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Toxicological exposure to phthalates mixtures and human health risk assessment of drinking water and fruit drinks packaged in plastics and tetra pak cartons

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Abstract

Background: This study estimates the migration and levels of phthalate esters in drinking water and fruit drinks packed in plastics and tetra pak cartons that are regularly available for consumption in Nigeria. The probable human health risk from the long-term consistent ingestion of the drinking water and fruit drinks products were also investigated.

Results: Nine (9) phthalates were detected in the analyzed samples and they all showed varying concentrations. The results showed that the total mean concentration of the analyzed phthalates in the drinking water and fruit drinks packed in plastic container were found with the range of 1740–2370 µg/L and 1340–2220 µg/L respectively while fruit drinks packed in tetra pak container showed comparatively low concentration range of 385–450 µg/L. Also, the health hazard (HQ) values for the exposure via oral ingestion by adults were recorded at 505.974, 390.353 and 64.161 respectively for water and, fruit drinks packed in plastics and tetra pak containers. Correspondingly, very high values of HQ were observed in children (2529.80, 2187.39 and 355.92). The overall carcinogenic risks estimated owing to oral ingestion in adults were 0.01, 0.02 and 3.3×10^{-4} for drinking water and fruit drinks packaged with plastics and tetra pak container respectively while higher carcinogenic (CR) values of 0.04, 0.08 and 0.02 were observed in children.

Conclusions: The result obtained showed comparatively low concentrations of phthalates in fruits drinks packaged in Tetra Pak cartons than drinking water and fruit drinks in plastics containers. The high values of hazard index (HI) and CR observed in drinking water and fruit drink packaged in plastics is an indication of future health challenges relating to carcinogenic effects on the favorite consumer of the drinks in which children are more vulnerable. In view of this, packages like tetra pak product and less toxic materials could be adopted for packing drinking water and fruit drinks to avoid exposing consumers to phthalates present in plastics containers which have attendant negative health effect.

Keywords: Phthalates, Plastics, Tetra pak cartons, Consumption, Health risk

Background

Fruit, vegetable-based juices and drinking water stored in cans, plastics and tetra Pak are significant contributors of vitamins, minerals and dietary fiber that offers a balanced diet and electrolytes to the body system (Taylor et al. 2005; Phillips et al. 2007). They are therefore regarded as an important ingredient that makes a healthy

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life (Kanchanamayoon et al. 2012; Hackney et al. 2012; Higgins et al. 2010).

Over the years, the use of plastics made from polyethylene terephthalate (PET) for packaging has been a usual practice in many parts of the world. Drinking water and fruit drinks are packaged in plastics in order to makes them handy and readily available at any point in time. However, these packaging materials usually have direct contact with water and edible food item they are packed with (Hackney et al. 2012).

Recently, different health concern arisen on the nature of packages used for food and water products meant for human consumption to ascertain and monitor its safety through the assessment of its potential health risk (Cai et al. 2003). Phthalates are synthetic chemicals in form of additives incorporated into packaging materials during production to modify their properties thereby improving its toughness and flexibility (Gevao et al. 2013; Cincotta et al. 2018). They are an important class of endocrine disruptors which affect multiple endpoints and exist as a constellation by constituting a group of health related symptoms. This effect are due to phthalate esters incorporation during plastic production (Chang et al. 2017).

Chemically, phthalates are covalently bound to the polymeric matrixes in which they are incorporated (Rusyn et al. 2012). As a result of this, they easily migrate from the polymer matrix either to the environment during production or to the content of the container they are used to package and their leaching increases over time thereby causing contamination of the content (Kereszrtes et al. 2013; Al-Saleh et al. 2011). Also, unsuitable storage conditions like degradation and oxidation could result in increase in the rate of migration of the phthalate compounds into the content of the container (Bach et al. 2012; Silano and Silano 2017).

The health risk associated with leaching of phthalate from packaging materials cannot be overlooked owing to their biochemical and toxicology implications on human. European Food Safety Authority (EFSA) and the US Environmental Protection Agency (EPA) has identified some congeners of phthalate esters as priority pollutants (USEPA 1991). The presence of phthalates in human body has been reported to result in adverse health conditions which includes endocrine system disruption, initiation of numerous cancerous reaction and developmental of abnormalities through interference with the functioning of various hormone systems (Lee and Koo 2007). Some other studies have shown that phthalates contribute to the risk of endometriosis, a disease in which endometrial cells emerge from the external section of the uterine cavity.

The present study aimed at determining the levels of phthalates and risk evaluation of some packaged drinking water and fruit-based drinks in plastics and tetra pak containers that are known to be immensely consumed in Nigeria.

Methods

Reagents and chemicals used

Analytical grade anhydrous sodium sulphate, silica gel, toluene and acetone were procured from the vendors of Sigma-Aldrich in Nigeria. Doubly distilled water was used for the washing and rinsing of apparatus used in the preliminary extraction stages. Phthalate standards (Diethyl phthalate (DEP), Bis (2-ethylhexyl) phthalate (DEHP), Dimethyl phthalate (DMP), Dibutyl phthalate (DBP), diphenyl phthalate (DPhP), and internal standard which is benzyl benzoate) of high purity (> 98%) were obtained from Merck (Germany).

