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Evaluation of health risk associated with consumption of food crops from electronic waste dumpsite using albino Wistar rat's model: Bayelsa state Nigeria case study

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Abstract

The alterations in some important health biomarkers associated with consumption of food crops harvested near E-waste dumpsite in Bayelsa State, Nigeria, was evaluated. Samples of soil, plant, water and sea foods were collected around E-waste dumpsites and control sites for laboratory screening. A standard animal feed was formulated (control group), and the feed formulated from plants harvested from e-waste dumpsites was used to feed the experimental animals (Test group) for a period of three months. The formulated feeds were screened for toxic metals using atomic absorption spectrometry. The study comprises of twenty-eight animals (fourteen each of male and female) of albino wistar strain, weighing 50-100g were divided into two groups of fourteen animals each. Health biomarkers such as C-reactive protein, TNF alpha, creatinine, alanine transaminase (ALT), aspartate transaminase (AST), alanine phosphatase (ALP), platelet count, and oxidative stress parameters were evaluated in both groups. Toxic metals content of samples collected from the E-waste dumpsite revealed significantly ($p<0.05$) higher levels of Cd, Co, Ni and Pb, which exceeded WHO permissible limits, compared with the control ($p<0.05$) site. Significant ($p<0.05$) differences between the test and control group for serum C-reactive protein, TNF alpha, creatinine concentrations, ALT, AST, ALP activities, platelet count, and oxidative stress parameters of the test group were all significantly ($p<0.05$) higher than the control group, suggesting the presence of oxidative stress trigger(s) among animals in the test group and these results were further affirmed by the histology results as presented. Conclusively, this study highlighted a strong correlation between consumption of food crops cultivated near E-wastes dumpsites and potential associated health risks. Hence, demands public awareness and a call on governments and concerned regulatory bodies to ensure and enforce ethical E-waste management and disposal practices to minimize E-waste exposure and toxicity.

Keywords: E-wastes; Wistar-rat; Toxic metals; Biomarker; oxidative-stress

1. Introduction

The emergence and production of electrical and electronic equipment (EEE) is one of the rapidly growing global manufacturing activities and fast economic growth, coupled with urbanization and a growing demand for consumer goods, has increased both the consumption and the production of EEE (Rames, *et al.,* 2007). The Indian information technology (IT) industry has been one of the major drivers of change in the economy in the last decade and has contributed significantly to the digital revolution being experienced by the world. New electronic gadgets and appliances have infiltrated every aspect of our daily lives, providing our society with more comfort, health and security and with easy information acquisition and exchange (Sinha, 2007). The knowledge society however is creating its own toxic footprints and the same hypertechnology that is hailed as a 'crucial vector' for future modern societal development has a not-so-modern downside to it and this is termed; electronic waste (e-waste) (Swerts, 2006). Electronic waste or E-Waste is the term used to describe old, end-of-life or discarded appliances using electricity in one form or the other

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which are destined for reuse, resale, salvage, recycling but most importantly disposal. It includes computers, cell phones (cell phone batteries), printers, fax machines scanners, MP3/CD players, cameras, washing machines, televisions (TVs), consumer electronics, fridges, medical equipment's etc, which have been disposed of by their original users or the repairers (WEEE and Monitor Recycling, 2009).

The increasing 'market penetration' in the developing countries, 'replacement market' in the developed countries and 'high obsolescence rate' make e-waste one of the fastest waste streams in developing country including Nigeria (Wankhede, 2005). This new kind of waste is posing a serious challenge in disposal and recycling to both developed and developing countries. While having some of the world's most advanced high-tech software and hardware developing facilities, India's recycling sector can be called medieval (Swerts, 2006). The dumping of e-waste, particularly computer waste, into India, China, Pakistan, Ghana and Nigeria from developed countries (Wankhede, 2005) ('green passport' according to Gutierrez (Harder, 2005), because the latter find it convenient and economical to export waste, has further complicated the problems with waste management especially in these countries with little or no technical expertise on how to manage this waste and its outcome. All these have made e-waste management an issue of environment and health concern especially in developing country like ours.

Electronic waste is made of a multitude of components some of which are toxic (lead, cadmium, mercury, beryllium, polyvinyl chloride and phosphor compounds) (Sinha, 2007) and have an adverse impact on the environment and human health if not handled properly and most often, these hazards arise due to the improper recycling and disposal processes used (Beary, 2008). It can have serious repercussions for those in proximity to places where e-waste is disposed, recycled or burnt. The health associate risk with lack of proper handling includes; toxic effects on various systems in the body such as the central (organic affective syndrome) and peripheral nervous systems (motor neuropathy), the hemopoietic system (anemia), damage to genitourinary system (capable of causing damage to all parts of nephron causing glomerular and tubular dysfunction) (Harrington and Baker, 2003). There is also evidence of carcinogenicity of various forms where data abound (Stewart and Kliehues, 2003) and other adverse effect on human health and environment (Rames *et al.,* 2007) due to the presence of hazardous compounds, and great care must be taken to avoid unsafe exposure in recycling or disposal operations and leaking of materials such as heavy metals and other toxic substances from landfills (Sinha, 2007). The soil contamination with heavy metals can be transferred to food crops and ultimately to consumers. For instance, plants accumulate heavy metals from contaminated soil without physical changes or visible indication, which could cause a potential risk for human and animal (Osma *et al.*, 2012). High industrial and traffic activities contribute high levels of heavy metals to the environments. Plants grown around such areas are likely to absorb these metals either from the soil through the roots or from atmospheric contaminants through the leaves (Fifield and Haina, 1997). This raises both immediate and generational concerns of the danger of electronic waste to the environment and humans (Rames, *et al.,* 2007). It's time to know the extent of harm and damage of e-waste in our respective communities and fine a rapid way of fixing the problem now. Thus, since such body of scientific information (scientific data on adverse health effects of e-waste) is scarce in Nigeria, this study is justified by the fact that it has established and added to the pool of information as per the heavy metals found in food crops grown around electronic waste dump sites.

