ISSN 2581-3463

AJMS
Asian Journal of Mathematical Sciences

REVIEW ARTICLE

# Determination of the Concentrations of Some Persistent Pollutants in Locally Brewed Alcohol *(Burkutu)* in Some Selected Local Government Areas of Adamawa State, Nigeria

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**Received: 02-02-2018; Revised: 10-03-2018; Accepted: 01-04-2018**

## ABSTRACT

*Burkutu*, a locally brewed alcohol obtained from five Local Government Areas of Adamawa State, namely Hong, Song, Yola North, Numan, and Ganye, was examined for the presence and levels of some residues of the pesticides dichlorodiphenyltrichloroethan (DDT), endosulfan, and lindane by high-performance liquid chromatography. The results showed that the *Burkutu* obtained in Song Local Government Areas has the highest concentration of DDT (4.1825 mg/dm$^3$), endosulfan (3.8320 mg/dm$^3$), and lindane (2.1510 mg/dm$^3$) compared to the other areas studied. The findings of this research work showed the presence of these persistent pollutants in all the *Burkutu* samples examined and may be attributed to the sources of water used for the local brewed. The agrochemical used on form produce during storage, mineralogical content, and soil texture, and also some can be traced down to the sorghum used which is the raw material used processing *Burkutu*. Therefore, the potential for its presence in the *Burkutu* is serious health risks, which is alarming and depict a threat to public health.

**Key words:** *Burkutu*, concentration, Nigeria, pesticide pollutants

## INTRODUCTION

When used, the pesticides are spread to all plant parts and the remaining waste load depends on the crop characteristics, its tissues, as well as the physicochemical properties of the substances. If the application is carried out in the foliage, for example, the dissipation of waste occurs more quickly as compared with the application in fruits.[1,2] Establishing continuum monitoring programs of pesticide waste in food for several consecutive years make it possible to know the profile of the existing waste and manage quality assurance, focusing on the education of farmers, control of selling pesticides, integrated pest management, and increase in organic farming. Waste management programs have been continuously applied in foods of plant origin, animal origin, grain cereals, and infant food in many countries.[3-5]

*Burkutu* is vinegar-like flavored alcoholic beverage prepared by steeping sorghum grains in water overnight, following which excessive water is drained. The grains are then spread out onto a mat or tray, covered with banana leaves, and allowed to germinate. During germination process, the grains are watered on alternate days and turned over at intervals. Germination continues for 4–5 days, following which the dried malt is ground into a powder. Sweet potato starch or raw grain starch is added to a mixture of ground malt and hot water in a ratio of one-part sweet potatoes to two-part malt and six-part water to form sweet liquid wort. The resulting mixture is allowed to ferment for

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2 days, boiled for approximately 4 h and allowed to mature for 2 days. The resulting product was a cloudy alcoholic beverage. The alcohol contents of *Burkutu* range from 3% to 8%. It is widely consumed in West Africa most especially North Eastern part of Nigeria, Adamawa State by the Bwachama/Mbula, Chamba, Yungur, Lunguda, Kilba, Highi, Marghi, and Fulani tribes within the state during occasions such as festivals, wedding, burial, farming, and daily, most especially the one produced on commercial basis. During the 1950s and 1960s, there was an enormous increase in the use of chemicals in agriculture, industrial manufacturing and around the home. Dichlorodiphenyltrichloroethane (DDT) was used to remove lice and control mosquitoes, and other pesticides were used to kill insects and control weeds in an effect to improve crop yields.[6-9] During the 1970s, we began to appreciate that even a small dose can harm sensitive individuals. In "Silent Spring," Rachel Carson sounded one of the first alarms about the effects of environmental contaminants.[10] Humans, being at the top of the food chain, accumulate DDT in fat; fat is mobilized during lactation, and mothers who breastfeed pass along the DDT to their infants, who receive a large dose due to their low weight. Many of the early pesticide and certainly the metals do not break down in the environment or do so only very surely. If persistent chemicals are released continually to the environment, the level tends to rise ever higher. The chlorinate pesticides accumulate in the fat of animals, with animals higher in the food chain accumulating more and more of these pesticides. Most species cannot metabolize or break down the compounds: Lead (Pb) accumulates in bone and methylmercury ($CH_3H_g$) in muscle. Moreover, finally, due to their persistent in the environment and accumulation in various species, the persistent toxicants spread around the world, even to places that never used them. Animals at the top of the food chain, such as polar bears and beluga whales, routinely have fat polychlorinated biphenyl (PCB) levels >6 ppm even though these animals live far from where PCB was used or produced.[10]