Sampling

A wide sampling distribution of different brands of drinking water and fruit drinks packaged in plastics and tetra pak containers were purchased from sales outlets in Osogbo, Osun State, Nigeria. Another set of samples were taken from each stratum and stored in a pre-cleaned and baked glass bottles coded as A, B, C, D, E, F, G and H and later stored in a cool place at room temperature prior to analysis.

Extraction of phthalates and clean-up

The extraction was done according to Farahani et al. (2007). 300 mL of each sample was extracted serially in a 1000 mL separating funnel with 30 mL of analytical grade toluene. This procedure was carried out in triplicate for each sample. The extracted samples were cleaned up with the aid of a chromatography column (1 cm internal diameter). The column was loaded to 5 cm with 10 g of activated silica gel (100–200 Mesh) and later with anhydrous Na_2SO_4 (1 cm). It was then washed with acetone and later with toluene. Subsequently, the extract was transferred into the column and eluted with 10 mL toluene and later concentrated to 0.5 mL. The recovered eluate was evaporated to dryness and then reconstituted with 1 mL of toluene and stored in the refrigerator at 4 °C prior to analysis using gas chromatography-mass spectrometry (GC–MS).

Standards preparation

The stock solution (1000 mg/L) for each phthalic ester was prepared in a 20 ml volumetric flask and diluted as appropriate, using a mixture of the phthalates and internal standard (I.S) at 1000 mg/L concentrations with ten replicate injections (1 μL). Different phthalate standards were prepared from stock separately in 10 mL standard flasks and a mixture of all the standard was made from the stocks at the same ratio for the standards, respectively.

Recovery analysis

Recovery analysis was conducted to ascertain the efficiency of the extraction as well as the instrumental analytical procedure. Mixture of 10 μg/mL of available concentration of phthalates were prepared and added to a known volume of working samples with vigorous shaking and left in a corked container overnight before extraction. Also, an equal volume of samples was prepared without spiking. The two samples were kept under the same conditions. It was then extracted and cleaned up accordingly and analyzed for their phthalates content. The % R was evaluated from the relationship:

$$\%R = \frac{A - B}{C} \times 100 \tag{1}$$

where A is the concentration of phthalate in the spiked sample, B is the concentration of phthalate in the unspiked sample, and C is the concentration used for spiking.

Instrumental analysis

The qualitative identification and quantification of phthalates were done with Varian 3800/4000 gas chromatography-mas spectroscopy (GC–MS) system (Agilent Technologies, Santa Clara, CA, USA) with a capillary column (VF-5 ms: length: 30.0 m, diameter: 0.25 mm). GC conditions such as oven/inlet temperatures, carrier gas flow, and detector temperature were optimized as follows: oven: initial temperature, 180 °C, ramp rate of 12 min, final temperature, 280 °C with 2.0 and 7.0 min hold times respectively; injector temperature: 180 °C, carrier gas which is nitrogen is set point of 2.0 ml/min. These conditions gave an analysis time of 17.33 min. The MS specifications were as follows: Ion source temp: 200 °C, interface temp: 240 °C, scan range: 40–650 m/z, event time: 0.5 s, solvent cut time: 5 min, start time: 5 min, end time: 35 min, ionization: EI (70 eV).

GC–MS quantification of phthalate ester in drinking water and fruit drinks samples

Each analyzed phthalate ester in the sample extract were identified by equating the retention times of each sample with benzyl benzoate (internal standard) while quantification was done by employing the calibration curve obtained for the phthalates. To obtain this, the extracts from the samples were accurately diluted in order to ensure linearity of the concentration with the calibration curve. However, phthalates which shows no well-defined peaks are recorded as not detected (ND). Concentration of each phthalate ester in the extract was determined from the expression below:

$$\text{Response Factor} = \frac{\text{Peak areas of phthalate esters}}{\text{Peak areas of internal standards}} = \frac{\text{Concentration of phthalate esters in the extract}}{\text{Concentration of internal standards}} \tag{2}$$

Human risk assessment

Model of health risk assessment obtained from USEPA was used to evaluate the carcinogenic and non-carcinogenic risk consumers are exposed to through the oral ingestion of the sampled drinking water and fruit drinks packaged in PET bottles and Tetra Pak cartons. Calculation of the carcinogenic risk (CR) was done from the relationships:

$$\text{EDI} = \frac{C \times \text{IR} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}} \tag{3}$$

$$\text{CR} = \text{EDI} \times \text{SF} \tag{4}$$

In which EDI = estimated daily intake (μg/L day^{-1}), C = chemical concentration in the beverages (μg/L), IR = beverage ingestion rate (0.6 L day^{-1}), EF = exposure frequency (365 days year^{-1}), ED = exposure duration (year) (for children: ED = 6, for adults: ED = 70), BW = body weight (children: BW = 14 kg, adults: BW = 70 kg), AT = average lifespan (children: AT = 2190 days, adults: AT = 25,550 days), SF = slope factor (kg day^{-1} mg^{-1}).

Estimation of the non-carcinogenic risk, hazard quotient (HQ) was obtained using the following equation:

$$\text{HQ} = \frac{\text{EDI}}{\text{RfD}} \tag{4}$$

where R_fD (μg kg^{-1} day^{-1}) is the reference dose of the contaminant via oral exposure route. The values of SF and R_fD are obtained from the USEPA Integrated Risk Information System.