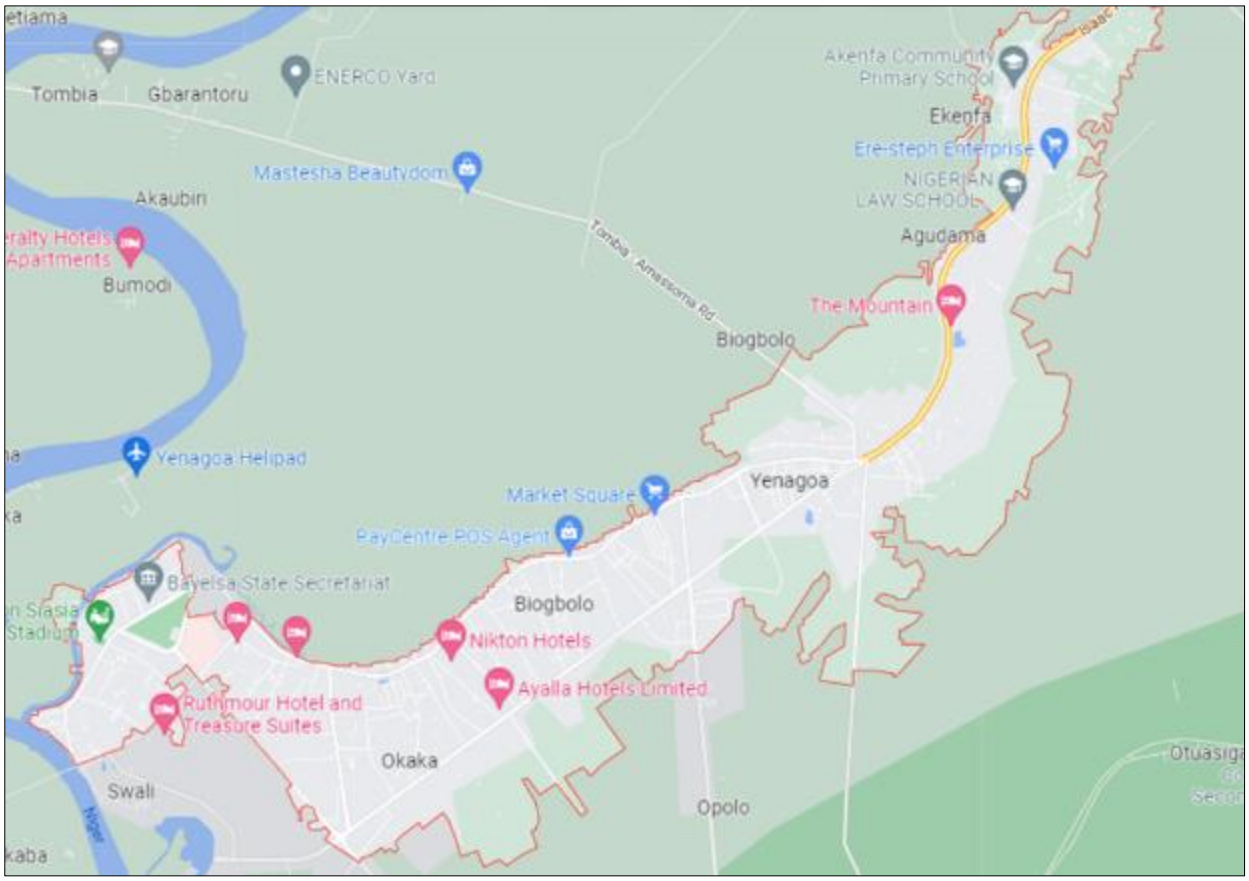
2. Material and methods

2.1. Study Area

The area selected for the study was Yenagoa, the Bayelsa State capital which is home to over 350,000 thousand people with hundreds of electronic equipment retail stores.

2.2. Sample collection

Questionnaires were designed on a four-linked scale and standardized. The questionnaires were randomly distributed to dealer and repairer of one or more form of electrical appliances stating how and where they dispose of end-of-life electrical appliances. The outcome from the questionnaires determined the specific sites in the above mentioned LGA where samples (soil, plant, water and sea foods) were collected for laboratory screening and after which the edible plants and some sea foods were obtained and prepared into feed which was used to feed the laboratory experimental animals for a period of three months.



Source: Google Map Data (2017).

Figure 1 Map of Yenagoa, Bayelsa state (Study Area)

2.3. Sample preparation

The plant samples (maize, fruited pumpkin, scent leaf) were washed with running tap water and rinsed with distilled water to remove sand and other possible contaminants. The leaves were cut into smaller piece with stainless steel kitchen knife and allowed to dry at room temperature (25 °C) alongside maize grains. Similar preparation process was applied to fish obtained from a nearby pond which was used as part of this study. The fish was oven dried at 45°C until a constant weight was obtained. The dried samples were pulverized, using a laboratory blender followed by sieving through a 0.5 mm mesh size sieve to obtain a fine powder but uniform particle size. Each plant sample was labelled and stored in polyethylene bags and stored at ambient temperature until when required for various analyses. The soil samples were also stored in well labelled polyethylene bags until required for analysis. The sample digestion method by Francek *et al.,* 1994 was adopted for the extraction of trace metals in the study.

2.4. Chemical characterization of the e-waste

The samples were screened for the presence of toxic metals such as; lead, mercury, Cadmium, nickel, copper, chromium, using a wavelength Perkin Elmer 1100 Atomic Absorption Spectrometer (Oxford Instrument, X-MET8000 series). Samples were oven-dried at 80°C for 18-20 hours. The soil, plants, water and fish samples were screened for the presence of heavy metals such as; Lead Chromium, Cadmium, Nickel, Coppers and Cobalt. Other toxic compounds assay for including; brominated flame retardant and dioxins were also assayed for using various standard laboratory methods as approved by the Association of Official Analytical Chemists (AOAC, 2013). Sample preparation and heavy metal analysis were conducted based on the standard method by American Public Health Association (APHA *et al., 1*999).

