© JUN 2026 | IRE Journals | Volume 9 Issue 12 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I12-1718754

Assessment of Volatile Organic Compounds in Personal Care Products Sold in Sango Ota, Ogun State, Nigeria.

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***Abstract-** In this study, presence and levels of Volatile Organic Compounds (VOCs) in four (4) personal care products: Nail Polish, Lipstick, Toilet cleaner and Air freshener are reported. A total of 12 samples were used to represent three samples of each product and were purchased from the superstore around Sango-Ota. Identification and quantification of VOCs was achieved using Agilent 88860 GC-FID coupled with 7697A Headspace Sampler. The data was then analyzed using the Agilent ChemStation CDS software. Among the 37 VOCs identified, only nine were common to all the four samples selected, which are 1,2-dibromo-3-chloropropane, Hexabutadiene, Dibromomethane, Toluene, 1,1-Dichloroethane, Dibromochloromethane, 1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene and Benzene. From the result it can be reported that Toluene has the highest concentration (111398.86 ppm) which is found in Nail Polish while 1,2-dibromo-3-chloropropane has the lowest concentration (1.43 ppm) found in Lip Stick. The Average Daily Dose and Hazard Quotient of all the VOCs studied shows that Dibromochloromethane, Toluene, and Benzene are present in the concentration of 31.19, 14.29 and 2.69 ppm respectively for Dermal while Toluene only was found in the range of (2.17E-8-1.23E-8) via inhalation. These values shows that all other VOCs are below the acceptable limit of 1 except Dibromochloromethane, Toluene & Benzene in dermal. It is noteworthy that benzene causes 4.5 times cancer risk and 8.3 times hazard quotient than any of the VOCs studied. Therefore, from this study, it could be deduced that the level of VOCs in the samples may cause adverse health challenges on the consumer/exposed individual.*

***Keywords:** Hazard Quotient, Personal care Products, VOCs*

I. INTRODUCTION

Volatile Organic Compounds (VOCs) are organic compounds which are found in many consumer products, readily evaporate and leak into the environment under certain conditions, due to their high volatility, mobility, and resistance to degradation, they can travel great distance in the environment (David & Niculescu, 2021). Personal care products (PCPs) constitute a broad range interior use commodities designated for sanitation, physical maintenance, and aesthetic enhancement (Wu T. et al., 2024). VOCs are hydrocarbons that can be either man-made or naturally occurring, and they are highly reactive. The World Health Organization defines VOCs an any organic compound with a boiling point ranging from 50-100 °C to 240-260 °C, which corresponds to having saturation vapor pressures greater than 102 kPa at 25 °C (Berenijian et al 2012). The aromatic hydrocarbons (benzene, toluene, ethyl benzene and xylene) and halogenated hydrocarbons (chloroethylene and trichloroethylene) are the most commonly detected volatile organic compounds (Pandey & Yadav, 2018). These compounds mainly originate from indoor sources, including emissions from building materials, furniture, and household products like cleaning agents and detergents. In homes and offices all around the world, there is the abundance of consumer products which emphasize their importance and impact in Indoor Air Quality (IAQ) via VOCs leading to olfactory annoyance and overall discomfort for occupants of buildings, in addition to posing detrimental effects on human health (Haug et al., 2024). Inhalation is the most prominent route of exposure while the risk associated with the presence of VOCs in the ambient environment is dependent on the nature of the chemical and exposure time (Masuck et al., 2011). In Nigeria, there have been several reports on VOCs most of which were air-quality focused, but studies of these compounds in consumer goods and their risk to human wellbeing are very scarce hence creating a knowledge gap. On a global scale, regulatory frameworks such as REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) and OSHA (Occupational Safety and Health Administration) offer comprehensive guidance regarding permissible exposure thresholds for VOCs. Nonetheless, the execution of these frameworks continues to be insufficient in developing nations, including Nigeria. This study reports on VOCs found in a common personal care products and the possible health risks associated with the exposure.

II. MATERIALS AND METHOD

Sample Collection and Preparation

A total of 12 samples of four categories of consumer products were used for this study. They are made up of three samples each of Nail Polish (NP), Lip Stick (LS), Toilet Cleaner (TC) and Air Freshener (AF) were purchased from the supermarkets in Sango -Ota. An Agilent 8860 GC-FID coupled with 7697A Headspace Sampler was used for the extraction, followed by the transfer of the VOCs in the sample to the GC. The data was then analyzed using the Agilent ChemStation software.

