



Determination of polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs) in some personal care products in Nigeria



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ABSTRACT

The study was carried out to determine the presence and concentration of polycyclic aromatic hydrocarbons (PAHs) and organochlorine pesticides (OCPs) in some personal care products in Nigeria. Commonly used consumer care products grouped into four classes, namely: plastics, cosmetics, disinfectants and washing products, were purchased from some supermarkets in Ile-Ife, Nigeria. The solid samples were pulverized and the PAHs and OCPs were extracted with n-hexane and dichloromethane, respectively using Soxhlet extraction method, while the liquid samples were extracted using liquid-liquid extraction method. The quantitative and qualitative determinations were carried out using Gas Chromatography coupled with Flame Ionization Detector (GC-FID) for PAHs, and Gas Chromatography coupled with Electron Capture Detector (GC-ECD) for the OCPs. The results for PAHs analysis gave an overall mean concentration of $3259.10 \pm 5223.16 \mu\text{g g}^{-1}$ for plastics and $8388.00 \pm 7106.55 \mu\text{g g}^{-1}$ for cosmetics. Comparatively, the concentrations of PAHs in the cosmetic samples were higher than in plastics samples, while both values were greater than the recommended limits of PAHs in consumer care products as stipulated by the World Health Organization. For the OCPs, disinfectant samples had a total mean concentration of $10.65 \pm 6.50 \mu\text{g mL}^{-1}$, while washing products had a total mean concentration of $35.31 \pm 39.31 \mu\text{g mL}^{-1}$. The concentrations of OCPs in washing products were higher than their concentrations in disinfectant samples. The results of the OCPs in some samples were greater than Maximum Residual Limit (MRL) recommended by the European Commission. The study concluded that consumer care products used in this study contained PAHs and OCPs at levels that could be risky to human health if the consumer care products are not used with caution.

1. Introduction

Consumer care products are household and personal care products or goods used at the home level. They are movable products that are essential for human uses. Household goods include air conditioners, plastics, fabrics care, foam control and polishes [1]. Personal care products differ from household products in that large amounts can be directly introduced to the environment. For example, these products (plastics, cosmetics, disinfectants, washing products etc.) can be released directly into recreational waters or volatilized into the air (e.g. musks) and because of this direct release, they can bypass possible degradation in publicly owned treatment works (POTWs). Also, in contrast to household products, less is known about the effects of these broad and diverse classes of chemicals on non-target organisms, especially aquatic organisms. Data are limited on the unexpected effects on

humans. For example, common sunscreen ingredients, 2-phenylbenzimidazole-5-sulfonic acid and 2-phenylbenzimidazole can affect DNA breakage when exposed to short wavelength ultraviolet light [2].

Persistent Organic Pollutants (POPs) such as polychlorinated biphenyls (PCBs), organochlorine compounds and polycyclic aromatic hydrocarbons cause environmental challenge and health hazards because of their persistency, bioaccumulation, toxicity, and long-range transport [3–5]. Similarly, PAHs are very stable organic pollutants in the environment generally occurring as complex mixtures of compounds. Polycyclic aromatic hydrocarbons usually occur naturally, but they can also be synthesized as individual compounds for research purposes. As pure chemicals, PAHs generally exist as colourless, white or pale yellow-green solids [6]. They are known to have carcinogenic, mutagenic neurodegenerative disorder, and teratogenic properties making their presence in consumer care products an environment

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health concern [7]. Furthermore, they have high boiling and melting points as well as high molecular weights and are able to survive high temperatures such as combustion of fuel from automobiles and airplane engines. Most of them have low water solubility [8]. Due to these properties as well as their persistence in the environment, they have been placed on the list of priority pollutants by the United States Environmental Protection Agency (US-EPA) and also the European Environment Agency [9].

There are several reviews about the assessment of risks of PAHs to human health [10]. A comprehensive review ‘Opinion of the Scientific Committee on Food on the risks to human health of Polycyclic Aromatic Hydrocarbons in food’ deals with the key aspects involving PAHs risks and effects on humans [11]. Trace occurrence of PAHs has been found in drinking water, cosmetics, food additives as well as factory emissions [12]. It is therefore important that their concentrations in the environment be monitored.

Organochlorine pesticides (OCPs) are group of chlorinated compounds that persist in the environment. They are used mainly in agriculture and for pest control in cities for several decades. Their widespread uses have resulted in their ubiquitous nature in various environments and bioaccumulation throughout the food chain. Many organochlorine compounds have been banned in many countries because of their mutagenic and carcinogenic effects. However, their metabolites are still present in the environment owing to their persistence and lipophilic properties. The toxicity, potential bioaccumulation and non-biodegradability of organochlorine compounds pose health risks to the environment [13]. When humans come in contact with these substances, they can be absorbed by the human system, redistributed among the organs, metabolized, stored in human body or excreted. Once these persistent organic pollutants are in the body, they can negatively impact the respiratory, reproductive and neurological systems or cause birth defects and cancer. Increase risk of Amyotrophic lateral sclerosis (ALS), a fatal neurodegenerative disorder characterized by degeneration of motoneurons have been linked with higher levels of the congener PCB 28 and the OCP metabolite p,p'-DDE [14]. Similarly, organophosphate and organochlorine pesticide exposure have also been reported as a potential health risk factor for hypospadias, a congenital anomaly that affects boys [15].

Since there is paucity of data on the levels of PAHs and OCPs in consumer care products that are commonly used in Nigeria, the present study is considered to be among the first set of investigations directed at determining the presence and levels of PAHs and OCPs in some commonly used consumer care products (plastics, cosmetics, disinfectants and washing products) in Nigeria. Several people come in contact with these products on daily basis. The aim of the study therefore was to evaluate the PAHs and OCPs that are present in the samples of the consumer care products and compare the results obtained with the European Community (EC) and World Health Organization (WHO) standards for consumer care products. This was with a view to determining which of the consumer care products could pose health hazards to users on the basis of their PAHs and OCPs levels. Thus, this work is novel and presents results that will become reference point for other related studies in future.