2.5. Experimental feed formulation

A standard animal feed was formulated from the powder of the above-mentioned materials. They were measured, mixed properly to obtain a homogenous mixture then constituted into a feed and the feed formulated from plants from farm around E-waste dumpsite was used to feed the animals in group B (Test group). Group A serves as control and were fed with commercial rat pellet. The formulated feeds contained maize as its main source of energy. Feed formulation was done using the method of Johnson *et al.*, 2022.

2.6. Experimental animals

Twenty-eight rats (fourteen each of male and female) of albino wistar strain, weighing 50-100g at the beginning of the experimental period were used for this study. The rats were obtained from the Department of Biochemistry, Faculty of Science, Niger Delta University, Amasoma, Bayelsa State Nigeria. The animals were allowed to acclimatize for a period of one week in the Department of Biochemistry, Federal University Otuoke, Bayelsa State animal house after which they were reweighed and housed in plastic cages with a wire-mesh bottom and top (North Kent Co. Ltd), under controlled environmental conditions of temperature (28±2^{0}C), relative humidity (50±5%) and 12-hour light/dark cycle. The facility was adequately ventilated.

2.7. Animal grouping and experimental protocol

The study comprised twenty-eight animals divided into two groups of fourteen (14) animals each per group (male and female). The normal control group (group A) was maintained on with commercial chow or pellet while the test group (group B) was placed on the feed formulated in the laboratory from plants, water and sea food (fishes) obtained around e-waste dumpsites, feed and water were provided *ad libitum.* The feeding schedule spanned to three months as shown in table 1 below.

Table 1 Experimental Design

Group	Type of feed	Number of animals	Duration
Normal Control (Male and female)	Formulated feed (NEWDS)	14	Three Months
TEST group I (Male and female)	Formulated feed (EWDS)	14	Three Months

Key: NEWS: Non E-Waste Dump Site, EWS: E-Waste Dump Site

2.8. Collection of blood and tissue samples for analysis

The animals were sacrificed twelve hours after the last day of feeding, whole blood was collected from the heart via cardiac puncture using sterile syringes and needles in accordance with guidelines of the European Convention for the protection of vertebrate animals and other scientific purposes ETS-123 (European Treaty Series, 2005). The blood samples were put into plain sample tubes. Serum was obtained from the clotted samples by letting it stands for 2 hours at room temperature to clot prior to centrifugation at 4000 rpm for 10minutes using MSE England bench top centrifuge. Sera obtained from each sample was gently separated using Pasteur pipettes and dispensed into respective dry specimen bottles labelled accordingly and were kept frozen in a freezer until needed for the various biochemical assays. The kidney, testes, ovaries were excised from the animals into sterile universal bottles with formaldehyde for histomorphological assessment.

2.9. Biochemical evaluation

All Biochemical investigations were done using standard methods with the aid of Randox kits and an AJ-Semi-Auto Biochemical Analyzer.

The estimation of Aspartate Aminotransferase (AST) and Alanine aminotransferase (ALT) activities was done using randox kits based on the method of Zoppini *et al.,* (2016), while catalase, Superoxide dismutase and glutathione peroxidase activities was determined by the method of Weydert and Cullen, (2010). Malondialdehyde concentration was estimated according to the method of Morales and Munne-Bosch (2019). Total Protein and albumin concentration was determined using randox kits based on the method of Tietz (1995) and Yu *et al.,* (2021) respectively. Serum creatinine level was determined using the method of Moore and Sharer (2017) while serum urea concentration was estimated by the method of Weatherburn (1967). However, the method of Tietz, (1976) was used to estimate the concentration of sodium, potassium, chloride, magnesium, bicarbonate in the serum.

2.10. Determination of haematological assay

Haemoglobin estimation, Pack Cell Volume (PCV) estimation was done using the method of O'Connor, *et al.,* (1994). More so, the estimation of total red blood cell, total white blood cells and differential white blood cell count was carried out as described Dacie and Lewis, (2012).

2.11. Histopathological examination

The principle is as presented by Drury and Wallington (2001) to examine the histology of the kidneys, testes, ovaries of rats in the control and test groups. Tissues fixed in 10% buffered formaldehyde were dehydrated via increasing concentration of ethanol (70, 90 and 95%).

FULGEN's staining technique was also adopted to specifically reveal some special features and thus pathologies in the kidneys, testes, ovaries like DNA etc. High powered photographs of the sections of the kidneys, testes, ovaries tissues were taken in bright field at X100 and X400.

2.12. Statistical analyses

Data obtained will be expressed as Mean ± SEM and analysis will be done using the Analysis of Variance 'ANOVA; f-ratio' (Welkowitz, *et al.,* 2006) and Statistical Package for Social Scientists (SPSS version 21.0), graph pad etc. Values at $P<0.05$ will be considered significant in comparison with appropriate controls.

3. Results

3.1. Result of renal function test

The results of the effect of feed formulated from materials obtained around E-waste dumpsite on renal function parameters are as presented in Tables 2 and 3.

3.1.1. Creatinine

Results revealed that CRT level of male animals in the test group (82.81 ± 1.1) was significantly ($p<0.05$) higher than that of the control group (56.74 ± 0.57). For the female animals, CRT levels of the test group (55.15 ± 1.35) was not significantly ($p>0.05$) different compared with that of the control group (54.66 ± 1.35).

3.1.2. Urea

Urea level of male animals in the test group (5.381 ± 0.02) was significantly higher ($p<0.05$) than that of the control group (3.11 ± 0.12). Urea levels of animals in the female test group (3.822 ± 0.03) was significantly ($p<0.05$) higher than that of the control group (2.75 ± 0.02)

3.1.3. Chloride

Chloride levels of male animals in the test group (89.842 ± 1.91) was significantly ($p<0.05$) lower than that of the control group (107.51 ± 1.19). More so, female animals Chloride levels for the test group (89.191 ± 2.01) was significantly ($p<0.05$) lower than that of the control group (102.46 ± 2.06)

3.1.4. Potassium (K)

Results showed that male animals in the test group (3.845 ± 0.02) showed no significant ($p>0.05$) changes in the potassium levels compared to the control group (4.21 ± 0.13). In the female group, potassium levels of animals in the test group (4.41 ± 0.06) were not significant ($p<0.05$) different compared with that of the control group (3.11 ± 0.05).

