# Assessment of some Endocrine Disruptors (Phenols and Parabens) in Selected Cosmetics in Port Harcourt Market

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**ABSTRACT**

*Endocrine-disrupting compounds (EDCs) such as phenols and parabens are widely incorporated into cosmetics, yet their occurrence in products sold in Nigerian markets remains poorly documented. This study assessed the concentrations of these contaminants in three commonly used cosmetics (aloe vera gel cream, pure white body lotion, and papaya cream) purchased from market in Port Harcourt, Rivers State, Nigeria. Samples were collected, homogenized, and subjected to solvent-based extraction followed by chromatographic determination. Results revealed substantial variation across product types: total phenols reached 1000 µg/kg in the same product, led by dichlorophenols and methylphenols; and total parabens peaked at 257 µg/kg in papaya cream, with propyl- and isopropyl-parabens as the main contributors. Pure White body lotion exhibited intermediate levels of all three classes with phenols 869 µg/kg and parabens 68 µg/kg. Although individual concentrations remained below current European Union and NAFDAC permissible limits. The co-occurrence of multiple EDCs in single products raises concern regarding potential additive or synergistic effects from daily dermal exposure. The findings confirm cosmetics as a modifiable source of EDC exposure in an urban Nigerian population and highlight product-specific contamination patterns influenced by formulation and intended function. The study provides data for these compounds in locally marketed cosmetics in Port Harcourt. It is recommended that NAFDAC introduce specific maximum limits and mandatory ingredient disclosure for EDCs, while manufacturers should prioritize safer alternatives. Expanded biomonitoring and broader product screening are urged to strengthen risk assessment and protect public health.*

***Keywords:*** *Endocrine disruptive compounds, parabens, phenols.*


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## INTRODUCTION

Endocrine disrupting compounds (EDCs) are synthetic or naturally occurring chemicals that interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body, thereby adversely affecting homeostasis, reproduction, development, and behaviour (Bergman et al., 2013). Among the most studied EDCs are phenols (particularly bisphenol A and triclosan), and parabens, which are widely incorporated into consumer products, plastics, personal care items, and pharmaceuticals. These compounds are of global public health concern because of their persistence, bioaccumulation, and ability to exert endocrine effects even at environmentally relevant low doses (Gore et al., 2015). In developing countries such as Nigeria, rapid population growth, uncontrolled urbanization, and inadequate waste management systems have intensified the release of EDCs into the environment. Phenols and parabens enter aquatic systems through untreated industrial effluent, domestic wastewater, and the widespread use of antimicrobial soaps and cosmetics (Afolabi et al., 2023). Several Nigerian studies have reported detectable concentrations of bisphenol A (BPA), methylparaben, and propylparaben in surface water, groundwater, and sediments, often exceeding international guideline values (Oluwaseun et al., 2022). Human exposure to these compounds occurs predominantly through dietary ingestion, dermal contact with personal care products, and consumption of contaminated drinking water (Konieczna et al., 2015). Vulnerable populations in Nigeria, including women of reproductive age and children who depend on shallow wells and sachet water, face heightened cumulative exposure (Ezejiofor et al., 2014). Biomonitoring studies conducted in southern Nigeria have revealed measurable urinary levels of BPA, and parabens in both urban and rural residents, indicating widespread internal exposure (Onyia et al., 2021). The adverse health outcomes associated with chronic low-dose exposure to these EDCs are well documented. Parabens and bisphenol A exhibit weak estrogenic activity and have been implicated in premature thelarche, altered pubertal timing, obesity, and increased breast cancer risk (Harley et al., 2019; Kim et al., 2020; Lee et al., 2020). Furthermore, prenatal and early-life exposure may induce epigenetic changes with transgenerational consequences. In Nigeria, where malnutrition and infectious diseases already compromise child development, co-exposure to EDCs may exacerbate developmental and reproductive health burdens (Awoyemi et al., 2023). Consequently, there is an urgent need for comprehensive, location-specific assessment of phenols and parabens in environmental compartments and biological matrices within Port Harcourt, River State, Nigeria. Such data are indispensable for establishing national reference values, designing evidence-based regulations, and implementing targeted public health interventions. The present study therefore seeks to fill this critical knowledge gap by determining the concentrations, distribution patterns, and potential human exposure risks of selected endocrine disrupting compounds in [specific location/region, Nigeria], thereby providing baseline information for policy formulation and future mitigation strategies.