The relevance of *Burkutu* to some inhabitants of Hong, Song, Yola-North, Numan, and Ganye Local Government Areas of Adamawa State cannot be overemphasized, as such, there is need for the awareness of the persistent pollutant present in the locally brewed alcohols (*Burkutu*) and health effects caused by these pollutants when is consumed. Several studies have being carried out to indicate the general taste and effect of alcohol to the human system but it is scarcely on *Burkutu*. On June 8 and 20, 2015, 8–35 people were killed aftermath of taking alcohol in Cross River State of Nigeria and India, respectively. Some reports were traced down to the chemical constituents present in the alcohol, for example, methanol which are the simplest form of alcohol. It is closely related to ethanol, the alcohol normally found in beer, wine, and spirits - but much more toxic. The potential for its presence in drinks made from home - distilled spirits is a serious health risk. Since the people of Adamawa State are more or less inclined to the consumption of locally brewed beer popularly called *Burkutu*, the need to study the chemical pollutants present in the beer cannot be overemphasized. The people of the state are distinct for the consumption of locally brewed alcohol (*Burkutu*) for a long time ago, the major defense was on their culture and as a man in those days, if you do not drink *Burkutu*, and you are considered as a weakling or not man enough. However, no conclusive research was carried out to determine the concentration of the persistent pollutant present in the *Burkutu*, most especially when it is ready for consumption, some of the guinea corn which is the raw material used for processing *Burkutu* is stored using agrochemicals to prevent it from pest and the containers such as drums and calabash used changes color with time and it serves as a breeding site for microbial growth which dissolves into the beer and leads to various diseases such as liver cirrhosis, cancer, skeletal fluorosis, kidney effects, and heart disease. Furthermore, the method of production of the *Burkutu* is pollution itself. Therefore, in this regard, an attempt to analyze the concentration of persistent pollutants found in *Burkutu* of five different Local Government Areas of Adamawa State was carried out to identify and know the concentration of the persistent pollutant present in the locally brewed alcohol (*Burkutu*).

## MATERIALS AND METHODS

### Sampling

The main purpose of sampling was to collect the sample of interest to represent the whole (bulk) sample of *Burkutu* needed for analysis. The *Burkutu* of interest was collected such that their quality represents the overall quality of the samples in question. Extra precaution was taken during

sampling to obtain samples representation of the whole area studied. The container that was used to collect the samples was 10 glass bottles of 1.7 L each for *Burkutu*. The sampling bottles were washed and rinsed with distilled water and the *Burkutu* to free it from impurities using sample handling techniques, especially designed for the collection of sample for the assessment of the persistent pollutants at trace levels. The samples were preserved by the addition of 5 ml of pretested 10% $HNO_3$/1.7 L of sample, depending on the time between sample collection and arrival at the laboratory.

## Samples and sampling areas

Samples of guinea corn were selected and obtained from the various Local Government Areas taking into account the requirements for the preparation of the brews. This information was obtained from the people who process and sell the brews. A sample raw material was obtained from marketplaces nearest to the beverage sampling stations. The sampling area was five Local Government Areas within Adamawa State, that is, Hong, Song, Jimeta-Yola, Numan, and Ganye, respectively, where they produce and sell locally brewed alcohol [Figure 1].

