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Histopathological transformation of tissues of guinea pigs fed with plants from four highway in parts of Obio/Akpor (Port Harcourt), Rivers State, Nigeria

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Abstract

The toxicity of air pollution has been proven to be the main threat to human as well as animals and it is associated with a lot of health risks. The outcome of vehicular emissions and anthropogenic activities on vegetation along four major busy highway (Aba road, Ikwerre road, East/West road and NTA road) with severe traffic density in parts of Obio/Akpor Local Government Area and a control (in Ozuguru, Ikwerre Ngwo) in Etche Local Government Area, Rivers State, Nigeria were studied. At each sampling location, four sampling points were ascertained. Eighteen guinea pigs were fed with the leaves of four test plants (Panicum maximum Jacq., Eleusine indica L., Xanthosoma mafafa Schott. and Amaranthus spinosus L.) to determine the effects of pollutants on their tissues (kidney and liver). The data obtained were analyzed statistically using descriptive statistics, one way analysis of variance (ANOVA). The result of the enzyme marker was observed that East/West road had the highest AST, ALP, ALT, GGT, urea and creatinine levels with values (84.67±2.2), (142.33±6.4), (72.67±0.9), (2.07±0.15), (37.67±1.76) and (3.1±0.12) respectively while NTA road had the least with values (71.67±0.88), (116.33 ± 2.91), (62.67±1.45), (1.63 ± 0.09), (34.0±0.58) and (2.5 ± 0.12) respectively. The enzyme markers from the exposed animals were higher than the reference values and their histopathological tissues revealed lysed tissues while the control and pretest group fell within the reference values and their tissues were healthy.

Keywords: Air pollution; Vehicular emissions; Enzyme markers; Histopathological tissues

1. Introduction

Air pollution is of global concern due to the risk it imposes on inhabitants (51). Air pollution can be defined as any substance that may cause damage to plants, humans, animals or materials (30). Polluted air is a major problem for dwellers in urban areas due to the quest for development which has led to the creation of more vehicles and factories that pollute the air and leaves it foul. Also, the increase in urbanization and industrialization together with the high purchase of vehicles and solid fuels have resulted to an ample disadvantage of air quality across the world (43). Nigeria is constantly exposed to outdoor air pollution emitted from both cars and heavy duty trucks, industrial plant sources, generators due to power failures (3). These pollutants are emitted as particulate matter and gaseous form (48). Also, they occur as dust particles and are very common in urban areas due to traffic congestions (42). Record has it that urban areas are known for excessive use of fossil fuels like solid fuels, petroleum and diesel gas and air pollution has been proven to impair visibility and disrupt traffic including air travels (2).

According to public health, the chemicals released as a result of air pollution is linked to lung and heart conditions as well as lung cancer (1). Report has it that higher air pollution levels and overcrowding are characteristics of urban populations (6) and these pollutants and other dangerous materials raise mortality and infectious illness risks.

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Consequently, there are several negative impacts on human health linked to exposure to these contaminants, such as vascular, neurological, cardiac, and pulmonary impairments (33). Also, urban dwellers frequently experience a number of ailments, such as respiratory issues and eye irritations (21). Thus, it is evident that the more dwellers in a given place, the higher the pollution and the higher the chance of developing ailments linked to air pollution (15).

Chronic kidney disease (CKD) is a severe problem in today's world (41, 35, 36). CKD occurs as a reduction in glomerular filtration rate (GFR< 60mL/min/1.73m^2) or observations of kidney damage like an unusual pathology (49). Chronic kidney disease is among the ten common reasons for death, and its victims have higher risks of dialysis and cardiovascular mortality. Particulate Matter (PM), a mixture of suspended solid and liquid particles in the air, is a normal pollutant with varying sizes and chemical composition (18). The rise in epidemiological findings implies that PM is a risk factor for chronic kidney disease (52). Findings have it that in the US, PM air pollution results in a decrease in GFR and is related to the widespread incidence of CKD (11, 12, 13, 39).

The susceptibility of the liver to toxins is so high due to its vital role in detoxification, which includes the processing of most drugs and chemicals that enter the bloodstream and the removal of chemicals that will not be easy for the kidney to excrete (29). The liver changes these chemicals into substances that can be removed from the body through urine or bile. Also, during this process in the liver, highly toxic and unstable bi-products are most times produced, and they can attack and injure the liver. The function of the liver in detoxification makes it very susceptible to toxins (20). The chemicals that cause damage to the liver are known as hepatotoxins, and hepatotoxicity is used to describe damaged liver by chemicals. Chemicals consumed or inhaled knowingly or unknowingly can result in the inflammation of the liver. Continual exposure to chemicals in the liver can lead to a genetic mutation that results in cancer (31). Some common chemicals that have been proven to cause cancer of the liver include arsenic, vinyl chloride, and herbicides. Toxic hepatitis can occur due to ingestion or inhalation of workplace chemicals, non-prescribed pain medication, herbs, alcohol, and prescribed medication (37).

