Water Contamination in Nigeria and Body Defense Issues

M.J. Adeniyi[1], *M.SC.* and T.J., Oni,[2] *M.SC.*

[1]*Department of Physiology, University of Benin, Benin City, Nigeria*

[2]*Department of Physiology, University of Ilorin, Ilorin, Nigeria*

Abstract

Water is essential for the survival of every living thing. Over time, human and natural activities have led to contamination of water thereby posing danger to plant and animal lives and the health status of Nigerians. Water contamination causes derangement in functions of digestive tract, nervous system, blood, kidney, liver, reproductive system and immune system. Moreover, increases in antioxidant enzymes such as superoxide dismutase and catalase, granulocytes and conditional increase in lymphocyte count are important coping strategies to exposure to water contamination in Nigeria. However, the coping strategies may not be enough to defend the body.

Key Words: superoxide dismutase, catalase, granulocytes, lymphocyte

Introduction

In human beings, the total body water is approximately 60% of the body weight forming more than two-third of the whole body weight [(1)]. The total body water in an adult human being weighing 75kg is 40 liters [(2)]. Despite change in climate, indiscriminate deposition of wastes on water body, sewage leakages, oil spillage and pipeline vandalism [(3)], there is no change with respect to the essentiality of water for living things in Nigeria.

Water forms an important medium, an internal environment (*milieu interieur)* where cells of living organisms are bathed, and alongside with air forms an external environment[(2)]. From inception, water has always served as a witness to basic and sophisticated functions of organisms. For example, body viscera, immune cells, enzymes, and protective bio-markers rely on the steadiness of water for their efficiency.

Water homeostasis describes the maintenance of steady water level in the body [(2)]. Upset in this balance either in terms of excess or shortage may produce scenarios known as hypotonicity and hypertonicity respectively. Hypotonicity and hypertonicity make the body cells swell and crenate respectively.

Water is derived majorly from the environment. Sources of water in Nigeria are rivers, wells, springs, lakes and sea [(3)]. Interestingly, cells of the body defense are water-based and their functionality is linked to the quantity and quality of water. The

quest for high quality water by human beings is unquenchable due to the association between external and internal environments.

The quality of water has a huge role to play in determining a health status of any living thing. For example, Akporhuarho *et al.*, (2011) [4] reported that exposure of cockerel reared under intensive system to crude oil contaminated water resulted in decrease in white blood cells. Decrease in white blood cells portends a challenge to the animal's immune capacity and its consumers which are the human beings.

An estimated 580 people in India are rumored to die of water pollution related diseases every day. In Nigeria, at least 27% of citizens do not have access to portable water [5]. This predisposes them to waterborne diseases. Such diseases range from gastrointestinal disorders such as vomiting, nausea, diarrhea, typhoid and hepatitis A to secondary diseases.

Despite the reality of water pollution, it is interesting to note that while mortality due to water borne diseases is substantive, some Nigerians who cannot afford the cost of portable water make do with contaminated water. Therefore, this literature review looks into the health implications of contaminated water and the physiological mechanisms that may be involved in adaptation of animals and humans in Nigeria to water contamination.

Overview of Water Contamination In Nigeria

Water contamination is an alteration in physical and chemical properties of water [6,7] making it unsafe for lives. Conditions which can alter physical and chemical properties include artificial factors such as man-made chemicals, pathogens, ozone thinning and natural factors such as presence of plant on water body, plant biomass, increase in environmental temperature and erosion of chemicals from earth surface into water body.

Plants are living things that are able to synthesis their foods using basic ingredients such as carbon dioxide and water. Contaminants contained in water may also be absorbed by plants and passed to animals and humans that consume them. This may result in morbidity and mortality. Herbicides and fertilizers used in the regulation of plant growth are associated with both acute and chronic neurotoxicity [8]. Nitrate in groundwater causes infant methemoglobinemia[8]. In Nigeria, the transportation and mining of crude oil often result in water contamination. Plant and animal lives exposed to such contamination may pose a great danger to human health, causing mutation in genetic makeup and possibly alteration in neurological and reproductive functions and cancinogenesis [9, 10].