## METHODOLOGY

### Sample collection

Pure white body lotion, Papaya cream and raw Aloe Vera plant were bought from three popular markets in Port Harcourt, River State. All samples were fully labelled and stored at 4 °C (and later –20 °C for reserves) pending analysis.

### Determination of phenolic compounds from cream-based cosmetics

### Sample preparation

To 1g of sample, 10 mL NaCl (36%) was added, and then the solid phase extraction procedure was applied. The C18 cartridge (Isolute C18, 100 mg, 6 mL) column was preconditioned with 8 mL of ethyl acetate, 5 mL of water. The wine diluted sample was then percolated by gravity flow through the cartridge. After 1 h of drying the compounds were eluted with 3 mL of ethyl acetate and then dried over $Na_2$ $SO_4$ during 4h. The sample was evaporated to dryness. The mixture was kept at room temperature for 1 h and completed with pyridine to 1 mL. A volume of 2 µL of sample was used for GC FID analysis.

### Instrumentation

Analysis was performed on a GC FID system (Agilent 6890).The GC was equipped with a HP-5MS of 30 m length and 0.25 mm internal diameter capillary column, with 0.25 µm film thickness. The carrier gas was helium set to flow at 1.5 ml/min. The injector was operated in splitless mode at the 280 °C temperature. The chromatographic working conditions were optimized for complete separation of the target compounds. The oven was programmed from 120 C (3.0 min) to 315 °C with 5 °C/min and maintained for 5.0.

### Determination of paraben compounds from cream-based cosmetics

A 0.5 g of the sample was dissolved in 5 mL of methanol. In this solution, 0.1M NH4OH was added to obtain pH 7. Insoluble excipients were separated by centrifugation for

10 min at 4000 rpm at 20°C. Then, 1.0 mL of the supernatant was applied to the cartridge and the SPE procedure was performed; prepared samples were subjected to HPLC analysis on Zorbax Eclipse Plus C8 (150x3.0 mm, 3.5 μm) columns. After optimization, the final adopted HPLC conditions were: Zorbax Eclipse Plus C18 column, the mobile phase consisting of a MeOH/phosphate buffer (pH=2.5) and a flow rate of 0.5 mL/min. The optimal volume ratio methanol vs. buffer was found to be different depending on the analyzed product. Thus, for syrup samples, the ratio MeOH vs. buffer was 60:40 (v/v), for gels 70:30 (v/v), while for hand creams the ratio of methanol vs. buffer was 55:45 (v/v). The temperature was kept at 35°C and the detection was carried out at 254 nm. For the monitoring of chromatographic system and data acquisition, the Agilent ChemStation program was used. HPLC analyses were performed on Agilent Technologies 1100 apparatus with diode array detector (DAD. The separation was carried out on Zorbax Eclipse Plus C8 (150 mm L x 3.0 mm i.d., 3.5 μmd.p.)

**Compliancy**

This study made use of a cross-sectional analytical design to evaluate the concentrations of parabens, phenols, in three cosmetic products (100% Aloe Vera, Pure White, and Papaya) using laboratory measurements reported in micrograms per kilogram (μg/kg). The primary objective was to assess compliance with regulatory standards (EU, US, and Nigerian) and perform a quantitative health risk assessment through dermal exposure pathways. The chemical analysis of the three cosmetics product revealed 12 parabens compounds, 13 phenolic compounds, and 16 phthalate esters in each of the cosmetic products. Results are expressed in micrograms per kilogram (μg/kg) of product as received. Non-detected values were treated as zero for conservative risk estimation. All statistical analyses were performed using IBM SPSS Statistics Version 27.0. For each chemical class (parabens, phenols, phthalates) and for each product, the following descriptive parameters were calculated using SPSS Explore and Descriptive procedures: Minimum, maximum, mean, and standard deviation (SD).These statistics were exported and used to generate composite bar charts to visually compare total paraben, phenol, and phthalate levels across the three products (100% Aloe Vera, Pure White, and Papaya.