Common causes of chronic liver disease and cirrhosis include alcohol-related liver disease, hepatitis C virus, chronic hepatitis B virus, and non-alcoholic fatty liver disease (40). However, heavy consumption of alcohol, non-alcoholic disease of the liver, and viral hepatitis are the major risk factors for liver disease worldwide (45). Current evidence shows that pollutants found in the environment (organochlorine, microcystins, aflatoxins, pesticides) aid in the development of liver disease. The use of pesticides have been connected to human cancers (9), and commercial farmers use these pesticides in farms, resulting in human exposure through the food consumed by humans (17, 44).

Reports abound showing that herbivores that consume these plant species are also eaten by humans, and the negative effect of these pollutants manifests in humans as food poisoning. Information on the effects of pollutants on roadside plants as they affect herbivores and their possible magnification along the food chain is largely lacking in the study area. This work exposed the health implications of consuming polluted plants/crops along the major roads of Obio/Akpor Local Government Area in Rivers State, Nigeria.

2. Material and methods

2.1. The Study Area

This research work was undertaken on four major roadsides (Aba Road, East/West Road, Ikwerre Road, and NTA Road), all in Obio/Akpor L.G.A, and a control site was established at Ozuguru in Ikwerre Ngwo in Etche L.G.A both in Rivers State Nigeria. East/West Road and Aba Road are the main Roads that link Rivers State to parts of Eastern, Western, and Northern States, which give rise to too many activities in the area. Several exhaust fumes emanate from cars and heavy-duty trucks, while Ikwerre and NTA roads are lesser traffic routes connecting residential areas and local roads. Ikwerre Ngwo (control site) is a rural area.

2.2. Sample Collection

Sampling was done in January and February 2023. The sample collection was placed between 6.30 am and 11.00 am. Four sampling stations were established on each road at a minimum distance of 1kilometre distance between each sampling station. Four plant species (*Zanthosoma mafia* (Schott), *Panicum maximum* (Jacq.), *Amaranthus spinosus*(L.), and *Elusine indica* (L.)) found within one hundred centimeters by one hundred centimeters of the experimental sites revealed equal environmental factors like temperature, light, and soil were collected. They were taken randomly from the same species of plants in the experimental sites and put in to create a composite sample. The test plants met the standard for selecting plant species as a biomonitor, which states that plant species must form more plant species over monitored sites without difficulty identifying the species (38). They were put into different well-labeled sterile

cellophane bags and moved quickly to the Department of Experimental Pharmacology and Toxicology animal house research unit, Faculty of Pharmaceutical Sciences, University of Port-Harcourt, Rivers State, Nigeria.

2.3. Experimental Animals

Eight-week-old 18 guinea pigs were purchased from the animal house research unit of the Experimental Pharmacology and Toxicology Department, Faculty of Pharmaceutical Sciences, University of Port Harcourt. Three among the 18 test animals were picked utilizing a randomized block design. Following their sacrifice and anesthesia with chloroform in a desiccator, their kidney and liver tissues, as well as blood samples, were used for an initial test to ascertain the level of enzyme markers in their blood and the effects of these heavy metals on the histology of the tissues of the guinea pigs. The target organs were removed with the aid of a surgical knife (23) while using a string; a heart puncture was used to obtain the blood samples. Using a randomized block design, the remaining 15 guinea pigs were divided into five distinct pens and given the appropriate labels (i.e., Aba Road, East-West Road, Ikwerre Road, NTA Road, and a control group). The test plants were fed to the animals (*Zanthosoma mafafa* (Schott), *Panicum maximum* (Jacq.), *Amaranthus spinosus* (L.), and *Elusine indica* (L.)) from the control location and several experimental sites every day for six weeks. They were then anesthetized using chloroform in a desiccator, sacrificed, and their tissues (kidney and liver) were taken to the Human Anatomy Laboratory for histology studies. The blood samples of the experimental animals were brought to an analytical lab to ascertain the enzyme markers of the experimental animals.

2.4. Histopathological Studies.

2.4.1. Fixation

After the guinea pigs were sacrificed, the tissues (livers and kidneys) were immediately taken to the histological laboratory at the Department of Human Anatomy, Faculty of Basic Medical Sciences, University of Port-Harcourt, for histological studies. They were fixed using formaldehyde for two days to preserve them in situ and prevent postmortem degeneration.