2. Materials and methods

2.1. Pretreatment of glass wares and storage vessels

Prior to extraction, all glass wares and storage vessels were washed with liquid detergent, soaked in 10% Nitric acid for 48 h and scrupulously rinsed with distilled water.

2.2. Reagents used and their sources

The analytical grade chemical reagents and materials used in this study are: Dichloromethane – BDH, n-Hexane-BDH, Acetone-BDH,

Table 1
Class of samples.

Class of samples			
Plastics	Cosmetics	Disinfectants	Washing Products
A1 = Washing bowl	B1 = Hair dye	C1 = Septol	D1 = Liquid soap
A2 = Keg	B2 = Hair cream	C2 = Izal	D2 = Bleach
A3 = Pencover	B3 = Hair gel	C3 = Harpic	D3 = Scouring powder
A4 = Disposable plate	B4 = Paint	C4 = Purity	D4 = Shampoo
-	B5 = Lip gloss	-	D5 = Conditional
-	B6 = Face cleanser	-	D6 = Handwash

Silica gel 60–120 mesh-Oxford Laboratory Reagent, Anhydrous sodium sulphate-M&B Laboratory Chemical, Nitric acid- BDH.

2.3. Purification of chemicals and reagents

Acetone, dichloromethane and n-hexane were further distilled to obtain high grade analytical solvents that precluded, to a large degree, all trace organic contaminants. The anhydrous sodium sulphate and silica gel were activated by heating in an oven at 450 °C and 120 °C overnight, respectively, and cooled in desiccators.

2.4. Sample collection and preparation

Four classes of commonly used consumer care products (plastics, cosmetics, disinfectants and washing products) were purchased from supermarkets and stores in Ile – Ife, Osun State, Nigeria. The plastic samples were cut into small sizes and pulverized with the aid of Agate pestle and mortar. All the representative four classes of the consumer care products purchased were stored in a cool dry place prior to extraction. Table 1 presents the class of samples used.

2.5. Extraction of OCPs from solid samples

A 10 g sample of each pulverized solid consumer care product was weighed into a pre-extracted Whatman extraction thimble. Using the method described by Reimer and Suarez [16], the sample extraction was carried out in a Soxhlet extractor for an average period of 16 h, with dichloromethane (DCM) as the extracting solvent. The resulting extract was concentrated to about 3 mL by distilling off the solvent using rotary evaporator at about 41 °C. The concentrated extract was cooled down to room temperature and then concentrated further to about 2 mL under a stream of 99.99% nitrogen in readiness for clean-up.

2.6. Extraction of OCPs from liquid samples

The samples were extracted with a mixture of dichloromethane and acetone. Accurately measured 20 mL of sample was quantitatively transferred from the graduated cylinder to a 250-mL separating funnel, 20 mL mixture of dichloromethane and acetone (ratio 2:1) was added to the sample in the separating funnel. This was followed by shaking of the separating funnel vigorously for 10 min with periodic venting to release excess pressure. The content was allowed to separate into layers for about 20 min for complete transfer of OCPs present in the sample into the extracting solvent. The procedure was repeated three times. Each time, the OCPs extract was run into a pre-treated 60 mL coloured bottles prior to clean-up [17].

2.7. Extraction of PAHs from solid samples

Ten gram (10 g) of each of the solid consumer care products was weighed into a pre-extracted Whatman extraction thimble. Using the method described by UNEP [18], the sample extraction was carried out

in a Soxhlet extractor for an average period of 8 h, with n-hexane as the extracting solvent. The resulting extract was concentrated by distilling off the solvent using rotary evaporator at about 60 °C to about 3 mL. The concentrated extract was cooled down to room temperature and then concentrated further to about 2 mL under a stream of 99.99% nitrogen in preparation for clean-up.

2.8. Extraction of PAHs from liquid samples

The samples were extracted with a mixture of n-hexane and acetone. A 20-mL sample was quantitatively transferred from the graduated cylinder to 250 mL separating funnel, 20 mL mixture of n-hexane and acetone (ratio 2:1) was added to the sample in the separating funnel. This was followed by shaking of the separating funnel vigorously for 10 min with periodic venting to release excess pressure and was allowed to separate into layers for about 20 min for complete transfer of PAHs present in the sample into the extracting solvent. The PAH extracts were then separated from the samples. This process was repeated thrice for each sample and the extracts were put in a pre-treated 60 mL coloured bottles prior to clean-up.

2.9. Clean-up and reconstitution of the extracts

A column of about 15 cm length by 1 cm internal diameter was packed first with glass wool and then with about 5 g activated silica gel prepared in a slurry form in n-hexane. About 1 g of anhydrous sodium sulfate was placed at the top of the column to absorb any water in the sample or in the solvent. Pre-elution was done with 15 mL of n-hexane, without exposing the sodium sulfate layer to air, so as to prevent the drying up of the silica gel adsorbent. The reduced extract was run through the column and allowed to sink below the sodium sulphate layer. Elution was done with 2 × 10 mL portions of the extracting solvent (DCM for OCPs and n-hexane for PAHs). The eluate was collected, dried with anhydrous sodium sulphate and evaporated to dryness under a stream of analytical grade nitrogen (99.99%).

Reconstitution was considered necessary to ensure that all the extracts were equally constituted. The dried eluates were reconstituted with 2 mL of n-hexane, which was finally analyzed with Gas Chromatography coupled with Electron Capture Detector for OCPs and Flame Ionization Detector for PAHs (Agilent Technology Model GC-7890 A, USA). A blank determination was also carried out for the OCPs by subjecting 60 mL mixture of dichloromethane and acetone (ratio 2:1) to clean-up protocol, drying up and reconstitution before taken for analysis.