Rivers are the important freshwater in Nigeria. Unfortunately, natural and artificial factors have culminated into their contamination and not being safe for animal and human consumption. Analysis of Asa River, one of Nigeria Rivers revealed it has a pH of 6.32-6.43. The liver and intestine of *Clarias gariepinus* fish was characterized by high bacterial density [11]. Fishes are staple sources of protein in Nigeria. Therefore,

consumption of this infected fish by countrymen and women may threaten their immune systems. In Abuja, water bodies receiving abattoir waste water were investigated by Nafarnda *et al.*, (2012) [(12)] for possible contamination. The results of this study did not actually rule out the possibility of pollution but hyped people's concerns about the quality of meat and food they consume and the safety of the entire ecosystem.

Water contamination is an endemic phenomenon in Niger Delta region of the country where oil spillage and oil vandalism have become a recurring decimal. Unfortunately, a sizeable percentage of Niger delta people who cannot afford portable water inevitably use the contaminated water and its contents for domestic purposes such as bathing, cooking, washing, drinking, source of protein meal [(13)] and medicine [(14)]. The Department for Petroleum Industry (DPR) in 1991[(15,42)] outlined the standard of major oil pollution impact indicators in oil field effluent released into fresh water. Deviation from this standard represents environmental hazard. On the effect of oil spillage on water quality and management in Emadadja area of Udu local government area of delta state, the areas affected by spill were claimed to be characterized by decreased water pH and dissolved oxygen and increased Biological Oxygen Demand (BOD) and total hydrocarbon contents [(15)]. The water content of cations (calcium, magnesium, sodium and potassium ions), anions (trioxonitrate (v), tetraoxosulphate (vi), tetraoxophosphate (vi) and chloride ions), heavy metal (iron, cadmium, lead and chromium ions), Chemical Oxygen Demand (COD) and dissolved carbon dioxide were also altered by oil spillage [(15)].

As far as pH is concerned, acidity or decrease in pH is known to increase the threshold for excitation. This may endanger the survival of fishes which are known to thrive within a narrow pH range. Fishes form a source of protein, fatty acids especially linolenic acid (Omega 3), carbohydrate, vitamins and minerals especially iron, calcium, sodium and selenium. Fishes reared under contaminated water ecological system were characterized by increase in markers of oxidative stress such as malondialdehyde, hydrogen peroxide, uric acid, C - reactive protein and lipid peroxide[(4)].

Shell fishes exposed to crude oil polluted water showed a rise in white blood cell at varying levels of the contamination. Rise in neutrophil and eosinophil values were higher in petrol- and diesel-contaminated water treated rats while absolute total white blood cell value increased in animals exposed to petrol-contaminated water[(4)].

Sources of Water Contamination in Nigeria

The sources of water contamination can be broadly divided into natural and artificial or man-made factors. In Nigeria, large percentages of sources of water contamination are preventable. The table below shows various sources of water contamination

Table 1.0: Sources of water contamination and the effect on water body in Nigeria [3]

S/N	ARTIFICIAL FACTORS	NATURAL FACTORS	EFFECT ON WATER BODY
1	Ozone thinning	Water weeds (water lettuce, water hyacinth)	Increase in water temperature. Alteration in chemical composition and appearance
2	Deliberate disposal of materials on water body	Erosion of earth surface into water body	Alteration in chemical composition and appearance
3	Sewage leakage	Weather and climate	Alteration in chemical composition and appearance
4	Application of agrochemicals on farmlands		Alteration in chemical composition and appearance. Increase in temperature
5	Combustion	Microorganisms	Increase in temperature
6	Oil spillage		Alteration in chemical composition and appearance. Increase in temperature
7	Mining and industrial activities		Alteration in chemical composition and appearance. Increase in temperature
8	Vandalism of oil pipe		Alteration in chemical composition and appearance. Increase in temperature
9	Accidental and deliberate disposal of counterfeited and expired substances on water body		Alteration in chemical composition and appearance. Increase in temperature

Health Consequences of Contaminated Water

National Bureau of Statistics (2009) [5] reported that at least 27% of Nigerians depended absolutely on streams, pond, river and rainwater for their drinking water source. This has no doubt resulted into exposure to water contamination. The first major entry route of water contaminants is the digestive tract. Other entry routes are respiratory tract and the integumentary system. The three routes are fortified with innate immune cells just as police men surround governor's arena. The development of a stronger immunity is sequel to invasion and infection. The manifestation of a disease condition specifically implies an absence or deficiency of immune strength.

