



Microbial and Heavy Metal Contamination of Commercial Potash Solution (Ngor) in Some Parts of Eastern Nigeria

Udujih, H. I.

Department of Medical Laboratory Science,
Faculty of Health science., Imo State University

Osuoha, C.

Department of Medical Laboratory Science,
Faculty of Health science., Imo State University

Dike-Ndudi, J. N.

Department of Medical Laboratory Science,
Faculty of Health science., Imo State University

Udujih, O. G.

Department of Public Health, School of Health Technology,
Federal University of Technology Owerri

ABSTRACT

Bacteria, heavy metal contamination of commercial ngor (potash solution) were assessed using culture, microscopy and biochemical characterization for bacterial detection, identification and quantification. Atomic absorption spectrophotometric (AAS) method was used for the determination of heavy metals. Results of this study showed bacterial and heavy metal contamination of commercially made potash solutions (Ngor). Out of the 50 potash solutions (Ngor) purchased from the various markets, 32 yielded significant bacterial growths. The total mean bacterial counts (cfu/ml) in the potash sample solution from the various markets in Imo and Abia state, were within the WHO permissible limits for water bacteria count. The following heavy metals were determined from the samples; Lead (Pb) Copper (Cu), Cadmium (Cd), Aluminium (Al), Nickel (Ni), Chromium (Cr), Mercury (Hg), Zinc (Zn), Cobalt (Co), Iron (Fe) and Manganese (Mn). Most of them (81.82%) had mean concentration that were higher and statistically significant when compared to the control ($P < 0.05$). They were above the WHO permissible limits except Copper (Cu) from Oriugba, Nkwoegwu and Afor-Ogbe market and lead (Pb) from Nkwoegwu market. It is therefore necessary that clean water should always be used in preparation of food by both vendors and consumers. Agricultural practices that lead to increased levels of heavy metals in the soil should be curtailed.

Key words: Bacteria, Heavy Metal, contamination

In Nigeria, potash solutions of certain vegetable matter or agricultural waste have been used locally in the production of an instant emulsion called ncha used in preparing dishes such as Nkwobi, isi-ewu, kpomo, ugba, abacha and otong (Uzodinma et al., 2014). These agricultural

wastes such as unripe banana peels, unripe plantain peels, maize cob and palm fruit bunch contains a good percentage of potash alkali especially for a wide range of uses comparable to the conventional and inorganic potash salt locally called akanwu in igbo or kawu in Yoruba language (Olabanji et al., 2012). Palm fruit bunch and unripe plantain peels are not only regarded as cheaper but are also thought to be safer than kawu or akanwu, the conventional potash. Most local women usually burn the dried unripe plantain peels or palm fruit bunch to ashes, soaks the ash in water and sieve it before selling the filtrate as potash solution for various uses, some of which have been earlier mentioned. The sources of the water used by the local processors in processing potash solution locally most times followed anthropogenic microbial and heavy metal contamination (Okeke et al., 2020).

Heavy metal contamination is a major environmental health challenge and is potentially dangerous because of bioaccumulation through the food chain (Aycicek et al., 2008). Heavy metals are naturally occurring elements that comprise essential (e.g., Cu, Fe, Ni, and Zn) and nonessential metals (Cd, Hg, and Pb) (Dércia et al., 2018). Human activities like industrial, mining, and agricultural processes have led to a widespread distribution of heavy metals in the ecosystems, posing risks to ecological and human health. Owing to their bio accumulative potential along the food chain, high toxicity, prevalence, and persistence in the environment, heavy metals have become a major public health concern (Dércia et al., 2018). Unlike organic pollutants, heavy metals are non-biodegradable and have tendency to accumulate in living beings. In fact, most of them are known to be potential carcinogens. Various adverse health hazards are known due to long term and continuous exposure to heavy metals. Since they are non-degradable and tend to bio-accumulate, suitable methods need to be established for their efficient removal from the environment (Manavi et al., 2019).

METHODOLOGY

Study Area

The study was carried out in Abia state (Umuahia) and Imo state (Owerri and Mbaise), Nigeria. Umuahia is the capital city of Abia State in southeastern Nigeria. It lies on latitude 5°32'N and longitude 7°29' along Umuahia/Ikot-ekpene road. It is at an altitude of over 122 m above sea level. It is located along the rail road that lies between Port Harcourt to its south and Enugu city to its north. Umuahia has a population of 359,230 according to the 2006 Nigerian census. Umuahia is indigenously Igbo.

