



Toxic Metal Contamination of Locally Produced Tobacco in Tamale Metropolis in Northern Region of Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. Authors GES and SAA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NJM and EA managed the analyses and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The study was to analyze and determine the toxic metal contamination level of locally produced tobacco sold in the Tamale Metropolis of Northern region. The study was carried out at the Tamale Metropolis of Northern region of Ghana within a period of 12 months. The study focused on the analyses of five (5) toxic metal contaminants in twelve (12) variant locally produced tobacco sold in various spots within the Tamale Metropolis of Ghana. Toxic metals including As, Cd, Hg, Pb and Cr were analyzed using Flame Atomic Absorption Spectrophotometer. The mean recorded concentrations of As, Cd, Hg, Pb and Cr were respectively in the ranges of 0.184 ± 0.011 to 0.515 ± 0.015 µg/kg, 0.0420 ± 0.010 to 3.100 ± 0.000 µg/kg, 0.176 ± 0.016 to 0.291 ± 0.009 µg/kg, 1.169 ± 0.019 to 3.195 ± 0.019 µg/kg and 1.600 ± 0.116 to 3.880 ± 0.369 µg/kg. The mean concentrations of As and Pb measured in all samples tested were below their respective WHO permissible limits of 4.00 ppm and 10.00 ppm. In the case of Cd, mean concentrations measured for all locally produced

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tobacco tested were above the WHO permissible limits of 0.30 ppm. For the metal Hg, levels measured in 75% of tested locally produced tobacco were slightly above the WHO permissible limit of 0.20 µg/kg. Cr levels measured in 30% of tested locally produced tobacco were below the WHO permissible limits of 2.00 µg/kg. The very presence of these metals typically raises health concerns on consumption in the instances where their levels exceeded permissible guideline limits. The study revealed that Cd, Hg and Cr levels in the locally produced tobacco studied were found to exceed the WHO permissible limits for human consumption by plant uptake with As and Pb levels well below their permissible thresholds. The analyzed locally produced tobacco essentially poses a threat of heavy metal toxicity to consumers via bioaccumulation and bio-concentration in human tissues.

Keywords: Tobacco; cigarette; toxic metal contamination; atomic absorption spectrophotometry; Tamale Metropolis.

1. INTRODUCTION

In 2016, 121 countries representing 4.7 billion people were protected against tobacco by implementing various control policies against the use of tobacco [1]. Due to the negative impact of tobacco smoking, many countries including Ghana have instituted laws and regulations to control its use. In Ghana, tobacco regulations are enshrined in Articles 61 to 68 of the Public Health Act of 2012 (Act 851) of the constitution. The Act, in Article 64, clearly prohibits the sale of tobacco without adequate labeling of its health hazards. Further legal provision for incorporating tobacco education on the hazards of smoking into school health programmes is given in Article 66 (4) of Act 851. The Act affirms Ghana's commitment to the WHO Framework Convention on tobacco control [1]. Besides, tobacco importation into the country is strictly upon the issuance of tobacco import permit and tobacco is also not allowed to be sold in many public places such as educational and health care facilities, parks, cultural centres, etc.

Tobacco is one of the important cash crops which is mostly used to manufacture cigarettes world-wide [2]. The leaves are cured and may be smoked, powdered and sniffed, or chewed for its inebriant (intoxicating) and stimulating properties. It is extremely popular and well known for its addictive potential [3] with nicotine as an active ingredient. Nicotine is second to only caffeine as the most widely used central nervous system stimulant and second to only alcohol as the most abused drug. Studies have shown that low doses of nicotine produce some degree of euphoria and arousal as well as relaxation [4]. According to [5] people choose to smoke because they appreciate the psychoactive and stimulant effect of nicotine. Smokers also report that smoking helps them concentrate, reason, and perform observations consistent with studies

demonstrating that nicotine improves attention, learning, reaction time, and problem solving. However, nicotine is a mood-altering and habit-forming drug. Smokers feel energized for a while and then feel tired and crave for more therefore has the tendency to make smoker addicted [6].