The concentration of OCPs and PAHs were calculated from the expression below:

$$\frac{Ax}{[X]} = F \left(\frac{As}{[S]} \right)$$

where Ax = peak area of analytes signal, [X] = Concentration of sample, F = Response factor, As = peak area of internal standard, [S] = Concentration of internal standard

2.10. Recovery experiment

The percentage recovery for PAHs was carried out by introducing 10 ppm of available PAHs standards, namely: fluorene, anthracene, phenanthrene and chrysene into a sample and was passed through the extraction and clean-up processes, then analyzed using GC-FID. The percentage recovery was calculated using the expression;

$$\% \text{ recovery} = \frac{A - B}{C} \times 100$$

where A = Concentration spiked sample, B = Concentration unspiked sample, C = Concentration of standard.

Table 2

Concentration (ppm) and the percentage recovery of PAHs in Spiked Sample.

PAHs	Samples		
	B6 (Unspiked)	B6(Spiked)	Percentage Recovery (%)
Fluorene	47.67	57.26	95.87 ± 4.88
Phenanthrene	85.32	94.61	92.87 ± 1.45
Anthracene	22.52	31.91	93.93 ± 2.50
Chrysene	211.59	221.11	95.18 ± 2.72

3. Results and discussion

3.1. Validation of analytical procedures adopted

The reliability of the analytical procedure adopted in this study was tested in terms of sensitivity, recovery, precision and accuracy. Table 2 shows the result of the spiking experiment and the percentage recovery of PAHs in spiked sample. The percentage recoveries of PAHs were Phenanthrene (92.87 ± 1.45%), Anthracene (93.93 ± 2.50%), Chrysene (95.18 ± 2.72%) and Fluorene (95.87 ± 4.88%). The method attained good precisions with relative low standard deviation, RSD values (1.45–4.88%). The percentage recoveries showed that the uncertainties in the methods of analyses used were within acceptable limit and the procedure adopted was effective. The chromatograms of the PAHs and OCPs standards showed a well-defined and distinct peaks of the constituents PAHs (Fig. 1) and OCPs (Fig. 2), while the chromatogram of the blank for the OCPs showed no peak (Fig. 3) and this further ascertain the effectiveness, purity and efficiency of the method and materials used.

3.2. Concentration of PAHs in plastics and cosmetics samples

The mean concentration of PAHs detected in plastics samples (Table 3) were in the order: Nap (595.40 ± 1185.41 µg g⁻¹) > Chr, (482.10 ± 815.13 µg g⁻¹) > Pyr (440.02 ± 824.92 µg g⁻¹) > Ace (428.39 ± 847.26 µg g⁻¹) > BaP (407.01 ± 679.39 µg g⁻¹) > DbA (395.06 ± 472.16 µg g⁻¹) > Ant (186.57 ± 0.00 µg g⁻¹) > BbF (155.28 ± 84.00 µg g⁻¹) > Phe (129.28 ± 172.84 µg g⁻¹) > Fla (100.74 ± 80.79 µg g⁻¹) > Flu (83.00 ± 113.14 µg g⁻¹) > BaA (55.17 ± 37.62 µg g⁻¹) > Acy (50.86 ± 68.77 µg g⁻¹) > InP (49.78 ± 21.93 µg g⁻¹) > Bpy (37.20 ± 11.29 µg g⁻¹) > BkF (24.20 ± 0.00 µg g⁻¹). It was observed that Nap (595.40 ± 118.41 µg g⁻¹) had the highest mean concentration followed by Chr (482.10 ± 815.13 µg g⁻¹), while BkF (24.20 ± 0.00 µg g⁻¹) had the least concentration.

Meanwhile, the highest concentration of PAHs (11,090.35 µg g⁻¹) was found in disposable plates, followed by 867.92 µg g⁻¹ in keg; 560.46 µg g⁻¹ in pen cover; and the least concentration (517.69 µg g⁻¹) was found in bowl samples. The presence of PAHs in plastics could be from the process of production because considerable amounts of PAHs are formed in processes involving heating of organic materials at high temperatures [19–21]. Polycyclic aromatic hydrocarbons are also formed during method of preparation such as charbroiling, grilling, roasting, heating [22–26].

The mean concentration of PAHs in cosmetics (Table 4) were in the order of InP (5431.91 ± 0.00 µg g⁻¹) > Chr (2697.47 ± 3937.32 µg g⁻¹) > BaP (1953.20 ± 279.49 µg g⁻¹) > BPy, (1099.17 ± 1629.97 µg g⁻¹) > BkF, (749.74 ± 794.49 µg g⁻¹) > DbA (749.74 ± 794.49 µg g⁻¹) > Nap (444.91 ± 447.18 µg g⁻¹) > Phe (383.79 ± 344.66 µg g⁻¹) > Pyr (382.88 ± 433.09 µg g⁻¹) > BbF (279.37 ± 287.89 µg g⁻¹) > Fla (183 Flu (58.09 ± 160.48 µg g⁻¹) > Acy (103.33 ± 150.94 µg g⁻¹) > Ant (70.39 ± 62.47 µg g⁻¹) > BaA (61.30 ± 75.51 µg g⁻¹) > Flu (58.09 ± 160.48 µg g⁻¹) > Ace (53.25 ± 39.57 µg g⁻¹).