2.4.2. Dehydration

Firstly, the tissues were slowly put through the alcohol of ascending grades (i.e., 50% for two hours, 70% for two hours, 90% for two hours, 95% for twelve hours, and lastly, absolute alcohol (100%) for two hours). This was done to remove water in the tissues since water does not mix with paraffin wax. The purpose of passing them through increasing alcohol concentrations is to stop the water from abruptly rushing out of the tissues that will distort and damage the cell structures.

2.4.3. Clearing

The tissues were then infiltrated twice with xylene for one to two hours. Xylene is a clearing agent that replaces alcohol and is soluble in paraffin wax. This clearing agent (xylene) makes an opaque tissue transparent.

2.4.4. Embedding

The tissues were then set in paraffin wax that had been melted at a steady temperature of about 50-55 °C in an oven; they were changed twice for about two hours.

2.4.5. Block Making

With forceps, the tissues were immediately placed in unique L-shaped metal blocks filled with molten paraffin wax with the surface of the cutting facing downwards. The paraffin was allowed to cool to enable the formation of a thin scum of solid paraffin wax on the base of the metal blocks, after which they were immersed in water. The unique L-shaped metal blocks were removed after the paraffin wax had solidified. The paraffin block with the tissue inside it having the same consistency was thus ready for sectioning or microtomy.

2.4.6. Sectioning

An extremely thin section of the tissues, about 5 to 15 microns, was made with a rotary microtome with a sharp disposable microtomy blade. The sectioned tissues were put on the slide's center and flooded with a 10% alcohol solution; they were allowed to float in a warm water bath at a temperature of about 50-55 °C to remove the folds on the sections. Water was drained from the slide with tissue paper, and the slides were placed on a hot plate at about 40 °C before being transferred into a 37^0C oven.

Before staining the tissues, the paraffin wax was removed by placing the slides in xylene, which dissolved the paraffin wax, while the xylene was removed by alcohol because xylene is not miscible with water. Before the tissues were blocked, they were completely dehydrated; hence, the tissues were hydrated slowly before the application of aqueous stains. This procedure was done by passing the slides through descending grades (i.e., 95% for twelve hours, 90% for two hours, 70% for two hours, 50% for two hours) of alcohol and then finally to water.

2.4.7. Staining

The stains were then applied to the slides, and they were dehydrated again by being exposed to increasing levels of alcohol (i.e., 50%, 70%, 90%, 95%) and absolute alcohol (100%). Then, the section was cleared again in xylene and mounted on a suitable mounting media under a cover slip. Haematoxylin and eosin dyes were used to stain the sectioned tissues to make them conspicuous and give them contrasting colours for easier recognition (8). Haematoxylin dye stains the nucleus violet or blue, while eosin stains the cytoplasm pink.

Hence, the following processes were used for the staining of a paraffin section with haematoxylin and eosin:

- The slides were deparaffinized in xylene for 1 minute.
- They were then immersed in absolute alcohol for 30 seconds to 1 minute.
- The slides were then immersed in 90% and 70% alcohol each for 30 seconds.
- They were then rinsed in water.
- After that, the slides were placed in an aqueous hematoxylin solution for 5 to 30 minutes.
- For Bluing, the slides were washed under running tap water for 5 to 10 minutes until the section's colour became blue (when viewed under a microscope, the nuclei were stained blue).
- The slides were then put in 1% aqueous eosin for 30 seconds.
- They were rinsed in water for a few seconds. Otherwise, eosin stains would be washed off.
- The slides were then immersed in 70% alcohol and 90% alcohol for 30 seconds in each step.
- They were then immersed twice in absolute alcohol for 30 seconds in each step.
- After a minute of xylene clearing, the sides were cleaned, blotted, and mounted in DPX or Canada Balsam beneath a coverslip to prevent air bubbles from entering.

2.5. Determination of Enzyme Markers of the Experimental Animals

After the guinea pigs were anesthetized, their blood was put in lithium heparin bottles before being carried to the analytical laboratory to ascertain the enzyme markers. On arrival, the blood was centrifuged at 4000 revolutions per minute (rpm) for ten to fifteen minutes to separate the serum from the whole blood.