Although, consumption of water is pleasurable, illnesses due to water contamination are not in any way fair as they are associated with a level of discomforts which vary with genetic, immune factors of the hosts and characteristics of the contaminants.

Water contamination affects almost all human and animal systems especially the digestive tract, immune system, nervous system, cardiovascular system and reproductive system. Well, it has also claimed the lives of several people.

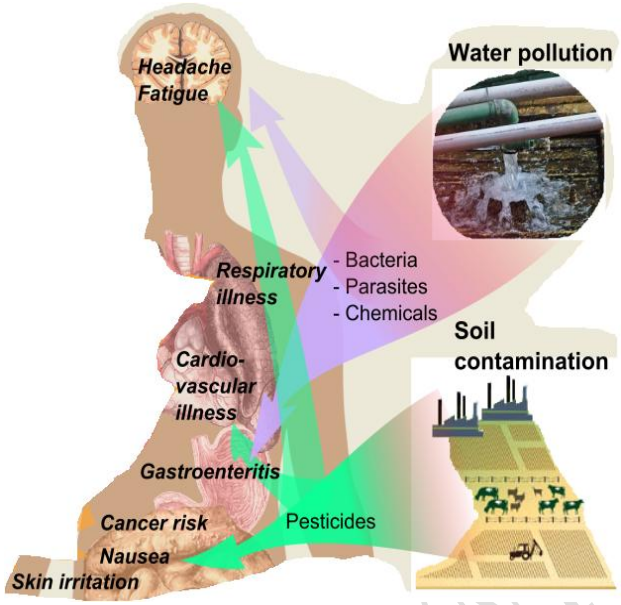

Figure 1: Health consequences of water contamination [16]

Consumption of contaminated water may result in morbidity because:

- Contaminants are toxic substances and they tend to overwhelm the body's constituted immune system.
- Pathogens present in contaminated water produce reactive oxygen species (free radicals) which overpowers the immune system.
- In response to contaminants, body tissues produce cytokines and these cause damage.

Water Contamination and Digestive Tract

Digestive tract is a tubular system and one of the first portals for ingesta. Located in the tract are lymphoid tissues most especially adenoid (nasopharynx), tonsil (back of mouth) and peyer's patches (ileum). Some contents of digestive juices also confer protection.

Contaminant induced digestive disorders include but are not limited to nausea, vomiting, gastritis, gastroenteritis, typhoid, ulcerative colitis, hepatitis A, diarrhea, dehydration and cholera. The first series of cholera outbreak in Nigeria was reported between 1970 and 1990 [17]. Cholera outbreak occurred in the first quarter of 2009 in Maiduguri, Biu, Gwoza, Dikwa and Jere council area [18].

Few years ago, rain water washing sewage into open wells and ponds where people obtained water for drinking and household needs was the cause of the outbreak of cholera and gastroenteritis in Nigeria states of Jigawa, Bauchi, Gombe, Adamawa, Taraba, Abuja, Cross river, Kaduna, Osun and Rivers [19].

Raji and Ibrahim (2012)[20] reported that in some towns of Northern Nigeria, prevalence of diarrhea was 6.23% in 2004 and this increased to 10.04% in 2005. Shuni recorded the highest (8.95%) incidences of diarrhoea infection in 2004, followed by Tambuwal (6.23%) and Sokoto had the least (4.81%) while in 2005 Sokoto had the highest (11.99%) followed by Tambuwal (10.23%) and Shuni had the least (7.55%) .

In another development, Oguwike *et al.*,(2014)[21] showed that oral exposure to petroleum products inhibit the growth of *streptococci pyogenes and candida alicaus* in oral cavity. Considering the enormity of adversity associated with oral contaminants, the use of crude oil probably as a means of sterilizing the mouth in Nigeria is not recommendable.

Water Contamination and Blood

Blood, a connective tissue is adversely affected by water borne contaminants. A study by Igwebuike *et al.*,(2007)[22] showed that exposure to high dose of crude oil contaminant decreased absolute white blood cell count. Decreased white blood cell count most especially lymphocyte count may indicate low immune strength. In another study, consumption of petroleum contaminated diet reduced the white blood cell count [23]. Petrol, kerosene and diesel contaminants are reported to decrease lymphocyte count, red blood cells count, packed cell volume and hemoglobin [24]. Long term exposure of rats to crude oil resulted in decreased hemoglobin and packed cell volume [13]. Hematological study of male road side mechanical professionals revealed a decrease in their hemoglobin and red blood cells [21]. Dwindling red cell counts, packed cell volume and hemoglobin may cause anemia and decrease tissue oxygenation.

