CURRICULUM VITAE

FULL NAME	**OSAYANMO IGBINOSA EGUAVOEN**
DATE/PLACE OF BIRTH	**August 28 1950; Benin City**
STATE OF ORIGIN	**Edo State, Nigeria**
NATIONALITY	**Nigerian**
PERMANENT HOME ADDRESS	**No. 8 House, Igun Street, Benin City**
CURRENT POSTAL ADDRESS	**Osayanmo Eguavoen** **P.O. Box 5084, Benin City, Edo State, Nigeria**
E-mail	**eguavoenosa@gmail.com**
PHONE NUMBERS	**08037455104, 08055450105.**
MARITAL STATUS	**Married**
SPOUSE/NEXT OF KIN	**Prof. (Mrs.) Agatha Eguavoen**

EDUCATION/QUALIFICATIONS

(with dates)

1. **B.Sc. Chemistry, (Special Honours, Upper 2nd Class Division) University of Lagos (1970-73)**
2. **Ph.D Chemistry, University of Lagos (1974-78)**
4. **Post Doctoral Research in C-13 NMR Spectroscopy, University of Salford, UK (1982)**

ACADEMIC HONOURS/AWARDS

1. ***Best Graduating Student (Chemistry) Faculty of Science, University of Lagos (1973)***
2. ***Federal Govt. Scholarship, 1970-73***
3. ***University Scholarship, UNILAG (1974-78)***
4. ***University Teaching Fellowship, University of Lagos (1974-78)***
5. ***UNESCO/ANSTI Academic Staff Exchange Fellowship as Visiting Professor to University of Ghana, Legon, 2002***
6. ***OMO N'OBA EREDIAUWA, Oba of Benin Award for a Benin achiever in academics, 2007***

PREVIOUS EMPLOYMENT/SALARY

Executive Director/CEO, Rubber Research Institute of Nigeria, Benin City. Salary Grade, CONTOPSAL

Visiting Professor, University of Benin 2015-2017 CONUASS 7 STEP 10

PROFESSIONAL AFFILIATIONS

- **Chemical Society of Nigeria (Fellow and Interim Chairman, Edo State Chapter 2000-02)**
- **Institute of Chartered Chemist of Nigeria (Fellow)**
- **New York Academy of Science (USA)**
- **International Association of Water Quality (UK)**
- **World Environment Movement for Africa (KENYA)**
- **Raw Materials Society of Nigeria (Founding Member)**
- **Science Association of Nigeria**
- **Science Teachers Association of Nigeria**
- **Biotechnology Society of Nigeria**
- **Polymer Institute of Nigeria (Fellow)**
- **International Rubber Study Group (IRSG) (SINGAPORE)**
- **Association of Natural Rubber Producing Countries (ANRPC) (MALAYSIA)**
- **International Rubber Research and Development Board (IRRDB) (MALAYSIA)**

RESEARCH

Basic Area: Physical Organic Chemistry-Reaction Mechanism, Structure/Properties Relationship in Organic Chemistry. We synthesize highly to moderately substituted benzenoid and heterocyclic aromatic compounds, investigate the kinetics of their reaction, analyse kinetic, thermodynamic and spectral data to elucidate the mechanistic pathways of their S_NAr reactions. From using physical methods to probe reaction mechanisms in organic chemistry, I have veered extensively into preliminary investigation of the industrial potentials of the abundant natural resources in the environment of my young University. This was motivated by two major factors. Firstly, there is a current urge in Nigeria to look inward in sourcing industrial raw materials. Secondly, it is **endogenous** and receives the patronage of postgraduate students to enhance their employment prospects. Also, this type of research occasionally attracts small grants from private enterprises in the near absence of government research subsidy. My current research thrust is multi-disciplinary encompassing chemical, basic medical and environmental sciences as shown below:

Applied Area: Natural Products Chemistry-: **Phytochemical studies** of biologically active local plant materials. Analytical/Environmental Chemistry-: Search for and elucidation of chemical indicators of **environmental pollution** and general **environmental impact assessment** (EIA)/abatement studies. **Natural rubber processing and utilization of by-products of natural rubber cultivation and processing industries.**My research findings have been published widely in International and Local Journals.

PUBLICATIONS

Reaction Kinetics/Mechanism:

1. **Eguavoen, O.I, (2003) Unraveling Chemical Events in Pyrex Vessels and Plastid,** ***17th Inaugural Lecture Series, Ambrose Alli University, Ekpoma.*** **pp.67**
2. **Eguavoen, Osa. (**1977) Cumulative effects of substituents as revealed in the kinetics of the reactions of some substituted anilines with picryl chloride. Ph.D. Thesis, University of Lagos. Nigeria. (***This thesis, 25 years old then, was selected and showcased as one of the best from the faculty of science at the 40th anniversary celebration of university of Lagos in 2002***)
3. Emokpae, T. A.,**Eguavoen, Osa**, Hirst, J. (1980) The Kinetics of the Reaction of Picryl Chloride with some Substituted Anilines, V. *J. Chem. Soc., Perkins Trans. II, (UK)* 1980, 829 – 831; **Chem. Abstracts 93, 9447z**
4. Emokpae, T. A.,**Eguavoen, Osa**, Hirst, J. (1980) The Kinetics of the Reaction of Picryl Chloride with some Substituted Anilines, VI. *J. Chem. Soc., Perkins Trans. II, (UK)* 1980, 832 – 834; **Chem. Abstracts 93, 9 448z**
5. **Eguavoen O. I**., Sagay, E., (1998).Mechanism of the Photodecomposition of the Octacyanide of Molybdenum IV, *Nigerian Annals of Natural Sciences, Vol. 4.*19 – 25
6. **Eguavoen, O.**, Ekhorutomwen, S.A. (1996), A Simulation of Factory Crumbling of Natural rubber for rapid evaluation.*Nigerian Annals of Natural Sciences Vol. 3.*102-106.
7. **Eguavoen, O.I**., and Egharevba, F. (2001), Impact Strength of Graft Copolymers of Polystyrene and Acrylonitrile *Journal of the Polymer Institute of Nigeria.*(In Press).
8. **Eguavoen,O**.I. (2004), Linear Free Energy Correlation in Nucleophilic Aromatic Substitution In Some Substituted Anilines. *Nigerian Annals of Natural Sciences.*Vol. 5. 28-34

Medicinal Plants Research:

9. Ogbeide, O. N.; Parvez, M.;**Eguavoen, O. I.**, (1988), Chrysophanic Acid – 9 – Anthrone, an artifungal principle from Cassia podocarpa. *Pakistan Journal of Science, Vol. 36 - 4*, 9 – 13.
10. Ogbeide, O.N.,**Eguavoen, O.I.**, Parvez, M. (1985).A Chemical study of the anthocyanins of flowers of some tropical medicinal plants.*J. Chem. Soc. Pak. Vol. 8*, No. 4, 545 – 41.
11. Ogbeide, O.N., **Eguavoen, O.I.**, Parvez, M. (1985).Identification of 2 – hydroxymethylanthraquinone in Curcuma domestica.*Pakistan Journal of Science, Vol. 37, No. 1-4*, 15 – 17.
12. Ogbeide, O.N.,**Eguavoen, O.I**., Parvez, M. (1986).Plastid Pigments of AcalyphaWilkesiana (Muel).*J. Chem. Soc. Pak. Vol. 8, No. 4,*364 – 8.

13. Ogbeide, O.N.,**Eguavoen, O.I**., Parvez, M. (1987).Potentials of Maesobotryabateri fruits in wine and food colorant industry. *Bull Sci. Assoc. Vol. 14, No. 1.26-30* Science Association of Nigeria, Lagos,
14. **Eguavoen, O.I.** and Parvez, M. (1987).Isolation of a Steroidal constituent from the root bark of Securinengevirosa.*Proceedings of the Workshop on Evaluation of Traditional Medicines* (Akubue, P.I.ed.) 238-45. U.N.N. Press University of Nigeria, Nsukka,
15. **Eguavoen, O.I.**, Parvez, M. (1987).Identification of pharmacologically active flavonoids in some tropical medicinal plants of Papillionaceae.*Proceedings of the Workshop on Evaluation on Traditional Medicines* (Akubue, P.I. ed.), 246-53 U.N.N. Press.University of Nigeria, Nsukka.
16. Agbonlahor, D.E., **Eguavoen, O.I**., Parvez, M. (1988).Antimicrobial, Antifungal, Insecticidal and Hemostatic activities of leaf and flower extracts of Aspilla (africana) latifoliaOliv.Et. Hiern.*Bulletin of the Biotechnology Society of Nigeria, Vol. 4*, 67-9
17. Oboh, P.A. and **Eguavoen, O.I.** (2004) Antimicrobial Activities Of Euphorbia Hirta and Erigeron Floribundus, Common Herbs of Southern Nigeria, Nigerian Annals of Natural Sciences Vol. 4, 22-8.

Food Plants and Cash Crops Research

18. Omorusi, V.I., Bosah, B.O., **Eguavoen, I.O.,** Osemwengie, O., Ogbebor, N.O., Igeleke, .C.L. (2014). Inhibitory efficacy of some potential leaf extracts on some root pathogens. American Journal of Research Communication.Vol.2(11), 115 - 125
19. **Eguavoen, O. I**., and Parvez, M. (1990), Characteristics and Fatty Acid Composition of the oils of Aspila (africana) latifolia.*La RivistaItalianaDelleSostanza Grasse. Vol. LXVII*, 417-18.
20. Onolemhemhen, P.O. and **Eguavoen, O.I.** (1996) Biological activities of peel oils of C.aurantium and C. aurantofolia. *Proceedings of the 35th Annual Conference of the Science Association of Nigeria*, Federal University of Agriculture, Abeokuta.
21. Onolemhemhen, P.O. and. **Eguavoen, O.I.** (2000) Insecticidal activities of the peel oil of C. aurantium and C. aurantofolia. *Nigerian Journal of Agriculture, Vol. 1* 1-8.
22. **Eguavoen O.I.**, and Okwu, U.N. (1995). A Study in the use of four tropical plant sourced coagulants as alternatives to formic acid in rubber latex coagulation.*Nigerian Annals of Natural Sci, Vol. 2* 84-88
23. Odia, A.E,**Eguavoen, O.I**,.andOnimawo,I.A. (2001) Nutrient Composition and Functional Properties of Pleurotus tuber- regium. *African Journal of Science 2: 344-355.*
24. Ihimire, G, **Eguavoen, O.I**,. Onimawo,I.A,.Ebulu, U.J, Chuke, A.C .(2001) Effect of sprouting on some functional properties and antinutrient constituents of lima bean (*Phaseoluslunatus* Linn) seed flour. *Proc. of the 32nd Annual Conference of the Nutritional Society of Nigeria*, 23-33.

25. **Eguavoen, O.I**., Ihimire, I.G. and Onimawo, I.A. (2003) Dehydrocyanation of Three Cultivers of Lima Beans *Phaaeoluslunatus*and Its Effect on Tryptophan Content. *J. Sci Food agric**84** 246-50*

26. Egwaikhide, P.A, Ihimire,I.G., Esekhaigbe, F, and **Eguavoen, O.I.** (2003) Effect of Sprouting on in-vitro Digestibility, Polyphenol Oxidase and Browning in Cajanuscajan. *World Journal of Biotechnology*, 1119-0975.

27. Ihimire, I.G., Odia, A., **Eguavoen, O.I.**Ugiagbe, O. (2003) Studies on Polyphenol Content of Malted Cowpea Vignaungniculata.*Nigerian Journal of Nutritional Sciences,Vol.*24. 2003, 35-37

28. Odia, A., **Eguavoen,O.I.,** Ehimare, B. and Ihimire,I.G.(2004) Studies on the Effects of Sproutjng on the Proximate Composition of Brown Variety of Lima Bean Phaseoluslanatus Linn. *Journal ofNutrition Society of NigeriaVol.25 No.* 1 *2004.*

29. **Odia, A.E, Onimawo, I.A.,** Eguavoen, O.I. **(**2004) Effect of chemical modification on the nutrient content and functional properties of *Pleurotus tuber-regium.Nigerian Journal of Nutritional Sciences,Vol.* 25. (**2**) 2003, 13-16

30. U.N.Okwuand **O.IEguavoen** (2003) Gel Permeation Chromatography of Funtumia Rubber. *Advances in Natural and Applied Sciences Research, Vol.2(1)* 115-120

31. Egwaikhide, P.A., **Eguavoen, O.I.,**Emua, S.A. (2004) Studies on Some Plants as Alternative Coagulants to Formic acid in Natural Rubber Coagulation. *Nigerian Annals of Natural Sciences, Volume 5 (2) 2004 pp*106-111

32. U.N.Okwu, **O.I. Eguavoen**, I.K.Okore (2005) Three Decades of Natural Rubber Production in Nigeria: Policies, Problems and Prospects. *Knowledge Review 11 (7)* 21-29.

33. Omorusi, V.I., **Eguavoen, I.O.,** Bosah, B.O., Ogbebor, O.N., Orumwense, K., Ijie, K. Okundia, R.O. (2014). Severity of Phytophthora leaf infection on some Rubber Heveabrasiliensis clones in Nigeria. Sci-Afric Journal of Scientific Issues, Research and Essays. Vol.2(6), 289 – 291

Environment Chemistry Research:

Pollution Monitoring, Abatement and Waste Management -:

34. **Eguavoen, O.I,** Asia, I.O. and Egwaikhide, P.A.(2003) Illumination and Heating With Locally Fabricated Lamps and Stoves Respectively During Night Trading : Environmental and Health Hazards. *Hestab Journal*, Vol. 1 N o.1, 15-26

35. Iwegbue, C.M.A, Nwajei, G.E. and **Eguavoen, I.O**. (2004) Distribution of Cadmium, Iron, Lead and Mercury in Water, Fish and Aquatic Plants from Ewulu River, Nigeria. Advances in Natural and Applied Sciences Research, Vol. 2 (1) 73-84.

36. J.E. Ebhoaye, **O.I. Eguavoen.** (2004) Water Repellency and Dimensional Stability of Chemically Modified Lignocellulosic Materials. *Advances in Natural and Applied Sciences Research, Vol.2(1)* 133-139.