**Quality Assurance**

The data were further evaluated against the cosmetic standards of the Europe, America and Nigeria using EU Cosmetics Regulation (EC) No 1223/2009 with 2025 amendments of (EU) 2025/877 for CMR bans; US Federal Food, Drug, and Cosmetic Act (1938) with MoCRA (2022) and CIR assessments and NAFDAC Act CAP N1 LFN 2004 (2004) with Labelling Regs. (2021) to check for conformity to approved standard. These standards are as stated: European Union |Regulation (EC) No 1223/2009 (as amended) lists prohibited substances (e.g., isopropyl-, isobutyl-, benzyl-, pentyl-, phenylparaben; BBP, DEHP, DBP, DIBP, etc.) = 0 μg/kg; permitted parabens ≤ 0.4 % single / 0.8 % mixture (4 000 000 / 8 000 000 μg/kg), United States Federal Food, Drug, and Cosmetic Act state bans (e.g., Washington 2025) | No federal numerical limits, but CIR safety levels and state prohibitions considered; prohibited = >0 μg/kg where banned; and Nigeria NAFDAC Cosmetic Products Regulations 2021 Aligns with EU prohibited list; CMR substances must be absent. The conformity or otherwise of these products were tabulated and denoted using < = conformity and > = non conformity.

**Health risk assessment of Endocrine disruptive compounds (phenols & parabens) in the studied cosmetics**

Finally, the health risk assessment of the three products (100% Aloe Vera, Pure White, and Papaya) was done by computing the Hazard Quotient and Hazard Index. This was done by computing the daily systemic exposure was using the standard SCCS worst-case scenario for body lotion using Systemic Exposure Dose as;

$$(SED_i, \mu g/kg\ bw/day) = C_i \times 10\ g/day \times 1.0\ /\ 60\ kg = C_i \times 0.1667 \quad (1)$$

Where $C_i$ measured concentration of an individual chemical compound i in the cosmetic product, expressed in micrograms per kilogram (μg/kg) of product.

Individual Hazard Quotient: $HQ_i = SED_i\ /\ TDI_i$ (2)

where $TDI_i$ = Tolerable Daily Intake (see Appendix).
Because all three chemical classes share endocrine-disrupting properties, the Hazard Index (HI) was calculated by dose addition (EFSA Scientific Committee, 2019): $HI = \Sigma HQ_i$ (across all detected compounds in a product).
Risk interpretation using the HI is as given below

- •-HI < 1 → acceptable
- •HI ≥ 1 → unacceptable
- • HI > 10 → high to very high risk

## RESULTS AND DISCUSSION

Figure 1 shows the concentration of total phenols across the three cosmetic samples. 100% Aloe Vera Gel recorded