3.1.5. Sodium (Na)

Results showed that male animals in the test group (135 ± 2.54) were significantly ($p<0.05$) lower than control group (150.67 ± 1.01). In the female group, Sodium concentration of the test group (121 ± 2.60) was significantly ($p<0.05$) lower compared with that of the control group (141.60 ± 2.87)

3.1.6. Bicarbonate (HCO_3)

Male serum bicarbonate concentration of the test group (18 ± 0.42) was not significantly ($p>0.05$) different from that of the control group (19.46 ± 0.44). In the female group, the serum bicarbonate concentration of the test group (22 ± 0.28) was significantly ($p<0.05$) higher than control group (16.39 ± 0.21)

Table 2 Effect of feed formulated from plants obtained around E-waste dumpsite on male's renal function parameters

Group	CRT	UREA	Cl^-	K^+	Na^+	$HCO3^-$
A	56.74 ± 0.57	3.11 ± 0.12	107.51 ± 1.19	4.21 ± 0.13	150.67 ± 1.01	19.46 ± 0.44
B	82.81 ± 1.1*	5.381 ± 0.02*	89.842 ± 1.91*	3.845 ± 0.02	135 ± 2.54*	18.00 ± 0.42

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, CRT: Creatinine, Cl: Chloride, K: Potassium, Na: Sodium; HCO_3: Bicarbonate, * = Significant at P<0.05 compared with the control group

Table 3 Effect of feed formulated from plants obtained around E-waste dumpsite on female's renal function parameters

Group	CRT	Urea	Cl^-	K^+	Na^+	$HCO3^-$
A	54.66 ± 1.35	2.75 ± 0.02	102.46 ± 2.06	3.11 ± 0.05	141.60 ± 2.87	16.39 ± 0.21
B	55.15 ± 1.35	3.822 ± 0.03	89.191 ± 2.01*	4.41 ± 0.06	121 ± 2.60*	22 ± 0.28*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, CRT: Creatinine, Cl: Chloride, K: Potassium, Na: Sodium; HCO_3: Bicarbonate, * = Significant at P<0.05 compared with the control group

3.2. Haematological indices

The results of the effect of feed formulated from materials obtained around E-waste dumpsite on haematological parameters are as presented in Tables 4 and 5.

3.2.1. Haemoglobin (Hb)

The male haemoglobin level of the test group (12.50 ± 0.049) was not significantly (p>0.05) different when compared with the control group (11.80 ± 0.05) and similar pattern was also observed for the female group where the haemoglobin level of the test group (12.60 ± 0.05) was not significantly (p>0.05) different when compared with the control group (12.00 ± 0.05).

3.2.2. Packed Cell Volume (PCV)

The results shows that the male PCV level of the test group (48.00 ± 0.04) was not significantly (p>0.05) different when compared with the control group (46.00 ± 0.02) similar to the female where the PCV concentration test group (48.00 ± 0.026) was not significantly (p>0.05) different when compared with the control group (44.00 ± 0.01).

3.2.3. Red Blood Cells (RBC)

The male animal's RBC level of test group (7.00 ± 0.03) showed no significant (p>0.05) changes compared with that of the control group (6.44 ± 0.02). The female's animals RBC concentration of the test group (6.47 ± 0.01) was not significantly (p>0.05) different compared with the control group (6.31 ± 0.03).

3.2.4. MCV

The MCV level of male animals in the test group (68.50 ± 0.18) showed no significant (p>0.05) changes compared with the control group (71.90 ± 0.028). Similarly, female's animals MCV concentration of the test group (75.00 ± 0.17) was not significantly (p>0.05) different from that of the control group (70.40 ± 0.03).

3.2.5. MCH

Male animal's MCH concentration of the test group (17.80 ± 0.07) indicates no significant (p>0.05) different compared with control group (18.30 ± 0.08). Female animal's MCH level of the test group (19.50 ± 0.09) also showed no significant (p>0.05) changes compared with the control group (19.00 ± 0.09)

3.2.6. MCHC

Result of male's animals MCHC level of the test group (25.90 ± 0.10) was not significantly (p>0.05) different compared with the control group (26.50 ± 0.11). Female's animals MCHC level of the test group (26.00 ± 0.10) was not significantly (p>0.05) different compared with the control group (27.00 ± 0.10).

3.2.7. White Blood Cell (WBC)

The male's animals white blood cells count of the test group (16.40 ± 0.10) was significantly ($p<0.05$) higher than control group (8.80 ± 0.06) while the female's white blood cells count of the test group (4.10 ± 0.08) showed no significant ($p<0.05$) different compared with the control group (4.70 ± 0.08).

3.2.8. Platelets

The male's animals' platelets count of the test group (614.00 ± 10.56) was significantly ($p<0.05$) higher than control group (454.00 ± 8.61). Female animals' platelet count of the test group (545.00 ± 10.10) significantly ($p<0.05$) higher than control group (492.00 ± 9.56).

3.2.9. Lymphocytes

The lymphocytes count of male's animals in the test group (88.00 ± 2.01) was not significantly ($p>0.05$) different from the control group (84.00 ± 2.60). Similarly, female's animals' lymphocytes count of test group test group (83.00 ± 0.18) was not significantly ($p>0.05$) different from that of the control group (91.00 ± 2.10).

3.2.10. MXD

Male MXD level of the test group (6.00 ± 0.05) was not significantly ($p>0.05$) different from that of the control group (7.00 ± 0.06). Female MXD value of the test group (9.00 ± 0.40) was significantly ($p<0.05$) higher than control group (5.00 ± 0.06).