Data analysis

Descriptive and inferential statistics was used to analyze the data obtained using Statistical Package for Social Scientists 16.0 (SPSS Inc., Chicago, IL, USA).

Results

Results of recovery analysis

The results of the recovery analysis of the samples are presented in Table 1 and the chromatogram showing the relative abundance and retention of the detected phthalates in Fig. 1a–d. The reliability of the analytical

Table 1 Response Factor and Recovery for the analyzed phthalates

Phthalate compound	Response factor	Percent recovery (%)
DMP	1.32	97.50
DEP	1.99	78.50
DBP	1.04	101.21
DEHP	1.50	95.20
DPP	1.15	85.96

DMP dimethyl phthalate, *DEP* diethyl phthalate, *DBP* dibutyl phthalate, *DEHP* di(ethylhexyl) phthalate, *DPP* diphenyl phthalate

procedures adopted in this study was tested on the basis of its sensitivity, recovery and accuracy. The obtained percentage recovery for the spiked phthalates ranged between 78.50 and 101.21% which fell within the acceptable range of 70–110% of recovery as stated by the assessment of European Union (2008). The recovery results established that the method adopted in this study is dependable and effective and so it is reproducible.

Phthalates characterization

Table 2 shows the mean concentrations of nine (9) phthalates (dimethyl-, dimethyl-iso-, diethyl-, di-n-butyl-, diphenyl, diisobutyl-, di(2-ethylhexyl)- and dimethyl (glycol) phthalate) detected at various levels in the drinking water and fruit drinks.

The result of the concentrations (μg/L) of phthalates in the plastic drinking water showed some significant differences in the phthalate concentration of different brands of the bottled drinking water with an indication that concentrations of phthalate esters content in the bottles varies or the rate of leaching of the mentioned phthalates is entirely different which could be due to diverse production and environmental factors. The observed total mean concentrations in the samples ranged between ND and 420 μg/L. The dominant phthalates identified in the plastic drinking water were DEP (19%), DBP (16%) DMP (15%), DiBP (14%) and BOP (14%), and DPP (13%) while DMIP, DEHP and DMGP showed relatively low contribution at 9%. Unlike the bottled drinking water samples, DEP, DMP and DPP congener were the most predominant phthalate detected in the bottled fruit drinks out of all the detected phthalates in the bottled fruit drinks samples as shown in Table 2.

However, the concentrations of phthalates detected in the fruit drinks packaged in tetra pak containers were reported at relatively low concentration as compared with both bottled water and fruit drinks. All other phthalates detected in these samples varied from ND to 90 μg/L with only DBP (120.00 μg/L) showing relatively high mean concentration.

Tetra Pak cartons are made of paper cardboard (75%), polyethylene (20%) and aluminum foil (5%) but however, the cover of the carton is made of plastic. A total mean concentration of 450 μg/L and 385 μg/L was detected in all of the nine (9) phthalates of the brand investigated.

Human health risk assessment

The major route of phthalates exposure to humans from drinking water and fruit drinks is oral ingestion. This assessment as presented in Tables 3 and 4 respectively for children and adult were the evaluation obtained for possible health risk associated with ingestion of the examined drinking water and fruit drinks samples which are based on the leaching of the incorporated phthalates in the polymer matrix used to make the package containers. The risk quotient, estimated daily intake (EDI), hazard quotient (HQ) and carcinogenic risk (CR) for oral ingestion in the analyzed drinking water and fruit drinks packaged with plastics and tetra pak as obtained from two population groups (children and adult) which have varying body weights as stated by USEPA (2019).

The likelihoods of developing cancer over a lifetime from exposure to phthalates was assessed through carcinogenic health risk, this value ranged between 10^{-6} to 10^{-4}. The overall carcinogenic risks estimated owing to oral ingestion in adults were 0.01, 0.02 and 3.3×10^{-4} for drinking water and fruit drinks packaged with plastics and Tetra Pak respectively while CR values of 0.04, 0.08 and 0.02 were observed in children.

Discussion

This investigation showed that samples of drinking water and fruit drinks packaged in plastics shows relatively high concentrations of phthalates compared with Tetra Pak containers.

It was observed that phthalate detected in this study have retention time in direct proportionality to their molecular mass which is similar to the report of Adewuyi and Olowu (2012) which stated that retention time increases as molecular weight increases**.** The results of this investigation is in agreement with the report of Oghenekohwiroro et al. (2016) which states that DPP and DEP are the common phthalates used in plastics production. Also, it can be inferred that the high concentration of some phthalates in the drinking water sample suggests leaching of phthalates used to manufacture the plastic bottles into the content of the container as a result of weak covalent bond that exist between the polymer matrix and the plasticizer used in its production which can migrate from the surface of the container into the food content in which it is packaged with, as they can undergo degradation and decomposition reactions over time (Silano and Silano 2017).

However, comparatively lower concentrations of phthalates were observed in tetra pak cartons and this could be due to the absence of polyethylene terephthalates incorporated in the container. Nevertheless, tetra pak carton cover can as well cause leaching of phthalates into the fruit drinks content as it is made of polyethylene terephthalate which could be accounted for by the phthalates values still detected in this study. Besides, these values could be due to phthalate contamination from treatment facilities such as pipes, storage tanks, as well as filtering systems in the course of production right before packaging (Leivadara et al. 2008). Besides, starting substances or additives can contain impurities, which also might leach into the food content.