37. E.E. Obasohan, **O.I. Eguavoen**, J.A.O. Oronsaye. (2005**)** Determination of Selected Heavy Metals in a Fresh Water Fish (*Erpetoichthyscalabaricus*) from Ogba River, Benin City. *ChemTech JournalVol. **1***170-178
38. Asia, I.O., **Eguavoen, I.O.,**Egwakhide, P.A. (2005).Oxygen Demand Test as an Index of Pollution Measurement in Domestic Waste Water. City. *ChemTechJourna.*Vol 2 (1) 206-211
39. Asia I.O, Enweani, I. B,**Eguavoen I. O.** (2005**)**.Characterisation of Sludge from a Petroleum Industry *African Journal of Biotechnology* Vol.5 (5) 461-466
40. **O.I. Eguavoen,**O.I. Osemwota, H.H.E. Isitekhale , K. Igbinosun (2005). Effects of Abattoir Effluent on the Growth of Maize (Zeamaysil). *ChemTech Journa*l.*Vol.**1*** 121-125
41. Obasohan E.E,**Eguavoen, O.I,**Oronsaye J.A.O,(2008)Seasonal variation of Bieaccumulation of Heavy Metals in Fresh water Fish *(Erpetoichtyscalabaricus)* from Ogba River, Benin City, Nigeria.*Indian Journal of Animal Reseach Vol. **42(3)**: 171-179*
42. Obasohan E.E, **Eguavoen, O.I**, Oronsaye J.A.O,(2007) Determination of Post-Dredging Concentration of Selected Trace Metals in Water Sediment and Fresh water Mud fish (Clariasgariepinus) from Ikpoba River, Benin City, Nigeria. *African Journal of Biotecnology, Vol. 6 (4):* 470-474.
43. Obasohan E.E, **Eguavoen, O.I**, Oronsaye J.A.O (2008) A comparative assessment of the heavy metal load in the tissues (gills, offal, muscle and liver) of a common Catfish (*Clariasgariepinus*) from Ikpoba River in Benin City, Nigeria. *African Scientist Vol. 9 (1):* 13-23.
44. Obasohan E.E, **Eguavoen, O.I**, (2008) Bioaccumulation of Chromium, Copper, Manganese, Nickel and Lead in a Fresh Water Cichlid *(Hemichromisfasciatus*) from Ogba River in Benin City, Nigeria. *Africn Journal of General Agriculture, Vol. **4 No. 3:*** 141-152
45. Obasohan E.E, Oronsaye J.A.O, **Eguavoen, O.I**, (2009) Impact of Drainage Effluents on the Diversity and Abundance of the Fish Population of Ogba River, Benin City, Nigeria. *African Journal of Biotechnology. Vol.8* (In-press)
46. **Eguavoen O. I,**Osemwota, O.I, Isitekhale, H.H.E, (2006) Effect of Abattoir Effluent on Some Soil Chemical and Physical Properties. *Advances in Natural and Applied Sciences Research, Vol.2 (2)* 76- 85.
47. IWEGBUE C.M.A, ARIMORO F.O., NWAJEI G.E., **OSA. EGUAVOEN**(2008) Heavy Metal Content In The African Giant Snail *ArchachatinaMarginata*(Swainson, 1821) (Gastropoda: Pulmonata: Achatinidae) In Southern Nigeria .***Polish** Journal of Ecology 39: 307 – 314*
48. Iwegbue C.M.A., Nwajei G.E**., O.I. Eguavoen,** Ogala J.E.(2009) Chemical fractionation of some heavy metals in soil profiles in vicinity of scrap dumps in Warri, Nigeria. *Chemical Speciation and Bioavailability (UK) **21** (2) 99-110*
49. Iwegbue C.M.A., Nwajei G.E., **O.I. Eguavoen**(2009). Metal distribution in some brands of cigarette Ash in Nigeria.*Journal of Science and Engineering.* (India)**.** 880/2008

50. **O.I. Eguavoen, F.** Egharevba, S.I. Eju (2003) Simulation of gasoline adulteration: A study of the effects and extent of gasoline adulteration with kerosene and diesel. *Advances in Natural and Applied Sciences Research.*Vol.1 No.1. pp. 136-14

51. Iwegbue C.M.A, Emu F.N, Bazunnu A.O, **Eguavoen O.I** (2009) Minreralisation of nitrogen in hydromorphic soils amended with organic wastes. *Journal of Applied Sciences and Environmental Management* . (Accepted for publication July 2009)

52. Iwegbue C.M.A, Arimoro F.O; C.E Iwegbue; **OsaEguavoen** (2009) Levels of Cd, Cu, Cr, Ni, Zn, Pb and Mn in some fish species from Orogodo River, Nigeria.*International Journal of Food, Agriculture & Environment-JFAE* Vol 7. (3&4) - 2009.

53. **Eguavoen, OI**, Iwegbue, C.M.A. (2009) Distribution of total heavy metals in core sediment of Orogodo River, Southern Nigeria. *International of Soil Sediment and Water.* USA.(accepted for publication Dec. 2009)

54. Iwegbue, CMA, Arimor, FO, Nwajei, GE, **Eguavoen, OI.** (2009) Concentration and distribution of trace metals in surface waters of Orogodo River, Southern Nigeria. *International of Soil Sediment and Water.* USA.(accepted for publication Dec. 2009

55. Iwegbue C.M.A, Arimoro F.O; C.E Iwegbue; **OsaEguavoen** (2009) Characteristic levels of heavy metals in canned sardines consumed in Nigeria. *Environmentalist* (Netherlands) *29: 431-435*

56. Iwegbue C.M.A, C.E Iwegbue; **OsaEguavoen** (2009) Heavy metal contamination of some vegetables and spices in Nigeria. *International Journal of Biol. Chem. Science* (accepted 2009)

57. Iwegbue C.M.A, Arimoro F.O; C.E Iwegbue; **OsaEguavoen** (2009) Characteristic levels of heavy metals in three species of fish from Orogodo River. *Jour. Chem. Soc. Nig* (in press)

58. Iwegbue, CMA; Opuene K, Nwajei, GE, **Eguavoen OI** (2009) Characteristic levels of heavy metals in muscle, liver and kidney of goats from Southern Nigeria. *ArhivVeternaski* (in press)

59. **Eguavoen,OI**, Iwegbue, CMA , Nwajei, GE (2009) Land use patterns and concentration of heavy metals in urban, semi-urban and rural zones in Delta State Nigeria. *Soil and Sediment Contamination* (in press)

60. Iwegbue, CMA, Emuh FN, Bazunu, A, **Eguavoen OI** (2009) Mineralization of nitrogen in wetland soils of Niger Delta amended with organic waste. *Jour. ApplSciEnv. Mgt.* (in press)

61. Ize-Iyamu, O.K.,**Eguavoen, I.O.** Asia, I.O., Egbon, E.E., Ize-Iyamu, O.C. and Egbesunun B. (2009): Comparative Studies on the Treatment of Brewery Sludge Using Locally Sourced and Conventional Coagulants. Adv. Nat. & Appl. Sci. Res. Vol. 7: 200 – 208

62. Ize-Iyamu, O.K.,**Eguavoen, I.O.,**Osuide, M.O., Egbon, E.E., Ize-Iyamu, O.C., Akpoveta V. And Ibuzugbe, O.O. (2011): Characterization and Treatment of Sludge From the Brewery Using Chitosan. The Pacific Journal of Science and Technology, Vol. 12 (1) pp 542 – 547.

63. Anegbeh, P. O., D. O., Okere, **O. I. Eguavoen** and U. N. Onyema. 2012. Germplasm collection and rootstock production of some high value indigenous fruit trees for integration with rubber in Agroforestry Systems in Nigeria. *Journal of Agricultural Production and Technology 1(1): 29 - 36*.

64. Ize-Iyamu, O.K.,**Eguavoen, I.O.,** Akpoveta O.V. Osakwe S.A. Egbon, E.E., Ize-Iyamu, O.C., Ibizugbe, O.O. (2012): Characterization and Treatment of Sludge from the Brewery Using Jatrophagossypifolia Stem Latex. International Journal of Green and Herbal Chemistry. Available online at www.ijghc.org. Vol.1. No.3, 237 – 244

65. Ize-Iyamu, O.K.,**Eguavoen, I.O.**, Egbon, E.E., Ize-Iyamu, O.C., Azih, M.C. and Ibizugbe, O.O. (2012): Physicochemical Treatment of Brewery Sludge with locally Sourced Coagulants (Chitosan and Clay). Nigerian Annals of Natural Sciences, Vol. 12(1) 8 – 16. Available online @ www.nansjournal.org.

66. Waizah Y., P.O. Anegbeh**.,**J. R. Orimoloye**,, O. I. Eguavoen**., S. O. Idoko and F.C. Izevbigie 2012. **T**he efficacy of poultry manure and inorganic fertilizers in improving soil fertility and growth of rubber seedlings in Iyanomo Southern Nigeria *Journal of Agricultural Production and Technoloyg. 1(2)*: 66 – 74

67. Ize-Iyamu, O.K.,**Eguavoen, I.O.,**Ize-Iyamu, O.C. and Chukwuedo, M.E. (2013): The Treatment of Sludge from the Rubber Processing Industry with Chitosan Bayero Journal of Pure and Applied Science, 6(1): 159 – 163.

Proceedings/Conference Papers

68. Omokhafe, K. O., **Eguavoen, I. O.** (2014) Climate change and tree crop agriculture as applicable in Nigeria. Conference of the Faculty of Agricultural Technology, Rufus Giwa Polytechnic, Owo, Ondo State, Nigeria, pp. 109 – 115.

69. **Eguavoen**, O. I., A. A. Awah., K. D. Afolabi, T. U. Esekhade., P. O. Anegbeh., B. C. Lalabe and P. O. Orimoloye., 2013. Effect of cooking on the nutritional value of rubber (*Heveabrasiliensis*) rubber seed seed meal-. Pp 302 – 305.*In* G. N. Akpan., F. A. S. Dairo., G. S. Bawa., I. P. Solomon., K. U. Amaefuele., A. A. Odunsi and A. O. Ladokun (Editors). Proceedings of the 18th Annual Conference of Animal Science Association of Nigeria. 8 – 12 September, 2013.Garki, Abuja, Nigeria.

70. Afolabi K.D., **Eguavoen O.I.**, Awah A.A., Orimoloye P.O and Abolagba E.O. (2013). The performance of weaner rabbits fed varying dietary levels of cooked rubber (Heveabrasiliensis) seed meal. Abstract presentation at the 11th world conference on Animal Production.

71. Abolagba E.O., **O.I. Eguavoen,** T.U. Esekhade and O.O. Abolagba (2012). Determinants of Agricultural Production. Proceedings of the 46th Annual Conference of the Agricultural Society of Nigeria. (ASN) Kano.

72. Omokhafe, K. O., **Eguavoen, I. O.,**Nasiru, I. (2012) Country trials of SALB tolerant clones; which way forward? Conference of Pathology Group, International Rubber Research and Development Board, Benin City, Nigeria, pp. 92 -93.

73. Orumwense, K. O., **O. I. Eguavoen**., A. I. Aigbodion., P. O. Anegbehand V. I. Omorusi 2012. Relative Abundance of Mistletoe in *Hevea* Plantation in Edo State, Nigeria. Pp 169. *In* James Jacob., Jacob Matthew and Rosamma Alex (Editors).Book of Abstract. International Rubber Conference. Kerala, India 29 – 30 October 2012.

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75. Anegbeh, P. O**.,** M. A. Amakiri, **O. I. Eguavoen**, E. E. Opowalibo., A. A. Awah, and T. A. T. Wahua 2011. *Inga edulis* Mart: a Valuable Woody Legume for Weed Control in a Sustainable Rubber-Based Agroforestry System. pp 329 – 334 *In*Popoola&Ogunsanwo, K and Idumah F (eds), Forestry in the Context of the Millennium Development Goals. Proceedings of the 34th Annual Conference of the Forestry Association of Nigeria 5-19 December 2011, Osogbo, Osun State, Nigeria

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University Chemistry Textbooks:

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80. **Eguavoen, O. I.,** Ebhoaye, J.E.(1995) Basic University Chemistry Part II. Department of Chemistry, Edo State University, Ekpoma. p. 100
81. **Eguavoen, O. I** (Ed), University Chemistry Module 1, *Chemistry Advancement Society, Nigeria*. 1996.
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83. **Eguavoen,O. I**. and Egharevba, F., Molecular Geometry and X-ray Diffraction,.*Chemistry Advancement Society, Nigeria*, 1997.

Chapters in books for tertiary institutions

84. **Eguavoen,O. I.(**1999) Units and Dimensional Analysis in Chemistry**;** *University Chemistry module I. Chemistry Advancement Society, ISBN 98 – 1884 – 03 – 02,*p.1 - 6

85. **Eguavoen,O. I**.(1999) Kinetic Theory of matter**;***University Chemistry module I. Chemistry Advancement Society, ISBN 98 – 1884 – 03 – 02, p.73 –* 83

86. **Eguavoen,O. I.(**1999) Behaviour of Gases (Ideal and Real)**;** *University Chemistry module I.*, *Chemistry Advancement Society, ISBN 98 – 1884 – 03 – 02,* p. 88 – 101

87. **Eguavoen, O. I. (**1999) Thermochemistry **;***University Chemistry module I.Chemistry Advancement Society,ISBN 98 – 1884 – 03 – 02* p. 113 – 117

88. **Eguavoen, O. I.** (1999) Electronic Theory of Organic Chemistry; *University Chemistry module I. Chemistry Advancement Society, ISBN 98 – 1884 – 03 - 02*p. 313 – 317

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91. **Eguavoen, O. I.** (2006)Chemical kinetics.*University Chemistry module II. Chemistry Advancement Society, ISBN 978 – 8028 – 39-X.* p. 201-227

92. **Eguavoen, O. I.**, Okwu, U.N., Ekhorutomwen, S.A. and Otuonye, J.C. (1981) Towards A Technically Specified Rubber Scheme for Nigeria, Federal Ministry of Science and Technology, RRIN, Benin City

93. **Eguavoen, O.I. (**1981) Locally sourced coagulants as alternative to formic acid in NR latex coagulation.*Annual Report of the Rubber Research Institute of Nigeria, Federal Ministry of Science and Technology, Benin City 1981*

94. **Eguavoen, O.I.** and other consultants (1993) Environmental Impact Assessment Reports for Shell Petroleum Development Co. / Nigeria National Petroleum Corp. Joint Ventures.

95. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2013. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Seventeenth Quarter Report.CFC-funded rubber-based agroforestry project. January– March 2014. RRIN, Iyanomo, Benin City, Nigeria 18 p.

96. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2013. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Seventeenth Quarter Report.CFC-funded rubber-based agroforestry project. October– December 2013. RRIN, Iyanomo, Benin City, Nigeria 18 p.

97. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2013. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Seventeenth Quarter Report.CFC-funded rubber-based agroforestry project. July– September 2013. RRIN, Iyanomo, Benin City, Nigeria 18 p.

98. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2013. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Sixteenth Quarter Report.CFC-funded rubber-based agroforestry project. April– June 2013. RRIN, Iyanomo, Benin City, Nigeria 20 p.

99. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2013. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Fifteenth Quarter Report.CFC-funded rubber-based agroforestry project. Jan– March 2013. RRIN, Iyanomo, Benin City, Nigeria 20 p.

100. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2012. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Fourteenth Quarter Report.CFC-funded rubber-based agroforestry project. October – December 2012. RRIN, Iyanomo, Benin City, Nigeria 20 p.

101. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2012. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Thirteenth Quarter Report.CFC-funded rubber-based agroforestry project. July – September 2012. RRIN, Iyanomo, Benin City, Nigeria 26 p.

102. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2012. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Twelfth Quarter Report.CFC-funded rubber-based agroforestry project. April – June 2012. RRIN, Iyanomo, Benin City, Nigeria 26 p.

103. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2012. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Eleventh Quarter Report.CFC-funded rubber-based agroforestry project. Jan – Mar 2012. RRIN, Iyanomo, Benin City, Nigeria 26 p.

104. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2011. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Tenth Quarter Report.CFC-funded rubber-based agroforestry project.Oct – Dec 2011. RRIN, Iyanomo, Benin City, Nigeria 25 p.

105. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2011. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Nineth Quarter Report.CFC-funded rubber-based agroforestry project. Jul – Sep 2011. RRIN, Iyanomo, Benin City, Nigeria 25 p.

106. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2011. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Eight Quarter Report.CFC-funded rubber-based agroforestry project. Apr – June 2011. RRIN, Iyanomo, Benin City, Nigeria 26 p.

107. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2011. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Seventh Quarter Report.CFC-funded rubber-based agroforestry project. Jan – March 2011. RRIN, Iyanomo, Benin City, Nigeria 26 p.

108. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2010. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Sixth Quarter Report.CFC-funded rubber-based agroforestry project. Oct – Dec 2010. RRIN, Iyanomo, Benin City, Nigeria 24 p.

109. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I**. 2010. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Fifth Quarter Report.CFC-funded rubber-based agroforestry project. Jul – Sep 2010. RRIN, Iyanomo, Benin City, Nigeria 23 p.

110. Anegbeh, P. O., Esekhade, T. U., Awah, A. A. and **Eguavoen, O. I.** 2010. Developing Economically Viable Rubber Smallholdings in West Africa (CFC/IRSG/21). Fourth Quarter Report.CFC-funded rubber-based agroforestry project. Apr – June 2010. RRIN, Iyanomo, Benin City, Nigeria 31 p.

PUBLIC LECTURE TO PROFESSIONAL, ACADEMIC and GENERAL AUDIENCE:

1. **Eguavoen, O. I**., (1981) Natural Rubber, It's Role In Our Economy In The 1980's Rubber Research Institute of Nigeria/ Nigerian Rubber Board Workshop for Natural Rubber Producers, University of Benin, Benin City.
2. **Eguavoen, O.I**, (1999) The Role of Computers In The Pursuit Of National Objective In Teacher Education. Workshop Organized by the College Of Education, Ekiadolor.
3. **Eguavoen, O.I**, (2006) "Global Warming: Causes, Effects and Control"AmbroseAlli University Secondary School End of Year Lecture .Ekpoma Nigeria.

ONGOING RESEARCH AND ARTICLES UNDER PEER REVIEW

Plant Food/Drug Research and Environmental Pollution Monitoring/Remidiation.

1. Iwegbue C.M.A., Overah C.L.s, Nwajei G.E. and **Eguavoen O.I.**Heavy metal content of some brands of cigarette and Marijuna (*Canabisstativa*) in Nigeria.*Journal of Science and Engineering* (India).
2. **Eguavoen O.I.,**Iwegbue C.M.A., Nwajei G.E., Opuene K. Toxic and Trace metal content in muscles, kidneys and liver of Pigs in Southern Nigeria. *Czech Journal of Animal Science*
3. **Eguavoen O.I.,**Iwegbe C.M.A., Nwajei, G.E., Overah C.L. Heavy metal content of urban street dust in Nigeria.*Trace Elements and Electrolytes* (Germany)
4. Iwegbue C.M.A., G.E. Nwajei and **O.I. Eguavoen**. Land use patterns and concentrations of some toxic elements in soils of urban, semi-urban and rural zones of Niger Delta, Nigeria. *Soil and Sediment Contamination.*(USA).
5. **Eguavoen, O.I.,**Iwegbue C.M.A., G.E. Nwajei, Opuene K. Heavy metal composition of some food seasoning agents consumed in Nigeria. Arabian Journal of Science and Engineering.
6. **Eguavoen O.I**., Iwegbue C.M.A., Arimoro F.O., Iwegbue C.E.E.Levels of Cd, Cu, Cr, Ni, Zn, Pb and Mn in some fish species from Orogodo River, Nigeria.*Journal of Chemical Society of Nigeria.*
7. **Eguavoen O.I,**Odia, A.E., Ihimare, I.G..Amino acid Composition of Cooked Pleurotus tuber-regium.*Food Chemistry*
8. **Eguavoen I.O.,** Asia I.O., Onimawo, I.A., Ihimare, I.G.Odia, A.E., Effect of Sprouting on the In-Vitro Digestibility and Anti-Nutrient of Pigoen Pea obtained from Esan land Edo State, Nigeria. *International Journal of Chemistry*, India
9. **Eguavoen I.O.,**Odia, A.E., Ihimare, I.G. Effect of Chemical Modification on the Functional Properties of Pleurotus tuber-regium.African Journal of Science.
10. **Eguavoen I.O.,** Awah A. Processing of Rubber seed for partial substitution of commercial poultry feed.
11. **Eguavoen I.O.** Rapid processing and Benefitiation of Gum Arabic

CONFERENCES ATTENDED (1997 – 2015)

LOCAL:

- Annual Conference of the Chemical Society of Nigeria 1997. Papers presented: (a) Dehydrocyanation of Lima beans *Phaseoluslunatus* Linn. (b) Rapid and Reliable Method of Detecting Adulteration of Gasoline.
- College of Education Ekiadolor's Workshop on Computers in Education (1999). Invited to give a lead paper entitled "The Role of Computers in the pursuit of National objective in Teacher Education"
- Annual Conference of the Polymer Institute of Nigeria Port Harcourt 1999 papers presented: (a) Impact Strength of Graft Copolymers of Polystyrene and Acrylonitrile. (b) Environmental and Health Hazards Of Polythene and Polystyrene Packaging Litters.
- Annual Conference of the Polymer Institute of Nigeria, Jos (2000). Paper presented: Production of High Detonating Explosives from Cellulosic Materials.
- World Intellectual Property Organisation/Federal Republic of Nigeria's Seminar on the Management of Intellectual Property for Research and Development and the Commercialization of R & D Results.(2000) Abuja.
- UNESCO National University Commission Workshop for Deans of Science and Engineering Faculties on Information Technology (INFOTECH) and University Education (2001) Abuja.
- Chemical Society of Nigeria, Edo Chapter 1st Annual Conference 29th July 2005
- 29th Annual International Conference of the Chemical Society of Nigeria, Sept. 2006, Lagos
- 30th Annual International Conference of the Chemical Society of Nigeria, Sept. 2007, Abuja
- 31st Annual International Conference of the Chemical Society of Nigeria, Sept. 2008, PTI, Warri

INTERNATIONAL:

INTERNATIONAL RUBBER RESEARCH AND DEVELOPMENT BOARD (IRRDB) ANNUAL INTERNATIONAL CONFERENCE / MEETING ON RUBBER CULTIVATION, IMPROVEMENT, TECHNOLOGY/ APPLICATIONS & MARKETING

- China, 2010
- Malaysia, 2011
- India, 2012
- London, 2013
- Philippines, 2014

ASSOCIATION OF NATURAL RUBBER PRODUCING COUNTRIES ANNUAL CONFERENC / MEETINGS

- Malaysia, 2010
- Sri Lanka, 2014

INTERNATIONAL RUBBER STUDY GROUP ANNUAL CONFERENCES

- Ivory Coast, 2013
- Singapore, 2014

UNITED NATIONS UNIVERSITY –INSTITUTE OF NATURAL RESOURCESIN AFRICA (UNINRA)

- Accra, Ghana, 2012

THESES SUPERVISTION

1. **Undergraduate: B.Sc. Chemistry/Industrial Chemistry**
   Supervised over 120 students' project in the areas of physical organic, natural products and analytical/environmental chemistry respectively

2. **Post-Graduate Diploma in Industrial Chemistry (PGDIC)**

Field	No. of candidates	Status
Phytochemistry	2	Completed
Analytical /Environmental chemistry	4	Completed
	Total = 6	

3. **M.Sc. Chemistry**

Field	No. of candidate	Status
Food chemistry	3	Completed
Analytical/ Environmental Chemistry	3	Completed
Reaction mechanism	1	Completed
Polymer Technology	1	Completed
	Total = 8	

4. **Ph.D. Chemistry.**

Field	No. of candidate	Status
Food chemistry	1	Completed
Environmental pollution management	3	Completed
Environmental pollution management	1	On-going
Natural products chemistry	1	On-going
Total = 6		

THESES EXAMINATION (EXTERNAL)

A. **Ph.D.**

Field	**No. of candidates**	**University**
Polymer/Pollution Management	1	UNIBEN
Analytical/Environmental Chemistry	2	UNICAL
Analytical/Environmental Chemistry	1	DELSU
Physical organic chemistry	2	Anan Univ. India

Total = 6

B. **M.Sc.**

Field	**No. of candidate**	**University**
Food chemistry	1	UNICAL
Analytical/Envir. Chemistry	9	DELSU

Total = 10

THESIS EXAMINATION (INTERNAL EXAMINER REPRESENTING AAU GRADUTE SCHOOL)

A. **Ph.D.**

Field	**No. of candidate**
Agronomy	2
Animal breeding	1
Microbiology	3
Geophysics	1

Total = 7

B. M.Sc.

Field	**No. of candidate**
Botany (Air pollution monitoring)	1
Law (Environmental law)	2
Zoology (Envir. Pollution monitoring)	1
Engineering (engineering materials)	1
Engineering (corrosion monitoring)	1

Total = 6

ASSESSMENT OF READERS and PROFESSORS CONDUCTED (2002 - Date)

A. **Prima facia Report.**

No. of Candidates	**Position**	**University**
1	Reader	DELSU
1	Reader	Igbinedion Univ.
3	Reader	AAU, Ekpoma
3	Professor	AAU, Ekpoma

Total = 8

B. **Full and Final Report**

No. of Candidates	Position	University
3	Professor	UNIBEN
4	Professor	UNICAL
1	Professor	CRUTECH
1	Professor	RSUST (PH)
3	Professor	UNIPORT
	Total = 12	

WORKING EXPERIENCE:

- Junior Mathematics/Science Master, Edo College Benin City, 1968-70
- Demonstrator in Practical Chemistry, University of Ibadan, Jos Campus, Jos - 1973-74 (National Youth Service Corps Pioneering Year)
- Teaching/Research Fellowship, Department of Chemistry, University of Lagos, 1974-78
- Senior Research Officer/Head of Division, Rubber Chemistry and Quality Control Division, Federal Ministry of Science and Technology, Rubber Research Institute of Nigeria, Benin City, 1979 - 1981
- Principal Research Officer/Head, Rubber Chemistry and Quality Control Division, Federal Ministry of Science and Tech., Rubber Research Inst. of Nigeria, Benin City, 1979-82
- Senior Lecturer 1982 - 1987; Bendel State University, Ekpoma
- Associate Professor 1987 -1995; Edo State University, Ekpoma
- Professor 1995 – 15th April, 2010; Ambrose Alli University, Ekpoma
- Executive Director / CEO 16th April, 2010 – Date; Rubber Research Institute of Nigeria
- Visiting Professor, University of Benin Benin City, 2015-20016

ADMINISTRATIVE POSITIONS AND RESPONSIBILITIES IN RUBBER RESEARCH INSTITUTE OF NIGERIA, IYANOMO , BENIN CITY (1979 – 1982)

Senior Research and later Principal Research Officer/Head of Rubber Quality Control Division

(i) Responsible to the Chief Executive on research into the production, processing, grading and utilization natural rubber (NR) latex and other by-products of Heveabrasiliensis cultivation.

(ii) Initiation and defense of new research proposal during annual cropping conference

(iii) Supervision and execution of research in rubber processing, utilization and beneficiation of natural rubber cultivation.

(iv) Production and sales of rubber lumps

(v) Training of peasant farmer on economic method of rubber latex extraction

(vi) Supervision of final year undergraduates on research attachment in the area of rubber chemistry and technology.

(vii) Research in the following areas were initiated during my tenure:

- Intensive stimulation of latex yield using ethrel
- Effects of ethrel yield stimulant on NR-latex properties
- Utilization of moribund rubber trees for furniture construction
- Analysis of NR-latex to establish seasonal variation in physicochemical properties
- Utilization of rubber seed in live stock feed formulation
- Utilization of rubber seed oil in waxes and paint production
- Establishment of scientific method of grading rubber for export.

Executive Director / CEO, Rubber Research Institute of Nigeria, 16th April, 2010 – 2015

i) Overall policy and direction of the Institute, including all research, administrative, management and other matters relating to the Institute, the Governing Board and the Supervisory Federal Ministry;

ii) Soliciting for funds for the implementation of the Institute's programmes and activities;

iii) Sourcing for foreign aids and bilateral assistance and training for staff;

iv) Budgeting through the Governing Board to the Ministry;

v) Final recommendation (in the case of all the Institute's Senior Staff) to the Board and final approvals (in the case of all Junior Staff) on recruitment, promotion and discipline;

vi) Recommendation of appointments of Heads of Departments, Heads of Divisions, Heads of Units, Project Coordinators and Officer-in-charge of the Institute's Extension Centres for the ratification of the Board;

vii) Liaising with the Institute's Management Committee or any other ad-hoc committee as appropriate

viii) Serving as the clearing house for all official visits and visitors to the Institute.

ix) Overall supervision and coordination of duties of Heads of Departments, Heads of Divisions, Heads of Units, Project Co-ordinators, and officer-in-charge of Extension Services;

x) Coordination and supervision of research in the upstream and downstream activities in the natural rubber value chain;

- Breeding for disease tolerant, wind resistant and high latex and timber yielding natural rubber clones
- Rubber tapping techniques for uptimum yield and bark regeneration

- Integrated rubber latex processing and effluent management for environmental preservation. Emphasis is on biogas generation from rubber processing effluent and recycling of waste water,
- Testing, grading and quality control of processed rubber,
- Modification and processing of rubber for engineering and sundry applications,
- Utilization of rubber seed / rubber seed oil:

  (a) Livestock feed (b) Alkyd resin (c) Lubricant and surface coatings
- Utilization of rubber wood for building construction and furniture
- Breeding for disease tolerant and high gum Arabic yielding A. Senegalese
- Processing and grading of gum Arabic for applications in food, pharmaceuticals and paint industry

xi) Dissemination of Research and Development (R & D) findings to government, participants in the rubber value chain and international academic audience,

xii) Identification of training needs and sourcing for grants for young scientists, engineers and technologists.

ADMINISTRATIVE POSITIONS AND RESPONSIBILITIES IN AAU, EKPOMA INCLUDING MY PIONEERING EFFORTS (1981/82 SESSION TO DATE)

1. **Special Adviser to the Sole Administrator, Edo State University, Ekpoma 1996-98**.(In a position equivalent to **Deputy Vice-Chancellor** we managed the university at the highest level for two years)

2. **Member, University Senate** 1982 –date; **Member of Governing Council**, Ambrose Alli University, Ekpoma 2005-Date

3. **Member (Co-opted) Academic Planning Committee, Bendel State University Ekpoma 1981-1982 Session** (Fine tuned the curriculum for Faculty of Natural Sciences at the commencement of 1981/1982 Session)

4. **Chairman, University Examination Committee, Bendel State University,** 1981-1982. (Supervised the conduct of the first sessional examination of the University, prepared and released results with a few permanent academic staff available; others being part time lectures and professors from sister universities)

5. **Founding Chairman, Academic Staff Union of Universities (ASUU), Bendel State University, Ekpoma Chapter 1982-1984** (As chairman of the academic staff union of my university, I successfully managed the industrial crises attendant to the closure, in 1983/84 session, of the faculties of medicine, education, agriculture and the department of chemical engineering. Lecturers in the rationalized departments/faculties were reabsorbed into related disciplines in the university through dialogue with university authority and State Government)

6. **Chairman, Pre-degree Committee** 1984-1985. (2years). (At the behest of the State Government the university was charged with the responsibility of producing science graduates to fill the gap in manpower needs in the State Teaching Service. My committee prepared admission requirements, curriculum and a blue print for the management of a self sustaining and revenue generating programme for the university.)