Table 4 Effect of feed formulated from plants obtained around E-waste dumpsite on male's haematological parametres

Group	Hb	PCV	RBC	MCV	MCH	MCHC	WBC	PLAT	LYM	MXD
A	11.8 ± 0.05	46 ± 0.02	6.44 ± 0.02	71.9 v 0.028	18.3 ± 0.08	26.5 ± 0.11	8.8 ± 0.06	454 ± 8.61	84 ± 2.60	7 ± 0.06
B	12.5 ± 0.049	48 ± 0.04	7.0 ± 0.03	68.5 ± 0.18	17.8 ± 0.07	25.9 ± 0.10	16.4 ± 0.10*	614 ± 10.56*	88 ± 2.01	6 ± 0.05

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, Hb: Haemoglobin, PCV: Pack Cell Volume, RBC: Red Blood Cell, MCV: Mean corpuscular volume, MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration, WBC: White Blood Cell, PLAT: Platelets, LYM: Lymphocytes, MXD: Mixed Cell Count, * = Significant at $P<0.05$ compared with the control group.

Table 5 Effect of feed formulated from plants obtained around E-waste dumpsite on female's haematological parametres

Group	Hb	PCV	RBC	MCV	MCH	MCHC	WBC	PLAT	LYM	MXD
A	12 ± 0.05	44 ± 0.01	6.31 ± 0.03	7.04 v 0.03	19 ± 0.09	27 ± 0.10	4.7 ± 0.08	492 ± 9.56	91 ± 2.10	5 ± 0.06
B	12.6 ± 0.05	48 ± 0.026	6.47 ± 0.01	7.05 ± 0.17	19.5 ± 0.09	26 ± 0.10	4.1 ± 0.08	545 ± 10.10*	83 ± 0.18*	9 ± 0.40*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, Hb: Haemoglobin, PCV: Pack Cell Volume, RBC: Red Blood Cell, MCV: Mean corpuscular volume, MCH: mean corpuscular hemoglobin, MCHC: mean corpuscular hemoglobin concentration, WBC: White Blood Cell, PLAT: Platelets, LYM: Lymphocytes, MXD: Mixed Cell Count, * = Significant at $P<0.05$ compared with the control group.

3.3. Liver function test

The results of the effect of feed formulated from materials obtained around E-waste dumpsite on liver function parameters are as presented on table 6 and 7

3.3.1. Total Protein

Male's animals' serum total protein concentration of the test group (76.925 ± 1.01) showed no significant ($p>0.05$) changes compared with that of the control group (65.00 ± 0.12). The female's animals' serum total protein concentration of the test group (75.589 ± 6.41) not was significantly ($p>0.05$) different from control group (67.61 ± 5.54).

3.3.2. Albumin

The results of the male serum albumin concentration of the test group (24.26 ± 0.10) were significantly ($p<0.05$) lower than that of the control group (41.00 ± 0.11). Female: The serum albumin concentration of the test group (30.00 ± 4.27) was significantly ($p<0.05$) lower than that of the control group (44.24 ± 2.51)

3.3.3. Globulin

The concentration of serum globulin of male's animals of test group (52.665 ± 0.30) was significantly ($p<0.05$) higher than control group (24.00 ± 0.10). The concentration of serum globulin of female's test group (45.589 ± 3.66) was significantly ($p<0.05$) higher than control group (23.17 ± 2.40).

3.3.4. Aspartate Transaminase (AST)

The serum activity of AST of male animals in the test group (38.24 ± 1.13) was significantly ($p<0.05$) lower than those of the control group (61.00 ± 1.41). The serum activity of AST of female animals in the test group (41.00 ± 4.30) was significantly ($p<0.05$) lower than control group (57.67 ± 5.20).

3.3.5. Alanine Transaminase (ALT)

The serum activity of ALT of male animals in the test group (13.01 ± 0.14) was significantly ($p<0.05$) lower than those of the control group (44.00 ± 1.16). The serum activity of ALT of male animals in the test group (90.00 ± 0.02) was significantly ($p<0.05$) higher than those of the control group (40.21 ± 3.20)

3.3.6. Alanine Phosphatase (ALP)

The serum activity of ALP of male animals in the test group (673.04 ± 5.61) was significantly ($p<0.05$) higher than that of the control group (70.00 ± 2.10). The serum activity of ALP of female animals in the test group (484.42 ± 12.64) was significantly ($p<0.05$) higher than control group (68.41 ± 4.52)

3.3.7. Total Bilirubin

The serum concentration of total bilirubin of animals in the test group (4.76 ± 0.14) showed no significant ($p>0.05$) different compared with that of the control group (5.30 ± 0.16). Female: The serum concentration of total bilirubin of animals in the test group Test group (5.23 ± 0.12) showed no significant ($p>0.05$) different compared with that of the control group (5.90 ± 0.14).

3.3.8. Conjugated Bilirubin

The serum concentration of conjugated bilirubin of male animals in the test group (1.231 ± 0.01) was significantly ($p<0.05$) lower than that of the control group (3.50 ± 0.04). The serum concentration of conjugated bilirubin of female animals in the test group (1.001 ± 0.01) was significantly ($p<0.05$) lower than that of the control group (3.60 ± 0.05).

Table 6 Effect of feed formulated from plants obtained around E-waste dumpsite on male's liver function parametres

Group	TP	ALB	Glo	AST	ALT	ALP	TB	CB
A	65 ± 0.12	41 ± 0.11	24 ± 0.1	61 ± 1.41	44 ± 1.16	70 ± 2.1	5.3 ± 0.16	3.5 ± 0.04
B	76.925 ± 1.01	24.26 ± 0.10*	52.665 ± 0.30*	38.24 ± 1.13*	13.01 ± 0.14*	673.04 ± 5.61*	4.76 ± 0.14	1.23 ± 0.01*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, TP: Total Protein, ALB: Albumin, Glo: Globulin, AST: Aspartate Transaminase (AST), ALT: Alanine Transaminase (ALT), ALP: Alanine Phosphatase, TB: Total Bilirubin, CB: Conjugated Bilirubin, * = Significant at P<0.05 compared with the control group

Table 7 Effect of feed formulated from plants obtained around E-waste dumpsite on female's liver function parametres

