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Effect of Heavy Metals in Brewery Water Sources and Pito Brewed from Them in Tamale Metropolis and Tolon District, Ghana

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Authors' contributions

This work was carried out in collaboration between both authors. Author CAA designed the study, performed the statistical analysis and wrote the draft of the manuscript. Author ENKS read through the work. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To assess the effect of heavy metals (iron, manganese, zinc and copper) in brewing water sources and Pito brewed from them in the Tamale Metropolis and Tolon District.
Study Design: A Nested Design was used for the experiment replicated in three locations.
Place and Duration of Study: Samples of water sources and Pito brewed from heavy metals were taken from Nyankpala in the Tolon District and Education Ridge and Fuo communities in the Tamale Metropolis from August 2014 to November 2014.
Methodology: A total of 32 samples of water and Pito brewed from heavy metals were analyzed at Water Research Institute of the Council for Scientific and Industrial Research, Tamale using the procedure prescribed by American Public Health Association (APHA) (2017), 20th Edition, Standard Methods for the Examination of Water and Wastewater (Buck Scientific 210VGP Flame Atomic Absorption Spectrophotometer (Buck Scientific, Inc. East Norwalk, USA).
Results: The results revealed that heavy metals mean concentrations in water sources and Pito brewed from them were 1.69 and 60.50 mg/L for iron, 0.02 to 1.88 mg/L for manganese, 0.17 to

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1.69 mg/L for zinc and not detected (nd) to 0.10 mg/L for copper respectively. Iron and manganese levels water sources and Pito brewed from them were significantly different (P= .05). However, mean zinc and copper concentrations in water sources and Pito brewed from them were not significantly different (P = .05).
There were positive and negative correlations between heavy metals in water sources and Pito brewed from them. The negative correlations were found to be significant (P=.01) and (P=.05) while the positive correlations were not significant (P=.01) and (P=.05).
Conclusion: The mean iron levels in water and Pito were above the World Health Organisation (WHO) standard. Manganese, zinc, copper in water and Pito brewed from them were within the WHO acceptable standards.

Keywords: Water sources; heavy metals; Pito; Tamale Metropolis; Tolon District.

1. INTRODUCTION

Metals and other elements can be naturally present in food or can enter food as a result of human activities such as industrial and agricultural processes. According to [1], Pito contains essential minerals such as zinc (Zn), calcium (Ca), magnesium (Mg), and Iron (Fe), which are responsible for body and tissue regulation.

Trace elements in beverages may originate from natural sources, such as soil and water; environmental contamination, including fertilizers and pesticides; industrial processing and contamination from containers, such as aluminum cans and possibly pet bottles [2].

The heavy metal composition in foods is of interest because of their essential as well as toxic nature. For example, iron, zinc, copper, chromium, cobalt, and manganese are essential elements, while lead, cadmium, nickel, and mercury are toxic at certain levels [3].

Many studies have been done to determine the trace metal ions including some body tissues and fluids and natural waters [4].

Also, an investigation into trace heavy metal contents in food samples including honey, vinegar, lemon juice, sour cream, yogurt, buttermilk, chocolate, cocoa, honey, molasses is an important part of analytical food chemistry [5].

As a result of the soil, atmosphere, underground and surface water pollution, foods and beverages are contaminated with heavy metals [6]. Some essential metals are involved in numerous biochemical processes and adequate intake of certain essential metals leads to the prevention of deficiency diseases. Iron (Fe) deficiency, that is anemia, for instance, affects one third of the world population. On the other hand, excessive iron intake has been associated with an overall increased risk of colorectal cancer [7]. Copper (Cu) and zinc (Zn) are essential metals which perform important biochemical functions and are necessary for maintaining health throughout life. Zinc (Zn) constitutes about 33 ppm of adult body weight and it is essential as a constituent of many enzymes involved in many physiological functions, such as protein synthesis and energy metabolism. Zinc (Zn) deficiency, resulting from poor diet, alcoholism and malabsorption, causes dwarfism, hypogonadism and dermatitis, while toxicity of Zinc (Zn) due to excessive intake may lead to electrolyte imbalance, nausea, anemia and lethargy [8]. Adult human body contains about 1.5 - 2.0 ppm of Cu which is essential as a constituent of some metalloenzymes and it is required in haemoglobin synthesis and in the catalysis of metabolic oxidation.

The interest of Pito consumers in terms of heath impact of their diet has become a growing concern across the world, particularly in Africa where majorities of the population patronize beverages unique to their traditional identity.