7. **HOD, Chemistry** 1982-1987; 1990-93; 2004-2005.(12 years)
(Pioneered the establishment of the Department of Chemistry, Bendel State University, Ekpoma which activities includes):
   i. Preparation of B.Sc., M.Sc and Ph.D. syllabuses and teaching the core courses therein. The courses include introductory chemistry courses at the foundation year, physical chemistry courses namely, chemical kinetics, statistical mechanics and thermodynamics, theory of atomic and molecular spectroscopy, applied spectroscopy, symmetry and group theory, structure and bonding; advanced organic chemistry course viz, physical organic chemistry, heterocyclic and natural products chemistry and organic synthesis
   ii. Re-engineered the department by infusing industrial chemistry courses with a view to imbuing in graduates of the department entrepreneurial skill in chemistry and allied industries
   iii. In my drive for academic excellence in science in general and chemistry in particular, the chemistry department, which I nurtured and headed for over a decade and half has produced two 1st class Honours Graduates and was adjudged the best department in the (score of 78%) in the University, and granted interim accreditation by NUC Accreditation Team 1999 and full accreditation in 2006 with a score of 87%)

8. **Dean, Faculty of Science, Edo State University, Ekpoma 1995-2002 (6 years)**
(During my tenure as Dean of Science (1995-2001)
   - The faculty of natural sciences was adjudged the best (rated 73%) in the university by the NUC accreditation Team in 1999, all current programmes in the faculty received full accreditation in 2008.
   - Six academic staff were appraised, assessed and elevated to the rank of professor.
   - Six academic staff were appraised, assessed and elevated to the rank of reader.
   - A new department, the department of computer science was created from the department of mathematics.
   - My faculty hosted Science Students Association of Nigeria's secretariat.

9. **Chairman, University Sports Council,** 1985-86

10. **Chairman, Student Welfare Committee,** 1999-2001. (A position now replaced with **Dean of Student Affairs)**

11. **Hall Master** (J.Mariere and Rev. Martins Halls respectively at different times from 1985 - date)

12. **Chairman, University Ceremonials Committee 1999-2001**

(Organised Convocation and Award Ceremonies during which the former Head of State General OlusegunObasanjo, GCFR, GCON was honoured)

13. **Director, Directorate of Foundation Programmes** 2006-Date

- Introduced cost cutting measures in running the Programme.
- Promoted adequate student teacher contact.

14. **Chairman, University Admissions Board, 2003-2006**. **(4yars)**

- Reorganised the activities of University Admissions Board UAB; admission racketeering and delays in releasing admission list were eliminated.
- Pioneered the inclusion of Post UME screening exercise into the admission process)

15. Served in variousSenate, **Governing Council and Governing Council/Senate committees**:

a. Chairman, Faculty of Natural Sciences Committee on the supervision of the construction of Science Laboratories and Space Allocation 1982 -1985

b. Member, Bendel State University Senate Committee on the upgrading of the College of Education Abraka to a degree awarding campus of the University 1986

c. Students Disciplinary Committee

d. Junior Staff Disciplinary Committee

e. Senior Staff Disciplinary Committee

f. Minor Works Committee

g. Car Loan disbursement Committee

h. Appointment and Promotion Committee (Academic) 2006-date

i. Chairman, Committee to prepare five years academic master plan for the University; (2008)

j. Organisation and Methods Committee (2009-)

16. **Chairman, University ICT Steering Committee 200-2002**

(Using my linkage with late Prof. G. Ajayi, former Director of Nigeria Information Technology Development Agency, Abuja, two staff of the University were trained in CISCO net-working. On my initiative, the Vice-Chancellor set up an ICT Steering Committee which I headed. My Committee sourced for a vendor who deployed the first V-sat in the university, thereby providing internet access and accruing benefits to the university from 2002-date)

17. Senate Representative on University ICT Committee 2006-date.

18. Senate Representative on ICPC'S Anti-Corruption Monitoring Unit of the University, 2008-date

RESEARCH LINKAGES WITH INSTITUTIONS OF HIGHER LEARNING:

(a) Queens University, Ontario, Canada

(b) University of Salford, UK

(c) University of Ghana, Legon- Ghana

(d) Rubber and Polymer Research Association (R.A.P.R.A), London

(e) Rubber Research Institute of Malaysia

(f) University of Austin in Texas

ACADEMIC RECOGNITION AMONGSTS PEERS:

1. EXTERNAL EXAMINER AND /OR EXTERNAL ASSESSOR

(a) Anna University Chennai, India

(b) University of Benin, Benin City

(c) Delta State University, Abraka

(d) University of Calabar, Calabar

(e) University of Port Harcourt, of Port Harcourt

(f) Rivers State University of Science and Technology, of Port Harcourt

(g) Igbinedion University, Okada.

(h) Benson Idahosa University, Benin City

(i) Cross River University of Technology, Calabar

(j) AuchiPolytchnic, Auchi

(k) College of Education, Benin

2. JOURNAL EDITORSHIP/REVIEWERSHIP

Editor-in-Chief:

a. Nigerian Annals of Natural sciences, 1996-2002.

b. Advances in Natural and Applied science Research 2002-

c. ChemTech Journal 2002-

Reviewer:

a ACTA ZoologicaLituania (Lituania)

b Environmental Geochemistry (Netherlands)

c International Journal of Environment and Waste Management, (IJEMW) (Netherlands)

d Environmental Monitoring and Assessment (UK)

e International Journal of Biological and Chemical Sciences IJBCS (Cameroun)

f Chemistry and Ecology (USA)

g Nigerian Annals of Natural sciences (Nigeria) i Chairman, technical session for the review of papers presented on chemical kinetics at the 17th Annual Conference Of The Chemical Society of Nigeria.

CONTRIBUTIONS TO THE NATION:

i. Pioneer member NYSC, 1973-74; duties:

   a. Chemistry and Biology Teacher, St. Joseph's College Vom 1973-74.

   b. Demonstration in practical chemistry and handling of tutorials in foundation chemistry courses, University of Ibadan, Jos Campus, Jos, 1973-74.

ii. **Establishment of Scientific Grading Criteria for Nigerian Technically Specified** Rubber (1979- 1981) at the instance of the Rubber Research Institute of Nigeria Benin City, an agency of the then Federal Ministry of Science and Technology.

iii. Membership of NUC Accreditation Team for Science Programmes in Nigerian Universities 1990- date

iv. Resource Person to JAMB(contribution multiple choice examination questions)

v. Examiner, West African Examination Council.

vi. State Coordinator (Chemistry), Sciences Teachers' Vacation Workshop.(Under the aegis of Bendel State Ministry of Education, I chaired a team of subject experts that organized refresher courses in chemistry for secondary school chemistry teachers in Bendel State 1986-88)

vii. Chairman, Federal Government Staff Audit Panel to Auchi Polytechnic, Auchi, 1999.

viii. Visiting Professor, Major Seminary of All Saints, Uhiele..

EXTRA-CURRICULAR ACTIVITIES:

Tennis, Traditional *Igun* Bronze Works and Computer Competence in MS Office, Graphics Applications, Computer Aided Learning and Information Technology

REFEREES

1. Prof. E.U. Emovon OFR,
   No. 7 Emovon Drive
   Off Ihama Road
   G.R.A. Benin City

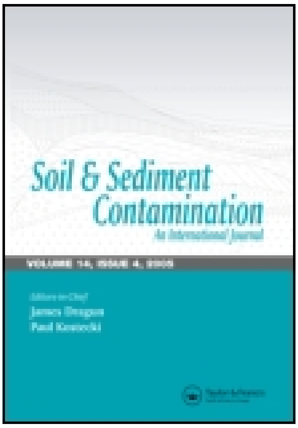
2. Prof. Emeritus J. Okogun
   Department of Chemistry
   Ambrose Alli University
   Ekpoma

2. Prof. Emeritus J.E.A. Osemeikhian
   fmr VC Ambrose Alli University,
   P.M.B. 14, Ekpoma.

RESEARCH

Basic Area: Physical Organic Chemistry-Reaction Mechanism, Structure/Properties Relationship in Organic Chemistry. We synthesize highly to moderately substituted benzenoid and heterocyclic aromatic compounds, investigate the kinetics of their reaction, analyse kinetic, thermodynamic and spectral data to elucidate the mechanistic pathways of their S_NAr reactions. From using physical methods to probe reaction mechanisms in organic chemistry, I have veered extensively into preliminary investigation of the industrial potentials of the abundant natural resources in the environment of my young University. This was motivated by two major factors. Firstly, there is a current urge in Nigeria to look inward in sourcing industrial raw materials. Secondly, it is **endogenous** and receives the patronage of postgraduate students to enhance their employment prospects. Also, this type of research occasionally attracts small grants from private enterprises in the near absence of government research subsidy. My current research thrust is multi-disciplinary encompassing chemical, basic medical and environmental sciences as shown below:

Applied Area: Natural Products Chemistry-: **Phytochemical studies** of biologically active local plant materials. Analytical/Environmental Chemistry-: Search for and elucidation of chemical indicators of **environmental pollution** and general **environmental impact assessment** (EIA)/abatement studies. **Natural rubber processing and utilization of by-products of natural rubber cultivation and processing industries.**My research findings have been published widely in International and Local Journals.



Soil and Sediment Contamination: An International Journal
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http://www.tandfonline.com/loi/bssc20

Impact of Land-Use Patterns on Chemical Properties of Trace Elements in Soils of Rural, Semi-Urban, and Urban Zones of the Niger Delta, Nigeria

Chukwujindu M. A. Iwegbue [a], Godwin E. Nwajei [a] & Osayanmo I. Eguavoen [b]

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Impact of Land-Use Patterns on Chemical Properties of Trace Elements in Soils of Rural, Semi-Urban, and Urban Zones of the Niger Delta, Nigeria

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The study of the concentrations of Cr, Zn, Cd, Pb, Ni, and Cu in soils under different land uses in rural, semi-urban, and urban zones in the Niger Delta was carried out with a view to providing information on the effects of the different land uses on the concentrations of trace elements in soils. Our results indicate significant variability in concentrations of these metals in soils under different land uses in rural, semi-urban, and urban zones. The maximum concentrations of metals in the examined soil samples were 707.5 mg.kg^{-1}, 161.0 mg.kg^{-1}, 2.6 mg.kg^{-1}, 59.6 mg.kg^{-1}, 1061.3 mg.kg^{-1}, and 189.2 mg.kg^{-1} for Cr, Zn, Cd, Pb, Ni, and Cu, respectively. In the rural zone, the cassava processing mill is a potent source of Ni, Cr, Cu, and Zn while agricultural activities are a source of Cd, and automobile emissions and the use of lead oxide batteries constitute the major sources of Pb. In the urban zone, soils around the wood processing mill showed elevated concentrations of Cu, Cr, Zn, and Ni, while soils around automobile mechanic works and motor parks showed elevated levels of Pb. Elevated Cd concentrations were observed in soils under the following land uses: urban motor park, playground, welding and fabrication sheds, and metallic scrap dump. The contamination/pollution index of metals in the soil follows the order: Ni > Cd > Cr > Zn > Cu > Pb. The multiple pollution index of metals at different sites were greater than 1, indicating that these soils fit into "slight pollution" to "excessive pollution" ranges with significant contributions from Cr, Zn, Cd, Ni, and Cu.

Keywords Anthropogenic activities, contamination/pollution index, heavy metals, land uses, surface soil

Introduction

Accumulation of heavy metals in soils is one of the main global ecological problems (Li and Li, 2001; Schwab et al., 2002; Gardea-Torresdey et al., 2005; Claus et al., 2007; Jankaite et al., 2008; Sayyad et al., 2009). Heavy metals are particularly hazardous due to their non-biodegradable nature and ability to accumulate over a relatively long period (Ding and Ji, 2010), which is related to the sorption capacity of the soils (During et al., 2002; Bai et al., 2010). Soil acts as a medium of both contaminant accumulation and distribution. Upon reaching the soil as dust, precipitation, or in other ways, contaminants accumulate

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in different combinations. From the soil, they can enter plants and through them to the food chains. They can also migrate into surface water, groundwater, and migrate a large distance to re-enter the food chain and poison living organisms (Jankaite et al., 2008). Heavy metal content of soil is of major significance in relation to fertility and nutrient status as well as toxicity status. Many metals, such as Zn and Cu, are essential elements for normal growth of plants and living organisms. However, at high concentrations these metals are toxic. Other metals that are not included in this group of essential elements, such as Cd, Pb, or Cr, may be tolerated by the ecosystem in low concentrations, but become very harmful at higher concentrations (Machender et al., 2010). For this reason, the presence of metal ions in the environment could be regarded as "a double-edged sword."

The migration and accumulation of heavy metals (HMS) in soil depend on interplay between several environmental factors, which include the chemical and mineralogical compositions of soil-forming rocks, the textural composition of the soil, soil solution pH, cation exchange capacity, soil organic matter, land use patterns, the nature of the contamination in terms of origin, and the characteristics of the deposition/composition and environmental conditions that may lead to weathering (Rogan et al., 2010).

Heavy metal contamination is introduced into the soil environment through a variety of land uses. Each land use pattern has its own associated anthropogenic activities which could contribute significant amounts of metals into the soil. For example, in land used for agricultural purposes, heavy metals may be added to soils through agricultural fertilizers and pesticides, soil amendments (e.g. lime and gypsum), and organic fertilizers (e.g. manure and composts) (Zarcinas et al., 2004).The study of metal concentration under different land uses gives a reference-based information on the types of metal contamination that are associated with different land uses. Information from such exercises is necessary for: (i) ranking potential sources of metal in soil environment and management of metal pollution; and (ii) remediation of heavy metals in soils.

The level of contamination of soils by heavy metals depends on the retention capacity of the soil, especially on physicochemical properties (mineralogy, grain size, organic matter) affecting soil particle surfaces and also on the chemical properties of the metals. These metals may be retained by soil components in the near surface soil horizons or may precipitate or co-precipitate sulphide, carbonates, oxides, and hydroxides with Fe, Mn, and and Ca (Moral et al., 2005).

The objective of the present study is to determine levels of Cd, Cu, Cr, Ni, Pb, and Zn in soil under different land uses in urban, semi-urban, and rural areas of the Niger Delta with a view to providing information on the relative levels and extent of contamination arising from such land uses.

Materials and Methods

Description of Study Areas

The study area covers three zones located in the Delta State of Nigeria (Figure 1). Emu-Uno, longitude 6° 14′E and latitude 5° 37′ N, is a typical rural setting. The major activities in this community are small-scale farming and cassava processing.