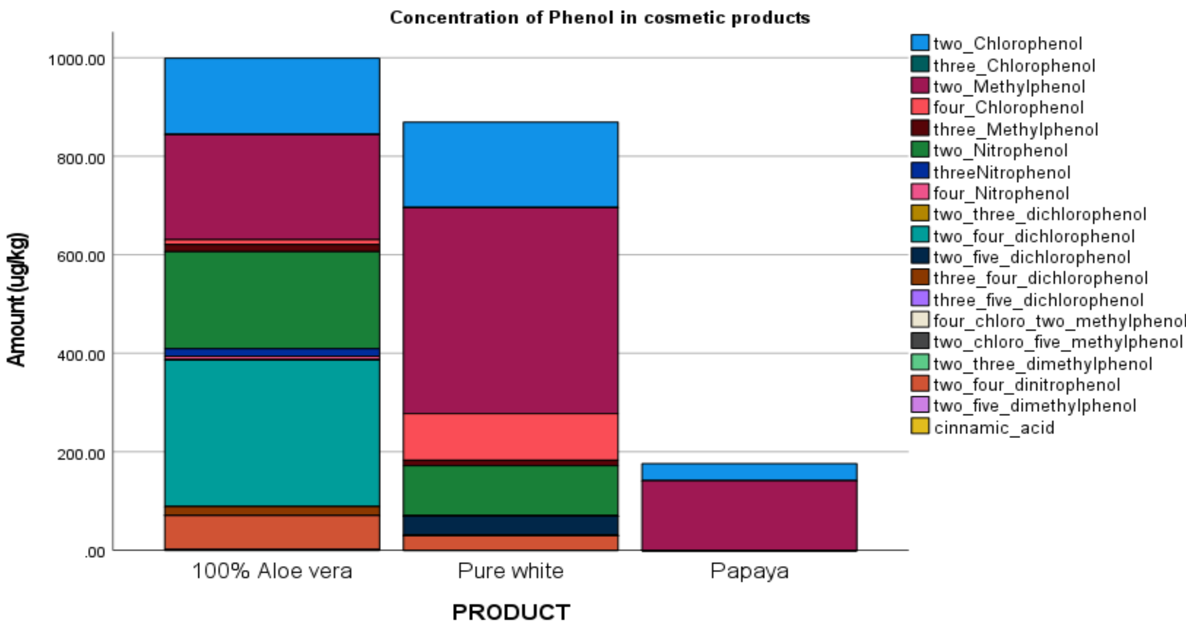


**Figure 1:** Bar chart comparing total phenolic concentrations across the three cosmetic products (µg/kg)

**Table 1:** Concentration of phenols in Selected Cosmetics (µg/g)

| PHENOL CONTENT | Amount (ug/kg) | | |
|---|---|---|---|
| | **Aloe Vera Gel** | **Pure White Body Cream** | **Papaya Cream** |
| 2- Chlorophenol | 154.21506 | 172.75598 | 34.90165 |
| 3- Chlorophenol | 1.18302 | 1.18856 | ND |
| 2-Methylphenol | 212.98702 | 417.88167 | 141.14381 |
| 4- Chlorophenol | 9.99624 | 94.70900 | 0.0000 |
| 3 – Methylphenol | 14.41104 | 11.07971 | ND |
| 2- Nitrophenol | 196.93886 | 101.88994 | ND |
| 3- Nitrophenol | 15.26321 | ND | ND |
| 4- Nitrophenol | 6.56147 | $3.71922e^{-1}$ | ND |
| 2 3-dichlorophenol | 1.21954 | ND | ND |
| 2 4- dichlorophenol | 297.67091 | ND | ND |
| 2 5- dichlorophenol | ND | 37.89339 | ND |
| 3 4- dichlorophenol | 18.09109 | 1.94231 | ND |
| 3 5 dichlorophenol | ND | ND | ND |
| 4-chloro-2-methylphenol | ND | ND | ND |
| 2-chloro-5-methylphenol | ND | ND | ND |
| 2, 3-dimethylphenol | ND | ND | ND |
| 2,4 dinitrophenol | 68.83567 | 29.65194 | ND |
| 2, 5-dimethylphenol | 1.72645 | ND | ND |
| cinnamic acid | ND | ND | ND |
| Resveratrol | ND | ND | - |
| | 1000.09959 | 869.36441 | 176.04546 |

the highest total phenolic concentration (1000.10 µg/kg), closely followed by Pure White Body Cream (869.36 µg/kg), while Papaya Cream had the lowest concentration (176.05 µg/kg). Conversely, Figure 2 demonstrates that Papaya Cream contained the highest total paraben concentration (257.01 µg/kg), followed by Pure White Body Cream (68.60 µg/kg), whereas Aloe Vera Gel had the lowest paraben burden (34.05 µg/kg). These contrasting distribution patterns indicate product-specific formulation strategies and potential differences in preservative systems.

## Occurrence and Distribution of Phenolic Compounds

The quantitative data presented in (Table 1) reveal marked inter-product variability in phenolic composition. Aloe Vera Gel (Cosmetic A) exhibited the highest cumulative phenolic burden (1000.10 µg/kg).

