

Full Length Research Paper

Analysis of the levels of arsenic in home-made brews, spirits, in water and raw materials using Hgaas in Nairobi county

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This study was carried out to determine the levels of arsenic in the home-made brews, home-made spirits, raw materials and water. One hundred and thirty two home - made alcoholic beverages, one hundred and ten water and eighteen raw materials samples obtained from various parts of Nairobi slums and its environs were analyzed for arsenic. The method of analysis was hydride generation atomic absorption spectroscopy. All home-made brews samples contained concentrations of arsenic that were lower than the standard for total arsenic allowed in water. The concentrations of arsenic in both brew and water ranged from ND to 0.88 ± 0.028 mg/L. These concentrations in these homemade brews and raw materials used varied depending on the brew. The recommended maximum contamination levels set by Kenya Bureau of Standards (KEBS) and WHO for arsenic in alcohols is 0.05 mg/L. Values of arsenic obtained in the drinks and the raw materials used were generally low. This also implies that the tap water and home-made brews are safe. In general, those consuming home-made brews are the young and elderly living in the slum areas in Nairobi County and it is these populations that is more vulnerable to over exposure of this metal. It is recommended that foods and drinks be tested for arsenic regularly to determine whether they meet the EPA/WHO standards.

Key words: arsenic, HGAAS, homemade brews.

INTRODUCTION

Arsenic

Arsenic occurs naturally in ground water in the form of inorganic arsenates (As (III)) and arsenate (As (V)) dissolved from rock. It is ranked 20th among the elements in abundance in the earth's crust. The toxicity characteristics will vary with the different ions of arsenic (Chasteen, 2009). Its abundance in the continental crust of the earth is generally given as 1.5 to 2 mg/g; making it relatively scarce (Chasteen, 2009). Arsenic exposure is natural but can be aggravated by human activities. We are exposed to arsenic in two chemical forms (The University of Arizona, 2013):

(1) Inorganic – Varying amounts of this poisonous (toxic forms) form can be found in:

(2) Organic – (arsenic compounds that contain carbon) – varying amounts of this non-poisonous (low-toxicity) form are found in the University of Arizona (2013):

- (i) Animals
- (ii) Plants
- (iii) Fish and seafood

Arsenic is mainly transported into the environment by water. The total amount of arsenic in the human blood has been estimated to be between 15 to 20 µg/L but

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concentrations of between 0.8 to 2.4 mg/L are toxic (Chasteen, 2009). Surface water can be contaminated by contact with soils, sediments and mine tailings (large piles of crushed rock left over after minerals have been extracted from the rocks which contained them) that contain arsenic, runoff and wastewaters contaminated with arsenic, arsenic-containing pesticides and industrial wastes (The University of Aroazona, 2013).

Most foods contain low levels of arsenic. Fish, seafood, algae and rice can contain elevated levels of organic forms of arsenic, however these forms of arsenic have much lower toxicities than inorganic forms (The University of Aroazona, 2013).

A WHO task group has estimated that a lifetime exposure to arsenic in drinking water at a concentration of 0.2 mg/L gave a 5% risk of getting skin cancer (Chasteen, 2009). It also causes inflammation, skin lesions and neurological effects (Chasteen, 2009). The arsenic levels in food regulations prescribe a maximum of 0.01 mg/L for water (Chasteen, 2009). Sources of arsenic in environmental pollution include; burning of wood treated with arsenic, use of geothermal energy, fertilizer, herbicides, fungicides, formation of arsine whenever hydrogen is being evolved in any step of an industrial process, such as manufacture of paints, dyes, insecticides, drugs and felt hats and curing hide, fumigation of buildings and treatment of electricity poles (Chasteen, 2009).

Health effects of arsenic to humanity

Most of the toxic effects arise from exposure to inorganic arsenic and affects nearly all organ systems of the body. Arsenic is known to cause cancer in humans (human carcinogen). Ingested inorganic arsenic increases a person's risk to develop lung, skin, bladder, breast, prostate, kidney and liver cancer. Other toxic effects of concern are related to:

- (a) Heart and blood vessels (cardiovascular)
- (b) Stomach and intestines (gastrointestinal)
- (c) Kidney effects
- (d) Liver
- (e) Nerves and nervous system (neurological)
- (f) Lungs (pulmonary)
- (g) Child birth (reproductive)
- (h) Respiratory
- (i) Blood & blood forming organs (hematology)
- (j) Dermal (skin)

Chronic exposure to arsenic levels over 10.0 parts per billion (ppb) has been linked to health complications, including cancer of the skin, kidneys, lung and bladder, as well as other diseases of the skin, neurological and cardiovascular systems (Garness, 2007). Health problems related to the intake of drinking water

containing high concentrations of arsenic have been encountered in some regions of Taiwan, Argentina, and Chile mainly in areas of volcanic activities (Chasteen, 2009). In 1999, the National academy of Science found out that drinking water polluted with arsenic caused bladder, lung, skin, liver and kidney cancers. Ingestion of inorganic arsenic also led to nasal and prostate cancer (USEPA, 2001). The arsenic poisoning is a tragic and unforeseen consequence of good intentions.

