SURVEY OF POLYCYCLIC AROMATIC HYDROCARBONS AND LEAD IN CHINESE TEAS SOLD IN NIGERIA: LEVELS AND HEALTH IMPLICATIONS

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ABSTRACT

Background. The belief that Chinese teas are of immense health benefits by many Nigerians has led to high consumption rate.
Objectives. This study has determined lead and polycyclic aromatic hydrocarbons (PAHs) levels of Chinese teas popularly consumed in Nigeria and to estimate the potential health risks.
Material and Methods. Twenty brands of Chinese teas commonly consumed in Nigeria purchased in October 2014 were used in the study. Tea samples were extracted and digested. Lead, and PAHs were analyzed using an atomic absorption spectrophotometric (AAS) and gas chromatographic methods, respectively. Daily intake, percent violations of permissible limits, target hazard quotients (THQ), Health Risk Index (HRI) of lead, and other cancer risk parameters of PAHs were estimated.
Results. All the tea samples except super natural green tea violated the WHO permissible limit of lead (0.01 mg/kg) by over 100%. The HRI ranged from $5.09 \times 10^{-5} – 7.20 \times 10^{-4}$. Among the single analyzed compounds, the pyrenes had the highest concentration of 14.31 mg/kg. The intake of benzo[a]pyrene was detected in 25% of the samples which ranged from 0.066 to 0.145 mg/kg and exceeded the permissible daily limit of benzo[a]pyrene intake. The estimated cancer risk from this study in an adult is 5.07×10^{-9}.
Conclusion. The present study suggests that consumption of Chinese teas in Nigeria may not be one of the factors responsible for the increased rate of cancer in Nigeria.

Key words: *lead, teas, permissible limits, risk assessment, food safety analysis, Nigeria*

INTRODUCTION

Tea also known as 'health beverage' because of its antioxidant properties and several beneficial health effects is a popular beverage in Nigeria. It is expected that such foods should be free from toxic substances such as heavy metals and polycyclic aromatic hydrocarbons [PAHs] [25]. Tea cultivation seems to be more widespread, but production is more concentrated in few countries. In 2000, five countries namely India, China, Sri Lanka, Kenya and Indonesia together produced almost 80% of the world's tea [17]. Some contaminants are important in tea, from food safety aspects, such as heavy metals and other organic pollutants.

Trade liberalization in Nigeria has led to the flooding of the Nigerian market with sundry items ranging from consumables to electronics. Chinese teas are highly reputed to restore the body's proper balance to maintain optimum health by many Nigerians. Some of these teas which are hawked openly in public places including motor parks and offices have been used both as food supplements and as medicines. It is known that the intake of food contaminated with some anthropogenic chemicals can lead to both acute and chronic diseases [7]. Due to their persistence resulting from lipophilic properties of some chemical contaminants, they tend to concentrate in the food chain, particularly associated with fat [34].

Consumers in the West are beginning to avoid items that display "Made in China" on the label in the light of safety concerns about a number of exported Chinese products. China was accused of exporting contaminated wheat gluten in the United States in 2007 [11]. The Consumer Product Safety Commission in 2007 recalled several children's items imported from China because of lead contamination. The world's largest toy manufacturer, Mattel, with operating plants in Asia for nearly

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50 years, recalled large volume of toys contaminated with lead-based paint in 2007 [1]. The FDA also issued an alert to consumers to avoid using contaminated toothpaste made in China [30]. Lead and polycyclic aromatic hydrocarbons have important public health implications in Nigeria [20 - 22].

The objectives of this study include to determine the current extent of lead and polycyclic aromatic hydrocarbons contaminations of Chinese teas popularly consumed in Nigeria and to estimate the potential health risks as cumulative non-carcinogenic and carcinogenic risks *via* the oral route of ingestion.