**Table 2:** Concentration of parabens in Selected Cosmetics (µg/g)

| S/N | PARABEN CONTENT | Amount (ug/kg) | | |
|---|---|---|---|---|
| | | **Aloe Vera Gel** | **Pure White Body Cream** | **Papaya Cream** |
| 1 | Methyl p-hydroxybenzoate | 1.23200 | ND | ND |
| 2 | Ethyl p-hydroxybenzoate | 3.23200 | $1.32035e^{-1}$ | 11.17508 |
| 3 | Propyl p-hydroxybenzoate | 4.33200 | 4.03383 | 96.92523 |
| 4 | Isobutyl p-hydroxybenzoate | 1.882 | 8.29157 | ND |
| 5 | Isopropyl p-hydroxybenzoate | 1.223 | 9.28663 | 72.17508 |
| 6 | Benzyl p-hydroxybenzoate | 4.445 | ND | 13.84824 |
| 7 | Heptyl p-hydroxybenzoate | 2.343 | 3.5171 | 2.26503 |
| 8 | Butyl p-hydroxybenzoate | 2.334 | $8.28636e^{-2}$ | - |
| 9 | Pentylparaben | 3.333 | 9.45601 | 9.46367 |
| 10 | Phenylparaben | 4.245 | 17.06147 | 50.42739 |
| 11 | Octylparaben | 3.879 | 1.70222 | ND |
| 12 | Sodium ethylparaben | 1..567 | 15.03246 | ND |
| Total | | 34.047 | 68.59619 | 257.0063O |

Major contributors included 2,4-dichlorophenol (297.67 µg/kg), 2-methylphenol (212.99 µg/kg), and 2-nitrophenol (196.94 µg/kg). Several of these compounds are classified as prohibited or carcinogenic, mutagenic, and reprotoxic (CMR) substances under EU Regulation (EC) No 1223/2009, as reflected in the compliance matrix (Table 1). Pure White Body Cream (Cosmetic B) showed similarly elevated concentrations, particularly 2-methylphenol (417.88 µg/kg), 2-chlorophenol (172.76 µg/kg), and 2-nitrophenol (101.89 µg/kg). In contrast, Papaya Cream (Cosmetic C) displayed a relatively simplified phenolic profile, dominated by 2-methylphenol (141.14 µg/kg), with most other phenolic analogues undetected. The lower phenolic diversity in Cosmetic C may reflect a reduced reliance on chlorinated preservatives or differences in manufacturing processes. Regulatory evaluation (Table 1) indicates widespread non-compliance with EU and Nigerian (NAFDAC) standards due to the detection of prohibited chlorophenols and nitrophenols. Although the US Cosmetic Ingredient Review (CIR) considers certain phenolic compounds “safe as used,” EU and Nigerian frameworks apply a precautionary zero-tolerance approach to several of these substances. This regulatory divergence mirrors global enforcement disparities highlighted by Kashuri et al. (2025), who documented increasing supervisory actions against non-compliant cosmetic products between 2021 and 2024. Toxicologically, chlorinated and nitrated phenols are recognized for their endocrine-disrupting properties and potential dermal toxicity. The cumulative presence of multiple phenolic EDCs in Cosmetics A and B therefore raises concerns regarding additive or synergistic effects. In emerging markets where regulatory oversight may be inconsistent, the need for strengthened pharmacovigilance and cosmetic surveillance systems has been emphasized (Harris, 2024).