2.5.1. Aspartate Aminotransferase (AST) and Alanine Transaminase (ALT)

The test tubes were labeled blank, and test and 0.5 ml of reagent 1 were added into the test tubes with the aid of a pipette, and 0.1 ml of the serum was also added into the tubes appropriately. The test tubes were incubated at 37^0C for 30 minutes, then 0.5 ml of reagent 2 was pipetted into the test tubes and incubated at 25^0C for 10 minutes. After this, 5.0 ml of 0.4 moles of sodium hydroxide (NaOH) was added to the sample test tubes. The spectrophotometer (Surgifeild England model SD 23) was zeroed with the blank at 540nm. The results of their absorbance were read and recorded.

2.5.2. Alkaline Phosphatase (ALP)

The test tubes were labeled as test, blank, and standard; 0.5 ml of reagent 1 was pipetted into the test tubes, and 0.05 ml of the sample was also added into the test tubes appropriately. They were then incubated at 37^0C for 10 minutes before adding 2.5 ml of reagent 2 into the test tubes. They were allowed to stand for 10 minutes at room temperature. The spectrophotometer was zeroed at 590nm. The results of the absorbance were read and recorded.

2.5.3. Gamma-glutamyl transferase (GGT)

The test tubes were labeled test and blank, and 1.0 ml of the reagents were added to all the test tubes using a pipette. 0.1 ml of the serum was added appropriately to the test tubes. The spectrophotometer was zeroed at 405nm, and the results of their absorbance were read and recorded at 1, 2, and 3 minutes and calculated.

2.5.4. Creatinine

The test tubes were labeled test, standard, and blank. A pipette introduced 1 ml of the reagent to all the test tubes. 0.1 ml of the serum was added appropriately to the test tubes, and they were incubated at 25^0C for 10 minutes before being subjected to a spectrophotometer that was zeroed at 590nm. The results were read and recorded.

2.5.5. Blood Urea Nitrogen (BUN)

The test tubes were labeled standard, test, and blank. 0.1 ml of reagent 1 was pipetted into all the test tubes. Then, 0.01 ml of the serum was added to the appropriate tubes. The tubes were incubated at 37^0C for 10 minutes, after which 2.5 ml of reagents 2 and 3 were added to all the test tubes, and they were allowed to stand for 15 minutes. The spectrophotometer was zeroed at 540nm. Then, the absorbance was read and recorded.

2.5.6. Precision and Accuracy

Focusing the microscope at the low position mechanical level controls and coaxial coarse and fine focus controls maintained precise control of the specimen's movement. Its excellent focus was observed at angle 45^0 in the machined nosepiece.

2.6. Data Analysis

Using the SAS 2007 version 9.1 statistical program, the acquired data were statistically examined using descriptive statistics and one-way analysis of variance with multiple comparisons using the Least Significant Difference (LSD) at the 5% level of significance.

3. Results

The result of the concentration level of enzyme markers analyzed using the blood from the experimental animals is shown in table 1 below.

From the results, it was observed that the concentration of AST, ALP, ALT, urea and creatinine were higher in the blood of the animals fed with the test plants from East/West Road. The lowest was observed in the blood of the experimental animals fed with the test plants from NTA Road. The enzyme GGT fell within the reference range for guinea pigs.

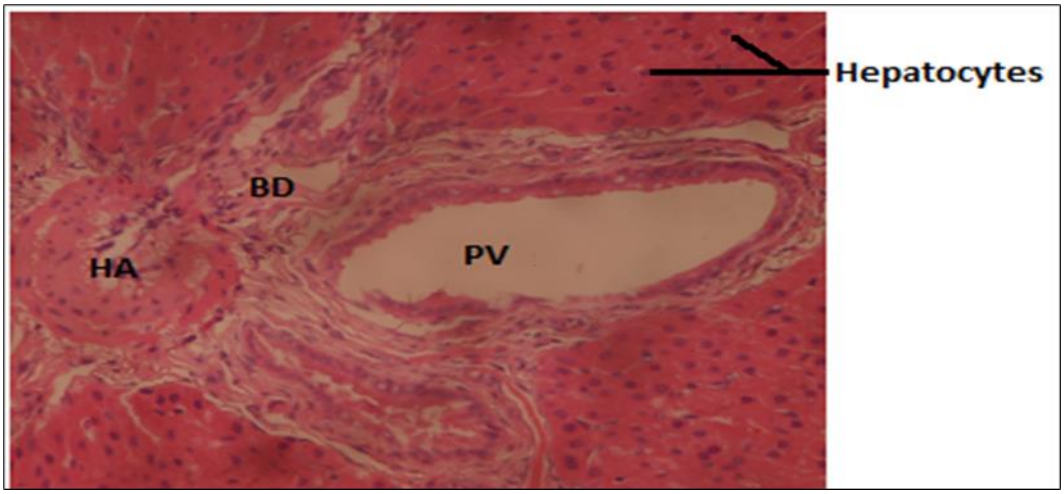
The concentration of the enzyme markers (AST, ALP, ALT, urea and creatinine) in the blood of the experimental animals fed with the test plants from the experimental sites were higher than the reference value for enzyme markers for guinea pigs while those fed with the test plants from the control site fell within the reference range for enzyme markers for guinea pigs.