From the highest to the lowest concentrations, the PAHs in the cosmetics followed the pattern: Lip gloss sample (15,834.20 µg

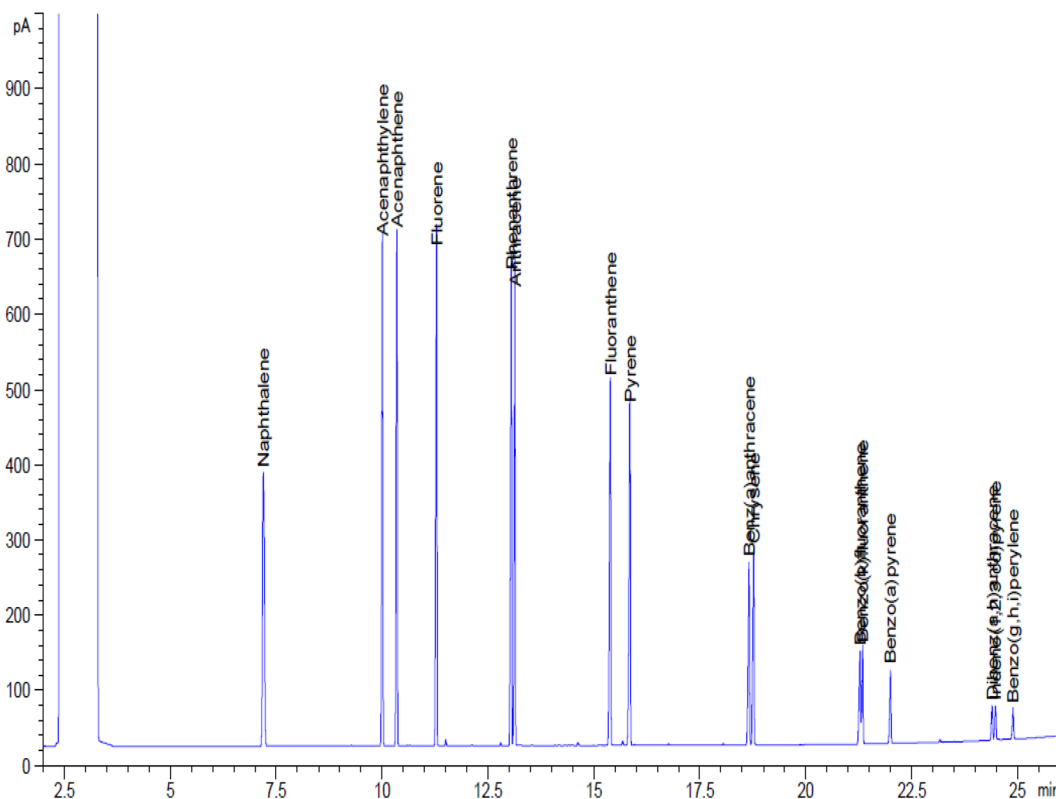


Fig. 1. Chromatogram of PAHs Standards.

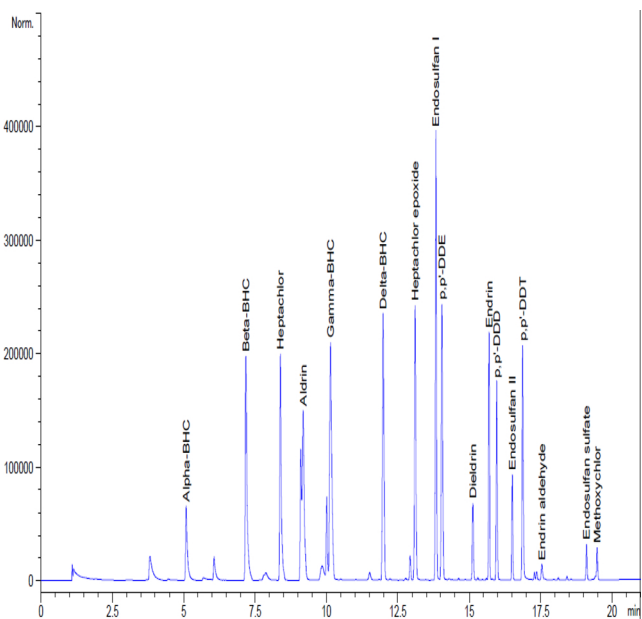


Fig. 2. Chromatogram of OCPs Standards.

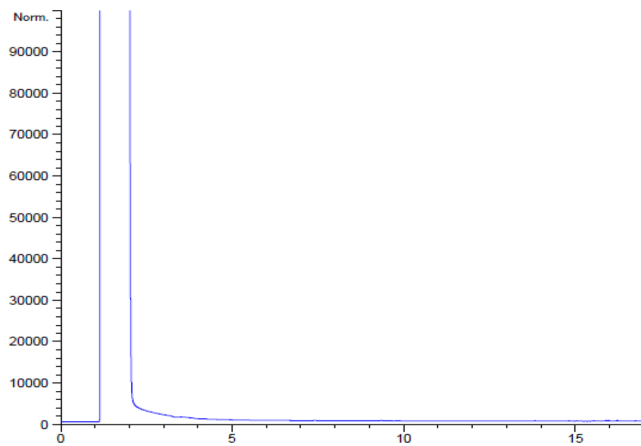


Fig. 3. Chromatogram of the Blank Sample for OCPs.

g^{-1}) > Dye ($14,288 \mu g g^{-1}$) > Paint ($1,405,214 \mu g g^{-1}$) > Hair gel ($1794.55 \mu g g^{-1}$) > Face cleanser ($894.26 \mu g g^{-1}$) > Hair cream ($526.26 \mu g g^{-1}$).

The mean concentrations ($\mu g g^{-1}$) distribution of PAHs in the plastics and cosmetic samples are presented pictorially in Fig. 4. Comparatively, it was observed that the concentration of PAHs in cosmetic samples was greater than the concentration found in plastic samples. This could be because petroleum fractions or products (e.g. petrolatum, coal tar) used in the production of many cosmetics normally constitute one of the major sources of PAHs [27].

In this study, the concentration ranges of PAHs found in plastics samples was from 517.69 to $11,090.35 \mu g g^{-1}$ (Table 3), while the concentration range in cosmetics samples was between 526.26 to $15,834.20 \mu g g^{-1}$ (Table 4). The concentrations in these samples were higher than the 0.20 ppm set standard by the World Health Organization [28]. This could mean a serious health implication to the teeming population of end users of these consumers' care products. To the best of our knowledge, there is paucity or few literature reports on PAHs concentrations in personal care products which indicate the novelty of the present study. However, the results obtained in this study are higher compared with 386 to $1996 ng g^{-1}$ PAHs concentrations in plastic pellets at different depths in a sandy beach [29] and 1.25 to $528 mg/kg$ obtained in carbon black-containing plastic consumer products from the Jordanian market [30]. Other reports in other matrices include PAHs ranged 106 to $9663 ng L^{-1}$ from river waters in China [31–33], 62.9 to $144.7 ng L^{-1}$ in the Mississippi river waters in New Orleans, Louisiana, USA [34], 0.02 to $2.87 mg kg^{-1}$ reported for

Table 3
Concentrations of PAHs in Plastic Samples ($\mu\text{g g}^{-1}$).