## Occurrence and Distribution of Parabens

Paraben concentrations (Table 2) showed a distinct pattern compared to phenols. Papaya Cream (Cosmetic C) contained the highest total paraben concentration (257.01 µg/kg), significantly exceeding levels detected in Pure White Body Cream (68.60 µg/kg) and Aloe Vera Gel (34.05 µg/kg). As illustrated in Figure 2, this indicates that Papaya Cream relies more heavily on paraben-based preservation systems. Propylparaben (96.93 µg/kg), isopropylparaben (72.18 µg/kg), and phenylparaben (50.43 µg/kg) were the dominant contributors in Cosmetic C. Importantly, several of these analogues such as isopropylparaben, isobutylparaben, benzylparaben, pentylparaben, and phenylparaben are prohibited under EU and Nigerian cosmetic regulations (Table 2). Consequently, despite the relatively low absolute concentrations compared to the EU maximum permitted limit for certain parabens (≤4,000,000 µg/kg), the presence of banned derivatives resulted in overall regulatory non-compliance for all three products under EU and Nigerian standards. The US CIR classification of many parabens as “safe as used” demonstrates regulatory heterogeneity across jurisdictions. Such divergence in national risk–benefit assessments has been discussed in broader healthcare policy contexts (Kim et al., 2025), underscoring how scientific interpretation and socio-regulatory priorities influence ingredient approval. The findings highlight the importance of harmonized international cosmetic safety standards, particularly in import-dependent markets. Although detected paraben levels were lower than historical concentrations reported globally, the mixture of multiple paraben chains remains toxicologically relevant due to potential cumulative endocrine-disrupting effects. The growing transition toward bio-based and eco-friendly alternatives in cosmetic preservation systems, including nanoparticle-based formulations (Omidi et al., 2026) and microbial-derived polymers (Rajput et al., 2025), reflects industry efforts to address such concerns.

## Human Dermal Exposure and Risk Characterization

Estimated Daily Dermal Exposure values (Table 3) ranged from 0.0058 µg/kg bw/day for Papaya Cream to 0.0138 µg/kg bw/day for Aloe Vera Gel. While these values

**Table 3:** Human Daily Dermal Exposure to endocrine disrupting compounds in selected cosmetics.

| Cosmetic Sample | Total Parabens (µg/kg) | Total Phenols (µg/kg) | Daily Dermal Exposure (µg/kg bw/day) |
|---|---|---|---|
| Aloe Vera Gel | 34.05 | 1,000.10 | 0.0138 |
| Pure White Body Cream | 68.60 | 869.36 | 0.0125 |
| Papaya Cream | 257.01 | 176.05 | 0.0058 |

**Table 4:** Compliance of Detected Parabens with EU, US, and Nigerian Cosmetic Regulations.

| Paraben (common name) | EU Status (Regulation (EC) No 1223/2009) | EU Limit | US CIR Status | Nigeria (NAFDAC) | Cosmetic A (µg/kg) | EU | US | Nigeria | Cosmetic B (µg/kg) | EU | US | Nigeria | Cosmetic C (µg/kg) | EU | US | Nigeria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Methylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 1.232 | ✓ | ✓ | ✓ | ND | ✓ | ✓ | ✓ | ND | ✓ | ✓ | ✓ |
| Ethylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 3.232 | ✓ | ✓ | ✓ | 0.132 | ✓ | ✓ | ✓ | 11.175 | ✓ | ✓ | ✓ |
| Propylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 4.332 | ✓ | ✓ | ✓ | 4.034 | ✓ | ✓ | ✓ | 96.925 | ✓ | ✓ | ✓ |
| Isobutylparaben | Prohibited | **0** | Safe as used | Prohibited | 1.882 | ✗ | ✓ | ✗ | 8.292 | ✗ | ✓ | ✗ | ND | ✓ | ✓ | ✓ |
| Isopropylparaben | Prohibited | **0** | Safe as used | Prohibited | 1.223 | ✗ | ✓ | ✗ | 9.287 | ✗ | ✓ | ✗ | 72.175 | ✗ | ✓ | ✗ |
| Benzylparaben | Prohibited | **0** | Safe as used | Prohibited | 4.445 | ✗ | ✓ | ✗ | ND | ✓ | ✓ | ✓ | 13.848 | ✗ | ✓ | ✗ |
| Heptylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 2.343 | ✓ | ✓ | ✓ | 3.517 | ✓ | ✓ | ✓ | 2.265 | ✓ | ✓ | ✓ |
| Butylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 2.334 | ✓ | ✓ | ✓ | 0.083 | ✓ | ✓ | ✓ | ND | ✓ | ✓ | ✓ |
| Pentylparaben | Prohibited | **0** | Safe as used | Prohibited | 3.333 | ✗ | ✓ | ✗ | 9.456 | ✗ | ✓ | ✗ | 9.464 | ✗ | ✓ | ✗ |
| Phenylparaben | Prohibited | **0** | Safe as used | Prohibited | 4.245 | ✗ | ✓ | ✗ | 17.061 | ✗ | ✓ | ✗ | 50.427 | ✗ | ✓ | ✗ |
| Octylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 3.879 | ✓ | ✓ | ✓ | 1.702 | ✓ | ✓ | ✓ | ND | ✓ | ✓ | ✓ |
| Sodium ethylparaben | Permitted | ≤4 000 000 | Safe | Permitted | 1.567 | ✓ | ✓ | ✓ | 15.032 | ✓ | ✓ | ✓ | ND | ✓ | ✓ | ✓ |
| | | | | | 34.047 | ✗ | ✓ | ✗ | 68.596 | ✗ | ✓ | ✗ | 257.006 | ✗ | ✓ | ✗ |