Heavy metals get their way into soils through different anthropogenic sources such as poor waste management, runoff from industrial, agricultural and sewage treatment plants which affect human health and the ecosystem [7]. Tobacco plants take up toxic metals through the roots which are subsequently transported to the leaves [8]. The toxic metals bioaccumulate and are conveyed via the food chain [9, 10] causing adverse health problems. Plant accumulation of a given metal is a function of uptake and intracellular binding sites [11]. Trace quantities of toxic metals are transferred from the cured tobacco leaves to the tobacco smoke and then absorbed into the nasopharyngeal and tracheobronchial regions in the alveolar sac depending on the particle size of the tobacco smoke.

Uptakes of toxic metals in polluted areas have been studied to a considerable extent [12-15]. Once the environment becomes polluted with metals, it begins its journey to man's body [16, 17] by being readily absorbed by plants [18].

Some metals such as Fe, Mo and Mn are useful as micronutrients while others such as Cu, Zn, Ni and Co with high concentration are toxic. Even though metals such as Hg, Cd, Pb, As and Sb do not have known nutritional functions but are more or less toxic to plants and microorganisms [19].

1.1 Impact of Tobacco Smoking on Health

Tobacco smoke contains many chemicals and particles that affect the airways and lungs of

users. Cigarette is known to contain about 600 ingredients with about 700 chemicals, some of them linked to cancer, when smoked [6]. It poses a threat to almost all the body organs, causes many diseases and generally reduces the health of users. It also leads to diseases, disability and harms almost the following parts of the body; mouth, throat, liver, stomach, bladder, skin and colon, etc. [20]. Smoking increases the risk of coronary heart disease and stroke by 2 to 4 times, lung cancer by 25 times, and can cause cancer almost anywhere in the body [21]. It can also damage blood vessels thickening and make the vessels narrower resulting in tachycardia and high blood pressure [22,23]. Smoking damages airways and alveoli giving rise to bronchitis, asthma and emphysema. Other health risks of smoking include rheumatoid arthritis, preterm delivery, stillbirth, low birth weight, ectopic pregnancy, orofacial clefts in infants, miscarriage, affects men's sperms, periodontal diseases; gum disease, teeth discoloration and tooth loss. Smoking causes general adverse effects on the body including inflammation and decreased immunity [24].

Smokers are also said to be at high risk of COVID 19 progression than non-smokers [25]. The use of smoking and e-cigarette is known to increase the risk and severity of pulmonary infections due to damage to upper airways and a decrease in pulmonary immune function. Combustible smoking is the leading cause of preventable death and in the US, about 480,000 people who smoke die from tobacco related illnesses with the youth being mostly vulnerable. It is said to kill more Americans than alcohol, car accidents, HIV, guns, and illegal drugs combined. Lung cancer and chronic obstructive pulmonary disease (COPD) has been one of the strongest risk factor associated with combustible cigarette smoking with tobacco use disorder and medical conditions having a genetic undertone [26]. Tobacco smoking results in health related problems, affect the reproductive health of women and can cause sexual impotence in men, damages heart and blood vessels as well as the lungs (American Cancer Society) [20]. Tobacco smoking among the youth is also known to result in school dropouts and unemployment. The impact is so damaging that smoking cigarette is culturally unacceptable in many communities in Ghana.

1.2 Related Work

Pappas et al. [27] analyzed ten toxic metals in tobacco with a newly developed 'triple

quadrupole' ICP-MS technology. The results revealed no significant differences in concentrations of toxic metals in tobacco from filler of cigars compared with concentrations of toxic metals in tobacco from cigarettes with the exception of nickel. The study which was carried out in Atlanta, USA also concluded that the shift in mass approach method offered by 'triple quad' ICP-MS made it highly effective and efficient in determining the concentrations of toxic metals.

Similarly, [28] analyzed the heavy metal content of ten (10) brands of Tobacco and Cigarettes sold in Wa Municipality of Upper West region, Ghana. Heavy metals of interest included arsenic, lead, copper, iron, zinc, manganese, cadmium, nickel, chromium and selenium. The study found the levels of lead, manganese and cadmium to be slightly higher than the recommended maximum permissible limits set by the WHO/FAO/JECFA.