MATERIALS AND METHODS

Determination of lead

Twenty brands of Chinese teas commonly consumed in Nigeria purchased in October 2014 from Uyo, Akwa Ibom State, Nigeria were used in this study. The samples were extracted and digested in Teflon lab ware that had been cleaned in a high-efficiency particulate air (HEPA) filtered (class 100), trace-metal-clean laboratory to minimize contamination. This protocol involved sequential cleaning of the lab ware in a series of baths in solutions (1 week each) and rinses (five per solution) in a three-step order, namely a detergent solution and deionized water rinses, then 6-NHCl (reagent grade) solution and ultrapure water rinses, finally 7.5 N HNO_3 (trace metal grade) solution and ultra-pure water rinses. The lab ware was then air dried in a polypropylene laminar air flow-exhausting hood. Dry ash method was used by adding 30 ml of each sample into a conical flask and heated on a hot plate at 200°C, for 45 min, then in a furnace at 500°C until the volume was reduced to near dryness. Digestion was done by addition of 10 ml conc. *aqua regia* (HCl:HNO$_3$, 3:1), it was then heated to dryness. Twenty milliliters deionized water was added, stirred and filtered. The filtrate was made up in standard volumetric flask and lead concentrations were assayed with atomic absorption spectrophotometry 205A. The limit of detection (LOD) of lead was 0.01 mg/kg with blank values reading as 0.00 mg/kg in deionized water with electrical conductivity value of lower than 5 μS/cm. Samples were analyzed in triplicates.

The Target Hazard Quotient (THQ) of lead was calculated using the method of [26].

$$THQ = \left(\frac{Efr \ \times \ ED \ X \ BIR \ \times \ C}{RfDo \ \times \ BW \ \times \ AT} \right) \times 10^{-3}$$

Where:
Efr - Exposure frequency = 365 days/year
ED - Exposure duration = 55 years, equivalent to average life time of a Nigerian adult
BIR - basic ingestion rate = 0.25 L/day equivalent to one cup per day of 250 ml

C - concentration of lead in tea = mg/L
RfDo - oral reference dose = 1.5 mg/kg/day for lead
BW - average body weight of adult = 65 kg
ATn - average exposure time for non-carcinogen in days (Efr x ED)
10^{-3} - the unit of conversion

Whereas the Health Risk Index (HRI) and Daily Intake of Lead (DIL) were calculated according USEPA 2002 [29] and *Li* et al 2008 [37] respectively as shown below:

$$HRI = \frac{DIL}{RfDo} \quad [29]$$

Where:
DIL = Concentration x Weight of food/Body weight [37].

The intake using the arithmetic mean according to [23] was calculated by multiplying contaminant level, that is, lead level by amount/volume of Chinese tea. For the estimated intakes of lead 0.25 liters was assumed to be the average volume of the Chinese tea.

Determination of PAHs

Glass wares were washed thoroughly with hot detergent solution followed by rinsing with purified water and acetone (analytical grade) respectively. These were finally baked in the oven at 100°C overnight. To avoid contaminations, different glass wares and syringes were used for standards and for solutions extracted from samples.

Sample extraction and GC analysis: Extraction of polycyclic aromatic hydrocarbons from the STP samples was done with a sonicator (Ultrasonic bath-Elmsonic S40H) in accordance with US SW-846 Method 3550. Tea samples were extracted with a 50:50 mixture of acetone and methylene chloride spiked with 1 ml of PAH internal standard and shaken thoroughly for proper mixing before placing in an ultrasonic bath. The concentrations of USEPA-16 PAHs (naphthalene, acenaphtylene, acenaphtene, fluorene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]anthracene, chrysene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-c,d]pyrene, dibenzo[a,h] anthracene, and benzo[g,h,i]perylene) were analyzed by gas chromatography (gas chromatograph (GC-FID) with GC recorder interfaced with a HP.

The USEPA-16 PAHs determination was conducted at Jaros Inspection Services Limited, Port Harcourt, Rivers State, Nigeria using Gas Chromatographic System (6890 series and 6890 plus) equipped with a dual detector (FID-ECD), dual column and TriPlus AS auto-sampler with helium carrier gas and a quadrupole Mass Spectrometer (Agilent 5975 MSD) based on USEPA method 8100 (EPA, 1984) [31]. A 2.00 μl of extracts were injected into the GC port set at column conditions: HP-5 cross-linked PH-ME siloxane, Length of 30 m,

Table 1. Lead concentration, percent violation Target Hazard Quotient (THQ), daily intake of lead (DIL) & Health Risk Index (HRI) of Chinese teas