The result for ALP showed no significant difference (P = 0.005) between the experimental sites. Also, the result for enzyme GGT showed no significant difference (P = 0.005) between the control and the pretest group.

Table 1 Level of Enzyme Markers in the Blood of the Experimental Animals

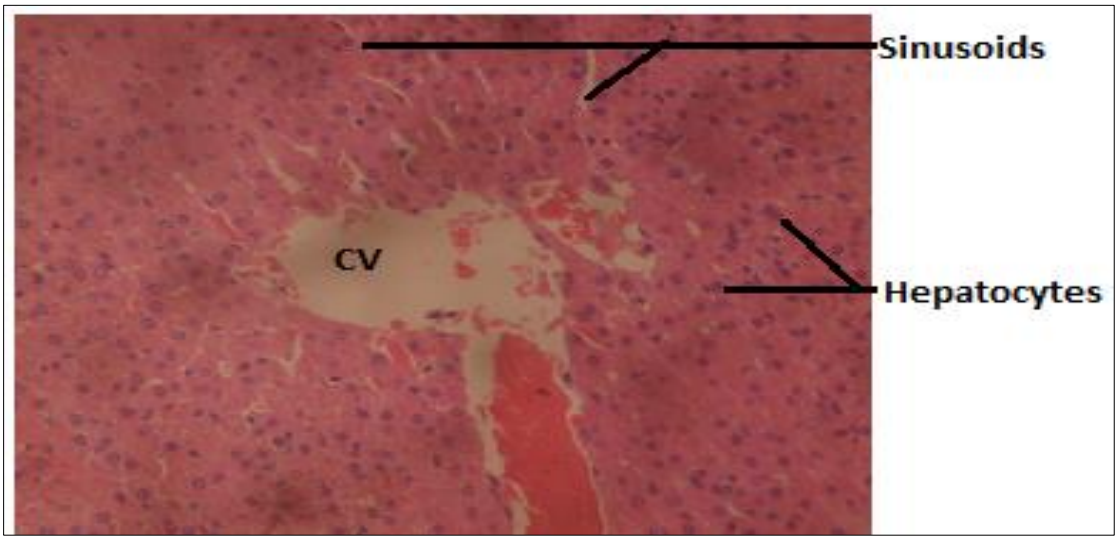
Enzyme Markers (IU/L)	Pretest	Control	Aba Road	East/West Road	Ikwerre Road	NTA Road	Reference Value
AST	40.67 ± 4.7^b	54.67 ± 4.3^b	78.67 ± 2.0^b	84.67 ± 2.2^b	72.67 ± 0.9^{ab}	71.67 ± 0.9^b	26 – 68
ALP	64.67 ± 4.1^a	80.0 ± 6.7^a	135.33 ± 6.1^a	142.3 ± 6.4^a	120 ± 3.2^a	116.33 ± 2.9^a	55 – 108
ALT	18.67 ± 1.2^c	29.67 ± 1.8^c	68.67 ± 2.3^c	72.67 ± 2.9^c	63.0 ± 1.2^{ab}	62.67 ± 1.5^c	10 – 59
GGT	0.16 ± 0.01^d	0.18 ± 0.02^d	1.9 ± 0.1^e	2.1 ± 0.2^e	1.67 ± 0.1^c	1.63 ± 0.1^e	9 – 32
Urea	15.33 ± 1.5^c	21.7 ± 2.0^c	36.0 ± 1.5^d	37.67 ± 1.8^d	34.3 ± 0.3^{bc}	34.0 ± 0.6^d	0.6 – 2.2
Creatinine	1.4 ± 0.2^d	1.7 ± 0.2^d	2.9 ± 0.1^e	3.1 ± 0.12^e	2.6 ± 0.1^c	2.5 ± 0.1^e	
LSD	8.137	10.553	8.778	9.509	4.519	4.301	

Row means ± standard errors with the same letters are not significantly different at a 0.05 significance level. Source for reference value: www.ahu.umn.edu/rar/refvalues.html