Water Contamination and Cardiovascular Function

Fumes are important means of water contamination in Nigeria. Azeez *et al.*,(2012) [25] reported that inhalation of petroleum hydrocarbon was associated with resetting of baroreflex sensitivity and arterial blood pressure in male rats. Baroreceptors are pressure sensors located in arteries [26]. They reset to maintain a high blood pressure [27]. Histological studies of rats' heart exposed to escravos crude oil contaminant revealed edema and increase in weight of the heart [28].

Water Contamination and Antioxidant/ Oxidant Balance

Antioxidant/oxidant balance is an integral component of innate defense. Either decrease in antioxidants or antioxidant enzymes or increase in oxidant will produce a decrease in the balance [29]. In animal study, oral exposure to bonny crude oil for 7 days decreased serum and testicular superoxide dismutase, catalase, glutathione S transferase, glucose 6 phosphate dehydrogenase and gamma glutamyl transferase and an increase in glutathione, hydrogen peroxide and malondialdehyde [30]. Co-factors are non-protein constituents required for activation of enzymes. Examples include vitamins and minerals. In a study conducted by Azubuike *et al.*,(2013) [31].Analysis of mineral concentration (iron (Fe), lead (Pb), zinc (Zn), nickel (Ni) and copper (Cu)) in erythrocyte, testes and liver following exposure to oral contaminants for seven days shows that oral contaminants affected the distribution of metals in tissues. According to the study, the trend of mineral distribution in tissues is as follows:

Blood: Fe> Pb >Zn

Liver: Ni>Zn>Fe>Cu>Pb

Testes: Ni>Cu>Pb>Zn>Fe

Iron: blood> liver>testes

Zinc: liver>blood>testes

Lead: blood>liver>testes

Copper: testes>liver>blood

Nickel: liver>testes>blood.

Water Contamination and Kidney

Kidney, one of the osmoregulatory organs in the body is affected by water contaminants. Increase in kidney weight was associated with ingestion of oral contaminant [28]. Histological studies of kidney provided evidence of glomerulonephritis. There is also marked deposition of collagen fibers, glomerulonephritis and atrophic glomeruli in rats. These indicate heavy compromise of tissue integrity and renal filtration disorder, decreased urinary urea and creatinine, [13,42]. Exposure of rats to hexane dione, an oral contaminant resulted in atrophy of the kidney [32]

Water Contamination and Liver

Liver is one of the largest metabolic organs in human being. It is involved in metabolisms of food stuffs, detoxification of substances and excretion of bile among others. It is interesting to note that production of metabolic enzymes increases in response to change in *milieu interieur*. Therefore features of rats' livers exposed to contaminants (hexane dione) include increases in creatine kinase, creatine, aspartate transaminase and alanine transaminase, bilirubin, urea, triglyceride, total cholesterol and low density lipoprotein, low high density lipoprotein and atrophy of the liver [28,32].

Water Contamination and Nervous System

Works on the effect of water contamination on nervous function showed disruption in brain's antioxidant system and an increase in hydrogen peroxide and lipid peroxidation. A decrease in molecular layer, granular layer and the density of purkinje cells of cerebellum [33] were also documented. Cerebellum constitutes an important inhibitory circuitry for motor function in the body. Structurally alteration in cerebellum may lead to functional derangement.

Water Contamination and Reproductive System

Studies have showed that ingestion of contaminated water reduced sperm count, sperm motility and normal morphology within seven days of administration [34,35]. Ovarian cysts and increase in weight ovary were also observed. There was an increase in estradiol and testosterone [28]. Exposure of rats to Bonny Light Crude Oil (BLCO) for 7 days resulted in decreased epididymal sperm number, daily spermatozoa production and sperm motility. Total sperm abnormalities were increased without affecting sperm viability. There was a severe congestion of interstitial vessel and high germinal epithelium, lesions in epididymis and testis and increase in number of vacuolization [10,28,36].