Abraka lies on longitude 6° 04′E and latitude 5° 54′ N. In the 1970s and 1980s, Abraka had a typical rural setting. The Abraka community rapidly transformed into a semi-urban area after the establishment of Delta State University in 1992. Abraka has an estimated

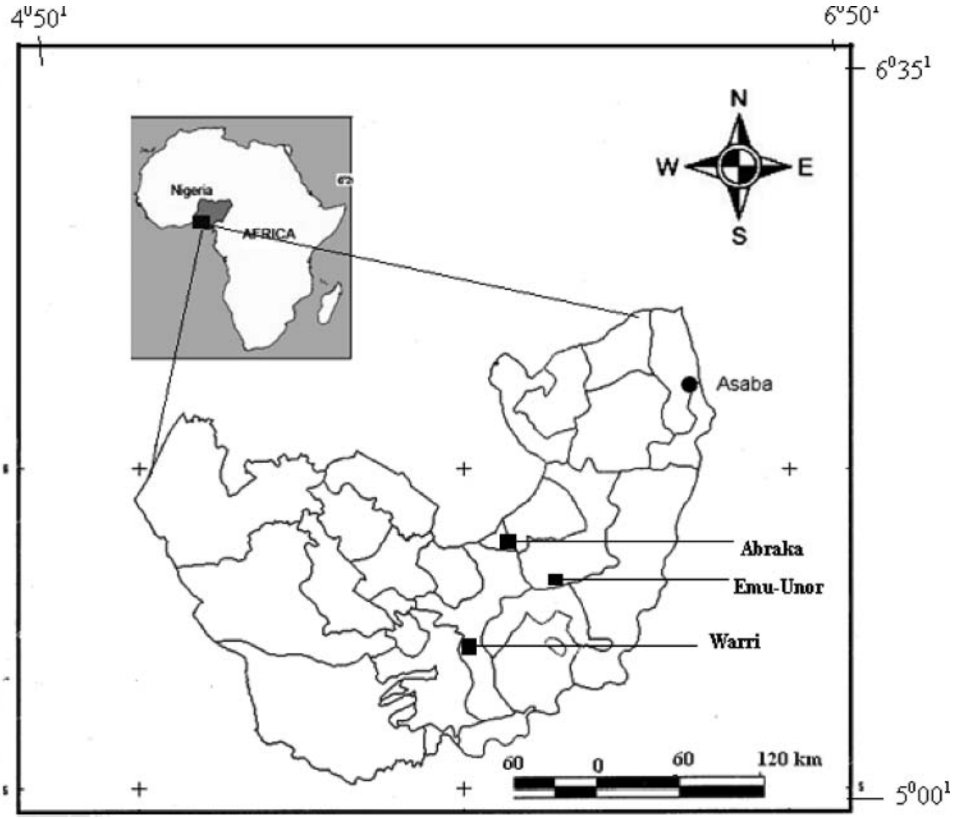

Figure 1. Map of Delta State showing the study areas.

population of 50,000 persons. Apart from being an educational town, the major activities in Abraka include farming and tourism.

Warri is one of the major industrial towns in the Niger Delta region of Nigeria and lies on longitude 6° 15′ E and latitude 4° 17′ 6″ N. Warri and its environs house a refinery, petrochemical plants, and a steel company. Other industries found in this area are those rendering services to the oil and gas sector and food processing industries. Warri has a population of about a million. Some of the different land uses in the three zones are displayed in Table 1.

Sampling and Analysis

At each zone, soil samples were collected at different sites associated with different land-use patterns (Table 1). At each sampling site, quadrants of various dimensions were constructed around the sites depending on the size of the area. Each quadrant was further divided into cells. For example, a motor park with an area of 1000 m^2 and a quadrant size of 100 × 100 m was constructed, which was further divided into a 10 × 10 m cells. Soils (at least five random samples) were collected from each cell at depth of 0–20 cm, using a plastic soil auger. In the laboratory, the soil samples were air-dried, sieved to pass a 2 mm sieve, and stored in polyethylene containers prior to analysis. Total organic matter was determined

Table 1
Some physicochemical and trace metal characteristics of soils under different land uses in rural, semi-urban, and urban areas

Zone/Site	Sample code	pH	OM (%)	Cr ($mgkg^{-1}$)	Zn ($mgkg^{-1}$)	Cd ($mgkg^{-1}$)	Pb ($mgkg^{-1}$)	Ni ($mgkg^{-1}$)	Cu ($mgkg^{-1}$)	Land use pattern/ anthropogenic activity
Rural Area	RS 1	5.5	1.5	51.9 ± 2.6	74.0 ± 3.0	0.60 ± 0.02	0.05 ± 0.0	92.0 ± 4.9	16.4 ± 0.7	Rural market
	RS 2	4.2	2.5	394.2 ± 19.2	91.2 ± 3.9	0.80 ± 0.02	7.3 ± 0.3	492.8 ± 24.6	98.4 ± 3.8	Rural cassava processing mill I
	RS 3	5.7	1.1	48.7 ± 2.0	12.0 ± 0.6	0.90 ± 0.05	3.4 ± 0.2	102.7 ± 14.4	14.6 ± 0.5	Rural play ground
	RS 4	6.7	0.9	68.5 ± 2.1	42.0 ± 2.1	0.75 ± 0.05	12.4 ± 0.6	73.1 ± 13.1	20.6 ± 1.0	Rural residential area
	RS 5	4.1	3.0	86.4 ± 3.9	75.0 ± 2.9	0.05 ± 0.00	12.1 ± 0.7	129.5 ± 16.2	25.9 ± 1.2	Rural cassava processing mill II
	RS 6	6.5	1.8	66.1 ± 3.3	30.5 ± 1.1	1.45 ± 0.07	0.05 ± 0.06	99.2 ± 14.7	19.9 ± 1.5	Rural farm land
Semi-urban Area	SU 1	4.8	1.2	61.5 ± 2.6	49.5 ± 1.9	0.35 ± 0.02	22.7 ± 1.1	92.2 ± 4.4	18.5 ± 0.9	Semi-urban market
	SU 2	5.2	0.7	60.9 ± 2.8	83.5 ± 4.2	1.05 ± 0.05	4.55 ± 0.2	92.4 ± 4.1	18.3 ± 0.9	Motor park
	SU 3	5.2	1.5	86.0 ± 4.0	62.0 ± 2.7	1.65 ± 0.05	4.10 ± 0.2	129.0 ± 5.8	114.8 ± 4.9	Residential area
	SU 4	6.5	0.8	76.5 ± 3.3	52.5 ± 1.8	1.45 ± 0.06	25.0 ± 1.1	114.8 ± 4.9	23.0 ± 0.8	University playground
Urban Area	UB 1	6.5	1.2	55.2 ± 2.4	44.0 ± 5.3	0.95 ± 0.06	17.3 ± 1.0	92.8 ± 4.8	16.6 ± 1.0	Industrial area
	UB 2	6.2	1.0	60.1 ± 3.0	61.2 ± 3.1	1.85 ± 0.11	0.05 ± 0.00	90.1 ± 4.6	18.0 ± 0.8	Childrens' playground
	UB 3	6.5	0.9	79.3 ± 4.0	115.5 ± 0.7	1.40 ± 0.03	59.6 ± 1.9	118.9 ± 5.5	47.55 ± 2.0	Urban motor park
	UB 4	5.7	1.6	61.9 ± 2.9	59.0 ± 2.1	1.20 ± 0.04	3.7 ± 0.2	92.8 ± 5.5	18.6 ± 0.4	Soil in the vicinity of metallic scrap site
	U B5	4.7	3.0	70.2 ± 29.7	12.5 ± 0.6	0.80 ± 0.03	6.8 ± 0.3	104.3 ± 5.2	21.05 ± 0.97	Soil in the vicinity of abattoir
	UB 6	4.8	2.8	707.5 ± 29.7	161.0 ± 6.9	0.10 ± 0.00	22.9 ± 1.0	1061.3 ± 53.1	212.3 ± 11.0	Soil in the vicinity of saw mill/wood processing industry
	UB 7	6.5	1.7	82.7 ± 4.1	8.9 ± 0.5	0.83 ± 0.03	59.1 ± 2.3	124.1 ± 4.7	24.8 ± 1.1	Mechanic workshop
	UB 8	7.2	2.0	630.5 ± 20.2	40.0 ± 18.0	0.95 ± 0.03	0.05 ± 0.00	945.8 ± 2.6	189.2 ± 9.5	Urban market
	UB 9	6.8	1.2	66.3 ± 2.5	83.0 ± 3.7	2.55 ± 0.09	11.2 ± 0.3	100.2 ± 5.1	20.1 ± 0.7	Welding and fabrication shed
	UB 10	5.9	1.3	44.0 ± 1.7	61.2 ± 0.3	0.60 ± 0.10	1.6 ± 2.5	66.0 ± 2.5	13.2 ± 0.8	Residential area

± SD (Standard Deviation); OM = organic matter; n = 5.

as loss in weight on ignition at 550°C and pH was determined (1:2.5 soil:water) using a Jenway digital pH meter (Abollino et al., 2002)

One gram from each sample was placed in a digestion tube followed by the addition of 15 mL of aqua regia (3:1, HNO_3: HCl). It was swirled to wet the sample and allowed to stand overnight. The following day, the tube was heated in a heating block at 50°C for 30 min and raised to a temperature of 120°C for 2 h. The digested material was dissolved with 0.25 M HNO_3, filtered through a Whatman No. 1 filter, and made up to 50 mL with 0.25 M HNO_3 (Radojevic and Bashkin, 1999). The sample solutions were analyzed for Cd, Cr, Cu, Zn, Pb, and Ni using flame atomic absorption spectrophotometry (GBC scientific equipment Sens AA, Australia) equipped with a deuterium arc background correction device. Quality control was assured by the used of blanks and spikes. The spike recovery method (SRM) was carried out by spiking some already analyzed samples with a known standard of the metals and reanalyzing. The spike recovery for the various metals was within 100 ± 10%. All reagents were of analytical grades and all samples were run in triplicate. The relative standard deviation for triplicate analysis was less than 6% for each metal.

Contamination/Pollution Index (C/PI)

The contamination/pollution index was quantified using the formula described by Lacatusu (2000).

$$C/PI = \frac{\text{Concentration of metal in soil}}{\text{Target value}}$$

This index represents the metal content effectively measured in soil and the reference value of contamination obtained using a standard value formulated by the appropriate regulatory body. The Department of Petroleum Resources (DPR) (2002) values for maximum allowable concentrations of heavy metals in soils (Table 2) were used for this purpose. Soil heavy metals contamination/pollution index varies from country to country based on chosen factors (Lacatusu, 2000). The significance of contamination/pollution index values is given in Table 3.

Table 2

Some international guidelines for heavy metals (mgkg^{-1}) in soils

Metal	DTV	AEIL	EC	CEQC Assessment criteria	Remediation criteria Target value: A	R/P	C/I	DPR target value	Crustal abundance value
Cd	0.8	33	3.0	0.5	4	4	8	0.8	0.11
Cr	100	400	—	20	750	250	800	100	1.00
Cu	36	100	140	30	150	100	500	36	50
Ni	35	60	75	20	150	100	500	35	80
Pb	85	600	300	25	375	500	100	85	14
Zn	140	20	300	60	600	500	1500	140	75

A = Agricultural purposes; R/P = Residential/Parkland; C/I = industrial/commercial; DTV = Dutch target values; AEIL = Australian EIL; EC = European communities; CEQC = Canadian environmental quality criteria; DPR = Department of Petroleum Resources target values.

Table 3
Significance of intervals of contamination/pollution index (C/PI) value

C/PI	Significance
<0.1	Very slight contamination
0.10–0.25	Slight contamination
0.26–0.5	Moderate contamination
0.51–0.75	Severe contamination
0.76–1.0	Very severe contamination
1.1–2.0	Slight pollution
2.1–4.0	Moderate pollution
4.1–8.0	Severe pollution
8.1–16.0	Very severe pollution
>16	Excessive pollution

Sources: Lacatusu (2000).

Results and Discussion

Table 1 presents the results for pH, percent total organic matter, mean concentrations of Cr, Zn, Cd, Pb, Ni and Cu, and the land use patterns/anthropogenic activities at the examined sites. Analysis of variance at ($p < 0.05$) showed no significant variation in the concentrations of Cr, Zn, Cd, Pb, Ni, and Cu in samples collected from a given quadrant. However, there are significant variations in the concentrations of Cr, Zn Cd, Pb, Ni, and Cu when the different sites are compared within a given zone. The variability in the concentrations of the metals in these soils can be related to soil physico-chemical characteristics, land use patterns, and associated anthropogenic input.

In rural areas, while soils of RS5 had the lowest pH value and highest mean% organic matter (OM), soils of RS4 had the highest pH value and lowest% OM. Among the six land uses in the rural area, soils from RS2 had the highest concentrations of Cr, Zn, and Ni when compared to other sites in the rural zone. The elevated levels of heavy metals in site RS2 were due to the fact that the cassava processing mill was constructed on an abandoned rural waste dump and input from the cassava processing activities. In soil environment, the cyanide ion from the cassava effluent forms exceedingly stable cyano-complexes with divalent metals (e.g., $Cd(CN)_4{}^{2-}$, $N_i(CN)_4{}^{2-}$, Cr $(CN)_4{}^{2-}$, and $Zn(CN)_4{}^{2-}$, etc). The cyano-complexes with divalent metals are responsible for the retention of metals in the soils in the vicinity of cassava processing mill. Similarly, site RS5 showed elevated metal concentrations, which is suggestive evidence that cassava processing and its effluent contribute significant levels of heavy metals to the soil. Mean Ni concentrations were highest in soils of RS2 and RS5. The high level of nickel could be attributed to emission from the diesel engine used for operating the cassava mill. Nickel and manganese are common additives for diesel fuel (Sheppard et al., 2000; El-Hassan et al., 2006). The high Zn concentrations of these sites (RS2 and RS5) are probably due to attrition of motor vehicle tire rubber which is used as a convoy belt in the mill and the use of lubricating oil which may have zinc as an additive in the form of zinc diphosphate (Jaradat and Momanni, 1999). The results of this study indicate that cassava processing mills are the most potent sources of Cr, Zn, Ni, and Cu to the rural soil environment than any other land uses. The mean concentrations of these metals in the examined sites in the rural area followed the order: Ni > Cr > Zn > Cu > Pb > Cd. The results showed that soils from rural farm (RS6) had the highest mean levels of cadmium compared to any other land uses in the rural area. This could be attributed to the use of fertilizer (Zarcinas et al., 2004). Overall, the rural farms (RS5) showed lower levels of other metals in comparison to other land uses in the rural zone. This is associated with the fact that the bush fallowing system is the more preferred farming system than continuous cropping with fertilizer or animal manure. The concentrations of metals in the rural farm land were below the Canadian environmental quality criteria for agricultural purposes (CCME, 1991). However, Ni concentrations in soils of RS6 exceeded the maximum permitted level under the European Communities regulation (Table 3), while the concentrations of Cd, Cu, and Ni in the rural soils exceeded the Dutch target value and DPR maximum allowable limits for soil protection. The highest level of Pb was observed in the residential area of the rural zone. High levels of Pb in the residential zone are due to automobile emissions and the use of lead oxide cells. The mean levels of Cr, Zn, Ni, and Cu obtained in this study were higher than values reported for soil collected from the rural zone in southwestern Nigeria (Umoren and Onianwa, 2005).

In the semi-urban sample area, the pH and% OM did not follow the same patterns as that in rural areas (Table 1).The residential area (SU3) in the semi-urban zone had the highest mean concentrations of Cr, Cd, Ni, and Cu compared to other land use patterns in the semi-urban zone. The motor park (SU2) soils had the the highest Zn concentration level. The high level of metals observed in the residential area is associated with the fact that this community does not have waste disposal facilities. In most cases, wastes are burnt, buried, or allowed to decompose in open dumps within the residential area. The use of wastes for reclamation flooded zones is also a common practice in these zones. Contrary to the general expectation, the results revealed that the university playground (SU4) and semi-urban market (SU1) have higher concentrations of Pb than levels found in the semi-urban motor park (SU2). The reason for the observed concentration depends on the duration of anthropogenic activities, proximity of the market to the major trunk “A” motorway, and waste generated within the market.