Maximum limits of Arsenic allowed in food and beverages

The WHO permissible limit of Arsenic for drinking water is 0.01 mg/L and the FAO permissible limit of Arsenic for irrigation water is 0.10 mg/L (Wijesekara and Marambe, 2011). For certain regions of the world where concentrations of inorganic arsenic in drinking water exceed 50 to 100 µg/L, some epidemiological studies provide evidence of adverse effects (WHO, 2011; the WHO guideline value of Arsenic in drinking water is 10 µg/L) (Wijesekara and Marambe, 2011). However, in other areas where arsenic concentrations in water are elevated but are less than 50 µg/L, though there is a possibility that adverse effects could occur as a result of exposure to inorganic arsenic from water and food, according to WHO (2011) and Wijesekara and Marambe (2011). these would be at a low incidence that would be difficult to detect in epidemiological studies. China have established maximum limits for total Arsenic in many foods, including 0.01 mg/L for drinking water, 0.5 mg/kg for raw cereals and/or cereal-based foods (except rice and rice-based products), vegetables, edible fugues, meat and its products, sugar, condiments, milk powder, coca and its products included in chocolates, and 0.1 mg/kg for the oil and fats as well as raw milk. China has also established the maximum limits for inorganic arsenic in rice and rice-based products (0.2 mg/kg), fish and fish-based condiments (0.1 mg/kg), other sea food and seafood-based condiments (0.5 mg/kg), cereal-based infant formula (0.2 mg/kg), and seaweed-based infant formula (0.3 mg/kg) (Wijesekara and Marambe, 2011).

Status of arsenic contamination in Asia

Concentrations of Arsenic in unpolluted surface water and groundwater are typically in the range of 1 to 10 µg/L, and elevated concentrations in surface water and groundwater of up to 100 to 5000 µg/L can be found in areas of sulfide mineralization (Wijesekara and Marambe, 2011). Elevated concentrations (> 1 mg Arsenic/L) in groundwater of geochemical origins have been found in Taiwan (Wijesekara and Marambe, 2011), West Bengal, India (Wijesekara and Marambe, 2011). Das Levels as high as 35 mg Arsenic/L and 25.7 mg Arsenic/L have been reported in areas

associated with hydrothermal activity (Wijesekara and Marambe, 2011). Reported levels of total arsenic in rice are < 0.01 to 2.05 mg/kg for Bangladesh, 0.31 to 0.70 mg/kg for China and < 0.10 to 0.76 mg/kg for Taiwan, 0.03 to 0.044 mg/kg for India, 0.11 to 0.66 mg/kg for the U.S.A., 0.03 to 0.47 mg/kg for Vietnam, and 0.08 to 0.38 mg/kg for Italy and Spain (Wijesekara and Marambe, 2011).

Raw materials for home brewed alcoholic beverages and spirits in East Africa

If a starchy food grain is fermented, it produces enzymes, which start to break the starch down into sugar. This is how growing plants derive energy; and this is how people release sugar from grains so that they can make alcohol from them, by brewing the grains into beer. In the nineteenth century, brewing was the usual process of making alcoholic beverages in most parts of East Africa; mostly the grain used was finger millet (*elevisine*) but some people used sorghum. Busaa is prepared from cereals, chang'aa is a distilled brew consumed in most parts of Kenya (Alcohol in East Africa, 2000). They are made from a variety of grains - malted millet and malted maize being the most common. It has a pleasant sweet flavour and contains at least 50% alcohol (Alcohol in East Africa, 2000); miti is prepared from boiled roots and honey, while muratina is prepared from sugarcane or honey, which is fermented using sausage plant (*Kigelia africana*). The conditions and raw materials used to prepare these homemade brews/spirits may introduce toxic materials into the alcohols and hence the need for continuous monitoring of the levels of nutrients in the alcohols to make sure that the population is not exposed to dangerous levels.

In the twentieth century, maize has become a common ingredient in the making of alcoholic brews (Alcohol in East Africa, 2000). There are many other raw materials as well, which include bananas, coconuts, palm fluid, honey, pineapples, paw paws and many other fruits. Some of the techniques used are by no means new. Other techniques like those for distilled brews are new. Brewing from grain takes several days. In most cases there is no attempt to control the yeast other than the constant reuse of the same containers for brewing. Once brewed, the beer lasts for only a day or two; as a 'live' brew, spoils quickly, and if not drunk within about forty-eight hours it will be spoiled. Nor can it be transported any great distance, for the continuing fermentation produces gases, which make it impossible to seal the beer in a container (Alcohol in East Africa, 2000).

Arsenic in plants

From other researchers, the highest concentration of

arsenic was found in plant roots, the intermediate level in vegetative tissues (leaves and stems), and the lowest level in reproductive tissue (fruits and seeds) (Chomkamon et al., 2013). Plants absorb arsenic fairly easily, so that high-ranking concentration may be present. Among many of public researches, most studies had focused on foods and not much on the information that was available on plants especially in the part of rhizomes although it was a high opportunity for arsenic accumulation (Chomkamon et al., 2013). The level of this metal in the environment and in foods needs to be monitored consistently. The goal of this study is to determine the arsenic levels in home-made brews, tap water and the raw materials used using UV – visible Spectroscopy in the Nairobi County.