Sample Preparation and Analysis

The method according to Adeyinka et al., 2024 was adopted. 2 g of each sample was weighed, transferred to a 10 mL headspace vial, capped tightly and placed in the headspace carousel. VOCs standard, 2000ppm (Catalog Number: M-502A-R10X) containing 54 VOCs components was purchased from AccuStandard (USA). Four (4) point serial dilution calibration standards (2.0, 0.5, 0.25, 0.12 mg/L) was prepared from the stock and used to calibrate the GC. Samples were analyzed using Agilent 8860 Gas chromatograph equipped with a flame ionization detector (FID), fitted with a DB-624 capillary column coated with 6% cyanopropyl/phenyl, 94% polydimethylsiloxane (30m length × 0.53mm diameter ×3µm film thickness).

The samples were injected in split mode (1:1) at an injection temperature of 250 ºC, at a pressure of 4.227psi and a total flow of 0.6mL/min. Oven was initially programmed at 35 ºC (5min) then ramped at 11°C/min to 60 ºC (1min). It then ramped to 220 ºC at 22 ºC /min. FID temperature was 300 ºC with Hydrogen: Air flow at 30mL/min, Helium was used as makeup gas at a flow of 18 mL/min. All analysis were performed in triplicate.

Statical analysis

All the data collected from personal care products were analyzed using Microsoft excel. Mean and standard deviation were determined.

Determination of health risk assessment:

This is the process of identifying, analyzing and finding possible solutions to the effects of potential hazard on human health and the environment. The health risk assessment of VOCs in all the samples was determined by calculating Hazard Risks (Eqn.. 3) to estimate the non-carcinogenic and carcinogenic risks for each VOCs via dermal (for NP, LP, and ATC) and inhalation (for AF) respectively. The Average Daily Dose (ADD), for inhalation and dermal were also calculated using Eqn. 1a and 1b (Zang, X. et al., 2022)

$$AD_{Dinh} = \frac{CA \times InhR \times EF \times ED}{PEF \times BW \times AT} \quad (1a)$$

where: CA is the concentration of the VOCs in air (ppm), InhR is the inhalation rate, which is 7.6 and 20 m3/day for children and adults respectively, ED is the exposure duration, set at 6 and 26 years for children and adults respectively, EF is the exposure frequency, assumed to be 350 days per year, BW is the body weight, with values of 15 kg for children and 70 kg for adults, AT is the average time or life expectancy, calculated as 2190 days for children and 9,490 days for adults, PEF is the particle emission factor which is 1.36E9 m3/kg (Adenuga A.A., et al 2022).

$$ADD_{dermal} = \frac{CA\ x\ SA\ x ET\ x EF\ x Kp\ x\ ED}{BW\ x\ AF} \quad (1b)$$

where C is the concentration of the VOCs (mg/kg), SA is the exposed skin area (for woman 153 dm3), Kp is the dermal permeability coefficient (DBCM 0.000289, Benzene 0.0186 & other VOCs 0.0001 dm/h), EF is the exposure frequency (365 Day/year), ED = Exposure duration (woman 78 years), BW (woman 59.6 kg) and Average Time (woman 28470 day) (Zang, K., et al 2021)

Hazard Quotient HQ: This is used to determine the extent of exposure of humans to volatile organic compounds. It is calculated using Eqn. 3 for the dermal and inhalation contact. HI is the addition of all HQ and gives information on non-carcinogenic risk. An exposure value ≤ 1 denotes acceptable risk while an exposure value higher than 1 denotes highly risky. (Cao FengMei et al., 2018)

$$Hi_n = \frac{ADDinh}{RFC} \quad (2)$$

$$HI = \sum HQ \quad (3)$$

Values of RfC for VOCs (PPM) (USEPA 1992 & MDH 2010)

VOC	RfC
Benzene	0,002
Toluene	3.265
1,1-Dichloroethane (1,1-DCE)	0.005
Dibromomethane (DCM)	0.016
1,2,4-Trichlorobenzene (1,2,4-DCM)	0.003
1,2-Dibromo-3-chloropropane(1,2-DM-3-CP)	0.0002
1,2-Dichlorobenzene (1,2-DCB)	0.653
Hexachlorobutadiene(HCBD)	0.073
Dibromomethane (DBM)	0.003

III. RESULTS

The total wt % of VOC for all the samples are as shown in Figure.1 below. The highest value was recorded in NP (84.85 wt.%) while AF has the lowest (18.19 wt.%). The results showed that NP has a low moisture content of (15.15 wt.%) and high VOC content of (84.85 wt.%) while the other three consumer products are high in moisture (in the range of 54.55-81.81 wt.%) and low VOC content ranged between (18.19 - 45.45 wt.%) (Lin, K. H., et al 2022).