Group	TP g/l	ALB g/l	Glo g/l	AST iμ/L	ALT iμ/L	ALP iμ/L	TB μmol/L	CB μmol/L
A	67.61 ± 5.54	44.24 ± 2.51	23.17 ± 2.40	57.67 ± 5.2	40.21 ± 3.2	68.41 ± 4.52	5.9 ± 0.14	3.6 ± 0.05
B	75.589 ± 6.41	30.00 ± 4.27*	45.589 ± 3.66*	41.00 ± 4.30*	90.00 ± 0.02 *	484.42 ± 12.64*	5.23 ± 0.12	1.001 ± 0.01*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, TP: Total Protein, ALB: Albumin, Glo: Globulin, AST: Aspartate Transaminase (AST), ALT: Alanine Transaminase (ALT), ALP: Alanine Phosphatase, TB: Total Bilirubin, CB: Conjugated Bilirubin, * = Significant at P<0.05 compared with the control group

3.4. Acute phase protein

The results of the effect of feed formulated from materials obtained around E-waste dumpsite on acute phase protein are as presented on table 8 and 9

3.4.1. C-Reactive Protein (CRP)

The serum concentration of C-reactive protein of male animals in the test group (152.69 ± 26.47) was significantly (p<0.05) higher than that of the control group (15.05 ± 2.31). The serum concentration of C-reactive protein of female animals in the test group (201.53 ± 22.61) significantly (p<0.05) higher than control group (21.65 ± 4.10).

3.4.2. Tumor Necrosis Factor α (TNF-α)

The serum concentration of TNF- **α** of male animals in the test group (110.25 ± 7.13) was significantly (p<0.05) higher than that of the control group (39.46 ± 4.76). The serum concentration of TNF- **α** of female animals in the test group (191.88 ± 18.72) was significantly (p<0.05) higher than those of the control group (42.52 ± 5.89).

3.4.3. α-Fetoprotein

The serum concentration of **α**-fetoprotein of male animals in the test group (9.33 ± 1.56) was not significantly (p>0.05) different from the control group (6.78 ± 1.14). The serum concentration of **α**-fetoprotein of female animals in the test group (76.29 ± 10.96) was significantly (p<0.05) higher than that of the control group (4.11 ± 0.32)

Table 8 Effect of feed formulated from plants obtained around E-waste dumpsite on male's serum acute phase proteins

Group	CRP	TNF –α	α – Fetoprotein
A	15.05 ± 2.31	39.46 ± 4.76	6.78 ± 1.14
B	152.69 ± 26.47*	110.25 ± 7.13*	9.33 ± 1.56*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, CRP: C-Reactive Protein, TNF-α: Tissue Necrosis Factor Alpha,; * = Significant at P<0.05 compared with the control group

Table 9 Effect of feed formulated from obtained around E-waste dumpsite on female's serum acute phase proteins

Group	CRP (ng/ml)	TNF – α (pg/ml)	α – Fetoprotein
A	21.65 ± 4.1	42.52 ± 5.89	4.11 ± 0.32
B	201.53 ± 22.61*	191.88 ± 18.72*	76.29 ± 10.96*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, CRP: C-Reactive Protein, TNF-α: Tissue Necrosis Factor Alpha,; *: Significant at P<0.05 compared with the control group

3.5. Antioxidant parameters

The results of the effect of feed formulated from materials obtained around E-waste dumpsite on antioxidant parameters are as presented on table 10 and 11

3.5.1. Catalase

Result indicates that the serum activity of catalase of male animals in the test group (128.22 ± 11.31) was significantly ($p<0.05$) higher than that of the control group (80.74 ± 9.70). The female animals' serum activity of catalase in the test group (196.71 ± 14.61) was significantly ($p<0.05$) higher than that of the control group (86.85 ± 6.80).

3.5.2. Superoxide Dismutase (SOD)

Result showed that the serum activity of SOD of male animals in the test group (74.65 ± 6.81) was significantly ($p<0.05$) higher than that of the control group (31.47 ± 2.61). Female serum activity of SOD in the test group test group (60.11 ± 4.03) was significantly ($p<0.05$) higher than that of the control group (23.26 ± 2.23).

3.5.3. Malondialdehyde (MDA)

The serum concentration of MDA of male animals in the test group (51.83 ± 4.71) was significantly ($p<0.05$) higher than that of the control group (29.00 ± 2.57). Female serum concentration of MDA of animals in the test group (56.19 ± 5.81) was significantly ($p<0.05$) higher than control group (27.22 ± 3.14).

Table 10 Effect of feed formulated from plants obtained around E-waste dumpsite on male's serum antioxidant indices

Group	Catalase	SOD	MDA
A	80.74 ± 9.7	31.47±2.61	29.00±2.57
B	128.22±11.31*	74.65±6.81*	51.83±4.71*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, SOD: Superoxide Distmutase, MDA: Malondialdehyde, *: Significant at $P<0.05$ compared with the control group

Table 11 Effect of feed formulated from plants obtained around E-waste dumpsite on female's serum antioxidants indices

Group	Catalase	SOD	MDA
A	86.85 ± 6.8	23.26±2.23	27.22±3.14
B	196.71 ±14.61*	60.11 ±4.03*	56.19 ±5.81*

Values are expressed as Mean±Standard Error of Mean (SEM), n=7; Key: A: Control, B: Test Group, SOD: Superoxide Distmutase, MDA: Malondialdehyde, *: Significant at $P<0.05$ compared with the control group.

The heavy metals constituents of e-waste, soil and plants around e-waste dumpsite and the effect of feed formulated from materials obtained around e-waste dumpsite on biochemical parameters was studied and the results are presented in Table 12.