MATERIALS AND METHODS

Samples and sampling

Eleven stations were targeted and ten samples of each brew and water were selected. A total of one hundred and fifty three home-made alcoholic beverages, thirty three water and eighteen raw materials samples were analyzed for arsenic. Samples of maize, millet, sorghum, honey, jaggery and muratina were selected. Three samples of each were obtained from various places in the eleven stations. These samples were randomly obtained from various parts of Nairobi County taking into account the requirements for the preparation of the brews (Figure 1). This information was obtained from the people who sold the brews. Sample of raw materials were obtained from market places nearest to the beverage sampling stations. A 100 ml samples were collected directly into specially cleaned, pretested, polypropylene bottles using sample handling techniques specially designed for collection of sample for the analysis of metals at trace levels. The samples were then either laboratory preserved by the addition of 5 ml of pretested 10% HNO₃ per litre of sample, depending on the time between sample collection and arrival at the laboratory.

Reagents, chemicals, solvents, standards and blanks

Arsenic standard

The analyst 800 auto sampler was used to prepare a calibration curve of 5, 10 and 15 µg/L from the 10 µg/l arsenic standard. A QC standard was also measured by this method, high purity standards TM-A, (Charleston, SC 29423) and was certified to be 15 µg/L arsenic (Davidowski and Sarojam, 1990). A volume of 1.0 ml arsenic stock solution was pipetted into a 1 L volumetric flask and brought to volume with reagent water containing 1.5% concentrated HNO₃ depending on the original concentrations of arsenic in the sample (Delgado et al., 2003). Then 10.0 ml of the primary dilution arsenic was pipetted into a 100 ml volumetric flask and brought to volume with reagent water containing 1.5% concentrated HNO₃/L (1 ml = 0.01 µg As).

Instruments and apparatus

All the weighing were done using a research analytical balance (Sartorius research, R 200D, model-40110044, Analos, Belgium). Other apparatus included the following; graduated pipettes (10 and

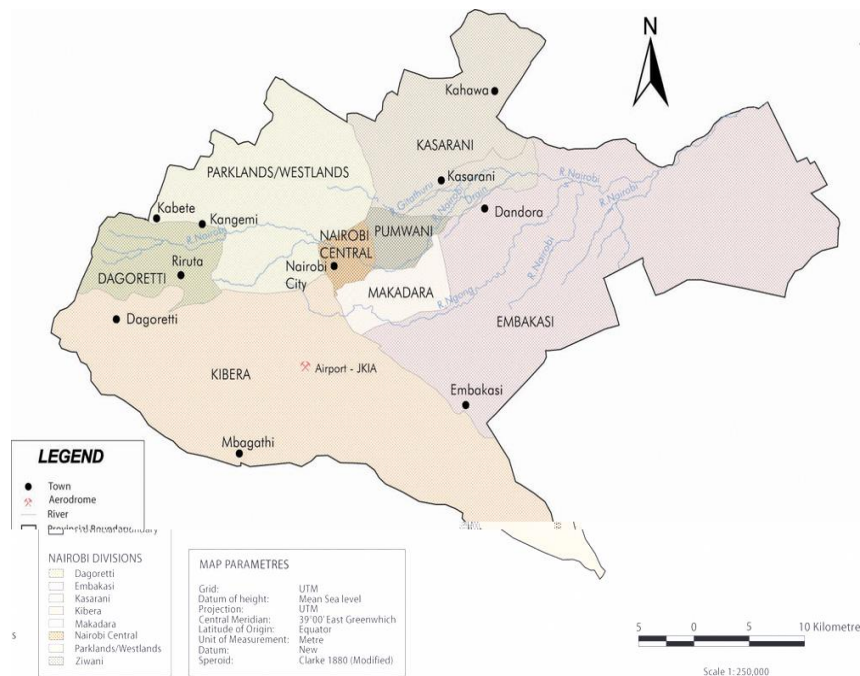


Figure 1. The map of Nairobi County.

5 ml), micropipettes (200 ml) and tips, test tubes (13 × 100 ml), small square of parafilm, volumetric flasks (50 and 100 ml) and computer.

HGAAS instruments

The arsenic concentrations were read on a Varian SpectrAA-40 atomic absorption spectrophotometer in conjunction with varian VGA-76 hydride generator and absorption cell (Hawthorn, 2011).

Cleaning of apparatus

Cleaning of apparatus was adopted from Mendham et al. (2002), and AOAC (2000) (William, 2000). Research apparatus as recommended by Association of Official Analytical Chemists (AOAC) were used. Sampler check blanks were generated in the laboratory or of the equipment cleaning contractor's facility by processing reagent water through the sampling devices using the same procedure sampling that is, bottles were cleaned with liquid detergent and thoroughly rinsed with reagent water. The bottles were then immersed in a hot (50 to 60°C) bath of 1 N trace metal grade HCl for at least 48 h. The bottle were then thoroughly rinsed with reagent water and filled with 0.1% (v/v) ultra pure HCl and double-bagged in new polyethylene zip-type bags until needed (USEPAOW, 1996). The apparatus were cleansed using detergents, water, rinsed with distilled deionized water and dried overnight in the oven at 100°C.