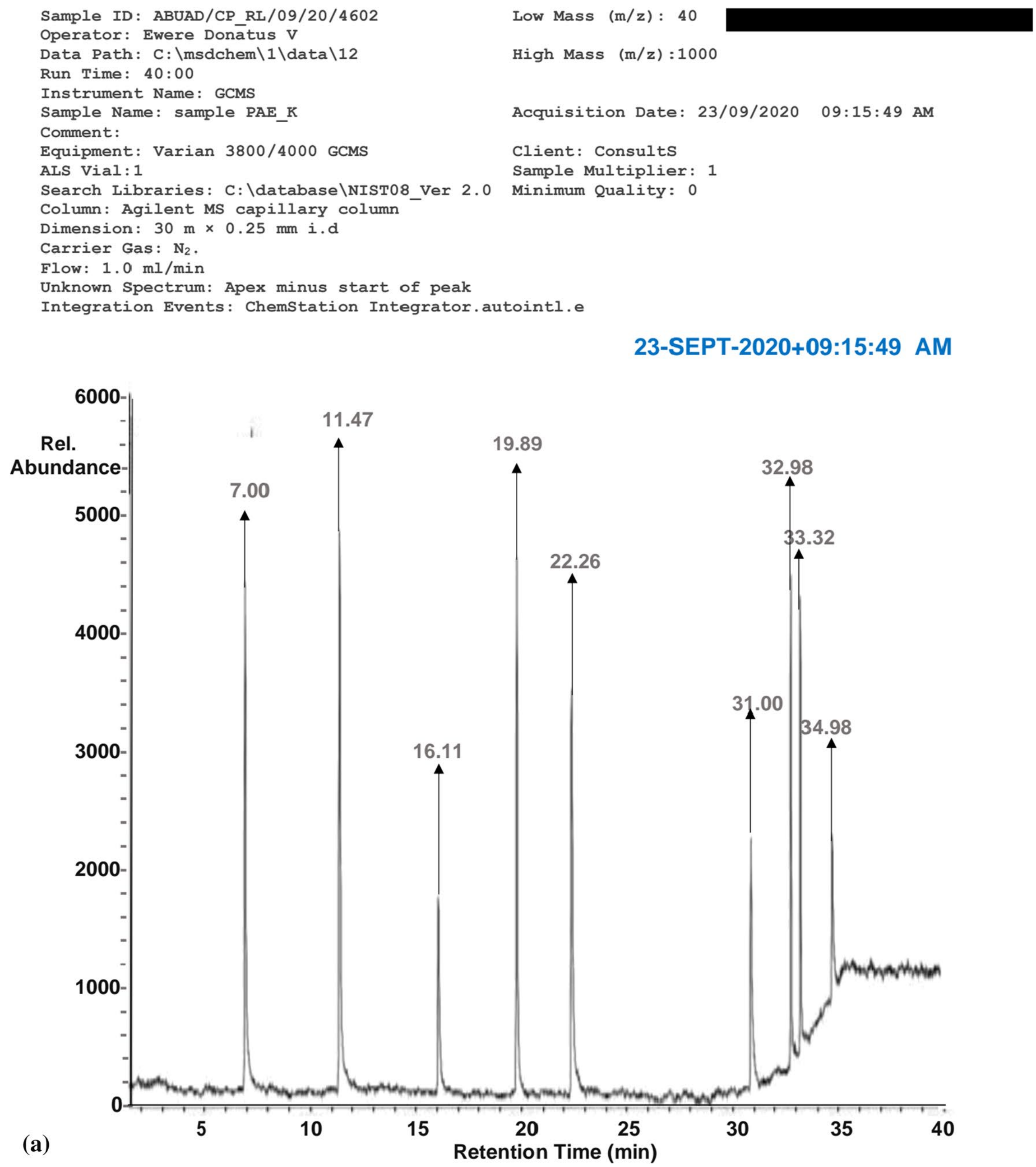

Fig. 1 **a**–**d** Chromatogram showing the retention times and relative abundance of the detected phthalates in samples