Pito is an alcoholic, slightly bitter and sweet sour beverage from Nigeria and Ghana with a fruity flavour made by fermentation of malted, mashed maize or sorghum (*Sorghum vulgare* and *Sorghum bicolor* [9,10]. It is popularly consumed in the three regions of the north and the Zongo communities (settlements of northerners in the southern sector) of Ghana.

Pito provides income for households otherwise considered cash-strapped households in rural areas [11]. In African, during festivals and ceremonies such as prayers for rain, communication with the ancestors, births, the handing-over of a dowry, circumcision and burial ceremonies, Pito is the toast of the people [12,13,14].

The main sources of contamination of Pito include human activities, sewage, raw materials, utensils, processing equipment and the environment, poor handling and storage conditions and rodents [15].

Water is often overlooked as a raw material but it must be pure in composition suitable for Pito brewing. Water should not be contaminated by chemicals, heavy metals, microbial and physical elements all of which may pose health risks if present above carefully defined limits [14]. The accumulation of lead in water and beverages could produce damaging effects in the hematopoetical, hematic, renal and gastrointestinal systems [16,17]. Water is a principal source of transmitting diseases like cholera, typhoid, bilharzia and malaria. It has been demonstrated that water of good quality is crucial to sustainable socio-economic development [17,18].

Tamale metropolis and Tolon District in northern Ghana face water problems during the rainy season and the dry season. This has led Pito brewers to resort to unwholesome water for brewing which the rainy season comes with numerous health challenges.

Research on Pito has been the focus of many researchers in recent times according to [11] owing to its popularity and the unique microbial culture associated with the fermentation of the drink. However, little research has been done on the different heavy metals associated with the processing of Pito and the water sources used for brewing.

This study therefore, sought to determine the levels of heavy metals in the water sources used in brewing Pito and the effect on the Pito brewed from the same water sources.

2. MATERIALS AND METHODS

2.1 Sampling

Simple Random Sampling and Purposive sampling were used to select the four (4) Pito brewers for the study. A total of thirty-two (32) samples of water and Pito were taken. Two (2) brewers in each District were sampled namely; Rain water and Pito brewed from it at Apullah'sPito bar in Nyankpala-Tolon. Pipe borne water and Pito brewed from it at Kampe's Pito bar at Nyankpala-Tolon, Well water and Pito brewed from it at Memuna's bar at Education Ridge and Dam water and Pito brewed from it at Cynthia's Pito bar, Fuo community both in the Tamale Metropolis.

2.2 Experimental Design

A Nested Design replicated independently in three locations; Nyankpala in the Tolon District, Education Ridge and Fuo in the Tamale Metropolis [19,20]. The model for this design is

$$y_{ijk} = \mu + A_i + B_{j(i)} + \varepsilon_{k(ij)} \qquad (1)$$

The $j(i)$indicates that the factor corresponding to j (Water Sources) is nested in the factor corresponding to i (Pito, Factor A). Thus, there is a different $\mathrm{B_j}$for each level i of A.

2.3 Laboratory Analysis

Heavy metals (Fe, Mn, Zn and Cu) in water and Pito samples were analyzed at the Water Research Institute (WRI), Tamale, according to the procedure prescribed by American Public Health Association [21] Standard Methods for the Examination of Water and Wastewater.

2.4 Determination of Heavy Metals Levels (Fe, Zn, Mn and Cu) in Water Sources and Pito Brewed from Them

Buck Scientific 210VGP Flame Atomic Absorption Spectrophotometer (Buck Scientific, Inc. East Norwalk, USA) was used to determine the levels of metals such as Iron (Fe), Zinc (Zn), Manganese (Mn), and Copper (Cu) in the water and the Pito samples. Thirty-two (32) samples of water sources and Pito brewed from the same water was allowed to stand for 24 h to allow its gases go off while the water samples were homogenously mixed before samples were taken for analysis. Five (5 mL) of each sample was measured into platinum crucibles. The samples were left to evaporate on hot plates till the all dried up. The crucible and the test portion were placed in the Muffle furnace at a temperature 550ºC for 8 hours. The crucible with ash was put in desiccator to cool. Five (5) mL of nitric acid of mass fraction not less than 65 %, having a density of approximately ρ ($HNO3$) = 1400 $mg.mL^{-1}$ was added, ensuring that all the ash came into contact with the acid and the resultant solution heated on hot plate until the ash dissolved.Ten (10) mL of 0.1 mol.L^{-1} nitric acid was added and filtered into 50 ml volumetric flask. The resultant solution was top up to the mark with 0.1 mol.L^{-1} nitric acid. Blank solution was treated the same way as the sample. The Flame Atomic Absorption Spectrophotometer was used to read the absorbance values at appropriate wavelength of the interested metal in the sample solution. Cathode lamps used were Cu (wavelength 324.8 nm, lamp current 1.5 mA), Fe (wavelength 248.3 nm, lamp current 7.0 mA), Mn (wavelength 217.0 nm, lamp current 3.0 mA), and Zn (wavelength 213.9 nm, lamp current 2.0 mA). Air/Acetylene gas was used for all the analysis. The metal content of the samples was derived from calibration curves made up of a minimum of three standards with minimal values of determination coefficient (R2).