appear low when considered independently, systemic exposure dose (SED) calculations and hazard modeling (Table 6) indicate significantly elevated cumulative risk. Aloe Vera Gel recorded a total SED of 171.96 µg/kg bw/day and a Hazard Index (HI) of 51.56, categorizing it as “very high risk,” primarily due to phenolic exposure (HQ = 51.54). Pure White Body Cream similarly fell within the “very high risk” category (HI = 29.62). Papaya Cream, though exhibiting lower phenolic exposure, demonstrated an “unacceptable risk” classification (HI = 2.57) due to elevated paraben-derived SED (42.72 µg/kg bw/day). Hazard Quotient values for phenols in Cosmetics A and B substantially exceeded unity, indicating potential systemic health risks under chronic exposure scenarios. Although individual paraben HQ values were below 1, cumulative exposure contributed to the overall hazard index. These findings reinforce the necessity of mixture-based toxicological assessment rather than single-compound evaluation. Given projected expansion in consumer goods sectors between 2024 and 2026 (Bureau for Economic Research, 2024), cosmetic consumption rates may increase, potentially amplifying aggregate endocrine-disrupting compound (EDC) exposure. In rapidly urbanizing and entrepreneurial ecosystems, particularly those characterized by informal cosmetic trade (Stroiko et al., 2024), regulatory gaps may further compound exposure risks.

## Regulatory and Public Health Implications

Compliance analyses (Tables 4 and 5) reveal that while US standards may tolerate certain detected compounds, EU and Nigerian frameworks classify many as prohibited. This regulatory misalignment poses significant public health challenges in