PAHs	Samples				Range	Mean \pm SD	CV%
	A1	A2	A3	A4			
Naphthalene(Nap)	0.89	4.07	3.12	2373.52	0.89 – 2373.52	595.40 \pm 1185.41	199.09
Acenaphthylene(Acy)	ND	ND	2.23	99.49	2.23 – 99.49	50.86 \pm 68.77	135.21
Acenaphthene(Ace)	0.39	6.21	7.60	1699.24	0.39 – 1699.24	428.39 \pm 847.26	197.78
Fluorene(Flu)	19.83	39.86	22.10	252.83	19.83 – 252.83	83.65 \pm 113.14	135.54
Phenanthrene(Phe)	32.84	62.15	35.99	388.34	32.84 – 388.34	129.28 \pm 172.84	133.69
Anthracene(Ant)	ND	ND	ND	186.57	-	186.57 \pm 0.00	0.00
Fluoranthene(Fla)	4.07	11.70	15.36	371.84	4.07 – 371.84	100.74 \pm 80.79	80.20
Pyrene(Pyr)	2.72	22.34	58.11	1676.93	2.72 – 1676.93	440.02 \pm 824.92	187.47
Benzo[a]anthracene(BaA)	28.57	81.78	ND	ND	28.57 – 81.78	55.17 \pm 37.62	68.19
Chyrene (Chr)	ND	11.74	11.22	1423.33	11.22 – 1423.33	482.10 \pm 815.13	169.08
Benzo[b]fluoranthene(BbF)	149.91	191.48	124.44	ND	124.44 – 191.48	155.28 \pm 33.84	21.79
Benzo[k]fluoranthene(BkF)	ND	ND	24.20	ND	-	24.20 \pm 0.00	0.00
Benzo[a]pyrene(BaP)	57.72	133.90	13.07	1423.33	13.07 – 1423.33	407.01 \pm 679.39	166.92
Dibenzo[a,h] anthracene(Dba)	186.49	202.26	215.94	1145.57	186.49 – 1145.57	395.06 \pm 472.16	119.52
Benzo[a]pyrene(BPy)	ND	35.15	27.07	49.37	27.07 – 49.37	37.20 \pm 11.29	30.35
Indeno[1,2,3-cd]pyrene (InP)	34.27	65.29	ND	ND	34.27 – 65.29	49.78 \pm 21.93	44.05
Total	517.69	867.92	560.46	11,090.35	517.69 – 11,090.35	3259.10 \pm 5223.16	160.26

A1 = Bowl, A2 = Keg, A3 = Pen cover, A4 = Disposable plate, SD = Standard deviation, CV%= Percentage Coefficient of Variation, ND = Not Detected.

contaminated synthetic industrial organic oils utilized in Northern Nigeria [35]. On the other hand, lower concentrations of PAHs (2 to 123 ng L⁻¹) were reported for 17 PAHs in York River and 24.1 to 91.1 ng L⁻¹ for Chesapeake surface waters [36]. Determination of PAHs in cosmetic samples using freezing lipid filtration-liquid-liquid gas chromatography method has also been reported [37]. However, all these results further confirm the presence of PAHs in trace amount irrespective of medium. Study on the health effects of PAHs external and internal occupational exposure on DNA damage and RNAs response in coke oven workers [38]; and in smoked fish species from markets in Southern Nigeria have also been investigated [39]. High exposure to PAHs could lead to lower Intelligent Quotient (IQ) and childhood asthma [40]. It is feared that the levels of PAHs identified in the plastics and cosmetic products in the present study could have long-term health effects on the regular consumers, and therefore, their use should be minimized or completely avoided where possible.

3.3. Concentration of OCPs present in disinfectant and washing products

The levels of OCPs in disinfectants in Table 5 revealed that Endrin aldehyde had the highest concentration of 10.25 $\mu\text{g mL}^{-1}$ with mean

Table 4
Concentrations of PAHs in Cosmetic Samples ($\mu\text{g g}^{-1}$).