2.5 Statistical Analysis

A General Linear Model was used to analyse the quantitative data on the Statistical Package for Social Sciences (version 17). A multivariate was selected for determining the levels of heavy metals in water and Pito samples. A Post Hoc was selected where Duncan's multiple range tests was conducted on all parameters to separate the means in Water and Pito samples at 5% level of significance, coefficient of variation, p-value and standard errors difference.

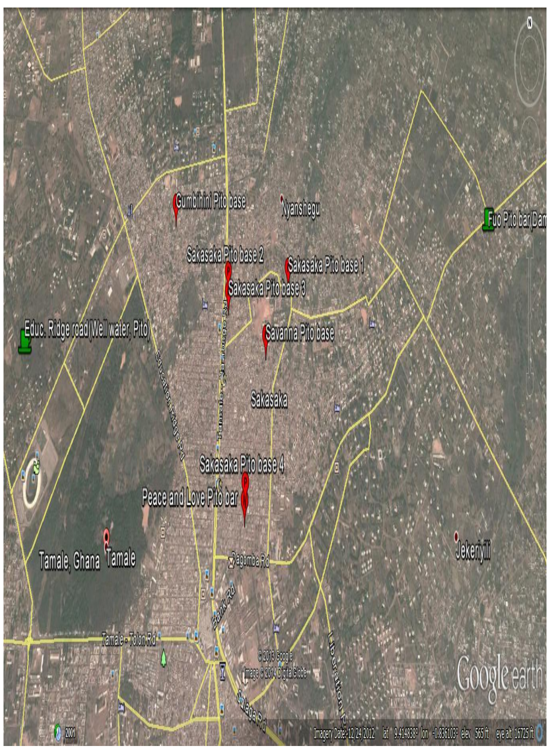

Fig. 1a

Fig. 1b

Fig. 1a. The location of Samples of Well water and Pito brewed from it at Memuna's Bar; Education Ridge and Dam water and Pito brewed from it at Cynthia's Bar, Fuo Dam, Tamale Metropolis (indicated green cups) and other Pito Bars courtesy Global Positioning System (GPS)

Fig. 1b. The location of Samples of Rain water and Pito brewed from it at Apullah'sPito Bar and Pipe borne water and Pito brewed from it at Kambe'sPito Bar (indicated Green cups) in Nyankpala Town, Tolon District and other Pito Bars courtesy Global Positioning System (GPS)

Plate A. Rain water used for Pito brewing in Nyankpala Town, Tolon District
Plate B. Pipe borne water used for Pito brewing in Nyankpala Town

Plate C. Fuo Dam water used for Pito brewing, Tamale Metropolis
Plate D. Well water used for Pito brewing at Education Ridge, Tamale Metropolis

Plate E. Water and Pito Samples from Pito Brewers for Laboratory Analysis

3. RESULTS AND DISCUSSION

Table 1 represents water sources used for brewing Pito. Heavy metals in water sources and Pito were compared with the World Health Organization acceptable Standards [22].

Table 1. Mean Iron (Fe), Manganese (Mn), Zinc (Cu), and Copper (Cu) Levels in Water Sources and Pito Brewed from them

Water samples	Iron (mg/L)		Manganese (mg/L)		Zinc (mg/L)		Copper (mg/L)	
	Water	Pito	Water	Pito	Water	Pito	Water	Pito
Rain	1.69[ab]	50.20[ab]	0.02[a]	1.88[c]	0.17[ns]	1.27[ns]	nd	0.02[ns]
Well	1.05[a]	60.50[c]	0.09[b]	1.04[a]	nd	1.41[ns]	nd	0.01[ns]
Dam	1.03[a]	49.50[b]	Nd	1.77[ab]	nd	1.69[ns]	nd	0.10[ns]
Pipe Borne	1.11[b]	38.20[a]	Nd	1.61[b]	nd	1.45[ns]	nd	0.01[ns]
CV	12.40	21.60	10.70	18.10	13.50	26.70	14.30	16.40
SED	0.28	7.60	0.08	0.39	0.33	0.37	0.15	0.17
p-value	0.509	0.012	0.002	0.037	0.415	0.898	0.450	0.513