## Instruments

The samples of interest were determined for pesticide residues in locally brewed alcohol (*Burkutu*) using high-performance liquid chromatography (HPLC). The method for the collection, preservation, and analysis of the brews was adopted according to William.[11]

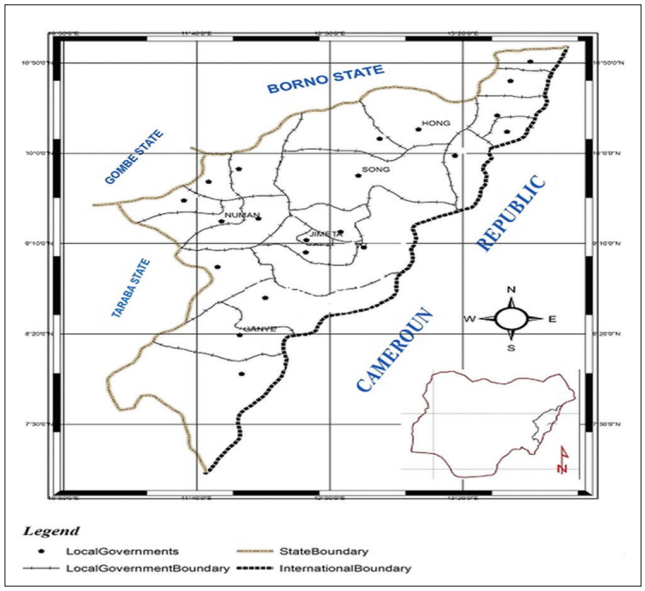


**Figure 1:** Map of Adamawa state and the study area

## The extraction of pesticide residues

Water and acetonitrile were HPLC grade; analytical grade dimethylformamide and anhydrous sodium sulfate were obtained from Fischer-Scientific. Acetic acid and sodium acetate from Merck were used for sample preparation. Analytical grade pesticide standards were obtained from Sigma-Aldrich. A standard mix solution was prepared from the individual stock solution to yield 10 mg/ml. The acetate buffered sample preparation method for pesticide was applied to all samples. 50 mg samples were homogenize with 100 ml acetonitrile. Then, 10 g of sodium chloride is added to it. Then, 6 g $NaSO_4$ were added to absorb moisture and shaken well. The extract was centrifuged at 5000 rpm for 6 min. Pesticide was eluted with 20 ml acetonitrile. Sample was concentrated using a rotary evaporator.

## Experimental procedures

The brew samples bottle (acid washed 1.7 L) was rinsed 3 times before sampling. It was filled approximately $^2/_3$ full, tight cap and freeze cruise. The sample bottles numbered were according to their Local Government Area and data sheet. All the brew sample bottles were rinsed first with the alcohol for alcohol samples before the brew samples were collected. 50 ml of the *Burkutu* sample was poured into a kadjiel flask, HCL, and nitric acid in 1:3 ratios were added to the 50 ml of the *Burkutu* sample. The mixture was wet digested at 100°C for 1 h. The mixture reduced and 5 ml of nitric acid was added, boiled for 15 min; then, it was allowed to cool and 5 ml of peroxide was added to the mixture and a clear solution was obtained. The mixture was transferred to 1000 cm volumetric flask and distilled water was added to the mark. 50 ml of the clear solution was transferred into a cuvette and labeled according to the Local Government Area it was obtained from afterwords taken for analysis. The same procedure was repeated for all samples to be analyzed for metals. Using the WinLab32 software for atomic absorption spectrometer, the method window was opened and a method was created, these include feeding the information in relation to the sample unit of measurement, replicate of analysis, delay time, etc., the information was

saved. After measurement of the standard and the blank samples were individually introduced to the equipment through the nebulizer into the flame, the measure icon was clicked, and after few seconds, the result was displayed in mg/L through result window.

### HPLC condition

Analytical Technologies 3000 series HPLC having UV/visible detector was used for identification and quantification of pesticides. Separation was performed on C18 (4.6 ID × 250 mm) column. Samples were injected manually through Rheodyne injector. Detector was connected to the computer for data processing. The working condition of HPLC was binary gradient, mobile phase was acetonitrile: water (70:30), flow rate was 0.8 ml/min, injection volume was 20 µl, pressure was 6–7 MPa, and the wavelength of the detector was fixed at 254 nm for the residual analysis of three pesticides endosulfan, carbendazim, and chlorpyrifos.

### Data analysis

The data collected were subjected to statistical analysis using simple descriptive statistics and one-way analysis of variance and *t*-test analysis.