Also, Ziarati et al. [29] also did comparative analysis of amount of cadmium and lead absorbed by filter parts of cigarette samples after smoking and the level of cadmium and lead in tobacco parts of cigarettes. The study which was done in Iran revealed that cadmium and lead contents in cigarettes and tobacco leaves were found to be below the WHO permissible limits for human consumption. The results also showed lower content of heavy metals in ash of tobacco leaves compared with selected cigarettes.

The related studies were all carried out in different locations. Pappas et al. study was carried in Atlanta USA, Sebiawu et al. at Wa municipality of Ghana and lastly Ziarati et al. study in Iran and this study is done in the Tamale Metropolis of Northern region of Ghana.

The current study sought to assess toxic metals in some locally produced tobacco sold in the Tamale Metropolis of Northern region of Ghana. Most of the tobacco products sold in Metropolis are smuggled through unapproved routes from neighboring Togo, Burkina Faso and Côte d'Ivoire into the three regions of the north of Ghana. These smuggled tobacco products are neither given certification or approved by the Food and Drug Authority (FDA) nor meet the regulatory standards of Ghana (illicit tobacco trade), [30]. The use of these substandard tobacco products is prevalent among the youth and elderly men in the Metropolis [31, 32, 33, and 34]. The natural and the raw tobacco are also locally grown and produced by the farmers within the Metropolis and the villages within the

neighboring districts. The outcome of the study is expected to influence policy directions in aspects of control, use, production, assessment of the quality of tobacco products on the Ghanaian market in general. This study is the first of its kind in the Tamale Metropolis of Northern region of Ghana.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out within the Tamale Metropolis of Ghana. The Metropolis is one of the twenty six (26) District Assemblies which make up the Northern region of Ghana and is the capital of the Northern region. The Metropolis has an approximate land size area of 922 square kilometers with a population size of about 233,252. Geographically, the Metropolis lies between latitude $9^{\circ} 16'$ and $9^{\circ} 34'$ North and longitudes $0^{\circ} 36'$ and $0^{\circ} 57'$ West. Tamale Metropolis is bordered to the north by Savelugu-Nanton Municipality, to the east by Mion District, to the south by East and Central Gonja Districts, to the west by Tolon District and to the north-west by Kumbungu District. The majority of inhabitants are Moslems with few Christians and Traditionalists [35]. Few immigrants from neighboring Burkina Faso, Togo and Mali can be found here who are primarily involved in various vocations [36].

2.2 Sample Size and Collection

Twelve (12) variant locally produced tobacco randomly purchased from various spots within the Tamale Metropolis for the study. Samples purchased for the study comprised raw (unprocessed) tobacco locally produced commonly used by the locals. Obtained samples were coded as follows: L1, L2, LB, LW, F, GS, OF, OU, PB, PW, R and SE.

2.2.1 Apparatus used

Glassware used were soaked in detergent solution, rinsed and soaked in 10% (v/v) HNO_3 overnight. Glassware were rinsed with distilled water followed by 0.5% (w/v) KMnO_4 . They were subsequently rinsed with distilled water; oven dried and allowed to cool prior to use [36, 37]. Thick walled 500 mL digestion tubes, digestion blocks and a hot plate of temperature range of $150\text{-}180^{\circ}\text{C}$ were used. The flame atomic absorption spectrophotometer (FAAS) was used in measuring the levels of arsenic (As), Cadmium (Cd), Mercury (Hg), Lead (Pb) and Chromium (Cr).

2.2.2 Reagents

All reagents used were of analytical grade (BDH Chemicals Ltd, Poole England). Double distilled water was used for the preparation of all solutions.