Product Name	Lead (mg/kg)	% Violation			THQ	DIL	HRI
		WHO (0.01)	USEPA (0.05)	EU (0.002)			
The ionique sex tea	0.0217	>100	NV	>100	0.0001	9.04×10^{-5}	6.03×10^{-5}
The Rheumatism Granula	0.1029	>100	>100	>100	0.0003	4.29×10^{-4}	2.86×10^{4}
Camel china green tea	0.0481	>100	NV	>100	0.0001	2.0×10^{-4}	1.33×10^{-4}
Hypertension glycerine the reduction	0.0712	>100	42.4	>100	0.0002	2.97×10^{-4}	1.98×10^{-4}
Joint care Tea	0.1697	>100	>100	>100	0.0005	7.07×10^{-4}	4.71×10^{-4}
Liver purifying eyesight improving tea	0.2364	>100	>100	>100	0.0007	9.85×10^{-4}	6.57×10^{-4}
Hemorrhoid tea	0.0694	>100	38.8	>100	0.0002	2.89×10^{-4}	1.93×10^{-4}
Cough relieving lung nourishment tea	0.1436	>100	>100	>100	0.0004	5.98×10^{-4}	3.99×10^{-4}
Anti-diarrhea tea	0.2592	>100	>100	>100	0.0007	1.08×10^{-3}	7.20×10^{-4}
Lemon slimming tea	0.0672	>100	34.4	>100	0.0002	2.80×10^{-4}	1.87×10^{-4}
Olive (Noni the healer)	0.0498	>100	NV	>100	0.0001	2.08×10^{-4}	1.39×10^{-4}
Black tea	0.1497	>100	>100	>100	0.0004	6.24×10^{-4}	4.16×10^{-4}
Decline the sugar tea	0.2346	>100	>100	>100	0.0007	9.78×10^{-4}	6.52×10^{-4}
Anti-heart failure tea	0.1179	>100	>100	>100	0.0003	4.91×10^{-4}	3.27×10^{-4}
Mensuration regulating tea	0.0542	>100	8.4	>100	0.0002	2.26×10^{-4}	1.51×10^{-4}
Tranquilizing brain nourishing tea	0.0234	>100	NV	>100	0.0001	9.75×10^{-5}	6.50×10^{-5}
Super natural green tea	0.0183	83	NV	>100	0.0001	7.63×10^{-5}	5.09×10^{-5}
De malaria (Plaudisme)	0.1196	>100	>100	>100	0.0003	4.98×10^{-4}	3.32×10^{-4}
Anti nicotine tea	0.0437	>100	NV	>100	0.0001	1.82×10^{-4}	1.21×10^{-4}
Ahmad mint green tea	0.1374	>100	>100	>100	0.0004	5.61×10^{-4}	3.74×10^{-4}

I.D: 0.25 mm, thickness of 1 μm with helium carrier gas set in the spitless, constant flow mode with 1.2 ml/min flow rate. Other GC and MS operating set-up were done according to the instrument's method development as specified in the operating instruction manual. Identification and quantification of individual PAHs was based on internal calibration standard containing known concentrations of the USEPA 16 PAHs. The specificity of the USEPA 16 PAHs sought for in the samples was confirmed by the presence of transition ions (quantifier and qualifier) as shown by their retention times which corresponded to the respective standards. The measured peak area ratios of precursor to quantifier ion were in agreement with those of the standards.

The detection limit (LOD), estimated as three times the background noise (IUPAC criterion), was similar for all analysed compounds and results were less than 0.015 μg/kg d.w. for all analytes. The blank values of analytical procedure remained always below the quantification limit (LOQ): 0.05 μg/kg d.w., estimated as 10 times.

Cancer risk

In the present study the average daily exposure based on the consumption of Chinese teas was calculated using the equation below [2]

$$\text{Dose} = \frac{\text{Concentration} \times \text{Intake Rate} \times \text{Exposure Factor} \times \text{Conversion Factor}}{\text{Body weight}}$$

dose = estimated exposure dose (mg/kg/day)
concentration = contaminant concentration (mg/kg)
intake rate = intake rate of tea 0.25 L

exposure factor = 5 times a week per year =260/365 unitless)
conversion factor = 10^{-6} kg/mg
body weight = body weight (assumed to be 65 kg)

The cancer potency factor (CPF) is the lifetime cancer risk estimated to result from continuous exposure to a substance at a concentration of 1 mg/kg body weight. The lifetime average daily exposure (ADE) is estimated by adjusting the ADE according to adult body weight (assumed to be 65 kg), the number of years of Chinese tea consumption (assumed to be 30 years) and the average lifetime (assumed to be 55 years).