Raji and Hart (2012)[10] reported a decrease in birth weight and survival rate of offspring delivered. BLCO treated female rats had irregular oestrous cycle with increased frequency of oestrous and metestrous phases and a decrease in the diestrous phase. A dose-dependent reduction in fertility success and birth weight of offspring of the BLCO treated females mated with normal males was reported. Histological study of the epididymis and testis showed BLCO treatment-related lesions.

Coping Strategies to Water Contamination in Nigeria

Responses of Immune System

Immune responses take a central role in body's adaptation to water contamination. 7 to 10 days following ingestion of live oral typhoid vaccines, the presence of gut derived circulating igA antibody-secreting cells (ASC) in lamina propria of the intestinal mucosa where they synthesize igA antibody [(37)] indicates tissue response in that microenvironment.

The body's ability to produce intrinsic antioxidant enzymes such as superoxide dismutase and catalase may also be involved in adaptation. In a study conducted by Achuba and Osakwe (2003) [(38)], catalase and superoxide dismutase of cat fish decreased 7 days of exposure but increased 14, 21 and 28 days of exposure to 1% and 1.5% oil in water dispersion. The change which occurred from 14 to 28 days of exposure to water contaminated by oil is a clear indication that there is an enhanced ability of the body to produce antioxidant enzymes with time. Also, superoxide dismutase, catalase, glutathione S transferase and glutathione peroxidase of erythrocytes, testes and liver of rats exposed to hexane dione increased in dose dependent manner in response to increase in free radicals [(32)].

Ita and Udofia (2011)[(39)] reported increases in white blood cells, neutrophil and eosinophil counts in rats exposed to oral contaminants. High neutrophil counts may signify anti-inflammatory responses. Increase in eosinophil is associated with allergic responses. Furthermore, study by Igwebuike *et al.*,(2007)[(22)] showed an increase in total leucocytes count only at low dose of oral contaminant. Lymphocytes are the engines of body immunity and their increase at a low dose of contaminant indicates a conditional response.

Limitation of the Copy Strategies

Ingestion of contaminated water often results in mortality. Although there is little information on the total number of people that have died as a result of waterborne related conditions in Nigeria, there is increasing evidence that waterborne related problems have claimed the lives of many Nigerians. For example, In February 2016, 13 people were reportedly dead after consuming tainted water and food in Saburi, an Abuja Municipal community [(40)]. Outbreak of methanol poisoning claimed the lives of 23 people in Ayadi and Ode-irele towns of irele local government area in Ondo state between April 14 and 26 2015 [(41)]. More than often, outbreak of cholera, diarrhea and other waterborne disorders is characterized by death [(17,18,19)].

Conclusion

Water contamination affects the health status of the body. Increases in antioxidant enzymes such as superoxide dismutase and catalase, neutrophil and eosinophil counts and conditional increase in lymphocyte count are the adaptive responses shown in Nigeria. However, the coping strategies may not be sufficient to defend the body.

Conflict of Interest

Nil

References:

1. Guyton Arthur C. (1991). "Textbook of medical physiology", (8th edition), Philadelphia , Saunders, p.274
2. K Sembulingam, Prema Sembulingam (2005). "Textbook of Essential Physiology"(3rd edition), New Delhi, Jaypee Brothers Medical Publishers, P. 37.
3. Owa, F.D.(2013). "Water Pollution: Sources, Effects, Control and Management", *Mediterranean Journal of Social Sciences MCSER Publishing, Rome-Italy, Vol 4 No 8*
4. Akporhuarho. P.O. (2011). "Effect of Crude Oil Polluted Water on the Haematology of Cockerel Reared under Intensive System" International Journal of Poultry Science 10 (4): 287-289, 2011 ISSN 1682-8356.
5. National Bureau of Statistics. (2009). "Social Statistics in Nigeria". 399 p. http:// www.nigerianstat.gov.ng/ext/latest_release/ssd09.pdf.Accessed: 10/10/20116Koschy and Nayar 1999:
6. World Health Organization (2013). "World development indicators".
7. Ovuru, S.S. and Ekweozor, I.K.E. (2004). "Haematological changes associated with crude oil ingestion in experimental rabbits", Afr. J. Biotechnol. 3:346-348.
8. Weisenburger Dennis D.(1993). "Human Health Effect of Agrichemical Use", Human Pathology, 24(6) 571-576.
9. Indarto, D and Izawa, M. (2001). "Steroid Hormones and Endocrine disruptors" Recent advances in receptor-mediated actions, Yonago Acta Medica 44:1-6.
10. Raji Y and Hart V. O (2012). "Influence of prolonged exposure to Nigerian Bonny light crude oil on fertility indices in rats", *Niger. J. Physiol. Sci. 27(June 2012) 055 – 063 www.njps.com.ng*
11. Olatunji M. Kolawole Kolawole T. Ajayi Albert B. Olayemi and Anthony I. Okoh (2011). "Assessment of water quality in Asa river (Nigeria) and its indigenous *Clarius gariepinus* fish", 8(11) 4332-4352.
12. Nafarnda WD Ajayi IE, Shawulu JC, Kawe MS, Omeiza, Nasani GK, Tenuche OZ, Dantong DD, Tags SZ (2012). "Bacteriological quality of Abattoir effluents discharged into water bodies in Abuja, Nigeria", ISRN Vet Sci. 515689.
13. Dede, E.B, Igboh, N.M, Ayalogu, O.A (2002). "Chronic study of crude petroleum bonny light, kerosene, and gasoline using hematological parameters. J Applied Sci and Environ Mgt., 6(1): 60-66".
14. Orisakwe, O. E.; Akumka D. D.; Afonne O. J.; Gamaniel K. S. (2000). "Investigation into the pharmacological basis for folkloric use of Bonny light crude oil in Nigeria", Ind. J. Pharmac., 32, 231-34.
15. Magini Endurance J. "Effects of oil spillage on water quality/management in Emadadja, Udu Local Government Area, Delta state, Nigeria" http://naulibrary.org/dglibrary/admin/book_directory/thesis/10386.pdf

16. Haggstrom Mikael (2014). "Medical gallery of Mikael Haggstrom". Wikiversity Journal of medicine, 1(2).
17. Lawoyin T.O., Ogunbodede N.A., Olumide EA.A., Onadeko M.O. (1999). "Outbreak of cholera in Ibadan, Nigeria", Eur J. Epidemiol, 15(4) 367-70.
18. Igomu T. (2011). "Cholera Epidemic: Far from being over", NBF News Nigerian best forum.com/blog/?p=6060321.
19. Gyoh S.K. (2011). " Cholera Epidemics in Nigeria: an indictment of shameful neglect of government", 33(1) 5.
20. Raji M.I.O and Ibrahim Y.K.E. (2012). "Prevalence of waterborne infections in Northwest Nigeria: A retrospective study". Journal of Public Health and Epidemiology Vol. 3(8), pp. 382-385.
21. Oguwike F. N, Ebede S., Onubeze D.P.M, Offor C.C. (2014)."Effects of Petroleum and Crude Oil in the Gastrointestinal System of Male Roadside Mechanics in Enugu State, Nigeria", *IOSR* Journal of Dental and Medical Sciences (IOSR-JDMS) e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 13, Issue 10 .
22. Udensi Maduabuchi Igwebuike, Igwebuike Udensi Maduabuchi, Reginald Ikechukwu Obidike, Shodeinde Vincent Olumiya Shoyinka, Chioma Uchenna Nwankwo *et al.*, (2007). "Effect of Nigerian Qua Iboe brent crude oil on spleen and hematological parameters", Portal of scientific journal of Croatia, vol 77 No 3
23. Adegoke A.O., Bamigbowu M.I, George-Opuda, T.A. Awopeju and S.A. Braid (2012). "Effect of cassava based diet on some hematological parameters in albino rats fed petroleum contaminated diet", International Journal of Applied Research in natural product, 5(1)
24. Ita S.O. and Udofia U. A. (2011). " Comparative study of some hematological parameter following ingestion of crude oil (Nigeria bonny light), petrol, kerosene and diesel", Asian Journal of biological sciences, 4: 498-505
25. Azeez O.M., Akhigbe R.E., Anigbogu C.N., Ige S.F. and Saka W.A.(2012). "Variability in cardiovascular functions and baroreflex sensitivity following inhalation of petroleum hydrocarbon", Journal of cardiovascular disease Res., 3(2) 99-103
26. Levy and Papponi (2007). "Cardiovascular Physiology", 9th edition, Maryland Heights, Missouri, Mosby Elsevier, P. 379
27. Guyton and Hall (2006). "Textbook of Medical Physiology", 11th edition, Philadelphia, Elsevier Saunders,p.209
28. Ogechukwu Okoye Jude , Ngokere Anthony Ajuluchukwu, Ogenyi Samuel Ifedioranma and Onyemelukwe Anulika Obianuju. (2014). "Histopathological and hormonal disrupting effects of Escravos crude oil on the ovary of Chinchilla rabbits," Journal of Toxicology and Environmental Health Sciences, vol.6(2), pp.31-37
29. Adeniyi[1] M.J., M.Sc., S.F. Ige[2]M.Sc. W.J. Adeyemi[3]M.Sc., T.J. Oni[3] M.Sc., P.O. Ajayi[3] M.Sc., S.O. Odelola[1] M.Sc., V.T. Adegbola B.Sc[1]. (accepted 2015). "Changes In Body