PAHs	Samples						Range	Mean \pm SD	CV%
	B1	B2	B3	B4	B5	B6			
Naphthalene(Nap)	ND	ND	125.56	993.44	215.72	ND	25.56 – 993.44	444.91 \pm 477.18	107.25
Acenaphthylene(Acy)	11.20	ND	14.12	101.24	24.12	365.15	11.20 – 365.15	103.33 \pm 150.94	146.08
Acenaphthene(Ace)	28.29	ND	14.24	ND	101.13	69.35	14.24 – 101.13	53.25 \pm 39.57	74.31
Fluorene(Flu)	26.61	ND	375.27	ND	182.79	47.67	26.61 – 375.27	58.09 \pm 160.48	276.26
Phenanthrene(Phe)	122.67	ND	809.40	ND	517.76	85.32	85.32 – 809.40	383.79 \pm 344.66	89.80
Anthracene(Ant)	97.72	2.04	ND	ND	159.27	22.52	2.04 – 159.27	70.39 \pm 62.47	88.75
Fluoranthene(Fla)	313.14	7.32	100.41	ND	481.86	16.62	7.32 – 481.86	183.87 \pm 207.13	112.65
Pyrene(Pyr)	ND	9.81	798.28	ND	715.31	8.12	8.12 – 798.28	382.88 \pm 433.09	113.11
Benzo[a]anthracene(BaA)	ND	74.26	162.96	ND	0.001	7.99	0.001 – 162.96	61.30 \pm 75.51	123.18
Chyrene (Chr)	2762.40	ND	415.86	601.07	9496.39	211.59	211.59 – 9496.39	2697.46 \pm 3937.32	145.96
Benzo[b]fluoranthene(BbF)	ND	121.15	685.54	273.45	ND	38.01	38.01 – 685.537	279.37 \pm 287.89	103.05
Benzo[k]fluoranthene(BkF)	3930.67	ND	ND	119.89	0.001	21.93	0.001 – 3930.67	1017.96 \pm 1942.40	190.81
Benzo[a]pyrene(BaP)	3973.01	137.04	349.73	5306.20	0.003	ND	0.003 – 5306.20	1953.20 \pm 279.87	14.33
Dibenzo[a,h]anthracene(Dba)	1952.52	105.67	641.50	1048.99	0.001	ND	0.001 – 1952.52	749.74 \pm 794.49	105.97
Benzo[a]pyrene(BPy)	1009.42	68.96	301.69	175.94	3939.86	ND	68.96 – 3939.86	1099.17 \pm 1629.97	148.29
Indeno[1,2,3-cd]pyrene (InP)	ND	ND	ND	5431.91	ND	ND	-	5431.91 \pm 0.00	0.00
Total	14,288.43	526.26	4794.55	14052.14	15,834.20	894.26	526.26 – 15,834.20	8388.31 \pm 7106.55	84.72

B1 = Dye, B2 = Hair cream, B3 = Hair gel, B4, = Paints, B5 = Lip gloss, B6 = Face cleanser SD = Standard deviation, CV%= Percentage Coefficient of Variation, ND = Not Detected.

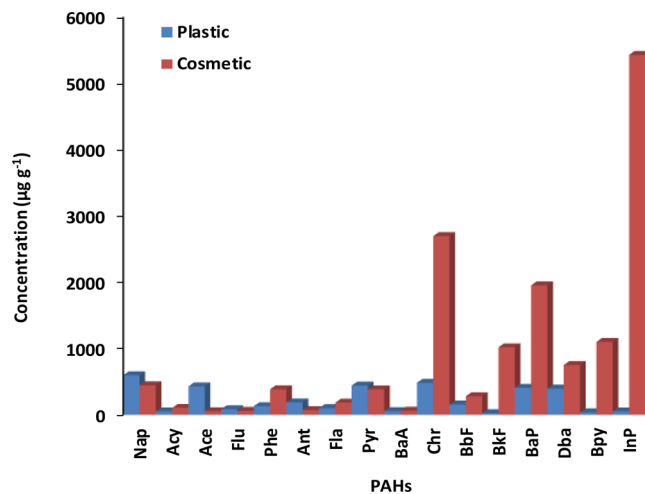


Fig. 4. Mean Concentrations ($\mu\text{g g}^{-1}$) Distribution of PAHs in the Plastics and Cosmetic Samples.

Table 5
Concentrations of OCPs in Disinfectant Samples ($\mu\text{g mL}^{-1}$).

OCPs	Samples				Range	Mean \pm SD	CV%	MRLs (ng mL ⁻¹)
	C1	C2	C3	C4				
Alpha-BHC	0.34	ND	ND	ND	–	0.34 \pm 0.00	0.00	0.07
Beta-BHC	0.30	ND	0.06	ND	0.06 – 0.30	0.18 \pm 0.17	92.90	0.18
Heptachlor	ND	0.07	0.13	5.66	0.07 – 0.13	1.95 \pm 3.21	164.13	0.20
Aldrin	0.36	0.03	0.10	0.15	0.03 – 0.36	0.16 \pm 0.14	87.73	0.20
Gamma-BHC	ND	0.00	0.00	ND	–	0.00	0.00	0.08
Delta-BHC	0.00	0.00	0.00	0.01	0.00 – 0.01	0.01 \pm 0.00	325.00	0.10
Heptachlor Epoxide	ND	0.00	0.00	0.03	0.00 – 0.03	0.01 \pm 0.01	166.67	0.25
Endosulfan I	0.02	ND	0.01	0.26	0.01 – 0.03	0.12 \pm 0.14	116.39	0.14
p,p'-DDE	0.06	0.00	0.00	ND	0.00 – 0.06	0.02 \pm 0.03	175.00	0.09
Dieldrin	0.46	0.04	0.07	0.33	0.04 – 0.46	0.22 \pm 0.20	91.07	0.22
Endrin	0.46	0.13	ND	2.96	0.13 – 2.96	1.19 \pm 1.55	130.55	0.15
p,p'-DDD	0.74	ND	0.71	0.00	0.00 – 0.74	0.48 \pm 0.42	86.96	0.08
Endosulfan II	1.08	0.16	ND	3.78	0.16 – 3.78	1.68 \pm 1.88	122.51	0.10
p,p'- DDT	0.27	0.06	0.16	0.05	0.05 – 0.27	0.14 \pm 0.10	75.18	0.20
Endrin aldehyde	10.25	4.79	ND	0.00	0.00 – 10.25	5.01 \pm 5.13	102.29	0.10
Endosulfan sulfate	4.76	0.73	0.21	ND	0.21 – 4.76	1.90 \pm 2.49	131.13	0.16
Methoxychlor	2.36	0.01	0.40	ND	0.01 – 2.54	0.92 \pm 1.26	136.19	0.26
Total	21.47	6.02	1.86	13.24	1.86 – 21.47	10.65 \pm 65.00	80.89	

C1 = Disinfectant 1, C2 = Disinfectant 2, C3 = Disinfectant 3, C4 = Disinfectant 4, S.D = Standard Deviation, CV% = Percentage Coefficient of Variation, ND = Not Detected.