The equation for estimating the lifetime ADE is the following:

$$\text{Incremental lifetime Cancer Risk} = \text{ADE}_{\text{lifetime}} \times \text{CPF}$$

$$\text{ADE}_{\text{lifetime}} = \frac{\text{ADE} \times \text{number of years drinking Chinese tea}}{\text{average lifetime}}$$

Where:
$\text{ADE}_{\text{lifetime}}$ = lifetime average daily oral exposure (mg/kg body weight/day) and CPF = cancer potency factor ((mg/kg body weight/day)$^{-1}$).
ADE = Average Daily Exposure
CPF = Cancer Potency Factor also called CSF "Cancer Slope Factor"(mg/kg/day)$^{-1}$; 7.3 (mg/kg/day)$^{-1}$ for B(a)P
Number of years drinking Chinese tea = assumed to be 30 yrs, average lifetime = 55 yrs,

RESULTS

Table 1 shows the different lead concentration, percent violations, target hazard quotient, daily intake of lead (DIL) and hazard risk index (HRI) from consumption of different Chinese tea from different manufacturers. The mean and range of lead concentrations in the tea samples were 0.1069 mg/kg, 0.0183-0.2592 mg/kg respectively. All the tea samples except super natural green tea violated the WHO permissible limit of 0.01 mg/kg by over 100%. The unique sex, camel china green, olive, tranquilizing brain nourishing, super natural green and anti-nicotine teas all fell within the USEPA standard, while others had varying degrees of violations ranging from 8.3% ->100%. All the samples violated the EU permissible limit by over 100%. The highest THQ value of 0.0007 was observed in liver purifying 'Eyesight improving tea', 'Anti-diarrhea tea' and 'Decline sugar tea'. All the THQ values were below 1. The highest intake of lead was from the consumption of anti-diarrhea tea. The HRI ranged from $5.09 \times 10^{-5} - 7.20 \times 10^{-4}$ which was calculated using the reference dose for Pb =1.5 and the DIL of each sample.

Table 2 shows the estimated weekly intake of lead. The intake of lead was estimated for a consumer who takes 0.25 L once or twice daily of Chinese tea for a week. The highest intake of lead was found to be 0.9072 mg/L and 0.524 mg/L for a consumer who takes 'Anti--diarrhea', 'Liver purifying' and 'Decline the sugar' tea and black tea respectively in one week.

Table 2. Weekly intake of lead

Lead Intake	0.5 x 0.2592 = 0.1296 x 7days = 0.9072 mg/L
Lead Intake	0.25 x 0.2592 = 0.0648 x 7days = 0.4536 mg/L
Lead Intake	0.5 x 0.1497 = 0.0749 x 7days = 0.524 mg/L
Lead Intake	0.25 x 0.1497 = 0.0374 x 7days = 0.2619 mg/L

(0.25 L was assumed to be volume of a single dose of the Chinese tea, which is multiplied by the highest concentration of lead from selected Chinese tea and eventually multiplied by 7 days: the volume of the Chinese tea was also doubled).

The concentration of 16 individual PAHs in Chinese teas are given in Table 3. Among the single analyzed compounds, the pyrenes had the highest concentration of 14.31 mg/kg. The lowest concentration of individual PAH is dibenzo[a, h]anthracene (0.028 mg/kg). The highest levels of total PAHs were that of Camel china CCT (4.887 mg/kg), "Rheumatism granula RMT' (4.629 mg/kg), 'Ahmad mint AMT' (4.629 mg/kg) and 'Anti-nicotine ANT' (4.586 mg/kg). The lowest were from 'Anti diarrhea ADT' (0.17 mg/kg), 'Joint care JCT' (0.47 mg/kg) and 'Decline the sugar DST' (0.369 mg/kg) respectively.

Table 4 shows the intake of PAHs in Chinese teas. The intake of benzo[a]pyrene was found in only four samples which ranged from 0.066-0.145 mg/kg which exceeded the permissible daily limit of B[a]P intake. Intake of carcinogenic PAHs in Chinese tea is highest in AMT (1.194 mg/kg) and the lowest intake is from consumption of 'Tranquilizing TRT' (0.145 mg/kg). The intake of PAHs expressed in mg/kg of body weight for a 65 kg adult was found to be highest from consumption of black tea BLT (1.013 mg/kg/day) and lowest from DST (0.001 mg/kg/day). Table 5 shows the Toxicity Equivalent (TEQ) of benzo[a]pyrene concentration in Chinese teas. The total TEQ was highest in 'Rheumatism granula RMT' with a value of 0.907.