## RESULTS AND DISCUSSION

The result for the determination of pesticide residues analyzed using the instrument HPLC is presented in Appendixes 1-5. The pesticide residues analyzed are pp-DDT, op-DDT, endosulfan, and lindane, respectively.

### The result of pesticide residues analyzed in *Burkutu* samples obtained in Hong Local Government Area

From the result of the analysis, the *Burkutu* obtained in Hong Local Government Area showed that pp-DDT values were 2.678 ± 0.5825 mg/dm$^3$, op-DDT values were 2.9588 ± 1.2024 mg/dm$^3$, endosulfan values were 2.0010 ± 0.5299 mg/dm$^3$, and the values for lindane were 0.4088 ± 0.2421 mg/dm$^3$. The mean ± standard deviation (SD) is in mg/dm$^3$ of the pesticide residues which were analyzed. The order of abundance of these pesticide residues in the *Burkutu* samples analyzed showed that op-DDT has the highest concentration with the value of 2.9588 ± 1.2024 mg/dm$^3$ as shown in Figure 2. The values obtained indicate the presence of organochlorine pesticides as detected. This shows that pesticides such as DDT and endosulfan are used in the environment, while lindane is used less in this location.

This also implies that pesticides used can lead the contamination of the sorghum, water source, and containers used for the production of the local brews. Other reason may be due to uptake of these pesticides in soil, plant roots, crops, and for storage of grains produced in this region. DDT, endosulfan, and lindane pesticides are mostly used on crops, cereal grains, stored products, and even animals (insects). It is also used as an insecticide for slow release on pest strips for pest control, in homes. No information is available on the control for the local brews at the time of research. However, the fact that the presence of the organochlorine was dictated, their effect on the human system cannot be overemphasized due to their widely use in controlling pests and microorganisms on farms, animals, stored products, and even homes. Therefore, the *Burkutu* obtained in Hong Local Government Area is unfit for consumers due to the presence of the pesticide residues which is toxic and none recommended for consumption.

### The result of pesticide residues analyzed in *Burkutu* samples obtained in Song Local Government Area

The result of the analysis for pesticides residue in *Burkutu* samples obtained in Song Local Government Area is presented in Figure 3. The mean ± SD values are all in mg/dm$^3$ of the pesticide residues levels which are analyzed. The abundance of the pesticide residues is as follows:

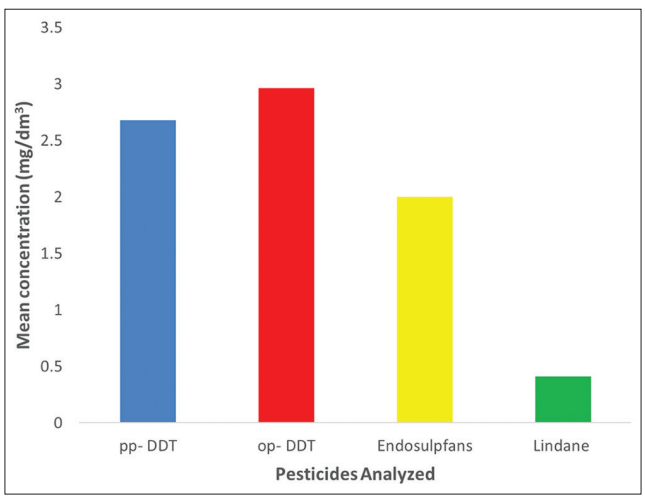


**Figure 2:** The level of pesticide residues from *Burkutu* obtained in Hong sampled area

pp-DDT 4.1835 ± 06058 mg/dm$^3$, op-DDT 3.8320 ± 0.5115 mg/dm$^3$, endosulfan 2.3070 ± 0.3755 mg/dm$^3$, and lindane 2.1510 ± 0.0750 mg/dm$^3$. Song sample showed the presence of the pesticide residues analyzed, with pp-DDT having the highest concentration with the values 4.18525 ± 0.6058 mg/dm$^3$. The result of the *Burkutu* samples obtained in Song Local Government Area has the overall concentration of all the pesticide residues compared to the rest of the other Local Government Areas analyzed. This implies that pesticides are highly in use in this environment. The presence of this toxic substance in this locally brewed alcohol is alarming and depicts a threat to the public health. Other reason may be attributed to the uptake of these pesticides in plants, water source, and soil texture found in this environment.