Table 12 Results of Heavy Metals Analysis for E-waste site Samples (Sampling location)

Sample/ Metal	Chromium (ppm)	Cadmium (ppm)	Nickel (ppm)	Copper (ppm)	Lead (ppm)	Cobalt (ppm)
Maize	0.0342±0.00	0.0456±0.00	0.8395±0.00	0.0924±0.00	0.0585±0.00	0.1226±0.00
Scent Leaf	0.0354±0.00	0.7942±0.00	3.8778±0.00	0.1147±0.00	0.0375±0.00	0.1149±0.00
Fluted Pumpkin	0.0333±0.00	0.7715±0.00	0.9272±0.00	0.0849±0.00	0.0588±0.00	0.1478±0.00
Soil	0.0267±0.00	0.5486±0.00	5.0367±0.00	0.0461±0.00	0.0471±0.00	0.1515±0.00
WHO	0.05	0.003	0.07	2.0	0.01	0.002

Values are expressed as Mean±Standard Error Mean (SEM)

3.6. Result of histology

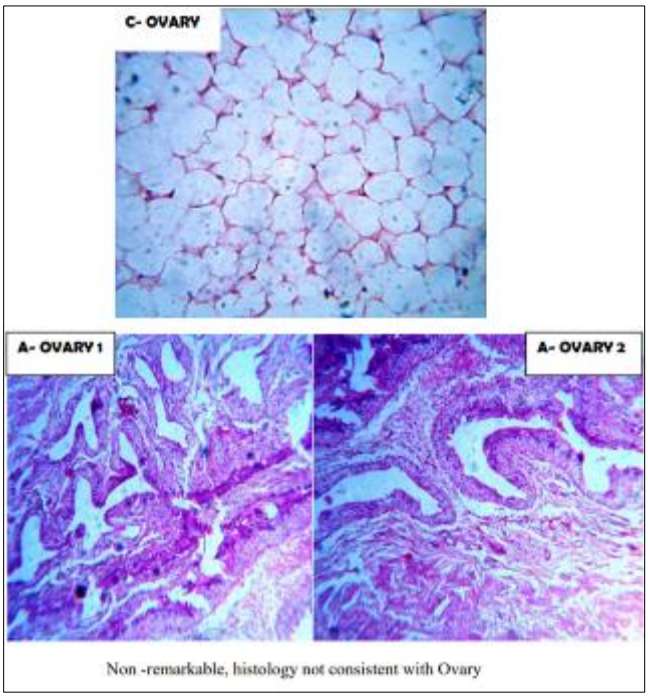
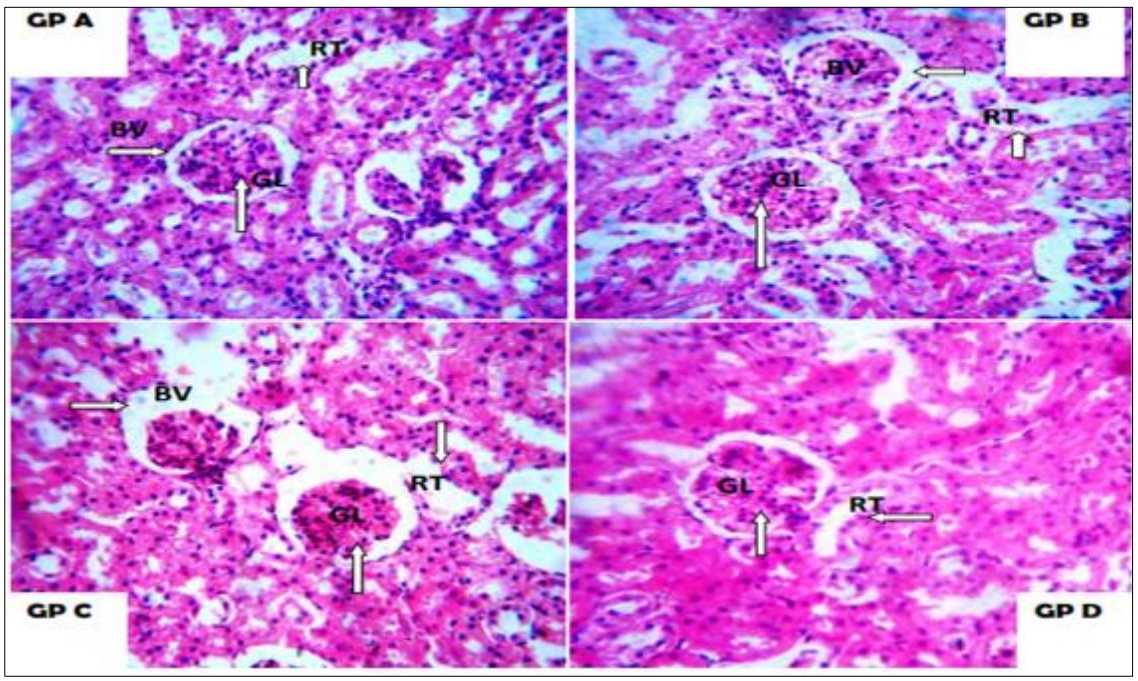


Figure 1 Transverse section of the ovary stained with haematoxylin and eosin ×400 Magnification



Conclusion: administered is toxic to the kidney; N/B: Causes of increase bowman volume include obesity, age and hypertension.

Figure 2 Transverse section of the kidney showing the cortex stained with haematoxylin and eosin ×400 Magnification. GP A and GP D shows the cortex displaying normal glomerulus (GL) with capillary tuft, renal tubules (RT) and bowman volume (BV). GP B shows mild dilation of the renal tubules with intact epithelium. The Glomerulus volume to the bowman volume is normal consistent with normal histology. GP c shows increase bowman volume with marked dilation of the renal tubules inconsistent with normal histology of the kidney