Sample collection and pretreatment

Water

All the water sample bottles were first rinsed with water before the

samples were collected. Preservation of water samples was performed in the field or in the laboratory. Laboratory preservation of water samples were done to expedite field operations and to minimize the potential for sample decomposition. Water samples and field blanks were then preserved in the laboratory immediately when received. Preservation involved the addition of 10% HNO₃ to bring the sample to pH < 2. For samples received at neutral pH, approximately 5 ml of 10% HNO₃ per litre was required (William, 2000). These were stored in a refrigerator at below 4°C to avoid further fermentation.

Brews

The brew sample bottle (acid-washed, 125 ml polyethene bottle) were rinsed 3 times before sampling. Filled to approximately 2/3 full, tighten cap and freeze cruise, cast Niskin bottle number were recorded on the bottle and data sheet. All the brew sample bottles were first rinsed with the alcohol for alcohol samples before the brew samples were collected. The samples were then filtered, the residue discarded and the filtrates from home made brews were decolorized using activated charcoal and re-filtered until the colour disappeared.

Raw materials

In the sample pretreatment, modified procedures for washing and drying proposed by Santos et al. (2004) and Kawashima and Soares (2003), respectively, were used. First, each raw material samples were first rinsed with distilled water to remove dirt and other debris. Then the raw material samples were brushed with polypropylene bristles and washed with deionized water. The raw materials were then grated with a polypropylene grater into porcelain containers. Then the containers with the raw material samples were dried in a laboratory oven at 65 ± 5°C for 24 h or until

Table 1. Microwave digestion program.

Step	Power	Ramp (min)	Hold (min)	Fan speed
1	750	10	10	1
2	1200	10	10	1
3	0 (cool Down)	0	15	3

reaching constant weight. Immediately afterwards, the samples were stocked in polypropylene beakers and covered with a Polyvinyl chloride (PVC) film. Finally, they were stored in a desiccators awaiting digestion (Rodrigo et al., 2011).

Sample preparation

Sample preparation for arsenic analysis

In the hydride generation for the analysis of arsenic, the hydride generator was set up according to the Varian Instruction Manual. Pumping rates were checked and adjusted to between 5 and 7 ml for the sample tube and between 0.8 and 1.0 ml for the reagent tubes (hydrochloric acid 75% and sodium borohydride 0.6% respectively (Hawthorn, 2011).

Sodium tetrahydroborate solution was prepared by weighing between 2 and 20 g of its pellets followed by 4 g of sodium hydroxide pellets into a 1 L beaker. A volume of 200 ml of water complying with the requirements of grade 2 water of (electrical conductivity less than 0.1 mS/m and resistivity greater than 0.01 MΩm at 25°C) and swirled to mix. This was then quantitatively transferred into a 1 L volumetric flask, filtered through a membrane filter using suction filtration apparatus. This was done through membrane filters of 0.8 μm pore size, made of cellulose ester or other material that cannot be degraded by sodium tetrahydroborate solution 9 (HSE, 1994).

Digestion of raw materials

One gram of the raw materials was weighed and digested using 6 ml of concentrated HNO₃, 0.5 ml of concentrated hydrochloric acid and 1 ml of H₂O₂ were added to each one in Teflon vessel in order to dissolve the organic matter. These were placed in the microwave and digested for 30 min. A multiwave 300 microwave oven (Perkin-Elmer, Shelton, CT USA) was used for the microwave-assisted digestion (Davidowski et al., 1990). A predigested spike of arsenic for arsenic, (or nitrate, nitrite and phosphate) was added to some of the samples to measure analyte recovery through the digestion process. The vessels were sealed and placed into the rotor for the microwave digestion (Davidowski and Sarojam, 1990) (Table 1).

After digestion process, the digestates were transferred to polypropylene 50 ml auto sampler vials (Perkin Elmer part number B0193234) and laboratory ASTM type 1 water was added to a final total weight of 25 g of the container and its content (Davidowski and Sarojam, 1990). The resulting solution was transferred into a 15 ml centrifuge tube and made to the mark with deionized water. To ensure a safe digestion, the multi wave 3000's IR sensor measures the temperature of each vessel. If a vessel nears its maximum operating temperature of 260°C then the microwave oven automatically decreases the applied power. Also, the pressure sensor sends data to the multi wave oven controller during the digestion. The multi wave oven will automatically reduce power if the maximum pressure of 60 bars was applied (Davidowski and Sarojam, 1990).