Other reasons may be, due to the agricultural activities done in Song, the inhabitant of this location is distinct for their large-scale production of farm produce, and to make farming easier for them, the people of Song use pesticides on their farms so as to enable they cultivate large farms. Therefore, the presence of this toxic substance in the *Burkutu* samples obtained in Song Local Government Areas makes it unfit for consumption.

### The result of pesticide residues analyzed in *Burkutu* samples obtained in Yola-North Local Government Area

For *Burkutu* samples obtained in Yola-North Local Government Area, the results of pesticide residues are presented in Figure 4. These results also indicate the presence of the pesticide residues in the locally brewed alcohol (*Burkutu*). The mean ± SD is all in mg/dm$^3$ of the pesticides levels analyzed. For the concentration of pp-DDT, the values were 0.5028 ± 0.2661 mg/dm$^3$, op-DDT values were 0.9883 ± 0.4310 mg/dm$^3$, endosulfan values were 0.3963 ± 0.09407 mg/dm$^3$, and lindane values were 0.6100 ± 0.5116 mg/dm$^3$. This implies that a trace of these pesticides is present in the environment but not much in use, this may be caused due to leaching or erosion and air pollution since most of the pesticides used are insecticides which are used on crops, stored products, farm, and in household. Therefore, the consumption of the *Burkutu* obtained in Yola-North can lead to the accumulation of the pesticide residues in the human system which can lead to disruption of the endocrine system. Therefore, it is not advisable to consume the *Burkutu* obtained from Yola-North to avoid futuristic health effects.

### The result of pesticide residues analyzed in *Burkutu* samples obtained in Numan Local Government Area

The result of the analysis for the determination of pesticides levels in the *Burkutu* sample obtained in Numan Local Government Area is presented in Figure 5. The presence of the pesticides analyzed is in mean ± SD all in mg/dm$^3$. The abundance of these pesticide residues in *Burkutu* obtained in Numan town showed the following values: pp-DDT values were 0.1750 ± 0.1069 mg/dm$^3$, op-DDT values were 0.5832 ± 0.4073 mg/dm$^3$, endosulfan values were 1.8745 ± 0.8951 mg/dm$^3$, and lindane values were 0.2058 ± 0.1378 mg/dm$^3$. The analysis reveals that endosulfan with the concentration of 1.8745 ± 0.8951 mg/dm$^3$ has the highest concentration compared to the other pesticide residues analyzed. These indicate that endosulfan is the pesticide mostly used in this location. This may also be attributed to the uptake of these pesticides in water sources, soil, vegetables, crops, and stored products.

However, the fact that the presence of these pesticides levels was dictated, the levels of their