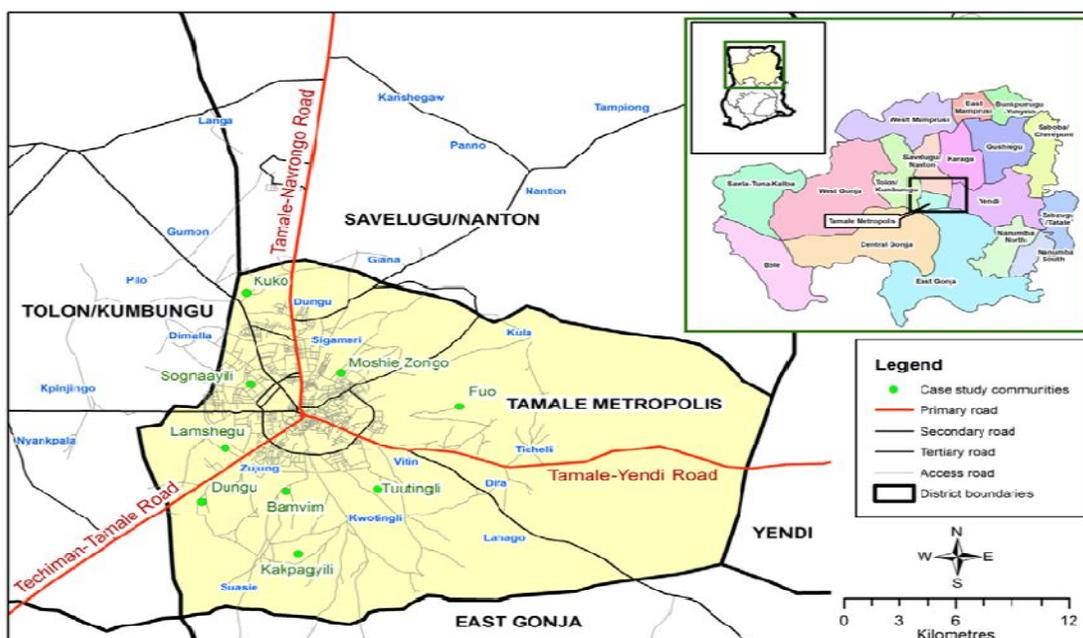


Fig. 1. Map of Tamale Metropolitan Area

2.2.3 Quality control measures for the of Atomic Absorption Spectrophotometry (AAS)

The AAS machine was calibrated using commercial stock solutions of As, Cd, Hg, Pb and Cr in each instance. Using serial dilution, a blank and series/range of calibrations solutions of known concentrations was prepared for each metal for the calibration of the AAS machine. Standard preparations were done with greatest quality control, the containers for the preparations were soaked in 1% HNO₃ solution overnight and well rinsed with de-ionized water. Chromatic lines and rays were aligned and the optimization was set to give a high sensitivity. Dropping spaces for blanks and known samples were provided. Hydride generation technique was used. The limit of detection prepared for all the metals analysed As, Cd, Cr, Hg and Pb were 0.002, 0.02, 0.03, 0.001, and 0.02 respectively. Optimization was automatically set for high sensitivity.

2.3 Sample Treatment

For each sample, 1 g of it was weighed into a 200 mL conical flask in each instance. A 10 mL of concentrated HNO₃ was added to the sample. Boiling chips were also added to allow the sample to boil smoothly without bumping. Using a hot plate, the mixture was heated to about 3 mL with a light coloured solution indicative of complete digestion. The contents of the conical flask were washed down with deionized distilled water and filtered into a 50 mL volumetric flask using a glass funnel and a Whatman 1 acid-washed filter paper. The filtrate was topped up to the 50 mL with deionized distilled water and subsequently transferred into washed plastic container for storage at 4°C [36,38]. Samples were analyzed at the Environmental Quality Laboratory of Anglo Gold Ashanti-Obuasi, Ghana.

2.3.1 Heavy metals analysis

The metals of interest As, Cd, Hg, Pb and Cr were analysed in triplicate using flame AAS from a previously wet digested samples. The blanks in each instance was first run through the AAS machine followed by the calibration (standard) solutions and their respective responses measured and a calibration graph plotted. AAS calibration was followed by the atomization of the test samples and measuring of their responses. Metal concentrations were estimated from the calibration curve in relation to the absorbance

obtained for the test solution [34]. The acetylene gas and compressor were fixed and compressor turned on and the liquid trap blown to rid of any liquid trapped. The Extractor was turned on and the AAS 220 power turned on. The capillary tube and nebulizer block were cleaned with cleansing wire and opening of the burner cleaned with an alignment card.