Owerri is the capital of Imo state and the Eastern heartland. It is transversed by Port Harcourt, Onitsha, Aba, Okigwe and Umuahia high ways. Owerri municipal is bounded on the southern axis by Rivers State, on the West by Owerri West Local Government Area of Imo State, on the Northern axis by Owerri North Local Government Area of Imo State, on the East by both Ikeduru Local Government Area and Oru-East Local Government Area of Imo State. It occupies a geographical land mass of 58km². It lies within latitude 4°45'N and 7°15'N and longitude of 6°50'E. It has a provisional census figure of 127,213 as at 2006 census. The area under study has a tropical climate and two main seasons namely: Rainy and Dry season (City Population, 2022). Mbaise is a region in Imo State in southeastern Nigeria. In the heart of Igboland, the region includes several towns and cities. Mbaise has a population density of over 1,000 people per square kilometer, Mbaise is West Africa's most densely-populated area; its 2006 population was 611,204.

Research Design

This is descriptive in nature. It is based on cross sectional survey to ascertain the bacterial profile and heavy metal presence in commercially sold potash solution (Ngor) in Abia and Imo state. Some of the potash solutions sold in the markets were observed for their bacterial profile and presence of heavy metals using standard laboratory techniques. A simple questionnaire was administered to the vendors in an interview after the purchase of the ngor solution

Study Population

A total of 50 potash solutions were obtained from different vendors from various markets in Umuahia, Owerri municipal and Mbaise. The potash solutions (Ngor) from various sources were collected from different vendors from the different markets in the study areas. All solutions were labelled and taken the laboratory for analysis.

Sampling Methods/Sample Size of Determination

A simple random sampling technique was applied in the selection of vendors. Taro Yamane's formula (1967) was used to obtain the sample size 50 from the population.

Research Design

This study is descriptive in nature. Some of the potash solutions sold in the markets were observed for their bacterial profile and presence of heavy metals using standard laboratory techniques.

Sample Collection

A total of 50 potash solutions were obtained from different vendors from various markets in Umuahia, Owerri municipal and Mbaise. All solutions were labelled and taken the laboratory for analysis.

Ten (10) samples of the locally-made liquid potash made with palm bunch ash and plantain peel were bought from each of the five local markets. Three markets in Umuahia, Abia state, one market in Owerri and one market in Mbaise, Imo state namely; Isi-gate Umuahia, Oriegba market Umuahia, Nkwoegwu market Umuahia, Douglas market, Owerri and Afor-Ogbe market, Mbaise. Control samples were prepared in the National soil plants and water laboratory, Umudike, Abia state. One kilogram (1kg) of plantain peel and palm bunch were washed and dried in the sun for 4 days and finally in an electric oven at 65°C for 6 hours. The dried sample was burnt to ashes and soaked with 1000 ml of distilled water for about 24 hours. The samples were filtered and stored in sample bottles which were used in the analysis as the control samples.

Heavy Metal Determination

Atomic absorption spectrophotometric (AAS) method was used for the determination of heavy metals. AAS quantitatively measures the concentrations of elements present in a liquid sample. It utilises the principle that elements in the gas phase absorb light at very specific wavelengths which gives the technique excellent specificity and detection limits. The sample may be an aqueous or organic solution; indeed, it may even be solid provided it can be dissolved successfully. The liquid is drawn in to a flame where it is ionised in the gas phase. Light of a

specific wavelength appropriate to the element being analysed is shone through the flame, the absorption is proportional to the concentration of the element (LPD lab services, 2021).

Sample Extraction by Multiple Nutrients Wet Digestion Method

Ten millilitres (10ml) of the samples were measured in 100 ml Pyrex beakers, 10ml of multiple nutrients extraction reagent (H_2SO_4 -Selenium salicylic acid) were added and placed on a digestion block set at 30°C to heat to dampness. Five millilitres (5ml) of concentrated Perchloric acid were added to the samples and the heating increased to 80°C until samples digested producing a profused porchlone white fumes. The samples were brought out of the digestion block and allowed to cool. They were dissolved in distilled water and transferred into a 100ml volumetric flask and made up to the mark. The digestion was used in the determination of aforementioned heavy metals using the USA buck scientific Atomic Absorption Spectrophotometer (AAS). (Novozamnsky et al., 1989, Modified by Nwosu et al., 2010).

Bacterial Analysis by Serial Dilution Method

The total bacterial colony-forming unit (TCFU) was determined using the serial dilution method under aseptic conditions as described by Wollum (1982). One millilitre (1ml) of each sample (inoculum) was diluted to 10ml using sterile distilled water and subsequently 1ml of the 10ml diluent was serially diluted to get the 7th (10^{-7}) diluent. The diluents were streaked on prepared all-purpose media using sterile wire loop. The plates were incubated at 37°C for 24-48hours. Preliminary identification was based on colony characteristics of the organism such as size, shape, colour, elevation, haemolysis on blood agar, odour and changes in physical appearance in media. The bacterial colonies were counted using colony counter and the total coliform count were calculated.