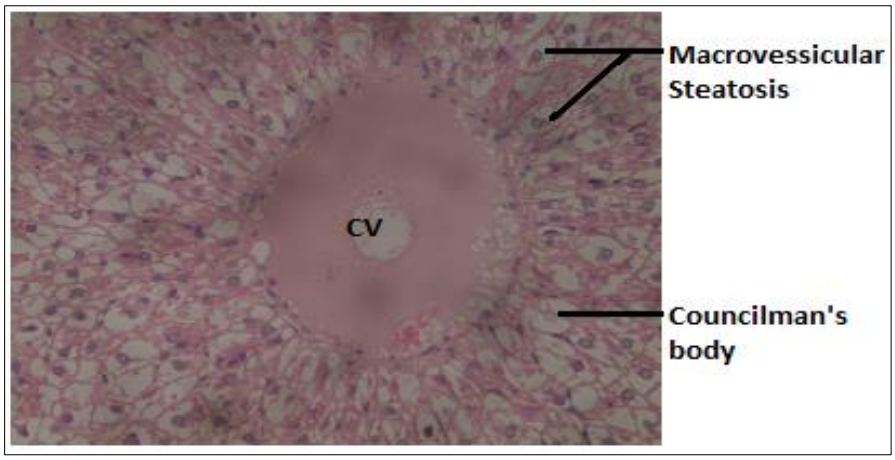
A. Portal triad: Portal Vein (PV), Hepatic Artery (HA), Bile duct (BD); B. Hepatocytes: Normal; C. Hepatic sinusoids: Normal; Impression: Normal

Figure 1 Pretest of liver X 400



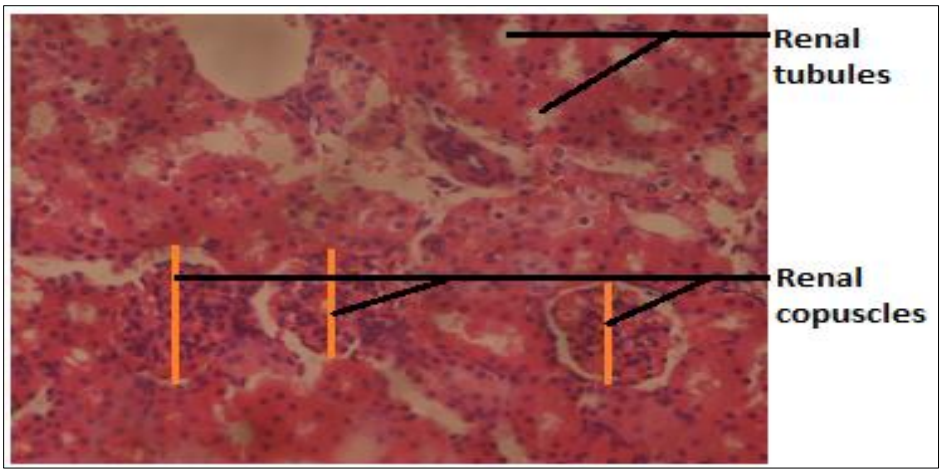
Hepatocytes: Normal; Central Vein (CV) ; Impression: Normal study

Figure 2 Control for liver X 400



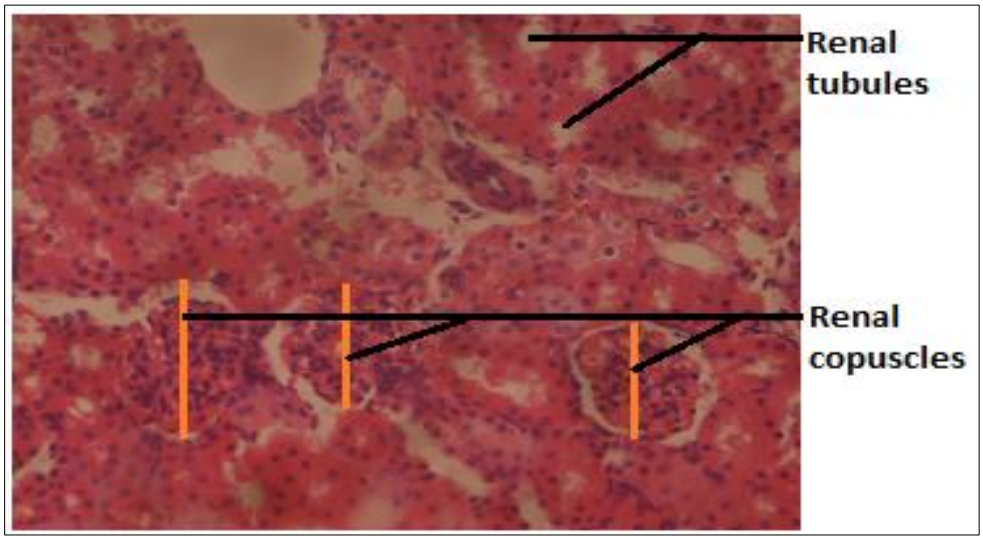
Central Vein (CV): Cloudy; Hepatocytes showing macrovesicular steatosis and councilman's body; Impression: severely damaged liver.