The worksheet of the AAS software on the attached computer was opened and the hollow cathode lamp inserted in the lamp holder. The lamp was turned on ray from cathode aligned to hit target area of the alignment card for optimal light throughput, and then the machine was ignited. The capillary was placed in a 10 ml graduated cylinder containing deionized water and aspiration rate measured, and set to 6 ml per minute.

The analytical blank was prepared, and a series of calibration solutions of known amount of analyte element (standards) were made. The blank and standards were atomized in turn and their responses measured. A calibration graph was plotted for each of the solutions, after which the sample solutions were atomized and measured. Metal concentrations from the sample solutions were determined from the calibration, based on the absorbance obtained for the unknown [34]

2.4 Analysis of Data

Heavy metal levels were expressed as mean \pm standard deviation (SD) using Minitab (17) statistical software. One-way ANOVA analysis was also performed using Minitab (17) statistical software to compare mean concentrations of the metals measured across tobacco products tested. Bar charts were generated with the aid of Microsoft excel (2016) software.

3. RESULTS AND DISCUSSION

Tobacco plants are known to absorb toxic metals through their roots as a result of type of fertilizers or pesticide used or the kind of anthropogenic activities within the area of cultivation. The toxic metals are subsequently transported to the leaves. Tobacco products both processed and unprocessed potentially contain varying levels of heavy metals. The presence of As, Cd, Hg, Pb and Cr in locally produced tobacco were confirmed in the present study.

Table 1 shows the mean concentrations of the above toxic metal contaminants detected in

twelve (12) variants of locally produced tobacco tested with Fig. 2 also showing the levels of these metals in the various samples tested.

The mean recorded concentrations of As, Cd, Hg, Pb and Cr were respectively in the ranges of 0.184 ± 0.011 to 0.515 ± 0.015 $\mu\text{g}/\text{kg}$, 0.0420 ± 0.010 to 3.100 ± 0.000 $\mu\text{g}/\text{kg}$, 0.176 ± 0.016 to 0.291 ± 0.009 $\mu\text{g}/\text{kg}$, 1.169 ± 0.019 to 3.195 ± 0.019 $\mu\text{g}/\text{kg}$ and 1.600 ± 0.116 to 3.880 ± 0.369 $\mu\text{g}/\text{kg}$. Mean concentrations of As and Pb measured in all locally produced tobacco tested were below their respective WHO permissible limits of 4.0 ppm and 10.0 ppm. In the case of Cd, mean concentrations measured for all locally produced tobacco tested were above the WHO permissible limits of 0.3 $\mu\text{g}/\text{kg}$. For Hg, levels measured in 75% of tested locally produced tobacco were slightly above the WHO permissible limit of 0.2 ppm. Cr levels measured in 30% of tested tobacco products were below the WHO permissible limits of 2.0 $\mu\text{g}/\text{kg}$.

The mean concentrations of the various metals across the tested samples showed significant

differences ($p < 0.05$) from one-way ANOVA analysis performed. For each metal, significant differences ($p < 0.05$) in mean concentrations were evident among the various samples tested.

Toxic metals are naturally present at background levels in soils principally via weathering with elevated levels primarily attributable to anthropogenic activities [39] including mining (especially galamsey), irrigation, application of synthetic fertilizers, organic manures and pesticides, contamination of agro ecosystems by industrial effluents, among others. Toxic metals in soils most often end up reaching and being assimilated into plants [40- 42] such as tobacco. Possibly, the levels of As, Cd, Hg, Pb and Cr measured in the present study came from the very soil in which the tobacco plants were cultivated. Again, heavy metal contamination of the tested locally produced tobacco may have occurred via contamination in the course of harvesting, cross contamination during processing and through the deliberate addition of metals for alleged health benefits [41].