RESULTS

Total Mean Bacterial Count (cfu/ml) of Bacteria Isolated from the Potash Solutions (ngor) Purchased from Various Market.

The total mean bacterial count (cfu/ml) of bacteria isolated from the potash solutions (ngor) purchased from various market were as follows: 1.75×10^{-4} (Isi-gate market), 8.63×10^{-3} (Orieugba market), 6.97×10^{-3} (Nkwoegwu market), 1.15×10^{-4} (Douglas market) and 8.90×10^{-3} (Afor-Ogbe market).

The Mean Concentrations of the Heavy Metals Present in the Potash Solutions Purchased in the Markets and the p-value of their Comparison with Control Potash Solution

The following heavy metals were determined from the potash solutions; Lead (Pb) Copper (Cu), Cadmium (Cd), Aluminium (Al), Nickel (Ni), Chromium (Cr), Mercury (Hg), Zinc (Zn), Cobalt (Co), Iron (Fe) and Manganese (Mn). The mean concentration of each of them extracted from the potash solutions from the different markets were compared with the mean concentrations in the control potash sample. Cadmium (Cd), Aluminium (Al), Nickel (Ni), Chromium (Cr), Mercury (Hg), Zinc (Zn), Cobalt (Co), Iron (Fe) and Manganese (Mn) were higher and statistically significant when compared to the control ($P < 0.05$). They were also all above the WHO permissible limits except Copper (Cu) from Orieugba, Nkwoegwu and Afor-Ogbe market and lead (Pb) from Nkwoegwu market.

DISCUSSION

In Africa, potash solutions are diversely used for both domestic and commercial purposes. It is often used as a tenderizer in cooking, an ingredient in certain foods and medicinal preparations. This study showed that out of the 50 potash solutions (Ngor) purchased from the various markets, 32 yielded bacterial growths. The total mean bacterial count (cfu/ml) in the potash sample solution from the various markets were 1.75×10^{-4} (Isi-gate market), 8.63×10^{-3} (Orieugba market), 6.97×10^{-3} (Nkwoegwu market), 1.15×10^{-4} (Douglas market) and 8.90×10^{-3} (Afor-Ogbe market). These total mean bacterial counts (cfu/ml) were within the WHO permissible limits for water bacteria count.

The following heavy metals were determined from the samples; Lead (Pb) Copper (Cu), Cadmium (Cd), Aluminium (Al), Nickel (Ni), Chromium (Cr), Mercury (Hg), Zinc (Zn), Cobalt (Co), Iron (Fe) and Manganese (Mn). The mean concentration of each of them extracted from the potash solutions from the different markets were compared with the mean concentrations in the control potash sample. Most of them showed significant statistical differences ($P < 0.05$) and were above the WHO permissible limits except Copper (Cu) from Orieugba, Nkwoegwu and Afor-Ogbe market and lead (Pb) from Nkwoegwu market. There was no WHO-based guideline value proposed/recommended for Zinc (Zn), Iron (Fe) and Aluminium (Al), however, heavy metal contamination is a major environmental health challenge and is potentially dangerous because of bioaccumulation through the food chain (Aycicek *et al.*, 2008). Anthropogenic sources of heavy metal contamination include agricultural activities (such as pesticide and herbicide application, contaminated irrigation water, fertilizer application) waste disposal, mining, traffic emissions, metallurgy, cigarette smoking, aerosol gas, sewage discharge and smelting (Merian *et al.*, 2004). Accumulation of heavy metals in agricultural soil through traffic emissions may result in soil contamination and elevated heavy metal uptake by crops; this affects food quality and safety (Garcia and Millan, 1998).

Among the five sites (markets) in this study, only Isi-gate market in Abia state and Douglas market in Imo showed higher levels of all the heavy metals assessed when compared to the control values and they were all statistically significant. Interestingly, both markets had lower total mean bacterial counts (cfu/ml) of 1.75×10^{-4} and 1.15×10^{-4} respectively. Syed *et al.*, (2021) opine that *heavy metals* disrupt many biochemical and physiological activities in *bacteria*, including *growth*, development, enzyme and hormone production. Thomas and Benov (2018), investigated the mechanistic behavior of Cd on *Escherichia coli* after heavy metal exposure. They reported that higher concentrations of Cd damage the DNA, denature the protein, and inhibit the process of cell division and transcription in bacterial cells. The lower total mean bacterial counts (cfu/ml) observed in Douglas and Isi-gate market are because of the inhibitory effects of the higher heavy metal levels in the ngor solution. The significantly high heavy metals in these markets' ngor solution could be as a result of heavy metal contamination of soil and water in these urban areas from industrial activities.