Figure 3 Exposed Guinea Pig (liver) X 400



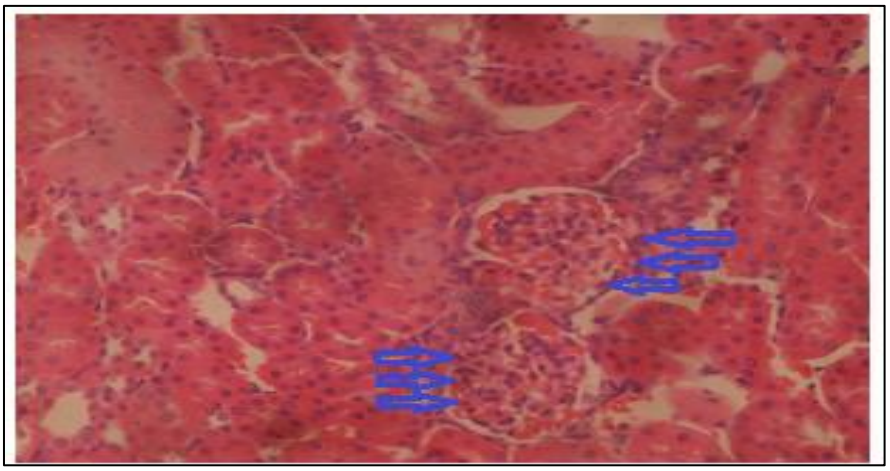
Renal tubules: Histologically good; Renal corpuscles: glomerular is normal, and bowman's capsule patent; Impression: Normal studies.

Figure 4 Pretest for kidney X 400



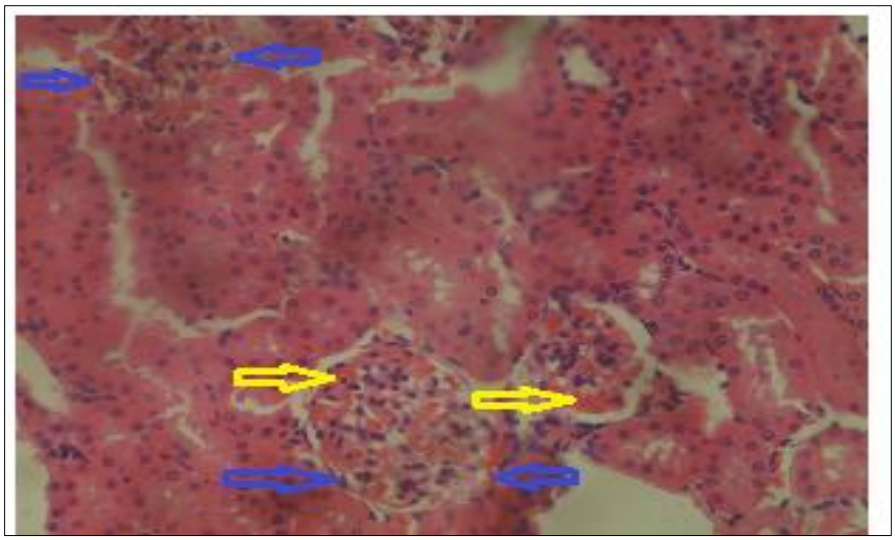
Renal tubules: Histologically good; Renal corpuscles: glomerular is normal, and bowman's capsule patent; Impression: Normal studies