concentration of $5.01 \pm 5.13 \mu\text{g mL}^{-1}$ in all disinfectants considered. The mean concentrations of the OCPs in disinfectants were in the order: Endrin aldehyde ($5.01 \pm 5.13 \mu\text{g mL}^{-1}$) > Heptachlor ($1.95 \pm 3.21 \mu\text{g mL}^{-1}$) > Endosulfan sulfate ($1.90\text{--}2.41 \mu\text{g mL}^{-1}$) > Endosulfan II ($1.68 \pm 1.88 \mu\text{g mL}^{-1}$) > Endrin ($1.19 \pm 1.55 \mu\text{g mL}^{-1}$) > Methoxychlor ($0.92 \pm 1.26 \mu\text{g mL}^{-1}$) > p,p'-DDD ($0.48 \pm 0.42 \mu\text{g mL}^{-1}$) > α -BHC ($0.34 \pm 0.00 \mu\text{g mL}^{-1}$) > Dieldrin ($0.22 \pm 0.20 \mu\text{g mL}^{-1}$) > β -BHC ($0.18 \pm 0.17 \mu\text{g mL}^{-1}$) > Aldrin ($0.16 \pm 0.14 \mu\text{g mL}^{-1}$) > p,p'-DDT ($0.14 \pm 0.10 \mu\text{g mL}^{-1}$) > Endosulfan I ($0.12 \pm 0.14 \mu\text{g mL}^{-1}$) > p,p'-DDE ($0.02 \pm 0.03 \mu\text{g mL}^{-1}$) > Heptachlor epoxide ($0.01 \pm 0.01 \mu\text{g mL}^{-1}$) > γ -BHC ($0.00 \pm 0.00 \mu\text{g mL}^{-1}$) = Delta-BHC ($0.00 \pm 0.01 \mu\text{g mL}^{-1}$). The overall mean value of the OCPs in disinfectants was $10.56 \pm 65.00 \mu\text{g mL}^{-1}$ (Table 5). Also, the highest concentration of OCPs was recorded in Septol ($21.47 \mu\text{g mL}^{-1}$) followed by Purity ($13.24 \mu\text{g}$

mL^{-1}) and Izal ($6.02 \mu\text{g mL}^{-1}$), while the least value was found in Harpic ($1.86 \mu\text{g mL}^{-1}$).

The mean concentrations of OCPs detected in washing products are presented in Table 6 and followed the order: Endosulfan II ($25.91 \pm 35.25 \mu\text{g mL}^{-1}$) > p, p'-DDT ($6.81 \pm 13.83 \mu\text{g mL}^{-1}$) > Endrin aldehyde ($4.81 \pm 4.09 \mu\text{g mL}^{-1}$) > Endosulfan sulfate ($1.64 \pm 1.23 \mu\text{g mL}^{-1}$) > Endrin ($1.19 \pm 0.74 \mu\text{g mL}^{-1}$) > Delta-BHC ($1.07 \pm 0.96 \mu\text{g mL}^{-1}$) > α -BHC ($1.03 \pm 0.60 \mu\text{g mL}^{-1}$) > Heptachlor ($0.58 \pm 0.50 \mu\text{g mL}^{-1}$) > Methoxychlor ($0.34 \pm 0.47 \mu\text{g mL}^{-1}$) > Aldrin ($0.26 \pm 0.25 \mu\text{g mL}^{-1}$) = p,p'-DDD ($0.26 \pm 0.02 \mu\text{g mL}^{-1}$) > β -BHC ($0.14 \pm 0.11 \mu\text{g mL}^{-1}$) > Heptachlor epoxide ($0.12 \pm 0.11 \mu\text{g mL}^{-1}$) > Endosulfan I ($0.05 \pm 0.05 \mu\text{g mL}^{-1}$) = p,p'-DDE ($0.05 \pm 0.08 \mu\text{g mL}^{-1}$) = Dieldrin ($0.05 \pm 0.15 \mu\text{g mL}^{-1}$) > γ -BHC ($0.04 \pm 0.07 \mu\text{g mL}^{-1}$). The highest concentration of OCPs was found in conditional sample ($81.67 \mu\text{g mL}^{-1}$)

Table 6
Concentrations of OCPs in Washing Product Samples ($\mu\text{g mL}^{-1}$).

OCPs	Samples						Range	Mean \pm SD	CV%	MRLs (ng mL ⁻¹)
	D1	D2	D3	D4	D5	D6				
Alpha-BHC	ND	ND	0.84	1.92	0.70	0.66	0.66 – 1.92	1.03 \pm 0.60	58.00	0.07
Beta-BHC	NAD	ND	0.29	0.15	0.04	0.08	0.04 – 0.29	0.14 \pm 0.11	78.17	0.18
Heptachlor	0.06	ND	ND	1.23	0.49	0.52	0.49 – 1.25	0.58 \pm 0.50	85.49	0.20
Aldrin	0.03	0.05	0.24	0.72	0.29	0.25	0.02 – 0.72	0.26 \pm 0.25	94.30	0.20
Gamma-BHC	ND	ND	0.14	0.00	0.00	0.00	0.00 – 0.14	0.14 \pm 0.00	197.22	0.08
Delta-BHC	ND	ND	0.11	2.40	0.88	0.89	0.11 – 2.40	1.07 \pm 0.96	89.99	0.10
Heptachlor Epoxide	0.27	ND	0.21	0.14	0.01	0.00	0.00 – 0.27	0.16 \pm 0.11	95.97	0.25
Endosulfan I	ND	ND	0.01	0.07	0.10	0.01	0.01 – 0.10	0.05 \pm 0.05	97.83	0.14
p,p'-DDE	0.00	0.00	0.01	0.20	0.10	0.01	0.00 – 0.20	0.05 \pm 0.08	150.00	0.09
Dieldrin	ND	ND	0.62	0.37	0.45	0.45	0.37 – 0.62	0.05 \pm 0.15	22.55	0.22
Endrin	ND	ND	ND	1.74	0.92	0.92	0.92 – 1.74	1.19 \pm 0.47	39.68	0.15
p,p'-DDD	ND	ND	ND	0.29	0.24	0.25	0.24 – 0.29	0.26 \pm 0.02	8.78	0.08
Endo-sulfan II	0.10	0.10	ND	0.29	64.28	64.77	0.10 – 64.77	25.91 \pm 35.25	136.08	0.10
p,p'- DDT	0.03	0.03	ND	31.49	2.27	0.23	0.03 – 31.49	6.81 \pm 13.83	202.94	0.20
Endrin aldehyde	ND	ND	0.12	2.66	8.15	8.32	0.12 – 8.32	4.81 \pm 4.09	84.91	0.10
Endosulfan sulfate	ND	ND	0.05	2.82	2.36	1.31	0.05 – 2.82	1.64 \pm 1.23	75.24	0.16
Methoxychlor	0.03	0.00	0.02	1.22	0.39	0.40	0.00 – 0.40	0.34 \pm 0.47	136.84	0.26
Total	0.50	0.18	2.71	47.71	81.67	79.10	0.18 – 79.10	35.31 \pm 39.31	111.34	