CONCLUSION

The results of this study showed that there were bacterial and heavy metal contamination of commercially made potash solutions (Ngor). The bacterial load was below WHO permissible limits. There was presence of heavy metals above WHO permissible limits. There is possible link between heavy metal presence and bacterial load in ngor solution.

References

- Akbar, B.; Rana, D.; Seid, M.J.; Leonard, W. (2019). Nanoencapsulated nisin: An engineered natural antimicrobial system for the food industry. *Trends Food Sci. Technol.*, 94, 20–31.
- Akbar, B.; Zahra, M.B.; Keith, S.; Seid, M.J.; Leonard, W. (2020). Efficiency of novel processing technologies for the control of *Listeria monocytogenes* in food products. *Trends Food Sci. Technol.*, 96, 61–78.
- Alaribe C.S., Oladipupo A.R., Cibedamosi S., Emaejeroke J.T. and Bashiru K.A. (2019). Determination of metals by atomic absorption spectrometry in unripe plantain peels ash and comparative geno toxicity studies with kawu “potash” using gel electrophoresis and diphenylamine assay. *Annals of Science and Technology* 7(2): 73-77.
- Alum, E.A, Urom, S.M.O.C, Ben, C.M.A (2016). Microbiological Contamination of Food: The Mechanisms, Impacts and Prevention. *International Journal of Scientific & Technology Research* 5(3): 65-78
- Ankrah E.A. (1974). Chemical studies of some plant wastes from Ghana. *Journal of the Science of Food and Agriculture*, 25(10):1229-1232.
- Ariwaodo, J.O and Harry-asobara, J (2015). Preliminary Investigation on Flowering and Fruiting Pattern in a Plantation Grown *Azadirachta indica* Sm Stand in Umuahia, Nigeria *American Journal of Plant Sciences* 06(01):219-227 DOI:10.4236/ajps.2015.61025
- Aycicek M., Kaplan O. and Yangi M. (2008). Effect of Cadmium on the germination, seedling growth and metal contents of sunflower (*Helianthus annuus*). *Asian Journal of Chemistry*, 20: 2663-2672.
- Barba, F.J.; Koubaa, M.; do Prado-Silva, L.; Orlie, V.; Sant’Ana, A.D.S. Mild processing applied to the inactivation of the main foodborne bacterial pathogens: A review. *Trends Food Sci. Technol.* 2017, 66, 20–35.
- Barceloux D. G (1999). Chromium *Journal of Toxicology: Clinical Toxicology*. 37(2): 173–194. DOI: <https://doi.org/10.1081/CLT-100102418>
- Barceloux DG. (1999). Copper. *Journal of Toxicology: Clinical Toxicology* 37(2): 217–230. DOI: <https://doi.org/10.1081/CLT-100102421>
- Behravesh, C. B., Williams I. T., and Tauxe R. V. (2012). Emerging Foodborne pathogens and problems: expanding prevention Efforts before slaughter or Harvest. In: Institute of Medicine (IOM). *Improving food safety through a one health Approach: Workshop summary* Washington, (DC): National Academies Press (US); A14.
- Bevilacqua, A.; Petrucci, L.; Perricone, M.; Speranza, B.; Campaniello, D.; Sinigaglia, M.; Corbo, M.R (2018). Nonthermal technologies for fruit and vegetable juices and beverages: Overview and advances. *Compr. Rev. Food Sci. Food Saf*, 17,2–62.
- Broadhurst CL and Domenico P (2008). Clinical studies on chromium picolinate supplementation in diabetes mellitus – a review. *Diabetes Techn and Therap.*; 8(6): 677–687. DOI: <https://doi.org/10.1089/dia.2006.8.677>
- Bryan, F.L. (1982). *Diseases Transmitted by Foods*. Atlanta: Centers for Disease Control; 1982.
- Bursby, Jr, W.F and Wagon, G. N., (1984). Aflatoxin in chemical Carcinogens, Searle, C. E. Ed. ACS monograph 182, American chemical society, Washington, D. C. Pp. 946.
- Cebrian, G.; Manas, P.; Condon, S. Comparative resistance of bacterial foodborne pathogens to non-thermal technologies for food preservation. *Front. Microbiol.* 2016, 7, 734.
- Cheesbrough, M. (2006). *District laboratory Practice in tropical countries part 2*, 2nd edition. Butterworth Cambridge University Press, 440p.