Table 1. As, Cd, Hg, Pb and Cr levels measured for the various Tobacco Products

| SAMPLE CODES | Metal (Mean concentrations in $\mu\text{g}/\text{mg} \pm \text{SD}$) | | | | |
|-------------------|---|-------------------|-------------------|-------------------|-------------------|
| | As | Cd | Hg | Pb | Cr |
| L1 | 0.445 ± 0.010 | 0.536 ± 0.045 | 0.252 ± 0.001 | 2.091 ± 0.005 | 2.346 ± 0.385 |
| L2 | 0.291 ± 0.001 | 0.420 ± 0.010 | 0.291 ± 0.009 | 2.630 ± 0.020 | 2.050 ± 0.082 |
| LB | 0.331 ± 0.013 | 0.900 ± 0.005 | 0.176 ± 0.010 | 1.169 ± 0.033 | 2.338 ± 0.091 |
| LW | 0.370 ± 0.005 | 0.920 ± 0.076 | 0.236 ± 0.010 | 1.226 ± 0.000 | 2.408 ± 0.314 |
| F | 0.451 ± 0.000 | 2.926 ± 0.116 | 0.181 ± 0.001 | 1.721 ± 0.035 | 3.880 ± 0.369 |
| GS | 0.455 ± 0.008 | 2.937 ± 0.079 | 0.230 ± 0.005 | 2.116 ± 0.000 | 1.830 ± 0.070 |
| OF | 0.515 ± 0.015 | 2.895 ± 0.018 | 0.191 ± 0.001 | 1.786 ± 0.073 | 2.097 ± 0.122 |
| OU | 0.515 ± 0.013 | 3.100 ± 0.000 | 0.231 ± 0.013 | 2.046 ± 0.040 | 1.600 ± 0.116 |
| PB | 0.186 ± 0.010 | 0.753 ± 0.052 | 0.201 ± 0.001 | 1.971 ± 0.008 | 2.058 ± 0.028 |
| PW | 0.184 ± 0.011 | 0.491 ± 0.005 | 0.211 ± 0.013 | 1.465 ± 0.013 | 1.878 ± 0.026 |
| R | 0.275 ± 0.018 | 0.926 ± 0.010 | 0.261 ± 0.012 | 3.195 ± 0.019 | 2.077 ± 0.034 |
| SE | 0.271 ± 0.005 | 0.871 ± 0.018 | 0.216 ± 0.005 | 1.601 ± 0.050 | 2.197 ± 0.044 |
| WHO LIMITS | 4.0 | 0.3 | 0.2 | 10.0 | 2.0 |

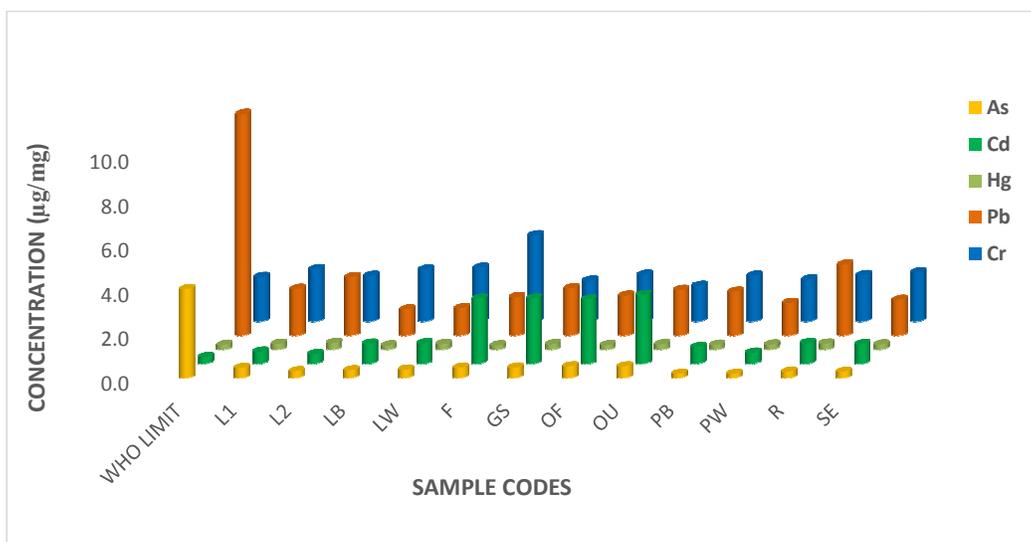


Fig. 2. Metal levels of the various Tobacco Products

Cd, Hg and Cr levels measured on grounds of exceeding their respective WHO permissible limits can be explicitly said to present a threat to human health on consumption. In respect of As and Pb however, though the levels measured were below the respective WHO permissible limits and typically suggest no threat to human health, their consumption could still be injurious to one's health on exceeding certain thresholds via bio-accumulation / bio-concentration.