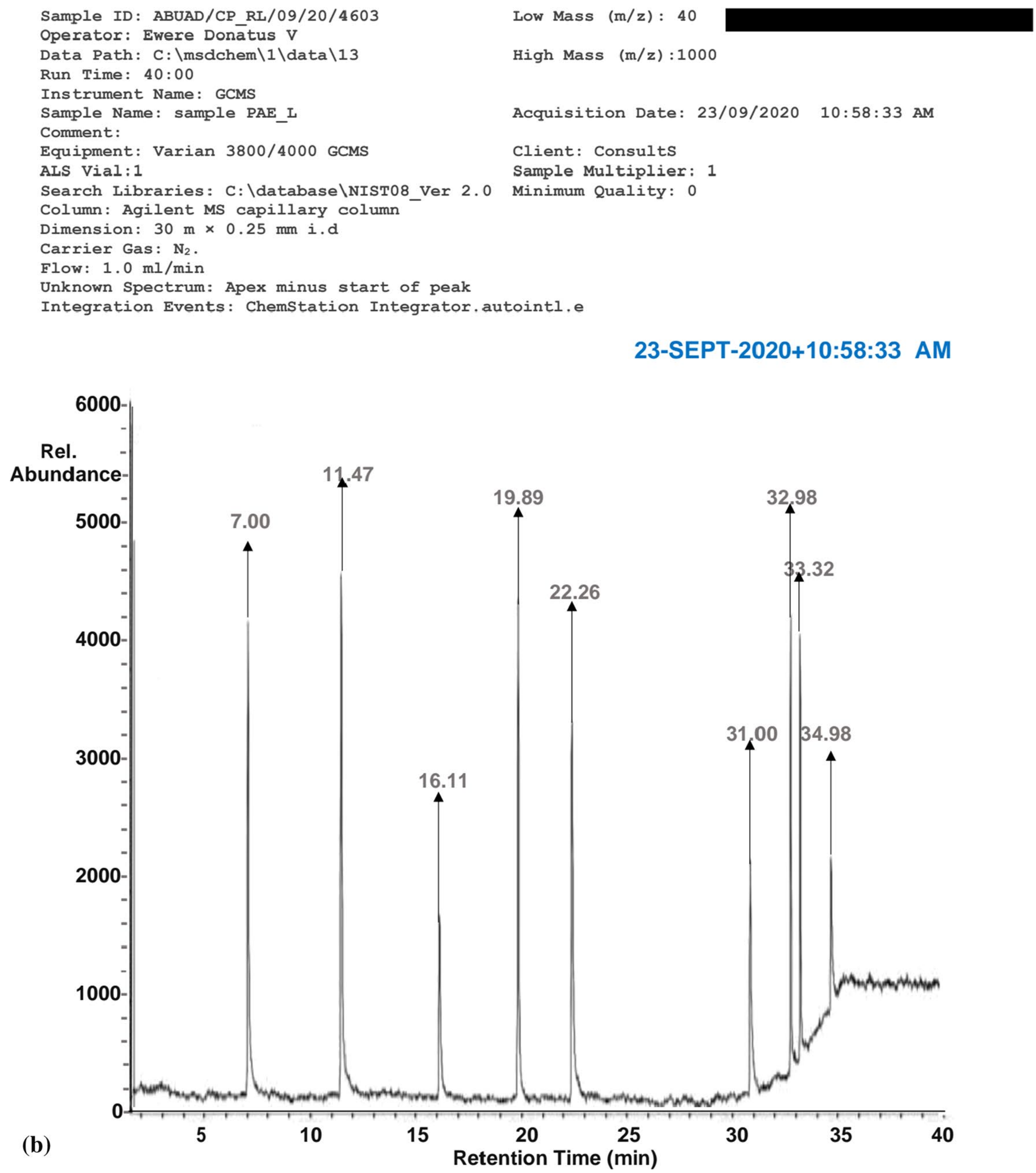

Fig. 1 continued

As earlier reported by numerous studies, many of the detected phthalates in the analyzed samples have been reported to cause a wide range of birth defects and permanent reproductive damage in exposed animals in the laboratory even at relatively low concentrations (Ema et al. 1998). Also, report have it that some of the metabolites of phthalates detected in this study can affect reproduction and development in humans and animal generally; testicular and sexual differentiation effects are common adverse effect on human (Ema et al. 1998).

In comparison with some other earlier research around the world, the concentrations of phthalates measured in this present study were found to be relatively very high. In Nigeria, Dada et al. reported concentrations range of