Centers for Disease Control and Prevention (1997). Outbreaks of *Escherichia coli* 0157:H7 infection and cryptosporidiosis associated with drinking unpasteurized apple cider – Connecticut and New York||. October 1996. *Morb Mortal – Wkly. Rep* vol 46, pp 4 – 8. 1997.

City Population (2022). Owerri Municipal (Local Government Area).
<https://www.citypopulation.de/en/nigeria/admin/>

Climate Data (2016) "Climate: Owerri". Climate-Data.org. <https://en.climate-data.org/africa/nigeria/imo/owerri-889379/>

David J.M., Ravel A., Nesbitt A., Pintar K., Pollari F (2014). Assessing multiple foodborne, waterborne and environmental exposures of healthy people to potential enteric pathogen sources: effect of age, gender, season, and recall period. *Epidemiol. Infect.*: 142(1):28–39

Dércia, S., Raquel, V., Ana, L and Luís F (2018). Zebrafish Early Life Stages for Toxicological Screening: Insights from Molecular and Biochemical Markers. *Advances in Molecular Toxicology*. Elsevier. Volume 12, Pages 151-179.

Diez, - Gonzalez F. T., Gallaway, T. R., Kizoulis, M. G. and Russel, J. B. (1998). Grain feeding and dissemination of acid resistant *Escherichia coli* from cattle *Science*.281:1666 – 1668.

Do Prado-Silva, L.; Brancini, G.T.P.; Braga, G.Ú.L.; Liao, X.; Ding, T.; Sant’Ana, A.S. Antimicrobial photodynamic treatment (aPDT) as an innovative technology to control spoilage and pathogenic microorganisms in agri-food products: An updated review. *Food Control* 2022, 132, 108527.

Dullah, H. (2018). Compatibility assessment for physical and mechanical properties of empty fruit bunch cement-bonded fibreboard. Thesis. 10.13140/RG.2.2.32026.08645.

Eddy, N. O. (2007). Applied statistics in designing special organic mixtures. *Journal of Pure and Applied Science*, 9, pp. 78-88.

Eddy, N. O., Udofia, P. J and Ukpog, I. J. (2004). The roles of leguminous plant in mineral nutrition. Published in the proceedings of the Chemical Society of Nigeria 27th International Conference (a supplement of the *Journal of Chemical Society of Nigeria*), pp329-332.

Eddy, N. O and Ukpog, I. J. (2006). Possible relationship existing between the distribution of electrolyte between soap and lye. *Journal of Applied Sciences*, 8, 1, pp. 60-64.

Encyclopedia (2019) "Potash" <https://www.encyclopedia.com/earth-and-environment/minerals-mining-and-metallurgy/mineralogy-and-crystallography/potash#>:

Ethiopia Mining. (2004). Ethiopia Economy Mining.
https://www.photius.com/countries/ethiopia/economy/ethiopia_economy_mining.html

Ferrario, M.I.; Guerrero, S.N. Inactivation of *Alicyclobacillus acidoterrestris* ATCC 49025 spores in apple juice by pulsed light. Influence of initial contamination and required reduction levels. *Rev. Argent. Microbiol.* 2018, 50, 3–11.

Fonterra (2013). Report of WPC 80 independent inquiry for Fonterra Board. Available online: <http://wpc80-inde-reportfonterra.com>. (Accessed on 10 Dec. 2013).

Garcia R and Millan E (1998). Assessment of Cd, Pb and Zn contamination in roadside soils and grasses from Gipuzkoa (Spain). *Chemosphere* 37: 1615–1625. DOI: [https://doi.org/10.1016/S0045-6535\(98\)00152-0](https://doi.org/10.1016/S0045-6535(98)00152-0)

Gidlow D.A (2004). Lead toxicity. *Occupational Medicine*: 54(2): 76–81. DOI: <https://doi.org/10.1093/occmed/kqh019>

Hald T., Aspinall W., Devleesschauwer B., Cooke R., Corrigan T., Havelaar A.H., Gibb H.J., Torgerson P.R., Kirk M.D., Angulo F.J., Lake R.J., Speybroeck N., Hoffmann S (2016) World health organization estimates of the relative contributions of food to the burden of disease due to selected foodborne hazards: a structured expert elicitation. PLoS One:11(1)

Hubbs-Tait L, Nation JR, Krebs NF and Bellinger DC (2005). Neurotoxicants, micronutrients, and social environments individual and combined effects on children's development. *Psy Sci in the Pub Int, Supp*; 6(3): 57–121.

Hussain, M.A (2013). Economic implications of microbiological food safety scares. *N. Z. Food Technol*, 48, 33.