In the urban area, the soils of UB6 had the lowest pH and the highest% OM. Results also showed that the urban zone soil samples collected in the vicinity of the saw mill/wood processing industries (UB6) had elevated levels of Cr, Zn, Ni, and Cu compared to any other sites in the urban area. This was followed by soil in the vicinity of the urban market (UB8). The results were contrary to the general expectations that soils in the vicinity of metal scrap dumps, automobile mechanic workshop, and metal works would have higher levels of these metals. It is important to note here that UB4, UB7, and UB9 sites have been in use for listed activities (Table 1) for 3–5 years only, UB6 (30 years), and UB8 (over 50 years). The elevated levels of Cr, Zn, Ni, and Cu in site UB6 could be due to the chemicals used in wood preservation. Chemicals such as copper sulphate, Boliden salt (BIS-salt) mixed with zinc sulphate, and chromated copper arsenate (CCA) have been used as preservatives for more than 50 years (Bhattacharya et al., 2002). Chromium, as present in preservatives, is generally reduced from Cr (VI) to Cr (III) in the presence of aromatic ring and carbon groups in lignin structure and forms insoluble complexes leading to fixation of As, Cu, and Cr (VI) in the wood. Moreover, Cr may be leached in significant quantities prior to complete fixation in freshly impregnated wood (Bhattacharya et al., 2002). In the urban zone, soils under different land uses have Ni concentrations higher than the DPR maximum allowed value of 35.0 $mg.kg^{-1}$. In the urban zone, soils with such land uses as market, saw mill, and motor park have copper levels above the DPR limit. In the semi-urban and rural zones, soils of the residential areas and cassava processing mill have Cu concentrations above the DPR limits. Zinc concentrations in soil under different land uses never exceeded the DPR permissible limits of 140 mg.kg^{-1}. The levels of Cd were comparable to Cd levels reported by Umoren and Onianwa (2005), while Pb levels in this study were lower than the values reported by Umoren and Onianwa (2005).

Bioavailabilities of metals in soils are due to changes in land use, redox conditions, and the quantity of organic matter in the soil (Bhattacharya et al., 2002), pH, cation exchange capacity of the solid phase, competition with other metal ions, composition and quality of the soil solution (Moon et al., 2000; Mapanda et al., 2005; Skordas and Kelepertsis, 2005). The mobility of metals is generally controlled by precipitation, diffusion, volatilization, and dissolution of unstable minerals, beside other surface complexation process (Bhattacharya et al., 2002). The sorption of cationic contaminants such as Cr, Cu, and Zn depends on soil pH and redox conditions, and in the pH range of 5.4–6.5 Cu and Zn are distinctly more soluble under oxidizing conditions than reducing conditions (Bhattacharya et al., 2002). The prevailing pH at these sites suggests that Cu and Zn are soluble in these sites. In the soil environment, Cr occurs in the oxidation states of a Cr (III) dominated system, the prevalent species being $CrOH^{2+}$ at pH 2–6, $Cr(OH)_3$ at pH 6.5–11.5, and $Cr(OH)_4{}^-$ at pH$>$ 11.5 (Bhattacharya et al., 2002). The prevailing pH conditions of the examined soils show that the predominant species of Cr in these sites are $CrOH^{2+}$ and $Cr(OH)_3$.

In the urban zone, the highest mean level of Cd (2.6 mg.kg^{-1}) was found in soil in the vicinity of wielding and fabrication workshop (UB9) compared to any other land uses in this zone. However, concentrations of Cd at the playground (1.9 mg.kg^{-1}), urban motor park (1.4 mg.kg^{-1}), and soils in the vicinity of the metallic scrap dump (1.2 mg.kg^{-1}) were also elevated and above the DPR maximum allowed value for Cd in soil. Elevated levels of Cd at the children's playground could lead to environmental exposure of children to Cd through inhalation of Cd-contaminated dust while playing. Dudka et al. (1996) reported Cd level in arable soil in industrial area of Upper Silesia, south Poland, to be 3.2 mg.kg^{-1} Cd while Umoren and Onianwa (2005) reported concentrations ranging from 1.7–23 mg.kg^{-1} Cd in soil around an urban industrial area in southwestern Nigeria. The levels of Cd found in the present study in the urban zone were lower than the ranges reported by these researchers.

Soils around the vicinity of the mechanic workshops and motor park contained higher levels of Pb compared to any other land use types in the urban area. High level of Pb at this site (UB7) was due to the fact that gasoline and oil containing a substantial quantity of Pb have been continuously spilled in the vicinity of automobile mechanic workshops. Oguntimehin and Ipinmoroti (2008) reported similar Cr levels, but higher Zn and Pb levels in soils in the vicinity of the automobile mechanic workshop in southwestern Nigeria. Elevated levels of Pb in soils of the urban motor park (59.6 mgkg^{-1}) could be due to automobile emissions. The levels of Pb found in soil under different land uses were lower than the DPR maximum permissible limit of 85 mgkg^{-1}. The levels of Pb found in the vicinity of the motor park (UB3) were relatively low compared with the mean value of 197 mg.kg^{-1} for soil in the higher traffic zone in Ibadan, southwestern Nigeria (Umoren and Onianwa, 2005). In general, the levels of metals (Pb, Cd, Cr, Ni, Cu) reported in this study were lower than values obtained for soil around the industrial zone in Ibadan, southwestern Nigeria (Umoren and Onianwa, 2005).

Contamination/Pollution Index

The computed contamination/pollution index is presented in Table 4. The contamination/pollution index value greater than one (1) defines a pollution ranges and when lower than one (1) defines contamination ranges. The C/P index indicates the relationship between measured concentrations of metal ions in the soil and country's regulatory standard for

Table 4
Contamination/pollution index for soil under different land uses

Sites	Cr	Zn	Cd	Pb	Ni	Cu	MPI
RS 1	0.52	0.52	0.75	0.00	2.63	0.45	2.63
RS2	3.94	0.65	1.00	0.09	14.07	2.74	21.8
RS3	0.49	0.09	1.13	0.04	2.91	0.41	4.04
RS4	0.69	0.30	0.94	0.14	2.01	0.57	2.01
RS5	0.86	0.53	0.06	0.14	3.70	0.72	3.70
RS6	0.66	0.21	1.81	0.00	2.80	0.54	4.60
SU 1	0.62	0.35	0.44	0.27	2.63	0.51	2.63
SU 2	0.61	0.57	1.31	0.05	2.64	0.51	3.95
SU3	0.86	0.44	2.06	0.05	3.68	3.19	8.93
SU 4	0.77	0.38	1.81	0.29	3.28	0.64	5.09
UB1	0.55	0.31	1.19	0.20	2.65	0.45	3.83
UB2	0.60	0.44	2.31	0.00	2.57	0.50	4.88
UB3	0.79	0.82	1.75	0.70	3.40	1.27	6.42
UB4	0.62	0.42	1.50	0.04	2.65	0.52	4.19
UB5	0.70	0.08	1.00	0.08	3.01	0.58	4.01
UB6	7.07	1.16	0.13	0.27	30.3	5.90	44.43
UB7	0.83	0.06	1.04	0.67	3.54	0.69	4.58
UB8	6.30	0.29	1.19	0.00	27.02	5.26	39.77
UB9	0.67	0.59	3.19	0.13	2.86	0.56	6.05
UB10	0.44	0.04	0.94	0.02	1.89	0.36	1.89

MPI = Multiple Pollution Index.

allowable concentrations of metals in soil. C/P index varies from one country to another based on various factors (i.e., the regulatory standards that vary from one country to another). The C/P index revealed that soil under different land uses in urban, semi-urban, and urban zones was severely contaminated with chromium, with the exception of site RS2 in the rural zone, which showed moderate pollution, and sites UB6 and UB8 in the urban zone, which showed severe pollution. The C/P index for lead and zinc indicated that the examined sites could be ranked as being from very slightly contaminated to severely contaminated, while soil under the different land uses can be ranked as being moderately polluted to excessively polluted with Ni. UB6 and UB8 have significantly higher C/P index for examined metals compared to any other sites. The soils were severely contaminated with Cu except for sites RS2, SU3, and UB6 that have C/P indices within the pollution range. Cadmium has a C/P index in the range of 0.06–3.19, which indicates 75% of the examined sites are either described as slightly polluted or moderately polluted with cadmium. However, 15% and 5% examined sites can be classed as being severely contaminated and moderately contaminated, respectively, with Cd. The contamination/pollution index for the screened metals in the examined sites follows the order: Ni > Cd > Cu > Cr > Zn > Pb. Some of these metals may have either antagonistic or synergic effects. The multiple pollution indexes were assessed by totaling only those whose index is at pollution range and assessed with the same criteria. The multiple pollution indexes indicate that the examined soils in the three zones fit into "the slight pollution" to "excessive pollution" range with significant contributions from Ni, Cd, and Cu. The multiple pollution index value could be

Table 5
Summary of impact of land uses on the observed chemical properties of soil

Site codes	Land use pattern	Associated metal pollutants
	Rural Zone	
RS1	Rural market	Ni
RS2	Rural cassava processing mill I	Cr, Cd, Ni, Cu
RS3	Rural play ground	Cd, Ni
RS4	Rural residential area	Ni
RS5	Rural cassava processing mill II	Cd, Ni
RS6	Rural farm land	Cd, Ni
	Semi-urban Zone	
SU1	Semi-urban market	Ni
SU2	Motor park	Cd, Ni
SU3	Residential area	Cd, Ni
SU4	University playground	Cd, Ni
	Urban Zone	
UB1	Industrial area	Cd, Ni, Cu
UB2	Childrens' playground	Cd, Ni
UB3	Urban motor park	Cd, Ni
UB4	Soil in the vicinity of metallic scrap site	Cd, Ni
UB5	Soil in the vicinity of abattoir	Cd, Ni
UB6	Soil in the vicinity of saw mill/wood processing industry	Cr, Cd, Zn, Ni, Cu
UB7	Mechanic workshop	Cd, Ni
UB8	Urban market	Cr, Cd, Ni, Cu
UB9	Welding and fabrication shed	Cd, Ni
UB10	Residential area	Ni

used to rank the different land uses in terms of extent of introduction of metals into the soil environment. For example, in the urban zone, soils under the following land uses of market and wood processing were more polluted with metals as compared to soils under other land uses. Table 5 displays a summary of the types of impacts on the heavy metal status of soils under different land uses. Concentrations of metals above the Department of Petroleum Resources of Nigeria permissible limits or crustal abundance values were assumed significant. As shown in Table 5, Cr, Cd, Ni, and Cu are the elements that occurred at concentrations that are either above the DPR permissible limits or the crustal abundance values. Therefore the different land uses contribute significant amounts of these metals to the soil environment.

Conclusion

The data obtained from this study revealed that the various land use patterns, whether in rural, semi-urban, or urban areas, contribute significant amounts of different metals to the soil. The concentration patterns indicate that Cr, Cd, Ni, and Cu were generally elevated in the soils under the following land uses: rural cassava processing mill, soils in the vicinity of wood processing mill, urban market, and industrial site. The concentrations of nickel in soils at all sites in three zones exceeded the Department of Petroleum Resources maximum allowed value for nickel in soils. The result revealed that each land use has its own associated metal types and distribution.

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HEAVY METAL CONTENT IN THE AFRICAN GIANT SNAIL *ARCHACHATINA MARGINATA* (SWAINSON, 1821) (GASTROPODA: PULMONATA: ACHATINIDAE) IN SOUTHERN NIGERIA

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ABSTRACT: Heavy metal concentrations in the African giant snail *Archachatina marginata* (Swainson) from nine localities in southern Nigeria ranged from 0.77 to 7.51 mg kg^{-1} Pb; 3.06–46.9 mg kg^{-1} Fe; 0.03–0.40 mg kg^{-1} Ni; 0.04–0.12 mg kg^{-1} Cu; 0.71–4.51 mg kg^{-1} Co; 0.67–1.27 mg kg^{-1} Mn; 0.99–3.28 mg kg^{-1} Cd; 0.08–0.22 mg kg^{-1} Zn; Cr was below the limit of detection. Concentrations of Pb, Fe, Ni, Cu, Co, Cd and Zn in the snail tissue varied significantly (95% confidence limit) between the localities. No significant variation was observed in the concentrations of Cr and Mn. Pb and Cd concentration exceeded the statutory safety limits for these elements in meat. The results indicate a heavy metal pollution of the habitats.

KEY WORDS: heavy metal pollution, African giant snail, *Archachatina marginata*, Nigeria

INTRODUCTION

In recent years, much research has focused on metal concentration in protein sources: beef, goat meat, mutton, poultry products, as well as fish and other sea foods. In Nigeria, the African giant snail *Archachatina marginata* (Swainson, 1821) is widely consumed by various ethnic groups. Since snail farming is not popular in Nigeria, the snails are usually collected in forests and transported to nearby urban markets. On the other hand, the rapid industrialisation of the Niger Delta region in Nigeria within the last two decades has resulted in a heavy pollution.

Heavy metals contained in the soil find their way into organisms of various trophic levels via detritivores or plants. Though their accumulation in predatory vertebrates has been confirmed (PURCHART & KULA 2007), the levels of accumulation for invertebrates do not depend directly on the trophic level or the body size (LINDQUIST & BLOCK 1997, PURCHART & KULA 2007). The metal load is probably associated with the physiological properties of the species rather than with the trophic level (SPURGEON & HOPKIN 1999).

Metal concentration in invertebrate tissues varies considerably not only among taxa, but also among conspecifics (TYLER et al. 1989). The metal content in the invertebrate body depends on the type of food and on the form in which the metal is bound (LINDQUIST & BLOCK 1997), on the conditions during intake (e.g. concentration in the soil, pH, availability of metals) and – most of all – on the physiological characteristics of the species, such as assimilation and excretion capacity (LINDQUIST et al. 1995, KRAMARZ 1997, PURCHART & KULA 2007). The African giant snail feeds on the debris from the soil surface which may be contaminated with heavy metals and organic pollutants; it may thus accumulate the pollutants to harmful levels. Very little is known of metal levels in the African giant snail consumed in southern Nigeria. This study was aimed at determining the levels of Cd, Pb, Ni, Cr, Fe, Mn, Cu, Co and Zn in the African giant snail, with special reference to hygienic and toxicological aspects.

MATERIALS AND METHODS

A total of 400 snail specimens were collected from nine widely spread locations in southern Nigeria from January to May 2007. The age of the snails was not considered; only fully grown specimens were collected since this is the product consumed by the local population.

In the laboratory the snails were washed thoroughly with distilled water. The shell was cracked with a wooden hammer; the body was again washed with distilled water and stored at –18°C prior to analysis. Samples (5.00 g muscle) were pre-digested in 10 ml concentrated HNO_3 at 135°C until the liquid was clear. Then 10 ml HNO_3 and 2 ml $HClO_4$ were added till the liquid became colourless. The digest was slowly evaporated till near dryness, coded, dissolved in 1 M HNO_3, filtered through Whatman No 1 filter paper and diluted to 25 ml with 1 M HNO_3. The resulting solution was analysed for Cd, Pb, Zn, Mn, Fe, Cu, Cr and Co with graphite furnace atomic absorption spectrophotometry (GBC Scientific equipment Sens AA).

Control procedure was carried out to ensure the reliability of the results. In all the metal determinations, analytical blanks were prepared in a similar manner. All glassware was soaked in 10% nitric acid solution for 48 h, followed by rinsing with deionized water. In order to check the reliability of the instrument a blank and known standards were run after every six samples. In addition, a recovery study of the total analytical procedure was carried out for metals in selected samples by spiking analysed samples with aliquots of metal standards and then reanalysing the samples. An acceptable recovery of more than 92% was obtained for the metals.