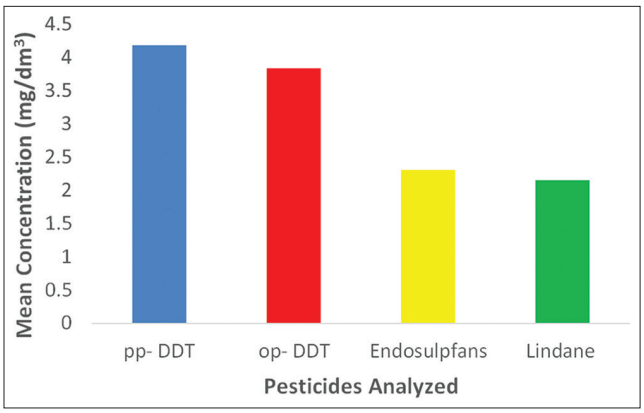


**Figure 3:** Levels of pesticide residues in *Burkutu* obtained from Song sampled area

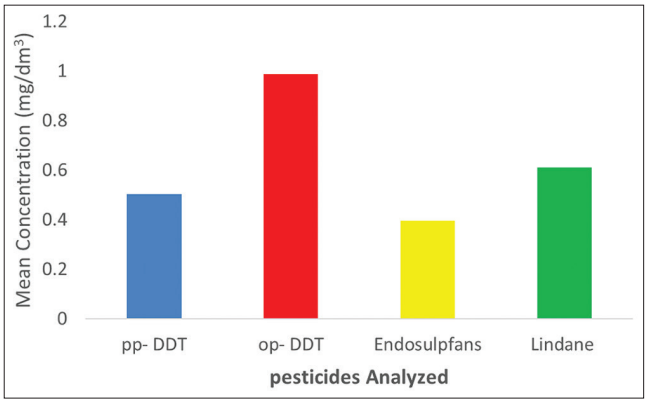


**Figure 4:** Levels of pesticide residues in *Burkutu* obtained from Yola-North sampled area

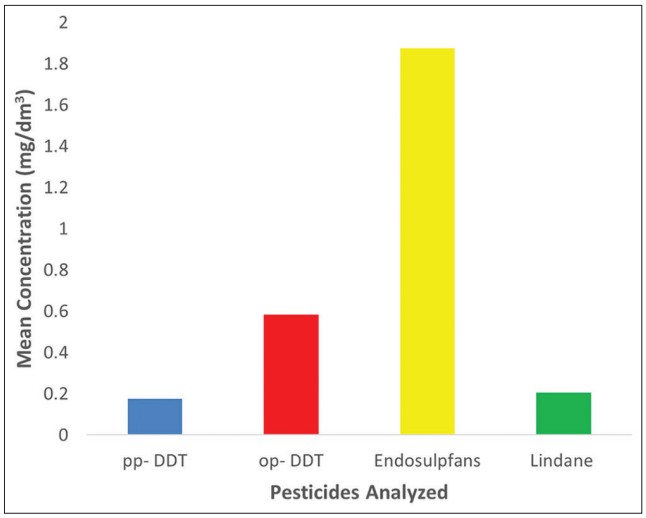


**Figure 5:** Levels of pesticide residues in *Burkutu* obtained from Numan sampled area

effect cannot be overemphasized as organochlorines are widely used to control pest and microorganisms in household, stored products, and farm produce and have been shown to have toxic effects in humans. Therefore, the *Burkutu* samples obtained in this location is not safe for consumption since no persistent pollutant is allowed for consumption by the environmental protection agency.

### The result of pesticide residues analyzed in *Burkutu* samples obtained in Ganye Local Government Area

The result of pesticide residues for *Burkutu* obtained in Ganye Local Government Area is presented in Figure 6. The mean ± SD values are all in mg/dm$^3$ of the pesticide residues levels which are analyzed. The results are as follows: pp-DDT values were 3.1110 ± 0.7080 mg/dm$^3$, op-DDT values were 2.8335 ± 0.9792 mg/dm$^3$, endosulfan values were 0.5888 mg/dm$^3$, and lindane values were 1.1650 ± 0.6676 mg/dm$^3$.

From the result of the analysis, it showed that pp-DDT with 3.1110 ± 0.7080 mg/dm$^3$ has the highest concentration of pesticide residues in the *Burkutu* samples of Ganye Local Government Area compared to the rest of the pesticides analyzed as seen from the chart. This shows that organochlorine is used as pesticide in this area studied. Other factors may be attributed to the uptake of these pesticides in soil, plants, plant roots, and stored products. The result of endosulfan 0.5888 ± 0.7688 mg/dm$^3$ showed the trace of the pesticide indicating the less use of the pollutant in this environment. Therefore, the presence of this pesticide level in the *Burkutu* obtained in Ganye Local Government Area makes the alcoholic drink unfit for consumers since no amount or dose of pesticides is recommended for consumption.

### Comparison of pesticide residues concentrations in *Burkutu* samples analyzed, among all the Local Government Areas studied

The values obtained show the presence of pesticide residues in the *Burkutu* samples obtained for all the five different Local Government Areas studied. The results obtained showed that the pesticides, pp-DDT and op-DDT, have the highest concentration of all the samples analyzed. This implies that DDT is much in use as an insecticide to control pest, which is also very toxic to human system, if consumed. Endosulfan is the second common pesticides dictated in these areas studied, though not much in concentration, its presence in the locally brewed alcohol is a threat to the consumers. The level of concentration for lindane seems to be at the trace levels in all the *Burkutu*, produced in these locations. Hence, there is need for orientation and awareness to the consumers as to reduce the level of accumulation in the human system. As at the time of this study there was no sufficient available literatures or for the control of pesticides residues in *Burkutu*, therefore a persistent environmental pollutants; quick fact provides us with information about whether the substance should be consumed or not.As at the time of this study there was no sufficient available literatures or for the control of pesticides residues in Burkutu, therefore a persistent environmental pollutants. These factors mentioned could lead to the presence of the pesticides analyzed.