Ihedioha JN, Ujam OT, Nwuche CO, Ekere NR and Chime CC (2016). Assessment of heavy metal contamination of rice grains (*Oryza sativa*) and soil from Ada field, Enugu, Nigeria: Estimating the human health risk. *Hum and Ecol Risk Assess: An Int J*: 22(8).

Ilgaz, A.; Emrah, T.; Fatih, E. Efficacy of gaseous ozone for reducing microflora and foodborne pathogens on button mushroom. *Postharvest Biol. Technol.* 2015, 109, 40–44.

Jaishanakar M., Tsetan T., Anabalaga N., Mathew B.B. and Beeregowda K.N. (2014). Toxicity, Mechanism and health effects of some heavy metals *Interdisciplinary Toxicology*, 7(2):60-72.

Laura, R. (2007) Microbial ecology in manufacturing Paper-based packaging materials for use in food industry. In: *Microbial Contaminants & Contamination Routes in Food Industry*. Gun Wirtanen & Satu Salovtt (eds), VTT Espoo, Finland. Pp 14-19. ISBN 978-951-38-6319-7

LPD lab services (2021). AAS - Atomic Absorption Spectrophotometry.
https://www.lpdlabservices.co.uk/analytical_techniques/chemical_analysis/atomic_absorbance.php

Kaarina, A. (2007). Effect of maintenance routines in food Processing on production hygiene: In *Microbial Contaminants & Contamination Routes in Food Industry*. Gun Wirtanen & Satu Salovtt (eds), VTT Espoo, Finland. Pp 36-38. ISBN 978-951-38-6319-7

Khan A.S., Khanl., Hussain K.B. and Ashtray N. (2008). Profile of heavy metals in selected medicinal plants. *Pakistan Journal of Weed Science Research*, 14(12): 101-110.

Khanh, T.K.P.; Huan, T.P.; Charles, S.B.; Yuthana, P. Nonthermal plasma for pesticide and microbial elimination on fruits and vegetables: An overview. *Int. J. Food Sci. Technol.* 2017, 52, 2127–2137.

Kim, J.H.; Min, S.C. Moisture vaporization-combined helium dielectric barrier discharge-cold plasma treatment for microbial decontamination of onion flakes. *Food Control* 2018, 84, 321–329.

Kostick, D (2006). "Potash" (PDF). 2005 Minerals Handbook. United States Geological Survey. p. 58.1.

Kruse, H., Kirkemo, A. M. and Handel, K. (2004). Widely as a source of zoonotic infections. *Emerg. Infect. Dis.* 10:2067-2072. Lindsay, J. A., (1997). Chronic sequelae of foodborne diseases. *Emerging Infection Disease*. 3, 4 (Oct – Dec. 1997): 443 – 452.

Kudva, I. Blanch, K. and Hovde, C. J. (1998). Analysis of *Escherichia coli* 0157: H& survival in Ovine or bovine manure and manure shury. *Appl. Environ. Microbiol.* 64: 3166 – 3174.

Lynch, M. F., Tanze, RV, Hedberg CW. (2009). The growing burden of foodborne outbreaks due to contaminated fresh produce: Risks and opportunities. *Epidemiology and Infection*. 137(3):307 – 315.

Mbaise Pioneers. (2019)
<https://web.archive.org/web/20190119121116/http://www.mbaisepioneerassociation.com/history.html>

Mahdieh, M.; Mohammad, R.S.; Faezeh, S.; Maryam, T.Z. A review of recent trends in the development of the microbial safety of fruits and vegetables. *Trends Food Sci. Technol.* 2020, 103, 321–332.

Manavi, Y., Radhika, G and Rakesh K.S (2019). Green and Sustainable Pathways for Wastewater Purification. *Advances in Water Purification Techniques Meeting the Needs of Developed and Developing Countries*. Elsevier. Pages 355-383.

McDowell LR (2003). *Minerals in Animal and Human Nutrition*. Amsterdam, The Netherlands: Elsevier.

Merian E., Anke M., Inhat M. and Steppeler M. (2004). *Elements and their compounds in the environments*. Wiley UCH, Weinheim, Germany. 214- 218.

Mikš-Krajnika, M.; Fenga, L.X.J.; Bang, W.S.; Yuk, H.G. Inactivation of *Listeria monocytogenes* and natural microbiota on raw salmon fillets using acidic electrolyzed water, ultraviolet light or/and ultrasounds. *Food Control* 2017, 74, 54–60.

Monteiro, C. A. (2010). Nutrition and Health. The issue is not food, nor nutrients, so much as processing. *Public Health Nutrition*, 12(5):729 – 316.

Mritunjay, S.K.; Kumar, V. Fresh farm produce as a source of pathogens: A review. *Res. J. Environ. Toxicol.* 2015, 9, 59–70.