DISCUSSION

The intake of food contaminated with chemicals may result to intoxication that can be described as acute or, when the disease appears after a latent period of time, long-term or chronic intoxications. Ingestion of contaminated food is the main route of human exposure to these noxious compounds, accounting for more than ninety percent compared to other routes [27]. The present study has highlighted the contamination profile of Chinese teas commonly consumed in Nigeria and the possible public health implications.

Chinese teas contain lead levels which ranged from 0.0183-0.2592 mg/kg and some of the levels of in these teas are above the WHO, USEPA, EU permissible limits and in violation of these permissible limits. The presence of the lead could be attributed to background levels of this metal in surface soil and ground water where these teas are grown arising from sundry anthropogenic activities. It could also be as a result of accidental contamination during the manufacturing process, such as grinding weights, lead releasing containers or other manufacturing utensils [35]. This lends credence to the report by [12] that lead contamination is not uncommon in Asian herbal products as at least 10% Asian patent medicines collected from herbal stores in California, USA contained at least 1 ppm lead.

The intake of lead in China has been reported to be higher than published data from elsewhere, namely France (0.20 μg/kg b.w./day in adults and 0.27 μg/kg b.w./ day in children), Canada (0.13 μg/kg b.w./day), Australia (0.12–0.13 μg/kg b.w./day in adults and 0.16–0.17 μg/ kg b.w./day in children), Lebanon (0.14 μg/kg b.w./day assuming a 60 kg default body weight), Germany (0.26 μg/ kg b.w./day), Korea (0.41 μg/kg b.w./day), Spain (1.21 μg/ kg b.w./day) and Italy (0.92 μg/kg b.w./day) [4, 14]. The dietary intake of lead arising from consumption of Chinese tea in this study tended to be lower than these figures.

These Chinese teas which are consumed regularly with the aim of managing one form of disease as their

Table 3. Polycyclic aromatic hydrocarbons (PAHs) concentration (mg/kg) in Chinese teas

PAH	AHT	ADT	IST	JCT	HGT	CRT	ANT	TRT	CCT	AMT	SNT	BTT	LPT	MCT	DMT	DST	OHT	RMT	HMT	LST	TOTAL
Naphtalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	NIL
Acenaphthylene	ND	ND	ND	ND	ND	ND	ND	0.511	ND	0.005	1.769	ND	ND	ND	ND	ND	ND	ND	ND	0.061	2.346
Anthracene	ND	ND	0.212	ND	ND	1.008	ND	ND	ND	0.741	ND	3.475	ND	ND	ND	ND	1.386	0.002	ND	ND	6.824
Acenaphthene	ND	ND	ND	ND	ND	0.131	ND	2.229	ND	0.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.008	3.268
Flourene	ND	ND	ND	ND	ND	0.148	ND	0.086	ND	0.041	ND	ND	ND	ND	ND	ND	ND	0.021	ND	0.041	0.337
Phenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.081	0.081
Flouranthene	ND	ND	0.604	0.471	ND	0.643	ND	ND	0.249	0.325	ND	ND	0.51	ND	ND	ND	0.839	ND	0.643	0.249	4.533
Pyrene	1.653	0.177	0.397	ND	1.653	0.645	2.653	ND	1.607	0.906	ND	ND	0.084	1.653	0.907	0.369	ND	ND	0.645	1.607	14.31
Benz(a)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	2.117	1.071	ND	ND	ND	ND	1.317	ND	ND	1.396	ND	ND	5.902
Chrysene	0.466	ND	ND	ND	0.466	ND	0.466	ND	0.914	0.721	ND	ND	1.308	0.466	ND	ND	ND	ND	ND	ND	4.807
Benzo(B,J,K)flouranthene	0.466	ND	ND	ND	0.466	ND	1.466	ND	ND	2.983	0.161	ND	0.657	0.486	ND	ND	ND	2.539	ND	ND	9.224
2-Bromonaphthalene	ND	ND	ND	ND	ND	ND	ND	0.674	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.674
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	0.579	ND	ND	0.266	ND	ND	ND	0.415	ND	ND	0.514	ND	ND	1.774
Indeno(1,2,3-Cd)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.194	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.194
Dibenzo(A,H)anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.028	ND	ND	ND	ND	ND	ND	ND	0.028
Benzo(G,H,I)pyrelene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.199	ND	ND	ND	ND	ND	ND	ND	0.199
Total	2.586	0.177	1.212	0.471	2.586	2.575	4.586	4.091	4.887	4.629	2.391	3.475	2.786	2.606	2.639	0.369	2.225	4.629	1.288	2.04	