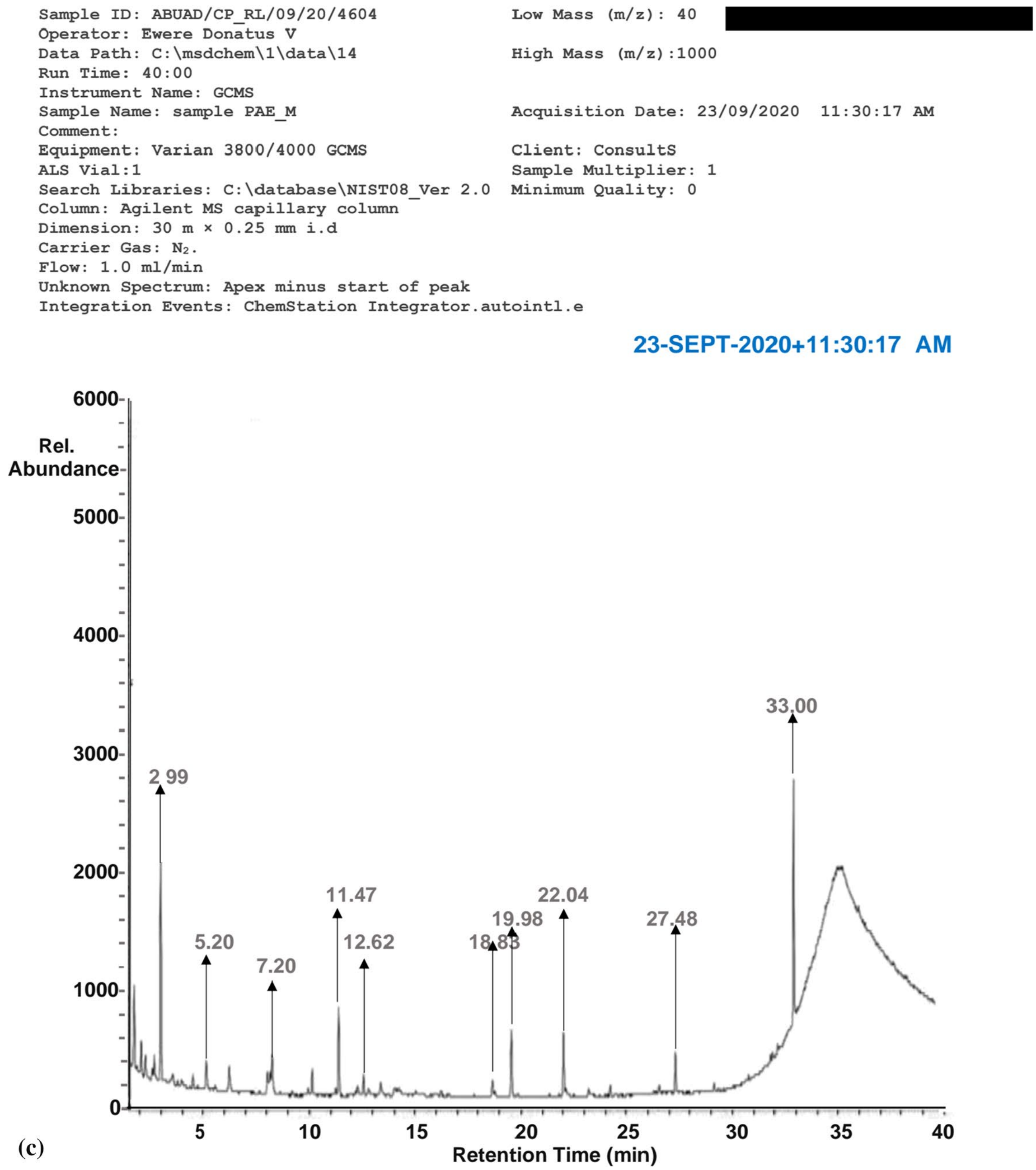

Fig. 1 continued

300 ± 7.00 µg/L, 240 ± 1.60 µg/L, and 400 ± 4.00 µg/L for DMP, DEP, and DBP in bottled water samples while Oghenekohwiroro et al. (2016) recorded extremely low phthalates concentration of 0.03–0.09 µg/L for DMP, 0.06–0.20 µg/L for DEP, and 0.00–0.03 µg/L for DBP in unpackaged drinking water samples. Also, analysis of bottled water in Thailand by Kamonwan et al. (2019) showed concentration range of 160–530, 110–540, and 170–330 µg/L for DMP, DEP, and DBP respectively which was still found lower that the findings of this present investigation.

This assessment of the health risks was categorized via non-carcinogenic and carcinogenic (USEPA 2019). Estimation of Hazard quotients (HQ) gives non-carcinogenic health risks assessment in which hazard quotient greater than 1 implies little or no associated potential harmful impacts on human health while HQ > 1 infers associated undesirable negative health impacts on human (USEPA