Murphy H.M., Pintar K.D., McBean E.A., Thomas M.K (2014). A systematic review of waterborne disease burden methodologies from developed countries. *J. Water Health*:12(4):634–655.

Negi, P.S. Plant extracts for the control of bacterial growth: Efficacy, stability and safety issues for food application. *Int. J. Food Microbiol.* 2012, 156, 7–17.

Nigeria galleria (2021). Imo state
https://www.nigeriagalleria.com/Nigeria/States_Nigeria/Imo/.

Ohio State University Extension (2015). FIC Member Estimates Foodborne Illness Costs \$77.7 Billion a Year. Available online: <http://fic.osu.edu/news/news-archive/fic-member-estimates-foodborne-illness-costs-777-billion-a-year.html>

Okafor, C. N. Umoh, V. J and Galadima, M (2003). Occurrence of pathogens on vegetables harvested from soil irrigated with contaminated streams. *Sci. Total Environ.* 311: 36 – 49.

Okareh, O. T., Adeolu, A. T. & Adepoju, O. T. (2015), Proximate and mineral composition of plantain (*Musa Paradisiaca*) wastes flour; a potential nutrients source in the formulation of animal feeds, *African Journal of Food Science and Technology*, 6, 2, pp. 53-57.

Okeke O, Aniobi C.C, Ezech E, Ochuba C.O, Ezejiolor C.C (2020). Microbial and Heavy Metal Evaluation of Solutions of Ash Produced from Unripe Plantain Peels and Oil Palm Fruit Bunch Sold in Market Outlets within Afikpo South L.G.A. in Ebonyi State. *International Journal of Science and Research (IJSR)* 9(4):1670-1676

Okeke O., Ezech E., Ozuah A.C. and Ezechiofor C.C. (2019). Effect of processing on the microbial load of cassava meal products sold within Enugu metropolis. *J. Chem. Biol. Phy. Sci.*, 9(3): 414-425

Olabanji O., Oluyemi E.A and Ajayi S.O. (2012). Metal analysis of ash derived alkalis from banana and plantain peels (*Musa spp*) in soap making. *African Journal of Biotechnology*, 11 (99): 16512-16518.

Onakpa M.M., Njan A.A and Kaly O.C. (2018). A review of heavy metal contamination of food crops in Nigeria. *Annals of Global Health* 84(3):488-494.

Onyeonoro, U. U., Ogah, O. S., Ukegbu, A. U., Chukwuonye, I. I., Madukwe, O. O., & Moses, A. O. (2016). Urban-Rural Differences in Health-Care-Seeking Pattern of Residents of Abia State, Nigeria, and the Implication in the Control of NCDs. *Health services insights*, 9, 29–36. <https://doi.org/10.4137/HSI.S31865>

Padan E., Bibi C., Ho M. and Krulwich T. (2005). Alkaline homeostasis in bacteria and fungi: new insights. *Bio Che. Biophys. Acta.*, 1717(2): 67-88.

Papachristodoulou, M.; Koukounaras, A.; Siomos, A.S.; Liakou, A.; Gerasopoulos, D. The effects of ozonated water on the microbial counts and the shelf life attributes of fresh-cut spinach. *J. Food Process. Preserv.* 2018, 42, e13404.

Parsons P.J and Barbosa F (2007) Atomic spectrometry and trends in clinical laboratory medicine. *Spectrochim Acta Part B Atom Spectroscopy*; 62:992-1003.

Peers, F. G., Gilman, G. A., and Linsel, C. A. (1976). Diet aflatoxins and human liver cancer; a study in Kenya. *Br. J. cancers* 17:167 – 176.

Prescott, L.M.S., Harley, J.P. and Lein, D.A. (1999). *Microbiology*. MacGraw-Hill publisher, New York, 4 th edition. pp 916-919.

Shark, R. C. (1981). *Mycotoxins and N-Nitros compounds: Environmental Risks*. Vol 1., Shank. R. C. Ed. CRC Press, Boca Raton, FL Pp 107 – 140.

Solomon, E. B., Potenski, C. J. and Mathews, K. R. (20002). Effect of Irrigation Method on Transmission to and Persistence of *Escherichia coli* 015:47 on Lettuce, *J. Food. Prot.* 65:673-676.

Stern, N.J. & Robach, M.C. 2003. Enumeration of *Campylobacter* spp. In Broiler Feces and in Corresponding Processed Carcasses. *J. Food Prot.*, 66, 1557–1563. Tangahu B.U., Abdullah S.R., Idris H.B., Anvar N. and Mukhlisin M. (2011). A review on heavy metals (As, Pb and Hg) uptake by plants through phyto remediation. *International Journal of Chemical Engineering*, 31:145-153.