**Table 5:** Compliance of Detected Phenolic Compounds with EU, US, and Nigerian Cosmetic Regulations.

| Phenol Compound | EU Status (Regulation (EC) No 1223/2009) | EU Limit | US CIR Status | Nigeria (NAFDAC) | Cosmetic A (µg/kg) | EU | US | Nigeria | Cosmetic B (µg/kg) | EU | US | Nigeria | Cosmetic C (µg/kg) | EU | US | Nigeria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2-Chlorophenol | Prohibited | 0 | Safe as used | Prohibited (CMR) | 154.22 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ | 34.90 | ✗ | ✓ | ✗ |
| 3-Chlorophenol | Prohibited | 0 | Safe as used | Prohibited | 1.18 | ✗ | ✓ | ✗ | 1.19 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 2-Methylphenol (o-cresol) | Prohibited | 0 | Safe as used | Prohibited | 212.99 | ✗ | ✓ | ✗ | 417.88 | ✗ | ✓ | ✗ | 141.14 | ✗ | ✓ | ✗ |
| 4-Chlorophenol | Prohibited | 0 | Safe as used | Prohibited | 9.99 | ✗ | ✓ | ✗ | 94.71 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 3-Methylphenol (m-cresol) | Prohibited | 0 | Safe as used | Prohibited | 14.41 | ✗ | ✓ | ✗ | 11.08 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 2-Nitrophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 196.94 | ✗ | ✓ | ✗ | 101.89 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 3-Nitrophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 15.26 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 4-Nitrophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 6.56 | ✗ | ✓ | ✗ | 0.37 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 2,3-Dichlorophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 1.22 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 2,4-Dichlorophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 297.67 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 2,5-Dichlorophenol | Prohibited (CMR) | 0 | Safe as used | Prohibited | 0 | ✓ | ✓ | ✓ | 37.89 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 3,4-Dichlorophenol | Prohibited | 0 | Safe as used | Prohibited | 18.09 | ✗ | ✓ | ✗ | 1.94 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 3,5-Dichlorophenol | Prohibited | 0 | Safe as used | Prohibited | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 4-Chloro-2-methylphenol | Prohibited | 0 | Safe as used | Prohibited | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 2-Chloro-5-methylphenol | Prohibited | 0 | Safe as used | Prohibited | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 2,3-Dimethylphenol | Prohibited | 0 | Safe as used | Prohibited | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| 2,4-Dinitrophenol | Prohibited | 0 | Safe as used | Prohibited | 68.84 | ✗ | ✓ | ✗ | 29.65 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ |
| 2,5-Dimethylphenol | Prohibited | 0 | Safe as used | Prohibited | 1.73 | ✗ | ✓ | ✗ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| Cinnamic acid | Permitted | No limit | Safe | Permitted | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| Resveratrol | Permitted | No limit | Safe | Permitted | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ | 0 | ✓ | ✓ | ✓ |
| | | N/A | N/A | N/A | 1,000.10 | ✗ | ✓ | ✗ | 869.36 | ✗ | ✓ | ✗ | 176.05 | ✗ | ✓ | ✗ |

**Table 6:** Systemic Exposure Dose (SED), Hazard Quotient (HQ), and Cumulative Hazard Index (HI) for the Three Cosmetic Products.

| Product | SED Parabens (µg/kg bw/day) | HQ Parabens | SED Phenols (µg/kg bw/day) | HQ Phenols | Total SED (µg/kg bw/day) | Hazard Index (HI) | Risk Level |
|---|---|---|---|---|---|---|---|
| 100% Aloe Vera (Cosmetic A) | 5.41 | 0.02 | 166.55 | 51.54 | 171.96 | **51.56** | Very high risk |
| Pure White (Cosmetic B) | 11.43 | 0.05 | 144.92 | 29.57 | 156.35 | 29.62 | Very high risk |
| Papaya (Cosmetic C) | 42.72 | 0.16 | 29.35 | 2.41 | 72.07 | 2.57 | Unacceptable risk |

markets reliant on imported cosmetic products. Strengthened surveillance and enforcement mechanisms, as recommended by Kashuri et al. (2025), are essential to mitigate the circulation of non-compliant products. From a sustainability standpoint, consumer behavior trends increasingly favor greener and safer cosmetic alternatives (Timpanaro & Cascone, 2025). The elevated hazard indices observed in this study support accelerating the transition toward safer preservative systems and bio-based antimicrobial agents (Rajput et al., 2025). Chronic exposure to endocrine-disrupting chemicals is particularly concerning for adolescents and women of reproductive age. Hormonal perturbations during adolescence may have long-term reproductive consequences (Hanprasertpong & Hanprasertpong, 2026). Considering the high frequency of cosmetic use within these demographic groups, cumulative dermal exposure represents a significant and under-recognized public health issue.

## Synthesis of Findings

The results collectively demonstrate:

1. Substantial phenolic contamination in Aloe Vera Gel and Pure White Body Cream (Table 1; Figure 1).
2. Highest paraben burden in Papaya Cream (Table 2; Figure 2).
3. Widespread regulatory non-compliance under EU and Nigerian standards (Tables 4 and 5).

Elevated cumulative Hazard Index values indicating very high or unacceptable risk classifications (Table 6). Although individual compound concentrations did not exceed certain quantitative international thresholds, the presence of prohibited substances and elevated cumulative hazard indices highlight significant regulatory and public health concerns. These findings provide region-specific empirical data on endocrine-disrupting compounds in Nigerian-marketed cosmetics and underscore the urgent need for harmonized regulatory enforcement, cumulative risk assessment frameworks, and sustainable reformulation strategies.

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