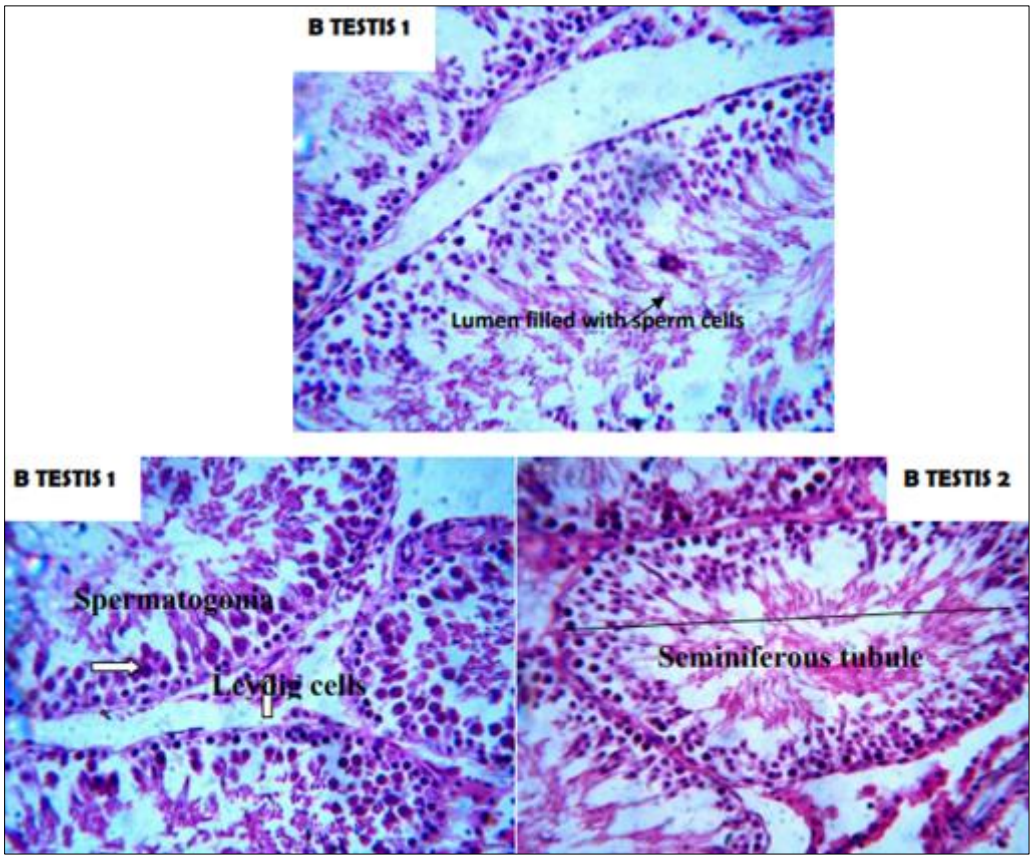


Figure 3 Transverse section of the testis stained with haematoxylin and eosin × 400 magnifications, Slide shows normal somniferous tubules with capsule lined by mature spermatogonia type A and B. Also seen is a company of Leydig cells within the interstitium

4. Discussion

This study aimed at evaluating the impact of e-waste contaminated environment on the food chain and consequently, to extrapolate the health risks/ trait it presents or possess using albino wistar rats' model where foods grown near E-waste sites were fed to experimental laboratory animals. Various health indicators were assayed for and their levels compared with a control group in order to ascertain the above stated effects alongside histological assessment of tissues. The results of our experiments revealed that the catalase, alanine transaminase, aspartate transaminase activities and serum sodium, malondialdehyde, acute phase proteins (C-reactive protein, alpha fetoprotein, TNF-alpha) levels of animals in the test group were significantly ($p<0.05$) different from that of the control. A study by Adias *et al.,* (2013); Bakare *et al.,* (2013) shows a similar significant ($p<0.05$) increase in CAT and SOD activities and MDA levels in mice fed with well water and leachate from e-waste sites when compared with the control. A significant ($p<0.05$) difference in ALT, AST and SOD activities in comparison with the control group was also observed in animals fed with e-waste contaminated leachate and well water (ground water). The significant change in values of the oxidative parameters may be linked to an onset of oxidative stress culminating from the intake of e-waste contaminated substances. The significantly ($p<0.05$) higher urea levels of the test group are suggestive of kidney function abnormalities possibly borne from e-waste exposure as some of the component chemicals/heavy metals of electronic waste are known to adversely affect kidney health. This seeming kidney dysfunction may be the reason for the significant ($p<0.05$) changes in kidney function parameters such as chloride levels, bicarbonate ($HCO3$) and potassium of the test group. Xiang *et al.,* (2022) observed elevated serum TNF alpha levels in children living in the e-waste polluted area compared to the children in the area without e-waste pollution. This study showed a correspondence between increased e-waste pollution and increased levels of the inflammatory cytokine, TNF α. The above study is concordant with our findings which presented significantly higher TNF α levels in both the male and female test groups in comparison with the control groups.

Platelets are major inflammatory cells with pivotal roles in innate and adaptive immune responses (Semple *et al.,* 2011; Vieira-de-Abreu *et al*., 2012). An increase in platelet count is associated with low grade inflammation and so platelet counts are a reliable marker of inflammatory responses as earlier reported by Adias *et al.,* (2013). A study by Dai *et al.*,

(2019) observed a similar pattern of higher platelet count values in children living in an e-waste polluted area whose data were compared to that of children living in an area without e-waste pollution. The significantly higher platelet counts in the test groups coupled with significantly ($p<0.05$) increased CRP levels in the same group; presents evidence of increased inflammatory responses in the animals since high CRP levels is also a known inflammatory marker. (Beneke *et al.,* 2012).

Our study showed a significant increase in creatinine and lymphocytes levels in the test group compared with the control group. This significant ($p<0.05$) increase in haemoglobin, lymphocytes and creatinine levels in an e-waste affected group was also recorded in a study by *Xu et al.,* (2015) where the effect of e-waste on residents of an e-waste dismantling area, were studied using some biomarkers including the aforementioned ones (creatinine, lymphocytes and haemoglobin).

5. Conclusion

Results obtained after laboratory assay and statistical analysis of samples from the group exposed to e-waste contaminated feed and the control group which was not exposed infers that e-waste exposure begets negative consequences on various physio-biochemical indices which are used as health markers. Many of the various bioindicators assayed for, exhibited significantly ($p<0.05$) different values from the control group which points to a shift from normal metabolism in the e-waste affected animals. Backed by other similar but isolated studies on the effects of e-waste on various living organisms, it can be concluded that electronic waste adversely affects the normal physiology/metabolism of body organs and systems such as; the immune system, kidneys and the liver.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of ethical approval

Ethical approval for this study was provided by Research and Quality Control Unit of Federal University Otuoke in line with guidelines of the European Convention for the Protection of Vertebrae animals used for experimental and other Scientific Purpose ETS-123.

This study adhered to all standard ethical practices as applied to this research.

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