## ACKNOWLEDGMENTS

The author gladly appreciates the contribution of each and every scientist, leading to the success of this work.

## CONCLUSIONS

This research work is limited only to the determination of the concentration of persistent pollutant in the locally brewed alcohol which is the final product, ready for consumption obtained from brewing sorghum. Therefore, the results of this research work reveals the presence of persistent pollutants in all the Burkutu obtained from all the selected areas considered for this study for the production of the local brews could

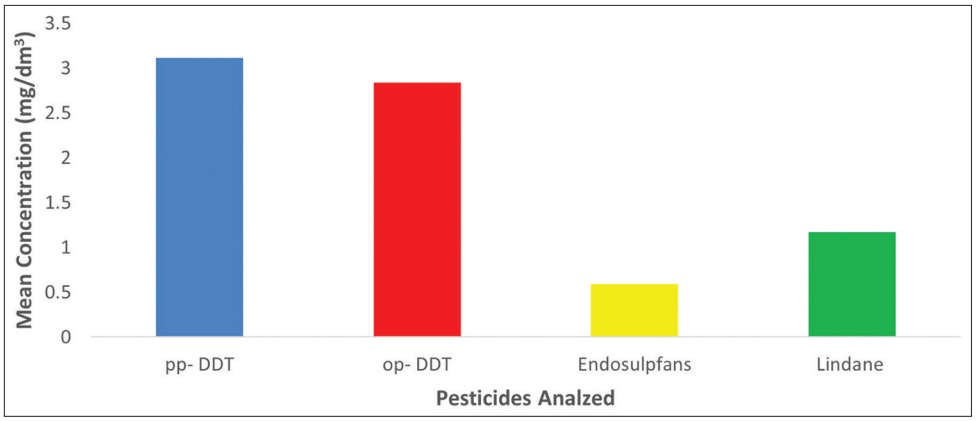


**Figure 6:** Levels of pesticide residues from *Burkutu* obtained in Ganye sampled area

be as a result of the source of water used for the local brews; and the containers, drums, calabash used for the local brews which change color with time serves as a breeding site for microbial activities and later dissolves into the beer, most have relatively accumulate and been the cause of this persistent pollutants which is present in the local brews. Furthermore, some may be attributed to the agricultural activities, the soil texture, agrochemicals used on farms, pesticides used on farm produce during storage, mineralogical content of the study areas, and environmental factors. The potential for its presence in the *Burkutu* is a serious health risk, which is alarming and depicts a threat to the public health.

Therefore, based on the findings of the study, the following conclusions were made:

i. The result of the analysis showed the presence of all the pesticide residues and their concentrations which make the *Burkutu* obtained from the five locations studied unfit for consumption because none of the pesticide residues is recommended for consumption.
ii. The result for pesticide residues showed that pp-DDT and op- DDT were abundant in Song Local Government Area compared to the samples obtained in the other four Local Government Areas studied.