The levels of each metal in the tested locally produced tobacco and their variations could also be explained in relation to the tobacco plant species and the rate of uptake of these metals influenced by the level of abundance of these metals within the soil where they grow or are cultivated. According to Annan et al. [43] plant species growing in different soils, accumulates different levels of metals.

The presence of the toxic metals- As, Cd, Hg, Pb and Cr in the various tobacco samples as established in the present study, corroborates the findings of similar studies that have reported the presence of diverse toxic metal contaminants in various tobacco products sold in Ghana [28].

3.1 Implications of As, Cd, Hg, Pb and Cr Contaminants in Tobacco Products

Environmental pollution by As occurs as a result of volcanic eruptions, soil erosion and anthropogenic activities [44]. Contamination with high levels of As can cause a number of human health effects. Several studies have reported As exposure and increased risks of both

carcinogenic and systemic health effects [45]. It can lead to conditions like neurologic and neuro behavioural disorders, diabetes, hearing loss, portal fibrosis, and hematologic disorder [46-48].

Cd is one of the non-essential elements that negatively affect plant growth and development and serve as a significant pollutant due to its toxicity and solubility in water [49]. Normal soil solution containing Cd concentration will range from 0.04 – 0.32mM [50] but with a concentration from 0.32 to 1mM can be classified as moderately polluted [51].

Cadmium is taken up by plants in nutrient solutions in the soil [51] and it's influenced by the soil pH. Cadmium is basically one of the metals used in industrial activities [52, 53]. Exposure to it also occurs through cigarette smoking or inhalation. Studies have shown that Cd levels in the blood and urine of cigarette smokers are higher [54, 55]. Acute Cd ingestion can cause gastrointestinal tract erosion, pulmonary, hepatic or renal injury and coma, depending on the exposure route of poisoning [56, 57]. The levels of Cd measured in the present study for instance is considered to be high as reported by Addo et al. [58] in their study on Mineral profile of Ghanaian dried tobacco leaves and local snuff.

Studies have indicated that Hg occurs naturally and contaminates the environment largely as a result of anthropogenic activities. It is a systemic toxicant that induces adverse health effects in humans, including cardiovascular diseases. Hg is strongly toxic to the reproductive and nervous systems [59].

Pb has no nutritive value and happens to be one of the most toxic heavy metals [60]. Progressive exposure to Pb results in a decrease in the performance of the nervous system and affects renal clearance [61]. When consumed beyond a certain threshold, Pb can increase blood pressure accompanied by debilitating effects on key organs such as the kidney and the brain [53]. Acute exposure to Pb induces brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, kidneys, and vitamin D metabolism [62, 63].

Cr is required nutritionally at low concentrations. Some studies indicate that high exposure might also result in contact allergic sensitization [64]. Studies have also indicated that Cr (VI) is cytotoxic and able to induce DNA damaging effects such as chromosomal abnormalities [65].

The exposure of these metals through the use of tobacco could therefore poses serious health challenges to tobacco smokers as indicated in the research. Every effort to control the production and use of tobacco is therefore in the right direction.

4. CONCLUSION

Cd, Hg and Cr levels in the locally produced tobacco studied were found to exceed the WHO permissible limits for human consumption by plant uptake with As and Pb levels well below their permissible thresholds. The analyzed locally produced tobacco essentially poses a threat of heavy metal toxicity to consumers via bioaccumulation and bio-concentration in human tissues.

Thus the need for Ghana's Food and Drugs Authority (FDA) to intensify locally produced tobacco and tobacco products inspection, monitoring, post market surveillance and evaluation to ensure strict conformance and certification of locally produced and imported tobacco products from neighboring countries into the Tamale Metropolis and Ghana at large.

Sustainable public education on the use of tobacco coupled with policy interventions is very necessary to reduce the effect of tobacco use on the health of the populace.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this piece of article. The ethical issues including plagiarism, data fabrication or falsification etc., have been witnessed by the authors.

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