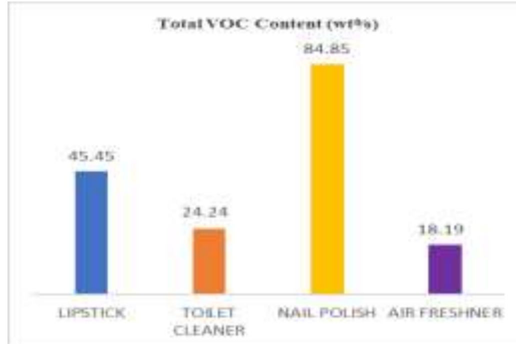

Figure 1. Percentage of the VOCs Content in all the Samples.

A total of 37 VOCs were identified in all the samples, but nine (9) were common to all as shown in Table 1.0. NP has the highest toluene concentration while LP has the lowest concentration (111398.86 and 2.21 ppm) respectively. Zong et al., 2019, Shin-Young et al., 2025 and Azeez et al., 2013 also recorded the presence of toluene in their studies (101.5 µg/m3, 2.55 µg/m3 and 349.59 µg/m3) respectively. The presence of toluene in these samples arises from its use as a solvent in the production. Although, Toluene isn't considered as carcinogenic but reports has shown that it causes detrimental effects on the central nervous system (CNS), cardiovascular system, hematopoietic system, reproductive system, and respiratory system, as well as the liver, kidneys, integumentary system, and sudden sniffing death due to its impact on myocardial sensitivity to epinephrine on exposure to elevated temperature (Kopelovich et al., 2015 & Saeedi et al., 2024). 1,2-dibromo-3-chloropropane (1,2-DB-3CP) was detected in all samples with a concentration value range between (1.43 ± 0.54 – 8.80 ± 0.92 ppm) while Hexachlorobutadiene was presents in all the samples except TC with a concentration value range between (24.36±2.48 - 195.75±279.19 ppm).

Table 1. Concentration of of VOCs (ppm) present in all the samples

VOCs	NP	LS	TC	AF
1,2dibromo-3-chloropropane	8.80 ±0.92	1.43 ±0.54	7.61 ±5.03	2.80 ±1.33
Hexachloro--butadiene	24.36 ±2.48	38.49 ±38.51	-	195.75 ±279.19
Dibromomethane	61.72 ±59.73	-	29.68 ±31.6	-

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DOI: https://doi.org/10.64388/IREV9I12-1718754

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Toluene	111398.86 ±96480.62	2.21 ±0.91	-	60.98 ±85.06
1,1-dichlo--roethane	233.97 ±158.42	135.409 ±60.02	378.54 ±38.49	-
Dibromo-chloromethane	84068.67 ±81694.43	5.70 ±4.98	40.25 ±41.99	-
1,2,4-tri-Chlorobenzene	-	-	2.35 ±1.66	-
1,2-dichloro--benzene	-	2.30 ±1.88	-	89.60 ±114.21
Benzene	111.63 ±175.70	-	-	-

*NP-Nail Polish LS-Lipstick , TC – Toilet cleaner, AF- Air Freshner, - = Not detected

These values are higher than what Cankaya et al., 2020 reported on 1,2-dibromo-3-chloropropane (1,2D-3CP) and hexachlorobutadiene (HCB) with concentrations in the range of (9.99±0.81 – 72.61±88.35 µg/m3) & (0.52 ±0.49 – 4.26±3.00µg/m3) respectively in their study. The presence of 1,1-dichloroethane is dominant in almost all the samples because of its as solvent, is in agrees with the result of Pandey & Yadav, 2018. Exposure to this compound can induce systemic effects, including hepatotoxicity, nephrotoxicity, and neurological symptoms such as CNS depression and unconsciousness. Localized effects may involve skin and eye irritation, dermatitis, and burns. Respiratory irritation, salivation, sneezing, and coughing, along with dizziness, lacrimation, and conjunctival reddening, are also observed. Severe cases may progress to cyanosis and circulatory failure (Bingham er al., 2001). Dibromochloromethane (DBM) is present in all samples except AF in the range of 5.70 – 85000 ppm while benzene was only recorded in NP with a concentration of 111.63 ppm. The values recorded for Dibromochloromethane and Benzene reported in this study were higher than the one reported by Ayri et al., 2020 (1.02 ×-3 – 2.47 ×-3 µg/g) and (5.44 ×-4 – 1.07 µg/g) respectively. Benzene has been reported by Tsai 2019 to cause leukemia. The value of 2.30 – 90.00 ppm recorded for 1,2- is in contrast to the ranges of value reported by Chin et al., 2014 (0.01 ± 1.50 µg/m3)