RESULTS AND DISCUSSION

Table 1 shows the mean values, standard deviation and ranges of concentration of the studied metals in the African giant snail. The highest mean Pb concentration was observed in Port Harcourt (7.51 mg kg^{-1}), the lowest – in Yenegoa. Samples from Warri and Port Harcourt – the two industrial areas – showed significantly higher Pb concentrations ($p>0.05$), compared to the samples from the other locations. The lead concentrations in these samples were alarming and indicated high levels of pollution. The main sources of lead pollution are automobile exhaust gases (anti-knocking agents added to gasoline), and untreated industrial waste which finds its way to irrigation channels, thus polluting fodder through soil

Table 1. Concentration of heavy metals (mg kg^{-1} weight) in the giant African snail from southern Nigeria

Location	Pb	Fe	Ni	Cu	Co	Mn	Cd	Zn	Cr
Warri	6.53±1.03	7.86±0.36	0.18±0.16*	0.08±0.03	1.42±0.47	0.86±0.06	1.47±0.55	0.13±0.05	<0.001
	5.16–7.87	7.51–8.41	0.07–0.46	0.06–0.13	0.63–1.89	0.77–0.91	0.53–1.95	0.10–0.21	
Agbor	2.46±1.27	3.06±1.24*	0.16±0.04*	0.06±0.04	1.44±0.17	0.85±0.08	2.33±0.22	0.11±0.04	<0.001
	1.15–3.90	1.30–4.15	0.11–0.22	0.02–0.11	1.15–1.58	0.73–0.93	2.01–2.53	0.07–0.17	
Port Harcout	7.51±0.93	46.90±15.49*	0.17±0.05*	0.04±0.02	1.54±0.22	0.98±0.10	0.99±0.18	0.10±0.04	<0.001
	5.92–8.12	35.48–65.08	0.11–0.21	0.02–0.06	1.15–1.67	0.87–1.11	2.72–1.19	0.05–0.15	
Asaba	2.31±0.83*	7.59±1.26	0.03±0.02*	0.09±0.06	1.39±0.75	0.94±0.11	3.28±0.38	0.22±0.06	<0.001
	1.05–3.05	6.34–9.64	0.01–0.06	0.03–0.17	0.72–2.39	0.82–1.08	2.81–3.59	0.16–0.31	
Benin	1.56±0.05	7.11±0.19	0.04±0.02*	0.07±0.02	1.08±0.12	1.06±0.06	1.94±0.09	0.12±0.03	<0.001
	1.51–1.64	6.82–7.34	0.01–0.06	0.03–0.90	0.95–1.24	1.00–1.12	1.82–2.05	0.08–0.15	
Ughelli	2.44±0.61	11.49±1.04	0.11±0.04*	0.12±0.03	0.71±0.19	1.27±0.12	1.64±0.62	0.22±0.05	<0.001
	1.38–2.82	10.10–12.41	0.06–0.15	0.08–0.16	0.49–0.93	1.07–1.39	1.16–2.64	0.17–0.30	
Yenegoa	0.77±0.13	11.18±1.31	0.40±0.07	0.13±0.05	4.56±0.21	1.19±0.22	1.15±0.20	0.11±0.03	<0.001
	0.56–0.92	10.01–12.64	0.33–0.49	0.07–0.19	4.43–4.93	0.91–1.43	0.93–1.47	0.09–0.15	
Onitsha	0.90±0.18	7.23±0.44	0.14±0.03*	0.06±0.02	1.99±0.34	1.01±0.07	1.79±0.05	0.09±0.03	<0.001
	0.67–1.16	6.55–7.65	0.10–0.18	0.03–0.08	1.64–2.54	0.93–1.09	1.71–1.86	0.05–0.13	
Sapele	4.02±0.10	19.39±4.80*	0.03±0.01*	0.07±0.02	1.74±0.04	0.69±0.08	2.07±0.07	0.08±0.02	<0.001
	3.88–4.15	15.86–27.63	0.01–0.04	0.05–0.09	1.68–1.77	0.61–0.81	2.01–2.19	0.06–0.11	

*Significant at $p>0.05$, concentration range of particular metals is given below mean value ± S.D.

(MARIAM et al. 2004). The mean Pb concentrations in the snails from different locations exceeded the ANZA permissible limit of 1.0 mg kg^{-1} Pb for meat, except for samples from Onitsha and Yenegoa. However, Pb concentration in all the samples was higher than 0.4 mg kg^{-1} (EC 2001) and 0.5 mg kg^{-1} (FAO 1983). Lead causes damage to human kidneys and liver (SAVIPERUNAL et al. 2007). MARIAM et al. (2004) reported 2.19 ppm, 4.25 ppm and 3.1 ppm for lean beef, mutton and poultry, respectively. There was no significant variation among samples within the locations, except for those from Agbor, Asaba and Ughelli. The levels of Pb found in the present study were comparable to 0.80–6.00 mg kg^{-1} Pb reported by WEGWU & WIGWE (2006). VIARD et al (2004) reported 21.3 mg Pb kg^{-1} in a land snail collected near a highway in France.

The mean iron concentration in the snail tissues ranged from 3.06 to 48.90 mg kg^{-1}; it varied significantly between the locations (p>0.05). Samples collected within the same location showed no significant variation, except for those from Agbor, Port Harcourt and Sapele. The highest mean Fe concentration was found in snails from the industrial Port Harcourt (46.90 mg kg^{-1}) while the lowest mean level was observed in samples from Agbor. Samples from Warri, Asaba, Benin and Onitsha had similar mean Fe concentrations. The observed iron concentrations were similar to those reported by WEGWU & WIGWE (2006).

The mean concentration of nickel was the highest in the samples from Yenegoa (0.40 mg kg^{-1}). The industrial regions (Warri and Port Harcourt) showed high Ni levels, compared to other locations. There was a significant variation among samples within the locations (variability coefficient 21% to 88.8%), except for those from Yenegoa. Nickel can cause respiratory problems and is carcinogenic (ATSDR 2004). The upper tolerable intake levels of nickel for children (1–3 years old) and adults (19–70 years old) are 7 and 4 mg d^{-1}, respectively. The mean concentrations of nickel found in the snail tissue were lower than the concentration ranges (3.20–10.4 mg kg^{-1}) reported by WEGWU & WIGWE (2006).

Copper concentrations in the snail tissue ranged from 0.04 to 0.13 mg kg^{-1}. There was a slight variation between the locations. In all samples the concentrations of copper were less than 0.2 mg kg^{-1}. The highest mean Cu levels were found in samples from Yenegoa. The observed levels of copper were low compared to the permissible limit of 20 ppm. Copper is an essential component of various enzymes and plays a key role in bone formation, skeletal mineralization and in maintaining the integrity of connective tissues. Its low concentration in the snails is not surprising in view of high requirements for and rapid turnover of the element in the organism.

Cobalt was detected in all the samples; its mean concentrations ranged from 0.71 to 4.4.56 mg kg^{-1} and were the highest in samples from Yenegoa (4.56 mg kg^{-1}), while the lowest mean Co concentration was found in samples from Ughelli. Mostly, there was no significant variation among samples within the locations. However, a significant variation (p>0.05) was observed among the samples from Warri and Onitsha. Cobalt is an essential nutrient for humans and an integral part of vitamin B12. The average intake of cobalt in all forms ranges from 0.30 to 1.77 mg/day (UNDERWOOD 1977). Cobalt is involved in blood pressure regulation and is necessary for the proper thyroid functioning (SIVAPERUMAL et al. 2007). Excessive ingestion of cobalt causes congestive heart failure and polycythemia and anaemia (SIVAPERUMAL et al. 2007). The levels of cobalt reported in this study were higher than the concentration ranges of 0.02–0.85 mg kg^{-1} reported for mollusc tissues by SIVAPERUMAL et al. (2007).

The mean levels of manganese in the Africa giant snail ranged from 0.61 to 1.27 mg kg^{-1}. The highest mean concentration was found in samples from Ughelli. No significant variation was observed between samples within or between the locations (95% confidence limit). Manganese is essential for both plants and animals and its deficiency results in severe skeletal and reproductive anomalies in mammals. It is widely distributed throughout the body with little variation and does not accumulate with age. The daily intake varies from 2.5 to 7 mg (SIVAPERUMAL et al. 2007). The levels of manganese reported in this study are comparable to concentration ranges of 0.08–3.7 mg kg^{-1} reported for some mollusc species in India (SIVAPERUMAL et al. 2007).

Cadmium concentrations in the snail tissue were generally high and alarming; the mean levels ranged from 0.99 to 3.28 mg kg^{-1}. There were no significant differences among samples within the locations, but the mean values varied between the zones. The highest mean Cd level (3.28 mg kg^{-1}) was found in samples from Asaba. Surprisingly, samples from a more industrialized zone (Port Harcourt) showed the lowest levels of cadmium. The results revealed high levels of cadmium pollution. The major source of cadmium contamination of the soil in these zones are oil and gas exploitation, and untreated industrial waste. The concentrations recorded in this study are above the legal limit of 0.1 mg kg^{-1} (EC 2001). MARIAM et al. (2004) reported mean levels of 0.33 ppm, 0.37 ppm and 0.31 ppm of Cd in lean beef, mutton and poultry, respectively. SAVIPERUMAL et al. (2007) found concentrations ranging from undetectable to 0.98 mg kg^{-1} Cd in some mollusc species in India. WEGWU & WIGWE (2006) observed a cadmium concentration range of 0.60–0.84 mg kg^{-1}. The levels of cadmium found in this study were higher than the range reported by these investigators, but lower than the 5.7 mg Cd kg^{-1} reported by VIARD et al. (2004) for land snails collected near a highway in France. Humans are exposed to cadmium through food and the average daily intake for adults is approximately 50 mg (CALABRESE et al. 1985). The threshold for acute cadmium toxicity is the total ingestion of 3–15 mg. Severe toxic symptoms are reported to occur with ingestion of 326 mg. Fatal ingestion of cadmium, producing shock and acute renal failure, occurs from the threshold of 350 mg (NAS-NRC 1982).

Zinc concentrations in the African giant snail ranged from 0.08 to 0.22 mg kg^{-1}. A significant variation (p>0.05) existed among the locations, and only slight differencs were observed within the zones. The highest Zn concentrations were observed in samples from Ughelli and Asaba (0.22 mg kg^{-1}). All the values recorded were below the permissible limit (150 ppm) set by ANZFA. SAVIPERUMAL et al. (2007) reported mean concentrations of 3.8–165 mg kg^{-1} Zn in some mollusc species; WEGWU & WIGWE (2006) reported 10.3–20.5 mg kg^{-1} for the African giant snail. The concentrations of zinc found in this study were relatively low compared to values given by VIARD et al. (2004), WEGWU & WIGWE (2006) and SAVIPERUMAL et al. (2007). The low concentration of zinc may be attributed to zinc-deficient soils, consequently the debris available to the snails is zinc-poor; combined with the fact that zinc is an essential metal of a high turnover rate it may results in a low tissue content of the element.

Chromium was not detected in any of the samples examined.

The concentrations of cadmium and lead in the snail tissues collected from different locations exceeded the permissible limits, while the remaining metals (chromium, copper, zinc, manganese, cobalt and iron) were present in levels below the permissible limits. The load these metals in human body is dependent on their concentration in snail tissues, frequency of consumption, amount consumed and the rate of detoxication of contaminants in human body. The choice of snail as a source of protein depends on culture and availability.

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Characteristic levels of heavy metals in canned sardines consumed in Nigeria

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Abstract Samples of some popular brands of canned sardines in soybean oil in the Nigerian market were analyzed for levels of cadmium, lead, iron, cobalt, nickel, manganese, chromium, copper and zinc after wet digestion with acids by graphite furnace atomic absorption spectrophotometry. The mean concentrations for the metals in the different brands were as follows: cadmium 0.11–0.26 µg/g, iron 8.04–48.18 µg/g, cobalt 0.01–7.23 µg/g, nickel 0.04–3.26 µg/g, manganese 0.64–1.37 µg/g, chromium 0.01–0.10 µg/g, copper 0.10 µg/g and zinc 0.09–4.63 µg/g. Significant differences were observed in the heavy metal levels in the different brands of canned sardines except for copper and chromium. Cadmium, nickel and lead exceeded statutory safe limits.

Keywords Heavy metals · Sardines · Daily intake · AAS · Nigeria

1 Introduction

During the last few decades, there has been growing interest in determining heavy metal levels in the marine and fresh water environment, and attention has been drawn to the measurement of contamination levels in public food supplies, particularly fish (Teriq et al. 1993; Kalay et al. 1999; Rose et al. 1999; Tarley et al. 2001; Ashraf 2006). Toxicological and environmental studies have prompted interest in the determination of toxic elements in foods. The ingestion of food is an obvious means of exposure to metals, not only because many metals are natural components of foodstuffs, but also because of environmental contamination and contamination during processing (Voegborlo et al. 1999; Yousuf and El-Shashawi 1999; Ashraf 2006). Most species of commercially caught marine fish are canned, thus making it more available for the consumption of humans living far from the sea (Dabeka et al. 1985). Heavy metal contamination of different foods constitutes a serious hazard depending on the relative levels. Some of these metals, such as cadmium and lead, injure the kidney and cause symptoms of chronic toxicity, including impaired organ function, poor reproductive capacity, hypertension, tumors and hepatic dysfunction (Abou-Arab et al. 1996). Moreover, lead can also affect brain function by interfering with neurotransmitter release and synapse formation. Exposure to lead has been associated with reduced IQ, learning disabilities, slow growth, hyperactivity, antisocial behaviors and impaired hearing (Dahiya et al. 2005). On the other hand, chromium, copper, iron, zinc and manganese are essential for human health. However, for these metals called micronutrients, there are fixed allowed levels for an adequate dietary intake. The adequate dietary intake in adults can range from 0.50 to 2.00 µg [Cr(III)], from 1.2 to 3.0 mg (Cu), from 10.0 to 50.0 mg (Fe), from 5.0 to 22.0 mg (Zn) and from 2.0 to 20.0 mg (Mn) [WHO 1995; Tarley et al. 2001]. At high concentrations, chromium, zinc and copper cause nephritis, anuria and extensive lesions in the kidneys (Abou-Arab

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et al. 1996). The main concern about the absorption of chromium depends on its speciation. Chromium (VI) penetrates cell membranes, whereas chromium III does not; thus, chromium (VI) may cause genotoxic effects and cancer, whereas chromium (III) does not (WHO 1995; Tarley et al. 2001). The concentrations of these metals in canned fish varies, depending on the type and origin of the food, pH of the canned product, oxygen concentration in the headspace, quality of the inside lacquer coating of cans, storage place, etc. (Tahan et al. 1995; Tarley et al. 2001).

The objective of this study was to determine the concentrations of metals (Cd, Co, Pb, Cu, Cr, Ni, Fe, Mn and Zn) in the main brands of canned sardines consumed in Nigeria.

2 Materials and methods

Cans of 125 g gross weight were purchased from retail shops in Agbor, Warri, Asaba and Onitsha in September 2006 and March 2007. The ten brands (types) of sardines canned in soybean oil were designated A, B, C, D, E, F, G, H, I and J. Forty-seven cans were collected randomly from each brand. In all analyses, the soybean oil was separated from the sardines after drainage for 10 min in a polyethylene sieve.

The samples for metal determination were digested with a mixture of HNO_3, $HClO_4$ and H_2O_2. Then 2.0 ± 0.1 g of the sardine samples was placed in a digestion tube and predigested using 10 ml of concentrated HNO_3 at 135°C until the liquor was cleared. Next, 10 ml of HNO_3, 1 ml of $HClO_4$ and 2 ml of H_2O_2 were added, and the temperature was maintained for 1 h until the liquor became colorless. Care must be exercised with fatty materials to maintain excess HNO_3 and a few ml of H_2O_2 until most of the organic materials are destroyed.