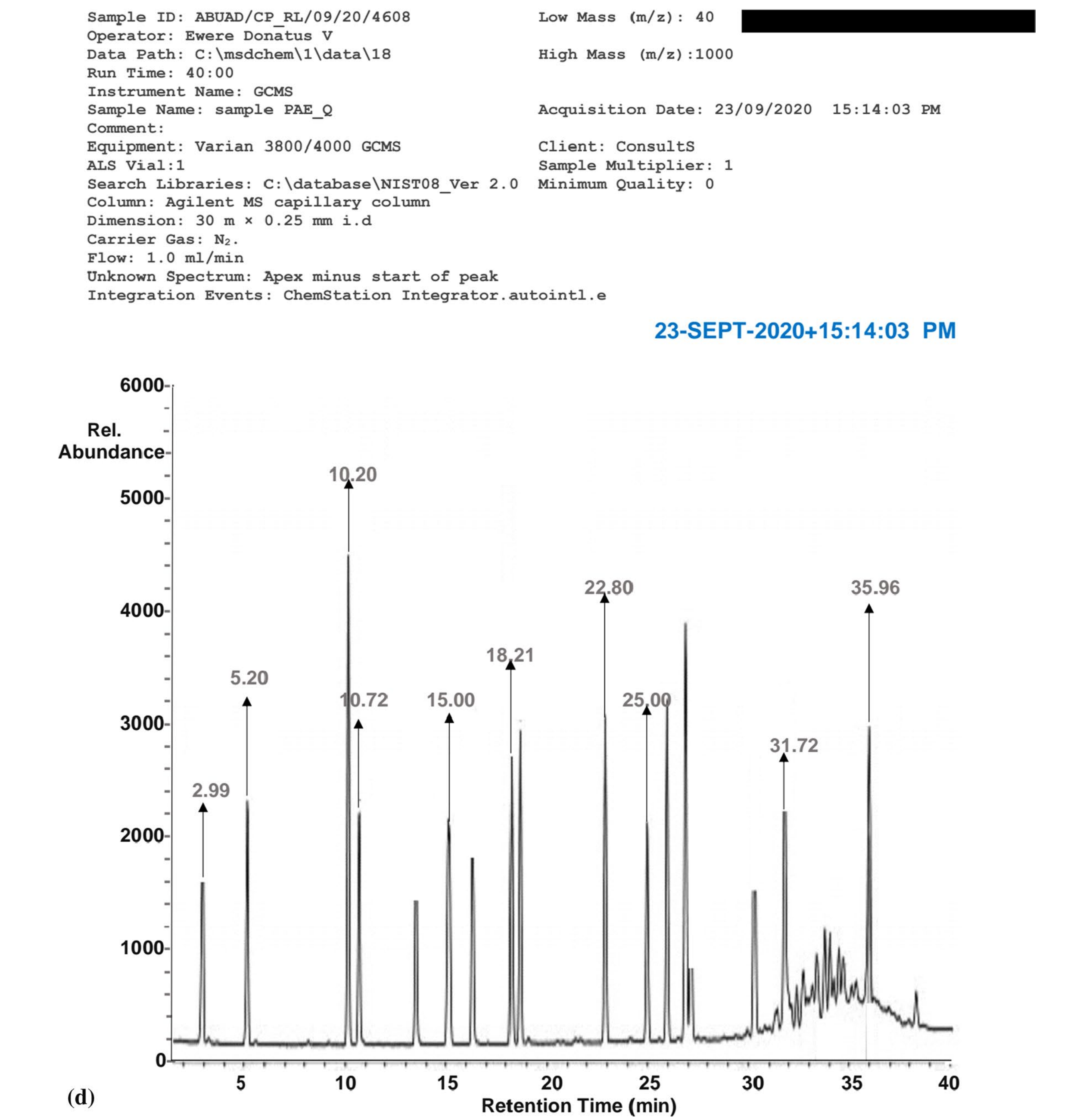

Fig. 1 continued

2019). Reference values and cancer slope factors (SFs) for many phthalates had not been defined and as a result of this, phthalates with no defined reference values of SFs were not studied.

The target hazard quotients were computed from the estimated daily intake and the oral reference dose. The result however indicated that the populations more susceptible to phthalates in the analyzed drinking water and fruit drinks packaged with plastics are children and this is as described.

Hazard index (HI) which is an estimation of associated non-carcinogenic health risk via ingestion of organic toxins is the total HQ for the analyzed phthalates. Children showed HI values of phthalates of 2529.80, 2187.39 and 355.92 while adult presented HI of 505.97, 390.35 and 64.16 for plastics drinks, plastics packaged fruit drinks and drink in Tetra Pak containers,

Table 2 Mean concentrations (µg/L) of the individual Phthalates in the samples

Compound	PET bottled water				PET fruit drinks		Tetra pak	Fruit drinks
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
DMP	390 ± 5.50	390 ± 1.50	160 ± 1.20	140 ± 4.50	120 ± 3.50	390 ± 2.80	40 ± 0.90	30 ± 0.25
DMIP	60 ± 1.20	60 ± 1.00	160 ± 1.00	170 ± 2.00	180 ± 1.20	40 ± 1.80	20 ± 1.20	ND
DEP	410 ± 2.70	400 ± 1.2	400 ± 2.50	380 ± 1.80	420 ± 4.20	40 ± 1.00	30 ± 0.50	30 ± 1.00
DEHP	60 ± 0.10	60 ± 0.50	100 ± 2.00	140 ± 5.00	140 ± 1.50	90 ± 0.50	90 ± 1.10	90 ± 1.80
DBP	380 ± 1.50	400 ± 7.00	280 ± 5.00	300 ± 2.70	310 ± 2.80	120 ± 1.50	90 ± 1.00	120 ± 2.50
DiBP	320 ± 5.00	300 ± 2.80	270 ± 1.20	340 ± 10.20	320 ± 5.10	ND	ND	ND
DPP	380 ± 4.00	360 ± 5.10	120 ± 0.50	280 ± 2.90	290 ± 1.50	520 ± 4.70	10 ± 4.50	35 ± 8.50
BOP	370 ± 2.50	350 ± 2.80	160 ± 1.00	330 ± 5.20	130 ± 1.20	50 ± 1.00	80 ± 0.50	60 ± 1.20
DMGP	ND	ND	090 ± 5.51	140 ± 1.50	120 ± 7.30	90 ± 0.80	90 ± 1.20	90 ± 1.50
Total	2370 ± 12.50	2320 ± 8.00	1740 ± 15.02	2220 ± 7.25	1930 ± 5.00	1340 ± 4.50	450 ± 2.00	385 ± 1.50

DMP dimethyl phthalate, *DMIP* dimethyl isophthalate, *DEP* diethyl phthalate, *DEHP* di(ethylhexyl) phthalate, *DBP* dibutyl phthalate, *DiBP* diisobutyl phthalate, *DPP* diphenyl phthalate, *BOP* bis-octyl phthalate, *DMGP* dimethylglycol phthalate

Table 3 Health risk assessment of phthalates for oral ingestion by children

Phthalates compound				Drinking water in plastic container			Fruit drinks in plastic container			Fruit drinks in tetra pak cartons	
	RfD	SF	EDI	HQ	CR	EDI	HQ	CR	EDI	HQ	CR
DMP	0.1	NA	13.41	134.14	–	9.26	92.57	–	1.50	15.00	–
DMIP	NA	NA	3.99	–	–	5.57	–	–	0.43	–	–
DEP	0.8	NA	17.27	21.59	–	12.00	15.00	–	1.29	1.61	–
DEHP	0.03	0.014	3.13	104.30	0.04	5.27	175.70	0.08	1.18	39.30	0.02
DBP	0.01	NA	15.13	1512.90	–	10.41	1041.40	–	2.89	289.30	–
DIBP	0.02	NA	12.69	634.30	–	14.14	707.15	–	0.00	0	–
DPP	0.1	NA	12.26	122.57	–	15.56	155.57	–	1.07	10.71	–
BOP	NA	NA	12.56	–	–	5.83	–	–	3.00	–	–
DMGP	NA	NA	3.86	–	–	1.29	–	–	33.86	–	–
Total			94.47	2529.80	0.04	79.33	2187.39	0.08	47.89	355.92	0.02