D1 = Liquid soap, D2 = Bleaching agent, D3 = Scouring powder, D4 = Shampoo, D5 = Conditional, D6 = Hand wash, S.D = Standard Deviation, CV% = Percentage Coefficient of Variation, ND = Not Detected.

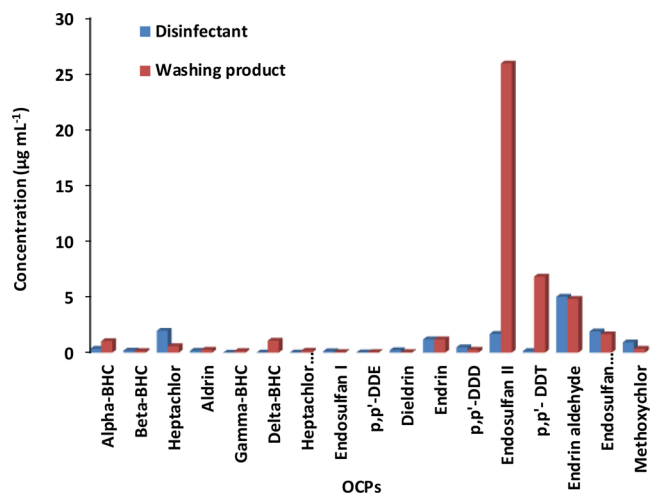


Fig. 5. Mean Concentrations ($\mu\text{g mL}^{-1}$) Distribution of OCPs in the Disinfectants and Washing Product Samples.

followed by Hand wash ($79.10 \mu\text{g mL}^{-1}$), Shampoo ($47.71 \mu\text{g mL}^{-1}$), Scouring powder ($2.71 \mu\text{g mL}^{-1}$), Liquid soap ($0.50 \mu\text{g mL}^{-1}$) and least concentration of OCPs was recorded in Bleaching agent ($0.18 \mu\text{g mL}^{-1}$).

Fig. 5 presents pictorially the mean concentrations ($\mu\text{g mL}^{-1}$) of OCPs detected in disinfectants and washing products samples. In most cases, the OCPs concentration was more in washing products than the disinfectants. This could probably be due to the incorporation of chlorinated compounds used in the production. The results of mean concentration of OCPs in disinfectants and washing products were greater than the set limit by the European Commission [41] except for Endosulfan I, Heptachlor epoxide, Delta-BHC, Aldrin in disinfectants; Beta-BHC, Heptachlor epoxide, Endosulfan I, p,p'-DDE and Dieldrin in washing products where concentrations lower than the set limit were recorded. In the present study, higher concentration of OCPs were recorded compared to previous studies on Culturama in Brazil [42] and water bodies from Ibadan, Nigeria [43]. The toxic effect of exposure to OCPs include reproductive failure [44], immune system malfunction [45], endocrine disruptions [46] and breast cancer [47] have been reported. Also, the serum level of OCPs exposure have been determined in general population residing in Larissa, central Greece and p,p'-DDE and Hexachlorobenzene (HCB) were most frequently detected analytes [48]. Health effect of chronic exposure to organochlorine pesticides as related to Cytochrome P450 (CYP) polymorphisms and associated pathological conditions have been investigated and reported [49].

Although the use of OCPs have been either banned or restricted in advanced countries, the laws have not been successfully enforced in developing nations where lip services are paid to regulation and use of toxic substances by the appropriate regulatory government agencies.

4. Conclusion

This study examined the concentration of PAHs and OCPs in some samples of consumer care products, namely: plastics, cosmetics, disinfectants and washing products. A total of sixteen (16) PAHs were identified in plastics and cosmetic samples and seventeen (17) OCPs were detected in disinfectant and washing products. The concentration of PAHs in cosmetics was generally higher than their concentrations in plastic samples. Also, the concentration of OCPs in washing products was higher than their concentrations in disinfectant samples. In all, the mean concentration of PAHs in plastic and cosmetic samples was higher than the recommended standard by the World Health Organization. Likewise, the concentration of OCPs in disinfectants and washing products were higher than the recommended EC-MRL standard, except for Endosulfan I, Heptachlor epoxide, Delta-BHC and Aldrin in disinfectant; and Beta-BHC, Heptachlor epoxide, Endosulfan I, p,p'-DDE and Dieldrin in washing product that were below the EC [41] MRL value.

The PAHs and OCPs values obtained in this study may present health risks over a long-term dermal exposure to the consumer care products studied. There is a strong feeling that a substantial portion of the PAHs might have been formed during the heat process of plastics production and hydrocarbon products being used as one of the major ingredients in making some cosmetics. With respect to the levels of OCPs detected in the samples investigated, it appeared as if OCPs containing materials were still being used as part of the ingredients for making some disinfectants and washing products. The study concluded that PAHs and OCPs were present in the consumer care products at levels that could present a long-term potential health risks to the consumers, if the use or direct contact with the products are not controlled or minimized.

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