The samples were evaporated slowly to almost dryness (avoiding prolonged baking), cooled and dissolved in 5 ml of 1 M HNO_3. The digested samples were filtered through Whatman no. 1 filter paper and diluted to 25 ml with 1 M HNO_3. The sample solution was analyzed with a graphite furnace atomic absorption spectrophotometry (GBC Scientific Equipment Sens A A) equipped with a D_2 background correction device.

In all metal determinations, analytical blanks were prepared in a similar manner. Glassware was properly cleaned with a solution of 1 M nitric acid for 48 h followed by thorough rinsing with deionized water. The reagents (nitric acid, perchloric acid, hydrogen peroxide and distilled water) were of analytical grades. Reagent blanks were used to correct all instrument readings. Calibration standards were made by dilution of high-purity commercial BDH metal standards for atomic absorption spectrophotometry. A recovery test of the total analytical procedure was carried out for the metals in selected samples by spiking analyzed samples with aliquots of metals and then reanalyzing the samples. There was an acceptable recovery of 92.6, 95.2, 102.3, 89, 98, 91, 94.5, 93.4 and 99.8% for cadmium, lead, copper, chromium, cobalt, nickel, iron, manganese and zinc, respectively.

3 Results and discussion

The mean values of cadmium, copper, lead zinc, chromium, cobalt, nickel, manganese and iron concentrations in canned sardines studied are given in Table 1. The values in parentheses represent concentration ranges of the studied metals. The concentrations of trace metals in these products are quite variable. The weight of a can of sardines varies from 125 to 132 g, but most of the brands weigh about 125 g. As canned sardines are not regular food items, an ingestion rate of 250 g per month was taken as an estimate for all metal intakes in this study (Table 2). The values in parentheses in Table 2 represent estimated weekly intake.

Iron is the most abundant of the metals examined. The highest mean level of iron was found in brand B, and the mean concentrations of iron in the canned sardines ranged from 8.04 to 48.18 μg/g Fe. Similarly, Tarley et al. (2001) reported the average concentration of iron in canned sardines from Brazil as 20.96 to 88.83 μg/g, and Ikem and Egiebor (2005) reported Fe levels in the range of 0.01–88.4 mg/kg in canned fish samples purchased in the states of Georgia and Alabama (USA). However, Abou-Arab et al. (1996) reported a mean concentration of 4.21 (0.82–12.6 μg/g Fe) for imported sardine samples collected from the great Cairo governorate. Two brands (A and E) had iron levels similar to the upper limits of the range reported by Abou-Arab et al. (1996). The estimated weekly intake of iron from consumption of any brands of the canned sardines examined ranged between 502.6 and 2,069.7 μg Fe per week (Table 2).

There was no significant variability ($P < 0.05$) in the concentrations of lead within the same brand. The intra-brand coefficient of variation ranged from 0.05 to 11.2%. However, significant variations ($P < 0.05$) were observed in the concentrations of lead when different brands were compared. The concentrations of lead in brands A, B, D, E and F are similar. The highest concentration of lead was found in brand J, with a mean level of 4.78 μg/g. The levels of lead observed in brands C and J exceeded statutory safe limits (2.0 mg/kg) for lead in foods. Ashraf et al. (2006) recorded lead concentrations ranging from 0.13 to 1.97 μg/g with an average of 0.835 μg/g in canned sardines. Similarly, Tarley et al. (2001) recorded lead levels

Table 1 Concentrations in (μg/g) of Fe, Co, Pb, Ni, Mn, Cr, Cu, Cd and Zn in canned sardines

Brands	Fe	Co	Pb	Ni	Mn	Cr	Cu	Cd	Zn
Queen (A)	21.95 ± 6.15 (8.91–27.54)	1.73 ± 1.39 (0.00–3.53)	0.01 ± 0.01 (0.01–0.01)	0.86 ± 0.30 (0.38–1.20)	0.90 ± 0.32* (0.61–1.43)	0.10 ± 0.05 (0.03–0.20)	0.01 ± 0.00 (0.01–0.01)	0.11 ± 0.96* (0.00–0.23)	3.40 ± 3.20* (0.49–9.09)
Exerta (B)	48.18 ± 2.47 (46.44–49.93)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	3.26 ± 0.14 (3.16–3.36)	1.29 ± 0.04 (1.26–1.31)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.00)	0.26 ± 0.02 (0.26–0.261)	3.24 ± 0.04 (3.21–3.28)
Titus (C)	18.01 ± 8.10 (7.45–32.49)	1.27 ± 0.94 (0.76–3.15)	3.0 ± 0.31 (2.66–3.46)	2.69 ± 0.09 (2.59–2.83)	0.89 ± 0.19 (0.56–1.09)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.29 ± 0.04 (0.20–0.28)	4.63 ± 0.96 (2.81–5.51)
Bonita (D)	11.01 ± 1.68 (8.55–12.35)	0.83 ± 0.53* (0.48–1.61)	0.01 ± 0.00 (0.01–0.01)	0.74 ± 0.13 (0.60–0.86)	1.37 ± 0.08 (1.26–1.46)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.24 ± 0.04 (0.09–0.29)	4.49 ± 0.47 (4.11–5.16)
Sepia (E)	8.04 ± 2.29 (5.10–8.34)	1.56 ± 0.13 (1.44–1.81)	0.01 ± 0.00 (0.01–0.01)	0.16 ± 0.04 (0.11–0.21)	0.73 ± 0.27 (0.45–1.28)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01 ± 0.01)	0.23 ± 0.06 (0.11–0.30)	2.45 ± 0.26 (2.08–2.69)
Flash (F)	33.11 ± 7.60 (26.43–41.75)	2.43 ± 0.41 (1.93–2.91)	0.01 ± 0.00 (0.01–0.01)	0.86 ± 0.16 (0.71–1.04)	0.91 ± 0.57 (0.36–1.53)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.17 ± 0.05 (0.12–0.23)	3.32 ± 0.45 (2.80–3.88)
Apollo (G)	12.75 ± 0.59 (12.34–13.91)	7.23 ± 0.73 (5.99–7.71)	1.72 ± 0.36 (1.46–2.34)	0.65 ± 0.06 (0.58–0.74)	1.71 ± 0.16 (1.51–1.90)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.19 ± 0.05 (0.18–0.20)	1.06 ± 0.10 (0.95–1.21)
Milo (H)	23.31 ± 1.88 (20.30–25.25)	1.87 ± 0.59* (1.51–3.05)	1.57 ± 0.18 (1.34–1.82)	0.04 ± 0.03 (0.01–0.09)	1.29 ± 0.09 (1.15–1.41)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.23 ± 0.06 (0.24–0.25)	0.33 ± 0.09 (0.20–0.45)
John West (I)	17.07 ± 2.31 (15.18–19.64)	3.09 ± 0.37 (2.74–3.48)	0.13 ± 0.02 (0.10–0.15)	1.00 ± 0.15 (0.83–1.13)	0.64 ± 1.10 (0.01–1.91)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.13 ± 003 (0.26–0.13)	0.25 ± 0.03 (0.21–0.28)
Princess (J)	20.38 ± 0.112 (0.30–20.45)	1.59 ± 0.08 (1.54–1.65)	4.78 ± 0.10 (4.70–4.86)	0.21 ± 0.03 (0.19–0.23)	1.19 ± 0.06 (1.15–1.24)	0.01 ± 0.00 (0.01–0.01)	0.01 ± 0.00 (0.01–0.01)	0.14 ± 0.06 (0.14–0.15)	0.09 ± 0.03 (0.08–0.11)

* Significant at $P < 0.05$

Table 2 Estimated daily intake from consumption of canned sardines (μg/day) based on estimated daily intake of 250 g per month

Brands	Fe	Co	Pb	Ni	Mn	Cr	Cu	Cd	Zn
A	196.0 (1,372)	15.45 (108.15)	0.09 (0.63)	7.22 (50.54)	8.04 (6.23)	0.89 (0.63)	0.09 (0.63)	0.89 (6.9)	30.36 (212.5)
B	430 (3,010)	0.09 (0.63)	0.09 (0.63)	29.11 (203.8)	11.52 (92.7)	0.09 (0.63)	0.09 (0.63)	2.32 (16.2)	28.93 (202.5)
C	160.8 (1,125.6)	11.34 (79.38)	26.79 (187.5)	24.02 (68.14)	7.95 (55.7)	0.09 (0.63)	0.09 (0.63)	2.59 (18.1)	41.34 (289.4)
D	98.3 (688.1)	7.41 (51.87)	0.09 (0.63)	6.61 (46.3)	12.23 (85.6)	0.09 (0.63)	0.09 (0.63)	2.14 (15.0)	40.10 (280.7)
E	71.79 (502.5)	13.93 (97.51)	0.09 (0.63)	1.43 (10.0)	6.52 (45.6)	0.09 (0.63)	0.09 (0.63)	2.05 (14.4)	21.88 (153.2)
F	295.67 (2,069.7)	21.70 (151.9)	0.09 (0.63)	7.68 (53.8)	8.12 (56.8)	0.09 (0.63)	0.09 (0.63)	1.52 (10.6)	29.65 (207.6)
G	113.86 (797.02)	64.56 (451.9)	15.35 (136.9)	5.80 (45.1)	15.27 (106.9)	0.09 (0.63)	0.09 (0.63)	1.70 (11.9)	9.47 (66.3)
H	208.16 (1,457.12)	16.69 (116.8)	14.02 (98.14)	0.36 (2.5)	11.52 (80.6)	0.09 (0.63)	0.09 (0.63)	2.05 (14.4)	2.95 (20.6)
I	152.44 (1,067.1)	27.59 (193.1)	1.16 (8.12)	8.93 (62.51)	5.72 (40.0)	0.09 (0.63)	0.09 (0.63)	1.16 (8.1)	2.23 (15.6)
J	181.79 (1,272.5)	14.19 (99.33)	14.20 (994)	1.87 (13.1)	10.61 (74.27)	0.09 (0.63)	0.09 (0.63)	1.25 (8.8)	0.80 (5.6)

Values in parentheses represent weekly intake

ranging from 0.93 to 2.15 μg/g in canned sardines from Brazil.

There were no major differences in chromium concentrations among the various brands of canned sardines (Table 1). The maximum value of chromium in canned sardines (0.10 μg/g) we obtained was lower than values obtained for canned fish in the USA (Ikem and Egiebor 2005), in canned sardines in Brazil (0.40–1.11 μg/g) (Tarley et al. 2001), imported fish in Egypt [sardines, 0.5–18.9 μg/g; mackerel, 3–20.4 μg/g (Abou-Arab et al. 1996); tuna fish (0.10–0.57 μg/g)(Ashraf 2006)]. Canli and Atli (2003) stated that the mean chromium concentration in the muscles of sardine samples from the Mediterranean in μg/g dry weight was 2.23. The examined samples had chromium levels below the Brazilian regulatory limit of 0.1 mg Cr per kg.

The levels of zinc in our samples ranged from 0.09 to 4.63 μg/g lower than values reported by Tarley et al. (2001). However, the mean values of zinc we obtained were similar to values obtained for imported sardines in Egypt (0.06–3.48 μg/g) (Abou-Arab et al. 1996). The recommended dietary allowance for a 60-kg adult for Zn, according to the Joint Expert Committee on Food Additives (JECFA) and WHO (1993), is 8 mgd^{-1} person. The daily intakes from consumption of any brand of canned sardines we examined ranged from 0.80 to 41.34 μg per day. This contributes ~0.00 to 0.05% of the total recommended dietary allowance for Zn per day. All samples examined had zinc at levels below the Food and Agricultural Organization (FAO) recommended limit of 40 mg/kg (FAO 1983).

The mean concentrations of manganese in our samples ranged from 0.64 to 1.71 μg/g. The mean values of manganese obtained in this study were lower than mean values of 1.53–17.55 μg/g reported by Tarley et al. (2001), but were comparable to 0.10–1.06 μg/g and 0.006–1.08 μg/g reported for imported sardines and mackerel, respectively (Abou-Arab et al. 1996). Also, Ikem and Egiebor (2005) reported similar levels of manganese (0.01–2.55 mg/kg) in canned fish in some parts of the USA. The dietary contribution of manganese in our study ranged from 5.7 to 15.2 μg per day for consumption of any of the brands. This represents about 0.5–1.38% of the recommended dietary allowance for manganese.

Food is the main source of cadmium for exposed people. The average concentrations of cadmium obtained in this study ranged from 0.11–0.23 μg/g, with brand D having the highest mean value. The mean values obtained for different brands in this study were similar to the mean values of 0.19–0.38 μg/g and 0.004–0.184 μg/g reported for canned sardines in Brazil (Tarley et al. 2001) and imported sardines in Egypt (Abou-Arab et al. 1996). Similarly, Ashraf et al. (2006) reported cadmium levels ranging from 0.02 to 0.38 μg/g with an average of 0.161 μg/g for salmon, 0.07–0.64 μg/g with an average of 0.227 μg/g for tuna and 0.010–0.690 μg/g with an average of 0.183 μg/g for sardines. The Joint Food and Agricultural Organization/World Health Organization (FAO/WHO) Expert Committee on Food Additives has suggested a provisional tolerable intake of 400–500 μg per week for men. The intake of cadmium from any of these brands was below the provisional tolerable intake.

We found the highest average nickel concentration in brand B, whereas the lowest mean value was observed in brand H. The mean levels of nickel ranged from 0.04 to 3.26 μg/g. The daily intake of nickel in our study ranged from 0.36 to 29.11 μg/day, which is below the recommended dietary allowance of 35–700 μgd^{-1}/person for nickel (WHO 1993). Ashraf (2006) has reported a mean nickel concentration of 0.16 μg/g in canned tuna fish from Saudi Arabia compared to the 0.04–3.26 μg/g we observed in our study.

The average cobalt concentrations in the canned sardines ranged from 0.01 to 7.23 μg/g. Brand G had the highest mean concentration of cobalt ($P < 0.05$) compared to the other brands. However, significant intra-brand variability ($P < 0.05$) existed among brands A, C, D and E. The levels of cobalt obtained in our study were higher than cobalt levels (0.0–0.10 mg/kg) reported in canned fish in the USA (Ikem and Egiebor 2005). Normal daily intake of cobalt is reported to be in the range of 2.5–3.0 mg/day. Poisoning occurs within the ranges <23–30 mg cobalt daily (Hokin et al. 2004). The daily intake of cobalt in this study ranged from 0.09 to 64.5 μg/day. This contributes about 0.03–21.5% of normal daily intake of cobalt.

In our study, there was no significant variation ($P < 0.05$) in the concentrations of copper in the various brands. The average concentration of copper in all brands was 0.01 μg/g. The average concentrations of copper reported in this study were by far lower than values reported by several investigators (Tahan et al. 1995; Tarley et al. 2001; Sharif et al. 1993).

4 Conclusion

Overall, our study showed that the concentrations of copper, chromium manganese, iron, zinc and cobalt were not present in the analyzed sardine samples at levels above the permissible limits. However, cadmium, lead and nickel are present at levels above the permissible limits in some brands. On the other hand, only brands C, G, H and J had levels above statutory safe limits for lead. The body burden of these metals is very dependent on the concentrations of these metals in canned sardines and the frequency of consumption of these materials, the amount consumed and the rate of detoxification of contaminants in the human body. The choice of the brand may vary considerably from one individual to another, and the choice of these kinds of products consumed is dependent on culture, income class and availability. Since the frequency of consumption of canned sardines is low, the dietary contribution of these metals from the consumption of sardines is relatively low.

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