Temperature And Intestinal Antioxidant enzymes In Healthy And Colitis Male Rats: Roles Of *Garcinia kola*, International Journal of Physiology", No 4032/IJOP/2015.

30. Farombi EO, Adedara IA, Ebokaiwe AP, Teberen R, and Ehwerhemuepha T (2010). "Nigerian Bonny light oil disrupts antioxidant systems in testes and sperm of rats", Arch. Environ.Cohtan.Toxicol.59(1): 166-74.
31. Azubike P. Ebokaiwe1, Isaac A. Adedara1, Olatunde Owoeye2, and Ebenezer O. Farombi (2013). " Neurotoxicity of Nigerian bonny light crude oil in rats", *Drug and Chemical Toxicology* ; 36(2): 187–195.
32. Adedara Isaac A., Abolaji Amos O., Odion Blessing E., Okwudi Isioma J., Omoloja Abiola A., Farombi Ebenezer O. (2014). "Impairment of hepatic and renal function by 2,5-Hexadione is accompanied by oxidative stress in rats", Journal of Toxicology,2014(2014), Article ID 239240, 9.
33. Ebokaiwe AT, Adedara IA, Owoeye O, Farombi EO, (2013). "Neurotoxicity of Nigerian bonny light crude oil in rats", Drug chem. Toxicology; 36(2) 187-95.
34. Orisakwe O. E, Akumka D. D, Njan A. A and Afonne O. J (2004). "Testicular toxicity of Nigerian bonny light crude oil in male albino rats", Reproductive Toxicology 18: 439–442
35. Adesanya, O. A., Shittu, L. A. J., Omonigbehin, E. A., Tayo, A. O. (2009). "Spermatotoxic impact of bonny light crude oil (BLCO) ingestion on adult male Swiss albino mice", International Journal of Physical Sciences Vol. 4 (5), pp. 349-353 *Niger. J. Physiol. Sci. 27 (2012): Raji et al Crude oil and fertility* 62
36. Nwafor A, Asiegbu L N, Adienbo MO and Mmom FC (2013). "Anti-fertility Activity of Ingestion of Nigerian Bonny Light Crude Oil Contaminated Feed in Male Rat Reproduction", A Possible Hypothalamo-Pituitary Axis Mechanism". America Journal of Research Communication. Vol 1(7)
37. Clin. Infect. Dis.(2007). "Cell-mediated immunity and antibody responses elicited by attenuated *Salmonella enteric serovar Typhi* strains used as live oral vaccines in human", 45 (supplement) S15-S19.Doi.10.1086/518140.
38. Achuba and Osakwe (2003). "Petroleum-induced free radical toxicity in African catfish (Clarius gariepinus)", Fish physiol. Biochem., 28 97-103.
39. "Tainted water, food kills 13 in Federal Capital Territory," Daily trust, Feb. 2016
40. "Methanol poisoning Death toll rises to 23 in Ondo", Thisday, 27 April 2015, Retrieved 2015 2015-04-28
41. DPR (1991). "Guidelines and standard for petroleum industry in Nigeria", The department for Petroleum Resources, the federal ministry of petroleum and mineral resources.
42. Azeez OM, Akhigbe RE and Anigbogu CN (2013). "Oxidative status in rat kidney exposed to petroleum hydrocarbon", Journal of Nat. Sci., 4(1) 149-154.