AHT= Anti-heart, ADT = Anti diarrhea, IST = Ionique Sex, JCT = Joint care, HGT = Hypertension Glycerine, CRT= Cough relieving, ANT= Anti-nicotine, TRT= Tranquilizing, CCT= Camel china, AMT= Ahmad mint, SNT= Super natural, BTT= Black tea, LPT= Liver purifying, MCT= Mensuration, DMT= De malaria, DST= Decline the sugar, OHT=Olive the healer, RMT= Rheumatism granula, HMT= Hemorrhoid, LST= Lemon slimming

Table 4. Intake of PAHs (mg/kg) in Chinese teas

Chinese teas	AHT	ADT	IST	JCT	HGT	CRT	ANT	TRT	CCT	AMT	SNT	BLT	LPT	MRT	DMT	DST	OHT	RMT	HMT	LST
Benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	0.145	ND	ND	0.066	ND	ND	ND	0.104	ND	ND	0.129	ND	ND
Carcinogenic PAHs	0.233	ND	ND	ND	0.233	ND	0.483	0.145	0.758	1.194	0.155	ND	0.535	0.238	0.433	ND	ND	1.151	ND	ND
Sum of 16 PAHs	0.646	0.044	0.305	0.118	0.646	0.644	1.146	1.019	1.222	1.150	0.598	0.869	0.696	0.651	0.659	0.092	0.556	1.157	0.322	0.511
Dietary intake /Body weight*/day	0.009	0.0007	0.005	0.002	0.009	0.009	0.017	0.016	0.019	0.018	0.009	1.013	0.011	0.01	0.01	0.001	0.009	0.018	0.005	0.008

Carcinogenic PAHs include benz[a]anthracene, benzo[a]pyrene, benzo[b] uoranthene, chrysene, dibenz[a,h]anthracene, and indenol[1,2,3-c,d]pyrene, which are probable human carcinogens according to the U.S. EPA.

Table 5. Toxicity Equivalent (TEQ) of benzo[a]pyrene concentration (mg/kg) in Chinese teas

Carcinogenic PAHs	TEF	AHT	ADT	IST	JCT	HGT	CRT	ANT	TRT	CCT	AMT	SNT	BTT	LPT	MCT	DMT	DST	OHT	RMT	HMT	LST
Benzo[a]Anthracene	0.1	ND	ND	ND	ND	ND	ND	ND	ND	0.212	0.107	ND	ND	ND	ND	0.132	ND	ND	0.139	ND	ND
Chrysene	0.01	0.005	ND	ND	ND	0.005	ND	0.005	ND	0.009	0.007	ND	ND	0.013	0.005	ND	ND	ND	ND	ND	ND
Benzo[b+j+k]Flouranthene	0.1	0.05	ND	ND	ND	0.05	ND	0.147	ND	ND	0.298	0.016	ND	0.066	0.049	ND	ND	ND	0.254	ND	ND
Benzo[a]Pyrene	1	ND	ND	ND	ND	ND	ND	ND	0.579	ND	ND	0.266	ND	ND	ND	0.415	ND	ND	0.514	ND	ND
Indenol[1,2,3-cd]Pyrene	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0194	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dibenzo[a,h]Anthracene	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.028	ND	ND	ND	ND	ND	ND	ND
TOTAL TEQ B[a]P		0.055	ND	ND	ND	0.055	ND	0.152	0.579	0.221	0.412	0.301	ND	0.107	0.054	0.547	ND	ND	0.907	ND	ND

Table 6. Exposure dose of carcinogenic PAHs in Chinese teas

Chinese Teas	AHT	ADT	IST	JCT	HGT	CRT	ANT	TRT	CCT	AMT	SNT	BTT	LPT	MCT	DMT	DST	OHT	RMT	HMT	LST
Dose	1.51 E-10	ND	ND	ND	1.51 E-10	ND	4.16 E-10	1.59 E-09	6.1 E-10	1.13 E-09	8.25 E-10	ND	2.93 E-10	1.48 E-10	1.49 E-09	ND	ND	2.49 E-09	ND	ND

names imply are taken by both infants and adults, and this may place the population at risk of lead intoxication. Children are more vulnerable to lead exposure because absorption from the gastrointestinal tract is higher in children than in adults and the developing nervous system is thought to be far more vulnerable to the toxic effects of lead than the matured brain [15].