Digestion of brews

No digestion was performed on unfiltered samples prior to analytical determinations. Portions of 20 ml of the neutralized filtered brew samples were evaporated to dryness in separate beakers. The residues were each cooled and extracted with 1 ml phenol disulphonic acid {prepared from 25 g of phenol crystals (BDH Chemicals Ltd, Poole, UK), 150 ml of concentrated H₂SO₄ (Fischer Chemicals, UK), 75ml of fuming H₂SO₄ (Fischer Chemicals, UK)} and each mixture heated for 2 h on water bath. All samples (homemade brews, water, raw materials) and blanks (n=3) were digested and diluted using the same procedure.

Sample analysis in HGAAS

Instrument calibration in the HGAAS

This was what was done for instrument calibration in the HGAAS, a 10 μg/L As standard was prepared for serial dilutions of a 1000 mg/L stock standard (PE pure, Perkin - Elmer part number N9300102) (Davidowski and Sarojam, 1990). The solution was acidified with 20 ml concentrated HNO₃ and diluted to 1.0 L. All solutions were prepared from analytical reagents: HNO₃ (65%), HCl (37%), V₂O₅ (Merck). Commercially available 1000 mg As/L (prepared from As₂O₃ in 5 M HNO₃; Tritisol; Merck) was used; All solutions were prepared with ultrapure water with a specific resistivity of 18 mohm/cm obtained by filtering double – distilled water through a milli – Q purifier (Millipore, Bedford, MA, USA) immediately before use (Davidowski and Sarojam, 1990).

Three samples were prepared using 10 ml aliquots of a water sample (or a smaller aliquot diluted to 10 ml) from the same sample. Each of these were spiked with 0.200 mg/L). The arsenic concentrations were read on a Varian SpectrAA-40 atomic absorption spectrophotometer in conjunction with Varian VGA-76 hydride generator and absorption cell (Hawthorn, 2011). Once ignited it was left for approximately 30 min to stabilize. The instruments were zeroed using the blank and calibrated using the 2 and 4 ng/ml As standards (Hawthorn, 2011). The 2 ng/ml standard was used to check the calibration. It was to be read after every 10 samples. If the result was out by more than 10% calibration was repeated. The hydride generator was flushed with blank solution for one minute between standard samples (Hawthorn, 2011).

Sample analysis in HGAAS technique

Aliquote volumes of 10 ml samples were placed in a specially designed reaction vessel and 6 M HCl in added in the HGAAS. Before analysis, 4% NaBH₄ solution was added to convert organic and inorganic arsenic to volatile arsines and care must be taken to produce the specific metalloid oxidation state before the sample is introduced into the hydride generation system. This was done by adding 5.0 ml of 20% potassium iodide to each standard, 1.25 ml of 20% potassium iodide to each blank. Standards were made up to 100 ml with 1 M hydrochloric acid and blanks were made up to 250

Table 2. Average concentration ($\mu\text{g/L}$) of arsenic in various homemade alcoholic beverages and water [Mean \pm SD].

Brew place	Kumi Kumi [n = 3]	Tap water [n = 33]	Kangara [n = 3]
KIBERA	0.27 \pm 0.30	0.34 \pm 0.01	NA
KARIOBANGI	NA	0.63 \pm 0.01	NA
KAWANGWARE	NA	0.58 \pm 0.01	NA
GIKOMBA	NA	0.29 \pm 0.01	NA
GITHURAI	NA	0.44 \pm 0.01	NA
UTHIRU	NA	0.29 \pm 0.01	NA
KANGEMI	NA	0.20 \pm 0.00	NA
MATHARE	NA	0.29 \pm 0.01	NA
KIAMBU	NA	0.51 \pm 0.01	NA
KILIMANI	NA	0.44 \pm 0.11	NA
RUNDA	NA	0.29 \pm 0.01	0.46 \pm 0.02
MEAN	0.27 \pm 0.30	0.39 \pm 0.138	0.49 \pm 0.02

ml with 1 M hydrochloric acid. After mixing, samples, standards and blanks were left to stand for one hour before reading. This was to allow the reduction of As (v) to As (iii) to take place (Hawthorn, 2011).

The arsines were purged from the sample on to a cooled glass trap packed with 15% OV- 3 chromasorb WAW-DMCSO or equivalent. The trapped arsines were thermally desorbed, in order of increasing boiling points, into an inert gas stream that carried them into the quartz furnace of an atomic absorption spectrophotometer for detection. The first arsine to be desorbed was AsH_3 , which represents total inorganic arsenic in the sample, is purged (via a high purity inert gas) into the optical cell via a gas transfer line to the atomizer. Quality was ensured through calibration and testing of the hydride generation, purging and detection systems (USEPAOW, 1996). This is followed by the AAS analysis. The AAS alone is limited by interferences, poor reproducibility, and poor detection limits (Chasteen, 2009).