Syed, A., Zeyad, M. T., Shahid, M., Elgorban, A. M., Alkhulaifi, M. M., & Ansari, I. A. (2021). Heavy Metals Induced Modulations in Growth, Physiology, Cellular Viability, and Biofilm Formation of an Identified Bacterial Isolate. *ACS omega*, 6(38), 25076–25088. <https://doi.org/10.1021/acsomega.1c04396>

The United States Geological Survey (USGS) (2008). Potash. *Minerals Yearbook*. United States Geological Survey. <http://minerals.usgs.gov/minerals/pubs/commodity/potash/myb1-2008-potas.pdf>

Thomas, M and Benov, L. (2018). The contribution of superoxide radical to cadmium toxicity in *E. coli*. *Biological trace element research*, 181(2), 361-368.

Timmons, C.; Pai, K.; Jacob, J.; Zhang, G.; Li, M.M. Inactivation of *Salmonella enterica*, Shiga toxin-producing *Escherichia coli*, and *Listeria monocytogenes* by a novel surface discharge cold plasma design. *Food Control* 2018, 84, 455–462.

Tropea, A (2022) Microbial Contamination and Public Health: An Overview. *International Journal of Environmental Research and Public Health* 19:7441-7445

Tropea, A.; Potorti, A.G.; Lo Turco, V.; Russo, E.; Vadalà, R.; Rando, R.; Di Bella, G. Aquafeed Production from Fermented Fish Waste and Lemon Peel. *Fermentation* 2021, 7, 272.

Truisswell, A. S. and Brand J. C. (1985). Processing food. *British Medical Journal*, 291(6503):1186 – 1190. United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Toxicological Profile for Cadmium; 2008.

United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. Toxicological Profile for Lead; 2007. <https://www.atsdr.cdc.gov/toxprofiles/tp13.pdf> Accessed August 29, 2017.

United States Department of Health and Human Services, Agency for Toxic Substances and Disease Registry. 2005; 1–397.

Uwagbale, E. (2020). How potash, kanwa were the common cooking salts in Nigeria until colonial era. *Scitech Africa*. <https://scitechafrica.net/how-potash-kanwa-were-the-common-cooking-salts-in-nigeria-until-colonial-era/>

Uzodinma E.O., Onwueluzo J.C. and Abugu S.N. (2014). Production and Evaluation of instant emulsion base (ncha) from oil palm biogenic waste. *African Journal of Biotechnology*, 13(49): 4529-4535.

Warde, P (2018). 'Trees, Trade and Textiles: Potash Imports and Ecological Dependency in British Industry, C .1550–1770'. *Past & Present*, 240(1):47-82

WHO (2015). WHO Estimates of the Global Burden of Foodborne Diseases. http://www.who.int/foodsafety/publications/foodborne_disease/fergreport/en/ Available online:

WHO (2008). Guidelines for Drinking Water Quality. World Health Organization; Geneva, Switzerland:

Wirtanen, G., Storgards, E. & Mattila-Sandholm, T. (2003). Biofilms. In: Caballero, B., Trugo, L. & Finglas, P. (Eds.) *Encyclopedia of Food Science and Nutrition*. Academic Press, London. Pp. 484–489. ISBN 0-12-227055-X.

Woo-Ju, K.; Sang-Hyun, P.; Dong-Hyun, K. Inactivation of foodborne pathogens influenced by dielectric properties, relevant to sugar contents, in chili sauce by 915 MHz microwaves. *LWT* 2018, 96, 111–118.

Xiao-Ting, X.; Tian, D.; Jiao, L.; Ju-Hee, A.; Yong, Z.; Shi-Guo, C.; Xing-Qian, Y.; Dong-Hong, L. Estimation of growth parameters of *Listeria monocytogenes* after sublethal heat and slightly acidic electrolyzed water (SAEW) treatment. *Food Control* 2017, 71, 17–25.

Yunbin, J.; Kimberly, S.; Georgios, P.; Philip, D.; Xihong, L.; Sudarsan, M.; Tony, J.; Xuetong, F. Cold plasma-activated hydrogen peroxide aerosol inactivates *Escherichia coli* O157:H7, *Salmonella typhimurium*, and *Listeria innocua* and maintains quality of grape, tomato, spinach and cantaloupe. *Int. J. Food Microbiol.* 2017, 249, 53–60.

Zhongwei, C.; Yulin, L.; Likun, W.; Shuyi, L.; Keke, W.; Jun, S.; Bin, X. Evaluation of the possible non-thermal effect of microwave radiation on the inactivation of wheat germ lipase. *J. Food Process. Eng.* 2017, 40, e12506.