## REFERENCES

1. Pizano MA, Baptista GC Residues of fenitrothion on fruit and vegetables (*Lycopersicon esculentum mill*) staked. Sci Agric 1998;55:203-9.
2. Montti MI, Visciglio SB, Raviol FH, Subovich GE, Munitz MS. Incidence of pesticides in fruit on the residual levels of citrus essential oils. Cien Doc Tecn 2013;24:187-218.
3. Reichstein I, Healy K, James A, Murray B. Australian National Residue Survey -Closing the Loop on Pesticide Residue Risk Management for Australian grain. 10th International Working Conference on Stored Product Protection; 2010. p. 425.
4. Szpyrka E, Kurdziel A, Matyaszek A, Podbielska M, Rupar J, Słowik-Borowiec M. Evaluation of pesticide residues in fruits and vegetables from the region of south-eastern Poland. Food Control 2015;48:137-42.
5. Nougadère A, Merlo M, Héraud F, Réty J, Truchot E, Vial G, *et al*. How dietary risk assessment can guide risk management and food monitoring programmers: The approach and results of the French observatory on pesticide residues (ANSES/ORP). Food Control 2014;41:32-48.
6. Bakırcı GT, Acay DB, Bakırcı F, Otles S. Pesticide residues in fruits and vegetables from the Aegean region, Turkey. Food Chem 2014;160:379-92.
7. United States Departament of Agriculture. Pesticide Data Program: Annual Summary, Calendar Year 2014; 2016. Available from: http://www.ams.usda.gov/pdp. [Last accessed on 2016 Mar 02].
8. European Food Safety Authority. The 2013 European union report on pesticide residues in food. EFSA J Parm 2015;13:4038.
9. Paoli D, Giannandrea F, Gallo M, Turci R, Cattaruzza MS, Lombardo F, *et al.* Exposure to polychlorinated biphenyls and hexachlorobenzene, semen quality and testicular cancer risk. J Endocrinol Invest 2015;38:745-52.
10. Walker CH. Organic pollutants: An ecotoxicological perspective and endocrine discrupting chemicals on health of children. Clin Toxicol 2001;40:457-65.
11. Ritter L, Solomon KR, Stemeroff MO, Leary C. Persistent Organic Pollutants (PDF). United Nations Environment Programmes; 2007. Available from: https://www.who.int/ipcs/assessment/en/pcs_95_39_2004_05_13.pdf.. [Last retrieved on 2007 Aug 16].

## Appendixes

**Appendix 1:** Results of *t*-test for pesticide residues in Hong L.G.A

| Pesticides | Mean ± SD | Significant difference |
|---|---|---|
| pp-DDT | 2.6783±0.58259 | 0.003 |
| op-DDT | 2.9588±1.20248 | 0.016 |
| Endosulfan | 2.0010±0.52996 | 0.005 |
| Lindane | 0.4088±0.24216 | 0.043 |

DDT: Dichlorodiphenyltrichloroethan, SD: Standard deviation

**Appendix 2:** Results of *t*-test for pesticide residues in Song L.G.A

| Pesticides | Mean±SD | Significant difference |
|---|---|---|
| pp-DDT | 4.1825±0.60582 | 0.001 |
| op-DDT | 3.8320±0.51153 | 0.001 |
| Endosulfan | 2.3070±0.37555 | 0.001 |
| Lindane | 2.1510±0.07508 | 0.000 |

DDT: Dichlorodiphenyltrichloroethan, SD: Standard deviation

**Appendix 3:** Result of *t*-test for pesticide residues in Yola-North L.G.A

| Pesticides | Mean±SD | Significant difference |
|---|---|---|
| pp-DDT | 0.5028±0.26611 | 0.032 |
| op-DDT | 0.9883±0.43104 | 0.019 |
| Endosulfan | 0.3963±0.09407 | 0.004 |
| Lindane | 0.6100±0.51166 | 0.097 |

DDT: Dichlorodiphenyltrichloroethan, SD: Standard deviation

**Appendix 4:** Results of *t*-test for pesticide residues in Numan L.G.A

| Pesticides | Mean±SD | Significant difference |
|---|---|---|
| pp-DDT | 0.1750±0.10696 | 0.047 |
| op-DDT | 0.5832±0.40735 | 0.064 |
| Endosulfan | 1.8745±0.89517 | 0.025 |
| Lindane | 0.2058±0.13788 | 0.058 |

DDT: Dichlorodiphenyltrichloroethan, SD: Standard deviation

**Appendix 5:** Results of *t*-test for pesticide residues in Ganye L.G.A.

| Pesticides | Mean±SD | Significant difference |
|---|---|---|
| pp-DDT | 3.1110±0.70801 | 0.003 |
| op-DDT | 2.8335±0.97927 | 0.010 |
| Endosulfan | 0.5888±0.76888 | 0.223 |
| Lindane | 1.1650±0.66766 | 0.040 |

DDT: Dichlorodiphenyltrichloroethan, SD: Standard deviation