Figure 5 Control for kidney X 400



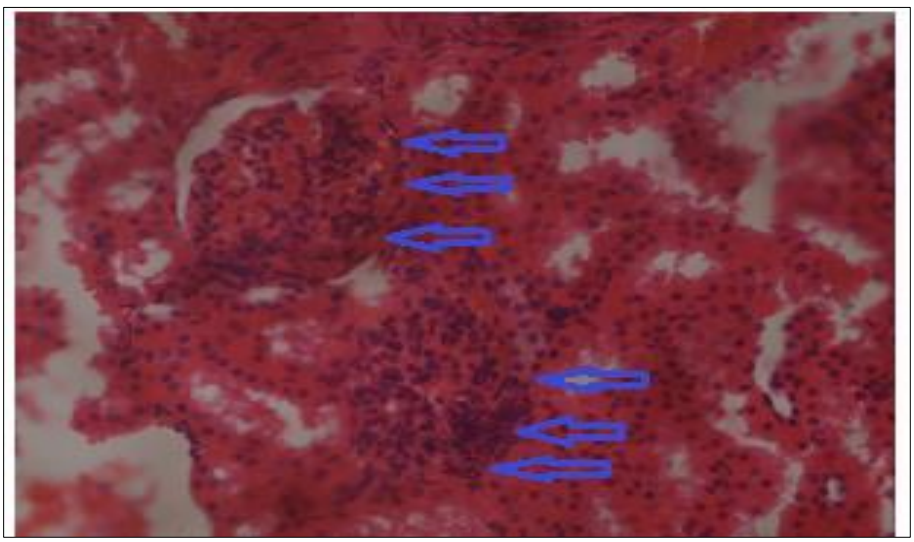
Renal tubules are histologically normal; Renal corpuscles: The capsular spaces are obliterated (blue arrow), and there are brownish deposits in the glomerular tufts; Impression: distorted kidney.

Figure 6 Exposed (kidney) X 400



Renal tubules are histologically normal; Renal corpuscles: Glomerular capsular spaces are obliterated (blue arrow), and there are brownish deposits in glomerular tufts (yellow arrows); Impression: distorted kidney.

Figure 7 Exposed X 400



Renal tubules are in good condition.; Renal corpuscles: glomerular capsular spaces occluded (blue arrow), and the tufts are hypercellular; Impression: distorted kidney.

Figure 8 Exposed X400

4. Discussion

In this study, the histopathological features of the tissues of the guinea pigs fed with polluted plants from different experimental sites were assayed using laboratory protocols to ascertain the integrity of the liver and kidney of the exposed animals relative to the exposure of polluted plants. One of the usual trends observed with liver function impairments is increased plasma activities of AST and ALT as markers of hepatocellular damage (28).

The studies conducted on the tissues (livers and kidneys) of the experimental animals revealed healthy tissues (figures 1, 2, 4, and 5) for the pretest and control groups. The livers from the pretest and control animals revealed healthy portal vein (PV), healthy hepatic artery (HA), healthy bile duct (BD), normal hepatocytes, and normal hepatic sinusoids, giving an impression of a healthy liver (figures 1 and 2). Nevertheless, the liver from the exposed animals (figure 3) fed with plants from the experimental sites revealed a cloudy central vein (CV), hepatocytes (liver cells) showing macrovesicular steatosis, and councilman's body. The whitish parts show that the nucleus in the cells has been extruded and replaced

with fat, giving an impression of a severely damaged liver. This study agrees with the findings that have it that exposure to organochlorine, especially dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenyldichloroethylene (DDE), causes liver tumors and hepatocellular carcinoma development in rodents (17, 19, 26). The histological features of the kidneys from the pretest and control group revealed healthy renal tubules, normal glomerular, and patent bowman's capsules. This result gives an impression of a healthy kidney (figures 4 and 5). Whereas the histological features of the kidney from the exposed animals fed with plants from the experimental sites revealed abnormal renal tubules, obliterated capsular spaces, brownish deposits in glomerular tufts, occluded glomerular capsular spaces (figures 6, 7, and 8), giving an impression of distorted kidneys. These findings agree with the studies that say that renal injury like hypertension, diabetes mellitus, and many environmental chemicals have been discovered to be major risk factors for renal injury (4, 33, 46, 47, 54).

5. Conclusion

Plants which make up human and animal diets get contaminated when in contact with polluted environmental media such as soil, air and water. These contaminants when ingested by animals cause deposition of residues in their tissues (5). The outcome of air pollutants in tissues of animals is of great interest for both human health and food safety due to its detrimental effects and poses a serious threat to life as they are passed to human and animals through food and other paths (7).

Therefore, it is vital to prevent the cultivation of plants, food crops, sales of fruits and vegetables, and grazing of farm animals along major roadsides. Cattle rearers should also inculcate the habit of siting their rangeland and ranches far off major or busy roadsides and also stop roadside grazing of farm animals. This will help control and reduce the diseases that might arise from the consumption of contaminated plants.

Significance Statement

This work revealed the risks associated with the consumption of heavy metal contaminated plants along major roads in parts of Obio/Akpor Local Government Area in Rivers State. It also exposed the adverse effects of heavy metal contaminated plants in the tissues of guinea pigs.

Compliance with ethical standards

Disclosure of conflict of interest

There was no competing of interest.

Statement of ethical approval

All applicable international, national and institutional guidelines for the care, handling and use of animals were followed.

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