The presence of PAHs in consumables is a matter of concern that requires continuous monitoring. The presence of PAHs in the Chinese teas may have resulted from deposition of gaseous or particle bound PAHs on growing leaves and/or exposure to combustion products during the processing of their leaves [8]. The waxy surface of some leaves can concentrate low molecular mass PAH mainly through surface adsorption. PAHs concentrations are generally greater on plant surface (peel, outer leaves) than in internal tissue. Careful washing may remove up to 50% of the total PAHs. Particle bound PAHs are easily washed off the surface whereas those in the waxy layer are less efficiently removed, washing may alter the apparent high to low molecular mass PAHs profile [8]. It is however worthy noting that during tea infusion only 12.6% of total PAHs present in tea leaves was released into the beverage [6].

Only recently *Jędrychowski* et al. [13] showed that the height growth deficit in children monitored over a nine-year period is significantly associated with prenatal PAH exposure levels above 35 ng/m^3. *Choi* et al. [5] reported that fetal PAHs exposure was significantly associated with reduced birth length by 0.5cm/ln-unit of PAH concentration.

Co-exposure to PAHs and heavy metals has been associated with the etiology and prognosis of many illnesses. Some workers have shown that exposure to PAHs or heavy metals could generate reactive oxidative species (ROS) to induce oxidative stress *in vitro* or *in vivo* [33]. *Valavanidis* et al. [32] reported that some heavy metals and PAHs may promote ROS generation which increase the burden of oxidative stress.

Depending on the Toxic Equivalence Factor (TEF) and carcinogenic slope factor (CSF), a probabilistic risk assessment framework was applied to estimate risk incurred from consumption of Chinese teas. In an attempt to estimate the potency of a PAHs moiety of a mixture, the total number of benzo[a]pyrene equivalents of the mixture is multiplied by the potency for B[a]P [21, 36]. TEFs adopted by the US EPA [21] provide values for: benzo[a]anthracene TEF = 0.1, chrysene TEF = 0.001, benzo[b]fluoranthene TEF = 0.1, benzo[k]fluoranthene TEF = 0.01, benzo[a]pyrene TEF = 1, dibenzo[a,h]anthracene TEF = 1, and indeno[1,2,3-c,d]pyrene TEF = 0.1. In turn, *Larsen* et al. [16] included the same PAHs than the US EPA, although with different TEF values and adding also benzo[g,h,i]perylene. TEF values were used to calculate PAH as benzo[a]pyrene equivalents for an

adult (65 kg body weight). As regards the carcinogenic risk associated with the intake of PAHs from Chinese teas, an acceptable daily intake of benzo[a]pyrene was calculated as the amount that would be associated with a $1/10^6$ increase in risk of cancer for an adult of 65 kg body weight [3, 9].

The estimated cancer risk from this study in an adult of 65 kg body weight is 5.07×10^{-9} . This value is not within the risk level of 10^{-4} - 10^{-6} as stipulated by USEPA. Exposures and estimated cancer risks were calculated for consumption of Chinese teas. Excess cancer risk is expressed as a portion of the population that may be affected by a carcinogen during a lifetime of exposure. An estimated risk of 1×10^{-6} predicts the probability of one additional cancer, over background, in an exposed population of one million. The estimated cancer risk from exposure to PAHs arising from consumption of Chinese teas were calculated to be less than the U.S. EPA cancer risk range of 1×10^{-4} to 1×10^{-6} [3]. Those who are chronically exposed to elevated levels of PAHs could have an increased risk of developing certain types of cancer.

Low and middle income countries (LMIC) are projected to contribute to more than 80% of the 1.27 million new cases of cancer and almost 1 million deaths by 2030 [28]. In Nigeria, the incidence and prevalence of cancer has been on the increase [10]. This was revealed by the data released by the Kano Cancer Registry [18]. Among children, PAH exposure can result in congenital defects in the neural tube [19] and affect neurodevelopment [24].

CONCLUSIONS

Taken together the present study tends to suggest that consumption of Chinese teas in Nigeria may not be one of the contributory factors for the increased rate of cancer in Nigeria.

Conflict of interest
The authors confirm no conflict of interest.

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