RESULTS AND DISCUSSION

Concentrations of arsenic ($\mu\text{g/L}$) various homemade brews, spirits and tap water

The levels of arsenic levels in various alcoholic brews, spirits and water from various places determined using the HGAAS and the results obtained from various stations are given in Table 2. The average concentrations were obtained by calculating the mean levels in the ten samples of each brew analyzed. The results are presented in Table 2. From the table, the highest levels of arsenic were obtained in muratina from Kibera which had the concentration of $0.88 \pm 0.03 \mu\text{g/L}$. The lowest arsenic levels were obtained in chang'aa from Kariobangi which had a concentration of $0.12 \pm 0.01 \mu\text{g/L}$. Busaa from Kibera, Kariobangi, Kawangware, Gikomba, Githurai, Uthiru, Mathare and Kangemi had low levels of arsenic concentrations ranging from $0.82 \pm 0.151 \mu\text{g/L}$ from

Kariobangi to $0.40 \pm 0.01 \mu\text{g/L}$ from Kibera. Busaa samples from other areas like Kiambu, Kilimani and Runda were not available and therefore not analyzed. This trend was also observed in chang'aa, miti and muratina. The arsenic levels in Chang'aa ranged from $0.12 \pm 0.01 \mu\text{g/L}$ for chang'aa in Kariobangi to $0.63 \pm 0.10 \mu\text{g/L}$ in the brew from Uthiru, while for miti the arsenic levels ranged from $0.22 \pm 0.03 \mu\text{g/L}$ for miti from Uthiru to $0.42 \pm 0.03 \mu\text{g/L}$ in the brew from Kariobangi. The arsenic levels in muratina ranged from $0.40 \pm 0.04 \mu\text{g/L}$ for muratina from mathare to $0.88 \pm 0.03 \mu\text{g/L}$ for the brew from Kibera. Kumi kumi and kangara had only values from one station analyzed hence they were not significant. The average concentrations were obtained by calculating the mean levels in the ten only one value for these samples could be obtained since handling these brews is illegal and only a few samples could be obtained. These values were found to be below the maximum allowable limits of 0.01 mg/L for water (EMCR, 2006). The consumers of homemade brews are still at risk of arsenic poisoning due to its accumulation in the body with the consistent use of the home made brews. Standard is based on life – time exposure to arsenic from drinking water, and takes into account the ability to measure arsenic and to remove it from drinking water supplies (Luong et al., 2009).

From Figure 2, busaa had the highest mean concentration of arsenic of $0.60 \pm 0.05 \mu\text{g/L}$ followed by muratina with $0.54 \pm 0.01 \mu\text{g/L}$. kumi kumi had the lowest concentration of $0.27 \pm 0.30 \mu\text{g/L}$. All these values were below the maximum allowable limit set by the environmental management and coordination (water quality) regulation (EMCR, 2006) and (KEBS, 2007b) at 0.01 mg/L this was also in agreement with the World Health Organization Drinking Water Standards (WHODWS) of 0.01 mg/L (Rasul and Jahan, 2010).

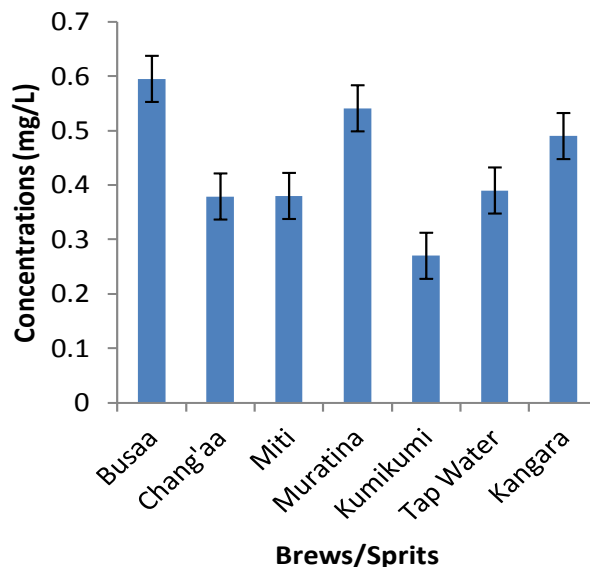


Figure 2. Overall mean concentrations of arsenic in the various home made brews/sprits and water.

Table 3. Average concentration ($\mu\text{g/L}$) of arsenic in various home-made alcoholic beverages and water [Mean \pm SD].

Brew place	Busaa [n = 24]	Chang'aa [n = 33]	Miti [n = 24]	Muratina [n = 33]
KIBERA	0.40 \pm 0.00	0.27 \pm 0.12	0.25 \pm 0.02	0.88 \pm 0.03
KARIOBANGI	0.82 \pm 0.15	0.12 \pm 0.01	0.22 \pm 0.03	0.57 \pm 0.01
KAWANGWARE	0.80 \pm 0.22	0.61 \pm 0.00	0.71 \pm 0.09	0.41 \pm 0.00
GIKOMBA	0.71 \pm 0.04	0.44 \pm 0.02	0.34 \pm 0.02	0.61 \pm 0.01
GITHURAI	0.71 \pm 0.04	0.22 \pm 0.01	0.35 \pm 0.01	0.41 \pm 0.20
UTHIRU	0.58 \pm 0.01	0.63 \pm 0.10	0.42 \pm 0.03	0.63 \pm 0.01
KANGEMI	0.34 \pm 0.01	0.35 \pm 0.01	0.40 \pm 0.00	0.42 \pm 0.00
MATHARE	0.40 \pm 0.01	0.43 \pm 0.02	0.35 \pm 0.02	0.40 \pm 0.04
KIAMBU	NA	0.37 \pm 0.00	NA	NA
KILIMANI	NA	0.35 \pm 0.22	NA	NA
RUNDA	NA	NA	NA	NA
MEAN	0.595 \pm 0.193	0.379 \pm 0.159	0.38 \pm 0.1497	0.541 \pm 0.1679

NA = Not analyzed, ND = Not detected.