Superscripts [a, b, ab, c]- show significant differences in the columns
[ns] - show no significant differences in the columns
CV - Coefficient of Variance; SED - Standard Error Difference
nd- not detected

3.1 Iron (Fe)

[23] found that metals are one of the many unintentional contaminants of food and when they present beyond recommended levels, they are toxic. Iron accumulates in food through air, water, soil, industrial pollution and other routes including food utensils.

Iron is an important element that is necessary in the haemoglobin of the red blood cells and myoglobin in the muscle [24]. The higher mean iron (1.69 mg/L) observed in rain water probably came from rusted roofs from which water is collected for brewing (Table 1). The results agreed with [25] and [26] who found that high levels of iron rendered water rusty coloured and unpleasant to drink. [27] observed that high levels of heavy metals in food can be toxic to yeast. The lower mean iron levels (1.03 mg/L) in dam water may also be due to low iron dissolutions from surroundings waste disposal sites, brewing equipment and soils.

Similarly, mean iron in Pito samples was much higher (38.20 – 60.50 mg/L) (Table 1) than the findings by [28] who recorded a 5.30 ppm iron level for fermented Pito in Nigeria. [29] also found the iron levels of sorghum varieties in India to range from 23.7 to 36.7 mg/kg which might have contributed to the high iron levels in the Pito.

It was however confirmed by [11] who found Na, K, Fe, Zn, Mn and Cu as essential elements measured relatively in higher concentrations in Pito, thus indicating that the consumption of Pito could be a good source of these trace metals. Again, [30] reported that iron toxicity can result in significant illness and reduced quality of life. All mean iron levels in Pito were above acceptable [22] standard of 0.3 mg/L and were unsuitable for consumption because [31] found that when iron-rich waters mix with tea, coffee, or alcoholic beverages, it assumes a black, inky appearance with an unpleasant taste.

3.2 Manganese (Mn)

Food is the most important source of manganese exposure to the general population. The intake can be higher for vegetarians because higher levels of manganese occur in food of plant origin. The highest tissue concentrations of manganese have been observed in the liver, kidney, pancreas, and adrenals. Available data clearly show that manganese can cause adverse effectsin humans, the most important target being the central nervous system. The syndrome known as manganism is characterized by apathy, anorexia, muscle pain and slow clumsy movement of the limbs.

Apart from mean manganese concentration in well water (0.09 mg/L) (Table 1), concentrations in water samples were below the [22] acceptable standard of 0.04 mg/L. The mean manganese in well water confirms the results of a study conducted by [32] who indicated that high concentration of manganese in groundwater from six regions and 30% of drilled boreholes in Ghana contained high levels of manganese. The general low levels of manganese indicated that the surrounding water bodies have soils with low manganese content.

The mean manganese concentration in Pito recorded an appreciable increase

(1.04 – 1.88 mg/L) (Table 1) which supports the findings of [11] who measured manganese in relatively higher concentrations in Pito from four cities of Ghana: Accra, Tamale, Wa and Bolgatanga and indicated that the consumption of Pito could be a good source of manganese. It again supports the findings of [33] who found manganese concentration in ''Zunnu'', an African sorghum beer to be 1.05 mg/L. [34] also supported the argument that iron and manganese are common water contaminants which are not health hazards but can cause offensive taste, appearance, and staining and undesirable characteristics making the Pito unsuitable for consumers. Also, the high manganese concentration in Pito could come from water sources and sorghum malt.

3.3 Zinc (Zn)

With the exception of rain water which recorded positive mean zinc value of 0.17 mg/L (Table 1), the other water samples recorded negative mean values which indicated that Zn ions were absent in rain water. Mean Zn concentrations in water were below the recommended [22] standard of 5 mg/L of zinc in drinking water.