The results for Average Daily Dose (ADD) and Hazard Quotient (HQ) for all the Samples are shown in Table 2 and 3 respectively. Dibromochloromethane can only be detected in dermal and has the highest concentration of 31.19 and 1949.37 ppm for ADD and HQ respectively, which are known to cause thyroid disease (Qun Lu et al 2025). Toluene has a concentration of 14.29 ppm while Benzene has a concentration of 2.67ppm, these concentrations are higher than the limits set by USEPA 1992. For ADD inhalation it can be found that Toluene concentration is in the range of (2.17E-8-1.23E-8) while there is absence of Benzene. This value is lower than the limits set by USEPA 1992. The concentration reported by Tsai 2018 Toluene and Benzene are higher and lower (20ppm and 0.5ppm) respectively than the one reported in this study due to the types of samples used.

Table 2: Average Daily Dose (ppm) for dermal and Inhalation

ADD for dermal contact			
VOCs	NP	LS	TC
	WOMAN	WOMAN	ADULT
1,2 D-3CP	0.001	0.0001	0.0009
HexaCBD	0.003	0.005	—
DBM	0.008	—	0.004
Toluene	14.29	0.0002	—
1,1-DCE	0.03	0.02	0.0001
DBCM	31.19	0.002	0.02
1,2,4-TCB	—	—	0.0003
1,2-DCB	—	0.0002	—
Benzene	2.67	—	—
ADD via inhalation (AF) in ppm			
VOC	CHD	ADT	

1,2DB-3CP	1.00E-9	5.60E-10
HexaCBD	6.99E-8	3.94E-8
DBM	_	_
Toluene	2.17E-8	1.23E-8
1,1-DCE	_	_
DBCM	_	_
1,2,4-TCB	_	_
1,2-DCB	3.20E-8	1.80E-8
Benzene	_	_

Table 3: Hazard Quotient and Index (ppm)

VOCs	NP	LP	TC
1,2DB-3CP	5.00	0.5	4.5
HCBD	0.04	0.07	-
DBM	2.67	-	1.33
Toluene	4.38	0.60E-4	-
1,1-DCE	6.00	4.00	0.02
DBCM	1949.37	0.13	1.25
1,2,4-TCB	-	-	0.1
1,2-DCB	-	0.30E-3	-
Benzene	1335.00	-	-
HI_{der}	3302.00	4.70	7.20
Inhalation			
VOCs	CHILD	ADULT	
1,2D-3CP	5.00E-6	2.80E-6	
HexaCBD	9.57E-7	5.39E-7	
DBM	-	-	
Toluene	6.64E-9	3.76E-9	
1,1-DCE	-	-	
DBCM	-	-	
1,2,4-TCB	-	-	
1,2-DCB	2.00E-6	1.12E -6	
Benzene	-	-	
HI_{Inh}	7.96E-6	4.46E --6	

*CHD = Children, ADT = Adult, - = Not detected

Tsai 2018 reported that Benzene and Toluene cause Leukemia and damages to visual & reproductive system. The individual HQder in this study were above the acceptable limit (1.0) presented by USEPA in NP except Hexachlorobutadiene. In LS all VOCs are below the acceptable limit (1.0) except 1,1-Dichloroethane while in TC 1,1-Dichloroethane & 1,2,4-trichlorobenzene were below the acceptable limit. All the VOCs detected vi HQ values obtained for all the VOCs detected were below the acceptable limits by USEPA via inhalation for both Adult and Children. Cankaya et al., 2018 also reported HQ lower than the acceptable limit by USEPA in all their samples except 1,2D-3CP. In 2023, Otgonbyamba, et al 2023 reported a high cancer risk of benzene and a permissible toluene risk in children. These shows that most of the VOCs in this study which shows values grater than 1 can be cancerous since via dermal contact according to the acceptable limit set by USEPA.

IV. CONCLUSION

The results in this study showcase the ranges of VOCs emitted in everyday use consumer products. The risk assessment showed a value higher than 1 for most of the VOCs in Dermal except in Inhalation. This study concluded that the presence of VOCs in these samples due to their concentration are a source of health challenges to the exposed individual.

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