Kenya Bureau of Standards had 0.1 mg/L for cereal based alcoholic beverages (KEBS, 2007b) and the same level applied for unmalted beer (KEBS, 2001a).

In Tables, 3, 4, and 5; statistical test of significance using analysis of variance (ANOVA) and descriptive statistics, revealed marked significant differences ($p < 0.05$) between the arsenic contents of all the home-made brews and tap water in the eleven samples the Nairobi County. The analysis was significant, $\{F(6, 40) = 2.562, p = 0.034, M = 0.435, SD = 0.1125, MAD = 0.917$ and confidence interval (95 %)}. The median was 0.39 $\mu\text{g/L}$ and the modes were as follows 0.595, 0.379, 0.38, 0.541, 0.27, 0.39 and 0.49 $\mu\text{g/L}$. From Tables 3, 4 and 5 since

$p < 0.05, F(2.562) > F_{\text{critical}}(2.3359)$ therefore, there is a statistically significant difference in the levels of arsenic in the homemade brews. A goodness-of-fit test indicates that the model fits the data very well, and observed and predicted probabilities of arsenic contamination are strongly correlated ($r^2 = 0.87033$). Nairobi County has a median arsenic concentration of 0.39 mg/L in the homemade brews, and the arsenic MCL of 0.02 mg/L is exceeded in 25.75% of the samples. Tap water also contributed positively towards elevating the levels of arsenic in the brews/sprits. The home made brews analyzed in this research had values above the WHO set limit of 0.02 mg/L for alcoholic beverages (WHO, 1981).

Table 4. Frequency table.

Frequency table	
Frequency	Frequency (%)
1	14.29
1	14.29
1	14.29
1	14.29
1	14.29
1	14.29

Table 5. ANOVA test on the levels of arsenic in the brews.

Variables	SS	df	MS	F	p
Between	0.397	6	0.066	2.562	0.034
Within	1.033	40	0.026		
Total	1.430	46			

Table 6. Descriptive statistics for arsenic in homemade brews.

Minimum:	0.27
Maximum:	0.595
Range:	0.325
Count:	7
Sum:	3.045
Mean:	0.435
Median:	0.39
Mode:	0.595, 0.379, 0.38, 0.541, 0.27, 0.39, 0.49
Standard deviation:	0.112006
Variance:	0.01254533
Mid Range:	0.4325
Quartiles:	Quartiles: Q ₁ -->0.379 Q ₂ -->0.39 Q ₃ --> 0.5155
Interquartile Range (IQR):	0.1365
Sum of Squares:	0.075272
Mean Absolute Deviation:	0.09171429
Root Mean Square (RMS):	0.4471892
Std Error of Mean:	0.04233427
Skewness:	0.06264447
Kurtosis:	1.646748
Coefficient of Variation:	0.2574849
Relative Standard Deviation:	25.74849%

Home-made brews and tap water in Nairobi County are not safe from arsenic pollution.

Concentrations of arsenic in various raw materials

The mean levels of arsenic in the raw materials used to

make the brews were determined and the results are represented in the Table 6 and in Figure 3. From the table muratina plant had the highest concentration of arsenic at $3.53 \pm 0.177 \mu\text{g/kg}$ followed by jaggery at $2.90 \pm 0.148 \mu\text{g/kg}$. Millet seeds had the lowest concentration at $1.50 \pm 0.19 \mu\text{g/kg}$. These were all below the maximum

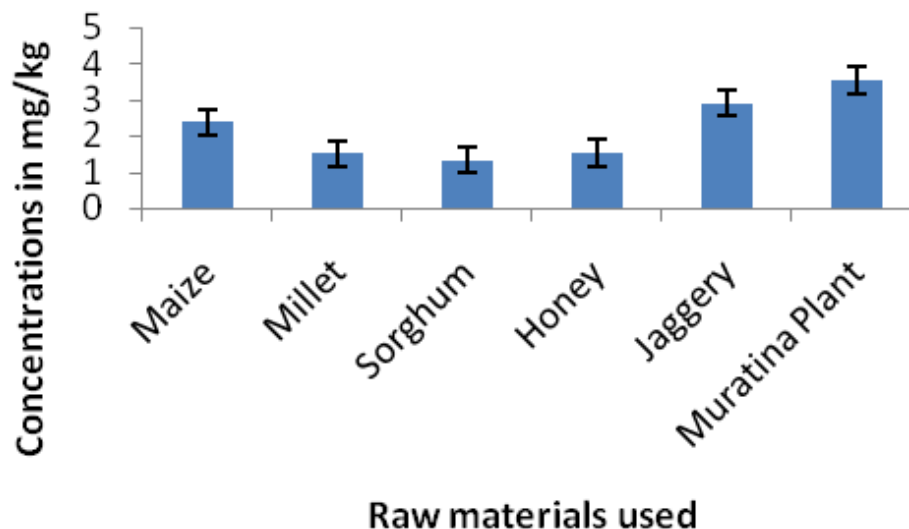


Figure 3. Mean levels of arsenic in the raw materials.