[11] observed a lower concentration of 0.456 mg/L of Zn in Bolgatanga Pito while the highest concentration was 0.910 mg/L for Pito in Accra. A high mean Zn in Pito brewed from dam water being 1.67 mg/L (Table 1) seem to be much higher than that reported by [11] for Zn in Pito for Bolgatanga and Accra. The study supports [11] that the presence of Cu and Zn in foods has both nutritional and toxic effects on humans. [33] found Zn levels in ''Kunnu'' beer in Nigeria to be 3.30 mg/L which were quite higher than this study.

Additionally, [29] found between 20.0 to 38.3 mg/kg of zinc in India sorghum varieties namely BSH1, Mahube, Phofu and Segaolane. It is therefore justifiable to suggest that sorghum malt and water sources, especially rain water used for brewing Pito contributed high zinc content to the Pito brewed.

3.4 Copper (Cu)

Copper (Cu) is a constituent of several enzymes and it is necessary for the synthesis of haemoglobin. The mean copper concentration in water samples recorded a high value of - 0.10 mg/L (not detected) (Table 1) in rain water due to the fact that the water sources and the surrounding soils lacked copper ions. Generally, mean copper in water samples was below the WHO acceptable standard of 2 mg/L for copper in drinking water.

The mean copper concentrations in Pito (0.01 - 0.02 mg/L) brewed from water samples (Table 1) were also lower than that of [11] who discovered the concentrations of Cu in Pito samples analyzed to range from 0.076 to 0.308 mg/L as well as Adebayo *et al.* (2010) who recorded a copper value of 1.09 mg/L in ''Kunnu'' beer in Nigeria.

The study however suggested that raw materials contributed to copper levels in Pito and this was confirmed by [29] who found copper in India sorghum varieties namely BSH1, Mahube, Phofu and Segaolane to range from 6.0 to 8.0 mg/kg. Mean copper in Pito was within the [22] guideline of 2 mg/L.

Table 2 represents the correlation between heavy metals in water sources and Pito brewed from them.

Table 2. Pearson's Correlation between Heavy Metals in Water Sources and Pito Brewed from them

	FeW	FeP	MnW	MnP	ZnW	ZnP	CuW	CuP
FeW	1.00							
FeP	-0.59 *	1.00						
MnW	0.03^{ns}	-0.05^{ns}	1.00					
MnP	-0.20^{ns}	-0.41^{ns}	-0.18^{ns}	1.00				
ZnW	0.18^{ns}	0.07^{ns}	-0.04^{ns}	0.03^{ns}	1.00			
ZnP	-0.58*	0.13^{ns}	0.01^{ns}	0.26^{ns}	-0.11^{ns}	1.00		
CuW	0.42^{ns}	-0.22^{ns}	0.34^{ns}	-0.44^{ns}	0.44^{ns}	-0.25^{ns}	1.00	
CuP	0.10^{ns}	0.11^{ns}	-0.80**	0.10^{ns}	-0.32^{ns}	0.08^{ns}	-0.54*	1.00

*** - correlation is significant (P=.01), * - correlation is significant (P=.05), ^{ns} -correlation not significant (P =.05)*
FeW- Iron in Water FeP- Iron in PitoMnW- Manganese in Water MnP- Manganese in PitoZnW- Zinc in Water ZnP- Zinc in PitoCuW- Copper in Water CuP- Copper in Pito

3.5 Correlation Coefficient between Heavy Metals in Water Sources and Pito Brewed from Them

All correlations coefficient of heavy metals were significant (P = .01) and were negatively correlated (Table 2). There were also some positive and negative correlations for heavy metals in water sources and their Pito that were not significant (P = .05). However, copper in Pito and manganese in water recorded a significant negative correlation (P = .01) (r = - 0.80) which was higher than the correlation of heavy metals in Sakumo (r = - 0.146) and lower than that in Kpeshie lagoon reported by [35]. Similarly, the same authors recorded 0.450 for zinc and copper, 0.490 for zinc and manganese in Sakumo (Ghana) which were higher than the results of the current study of - 0.25 for zinc in Pito and copper in water. The levels of heavy metals in water sources were likely to have an effect on their levels in Pito. Therefore, Pito's heavy metals could be emanating from brewing equipment and water sources used for brewing.

4. CONCLUSION

Among the heavy metals analyzed in Tamale and Tolon Districts in this study, water sources, Pito brewing equipment, sorghum malt and corn mills were the main causes of high levels of heavy metals such as Iron, Copper, Zinc, and Manganese in Pito.

Iron levels were higher in Pito than the acceptable WHO standard in beverages. Copper, manganese and Zinc were within acceptable WHO standard (WHO, 2011) in both drinking water and Pito and therefore will pose no threat to the health of consumers.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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