradation and rural economy.*Journal of Management Science,* 48, *47-53.*

19. Onosode, G. (2006). Environmental management and sustainable development in the Niger-Delta.In Osunoke, A. (Ed).Environmental problems of the Niger Delta Lagos.Friedrich Ebert Foundation.

20. Ruwani, B. (2018). Nigeria economy and oil: A trajectory to no where. A publication of financial derivatives 2018.

21. Nigeria National Petroleum Cooperation (2015).Trepiline mishaps and oil spills 2000-20 12. An NNPC Publication.

22. Haruna, M. (2006).An overview of the petroleum industry and associated environmental issues in the Niger Delta. vw.htp:ptro1eurnindustryandenviroimenLcom_retrieved 2 December, 2019.

23. YarAdu, M. (2007).The Nigeria economy.A presidential medterm address on the Nigeria economy, Abuja, Lagos.

24. Anyaegbunam, 0.E. (2006).The geography of the Niger Delta and the politics of oil exploration and exploitation.*Journal of Humanities,* 15, 342-348.

25. Osuntokun, A. (2006). Oil exploitation in the Niger-Delta and the environment.*Journal of Humanities, 49: 67-74.*

26. Ogbonaya, 0.(2019). Gas flare out in Nigeria.A ministerial briefing Federal Ministry of Science and Technology, Abuja - Nigeria.

27. Emefiele, G. (2019). The state of Nigeria economy.An annual Nigeria monetary policy meeting, Nigeria. Central Bank Governor, Abuja.

28. Adeosun, K. (2017). The Nigerian economy and economic recovery and growth plan. A press briefing.Ministry of Finance, Abuja, Nigeria.

29. Nigeria Society for Environmental Management (2018).Nigeria oil economy and environment degradation.World Environment Day Press briefing.

30. Peterson, J. and Gold, D. (2016).The physicochemical properties of crude petroleum.retrieved 12 October, 2019.

31. Jane, C. P. and Bell, W. The chemistry of crude oil and the environment.*Journal of Environmental Monitoring, 15:* 428-434.

32. Susil, A. A., Abowei, MFN, Onyeme, J. 0. (2012). Oil spills in the marine environment and the aquatic organisms. *Journal of marine Science*

33. GIS based Mapping and Analysis of Oil Pollution in Niger Delta Coastal Environment - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Map-of-Niger-Delta-Showing-States_fig1_321106825 [accessed 2 Jun, 2020]