Table 7. Average concentration ($\mu\text{g}/\text{kg}$) of arsenic in various raw materials used [Mean \pm SD].

Raw materials	Arsenic ($\mu\text{g}/\text{kg}$)[n = 18]
Maize	2.38 \pm 0.440
Millet	1.50 \pm 0.190
Sorghum	1.33 \pm 0.217
Honey	1.53 \pm 0.070
Jaggery	2.90 \pm 0.148
Muratina fruit	3.53 \pm 0.177

limit of 0.4 mg/kg weight set by FAO/WHO (WHO, 1981). These levels are safe and therefore do not pose health risks to the consumers. Maize, millet and sorghum used in the preparation of busaa had high levels of arsenic, 2.38 \pm 0.440, 1.50 \pm 0.190 and 1.33 \pm 0.217 $\mu\text{g}/\text{kg}$ respectively. The mean levels of arsenic in raw materials used in the home made brews and spirits was collected and results used to plot the graph in the figure.

The mean levels of arsenic in various raw materials used were used to determine whether there was any significant difference between the levels of arsenic in the various raw materials using the t-test. A one-way analysis of variance (ANOVA) and descriptive statistics (Tables 7, 8, 9 and 10) were conducted on the raw materials used in making the homemade brews in Nairobi County. The analysis was significant, $\{F(5, 12) = 42.855, p = 0.000, M = 2.195, SD = 0.893, MAD = 0.742$ and confidence interval (95%)}. The median was 1.955 $\mu\text{g}/\text{l}$ and the modes were 2.38, 1.50, 1.33, 1.53, 2.90 and 3.53 $\mu\text{g}/\text{L}$. From Tables 3, 4 and 5, the P-value of 0.000 is less than the significance level (0.01) and F (42.855) is greater than F crit (3.1059), it implies that there were no

significant differences between the levels of arsenic in the raw materials used. Nairobi County has a median arsenic concentration of 1.955 mg/L in the raw materials used, and the arsenic MCL of 0.02 mg/L is exceeded in 40.68% of the samples. A goodness-of-fit test indicates that the model fits the data very well, and observed and predicted probabilities of arsenic contamination are strongly correlated ($r^2 = 0.95676$). But there were no significant differences between the levels of arsenic in raw materials used.

Conclusion

The levels of arsenic were found to be generally below the maximum contamination levels of 0.05 mg/L set for water. The Kenya Bureau of Standards did not have standards levels for arsenic in the local brews and alcohols. Hence Kenyan waters and brews are not heavily contaminated with arsenic. Historical alcoholic beverages and water quality data bases may be useful in epidemiological studies that categorize by relative levels

Table 8. Descriptive Statistics for arsenic in raw materials used.

Minimum:	1.33
Maximum:	3.53
Range:	2.2
Count:	6
Sum:	13.17
Mean:	2.195
Median:	1.955
Mode:	2.38, 1.50, 1.33, 1.53, 2.90, 3.53
Standard deviation:	0.892967
Variance:	0.79739
Mid range:	2.43
Quartiles:	Quartiles: Q ₁ -->1.5 Q ₂ -->1.955 Q ₃ --> 2.9
Interquartile range (IQR):	1.4
Sum of squares:	3.98695
Mean absolute deviation:	0.741667
Root mean square (RMS):	2.34148
Std error of mean:	0.364552
Skewness:	0.409809
Kurtosis:	1.38818
Coefficient of Variation:	0.406819
Relative standard deviation:	40.6819%

Table 9. Frequency table.

Frequency table		
Value	Frequency	Frequency (%)
1.33	1	16.67
1.50	1	16.67
1.53	1	16.67
2.38	1	16.67
2.90	1	16.67
3.53	1	16.67

Table 10. ANOVA test on the levels of arsenic in the raw materials used.

Variables	SS	df	MS	F	P
Between	11.961	5	2.392	42.855	0.000
Within	0.670	12	0.056		
Total	12.631	17			

of these nutrients in water in order to assess the association of this exposure with health outcomes. The results were higher than the published maximum permissible contents of arsenic in some home-made

brews and tap water. Therefore consumption of these homemade brews as food may pose possible health hazards to humans at the time of the study. Brewers of home-made brews in these areas should be educated on

the needs to recognize hygiene. The concentrations of the arsenics in the home-made brews and tap water obtained in this study would go a long way in providing a baseline data for the assessment of the levels of arsenic in the brews and tap water obtained in Nairobi County, Kenya. Note that the EPA/WHO do not have an arsenic standard for foods other than bottled water and the byproducts of animals treated with veterinary drugs (The University of Arozona, 2013).

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