DMP dimethyl phthalate, *DMIP* dimethyl isophthalate, *DEP* diethyl phthalate, *DEHP* di(ethylhexyl) phthalate, *DBP* dibutyl phthalate, *DiBP* diisobutyl phthalate, *DPP* diphenyl phthalate, *BOP* bis-octyl phthalate, *DMGP* dimethylglycol phthalate, *RfD* reference dose, *SF* slope factor, *EDI* Estimated daily intake, *HQ* hazard quotient, *CR* Carcinogenic risk

Table 4 Health risk assessment of phthalates for oral ingestion by adults

Phthalates compound				Drinking water in plastic container			Fruit drinks in plastic container			Fruit drinks in tetra pak cartons	
	RfD	SF	EDI	HQ	CR	EDI	HQ	CR	EDI	HQ	CR
DMP	0.1	NA	2.68	26.83	–	1.85	18.51	–	0.30	3.00	–
DMIP	NA	NA	0.80	–	–	1.11	–	–	0.09	–	–
DEP	0.8	NA	3.45	4.32	–	2.40	3.00	–	0.26	0.32	–
DEHP	0.03	0.01	0.63	20.87	0.01	1.05	35.13	0.02	0.02	0.80	3.34E−4
DBP	0.01	NA	3.03	302.60	–	2.08	208.30	–	0.58	57.90	–
DIBP	0.02	NA	2.54	126.85	–	1.89	94.30	–	0	0	–
DPP	0.1	NA	2.45	24.51	–	3.11	31.11	–	0.21	2.14	–
BOP	NA	NA	2.51	–	–	1.17	–	–	0.60	–	–
DMGP	NA	NA	0.26	–	–	0.99	–	–	0.77	–	–
Total			18.34	505.97	0.01	15.66	390.35	0.02	3.58	64.16	3.34E−4

DMP dimethyl phthalate, *DMIP* dimethyl isophthalate, *DEP* diethyl phthalate, *DEHP* di(ethylhexyl) phthalate, *DBP* dibutyl phthalate, *DiBP* diisobutyl phthalate, *DPP* diphenyl phthalate, *BOP* bis-octyl phthalate, *DMGP* dimethylglycol phthalate, *RfD* reference dose, *SF* slope factor, *EDI* Estimated daily intake, *HQ* hazard quotient, *CR* Carcinogenic risk respectively. The high values of HI observed in children as compared to adult are an indication of significant exposure by children. Correspondingly, the calculated HI values in this investigation were found greater than 1 signifying associated detrimental effect from exposure to phthalates. The results thereby showed that drinking water and fruit drinks packaged in plastics has the highest recorded values of HI and CR which could be due to leaching of phthalates present in the polymer matrix of the plastics into its content. This is an indication that packaging drinks and consumables with tetra pak can reduce exposure to phthalates because they made from polyethylene material.

Conclusions

The results of this investigations show the concentration of nine phthalates (DMP, DMIP, DEP, DEHP, DBP, DiBP, DPP, BOP and DMGP) in different brands of drinking water and fruit drinks packaged in plastics and tetra pak containers. Concentration range of 1740–2370 μg/L were observed in plastic drinking water, followed by that fruit drinks (1340–2220 μg/L) in plastics while the least concentrations of phthalates recorded was from fruit drinks packaged in tetra pak (385–450 μg/L). The results indicated that the packaged materials used for drinking water and fruit drinks in plastics could be responsible for leaching out of phthalates into the content in which it is used to pack.

The high values of HI and CR observed in drinking water and fruit drink packaged in plastics is an indication of impending health challenges of carcinogenic effects being imposed on the favorite consumer of the drinks in which children are more exposed. In view of this, packages like tetra pak product and less toxic materials could be adopted for packing drinking water and fruit drinks to avoid exposing consumers to phthalates present in plastics containers which have attendant negative health effect.

Abbreviations

CR: Carcinogenic risk; EDI: Estimated daily intake; GCMS: Gas chromatography mass spectrometry; C: Chemical concentration; IR: Ingestion rate; EF: Exposure frequency; ED: Exposure duration; BW: Body weight; AT: Average lifespan; SF: Slope factor; HQ: Hazard quotient; RfD: Reference dose; DMP: Dimethyl phthalate; DMIP: Dimethyl isophthalate; DEP: Diethyl phthalate; DEHP: Di(ethylhexyl) phthalate; DBP: Dibutyl phthalate; DiBP: Diisobutyl phthalate; DPP: Diphenyl phthalate; BOP: Bis-octyl phthalate; DMGP: Dimethylglycol phthalate.

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Author contributions

AOA designed and supervised the study; RMO and AKA carried out the research, analyses and wrote the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that no competing interest of any sort existed.

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