RESEARCH PAPER

Assessment of Knowledge Regarding Chemical Ingredients in Cosmetic Products and Its Potential Adverse Effects During Pregnancy Among Antenatal Women

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Abstract

The use of cosmetic and personal care products (PCPs) among women of reproductive age remains widespread during pregnancy, primarily to manage physiological skin changes such as hyperpigmentation, acne, and stretch marks. However, many cosmetic formulations contain potentially harmful chemical ingredients, including retinoids, hydroquinone, parabens, phthalates, triclosan, ultraviolet (UV) filters, heavy metals, and volatile organic compounds, which may be systemically absorbed and cross the placental barrier, posing potential risks to fetal development. Despite growing scientific evidence regarding these hazards, awareness of cosmetic ingredient safety among antenatal women remains inadequate. This review aimed to evaluate the existing knowledge of antenatal women regarding chemical ingredients in cosmetic products and their potential adverse effects during pregnancy while summarizing current evidence on toxicological mechanisms, epidemiological findings, and preventive strategies. A comprehensive literature search was conducted using PubMed, Embase, Scopus, Web of Science, and Google Scholar, including peer-reviewed studies published up to mid-2026 that investigated cosmetic use during pregnancy, maternal knowledge, placental transfer, toxicological mechanisms, and pregnancy outcomes. The available evidence consistently demonstrates a considerable gap between frequent cosmetic use and awareness of ingredient-related risks. Although many pregnant women recognize that environmental chemicals may affect pregnancy, only a small proportion can accurately identify hazardous ingredients listed on cosmetic labels. Prenatal exposure to certain cosmetic chemicals has been associated with congenital anomalies, endocrine disruption, impaired fetal growth, preterm birth, neurodevelopmental disorders, and long-term metabolic consequences. Factors such as educational status, socioeconomic background, parity, and access to reliable health information significantly influence knowledge levels. Furthermore, cosmetic safety is rarely addressed during routine antenatal counseling, limiting opportunities for effective risk communication. The review highlights the urgent need to integrate cosmetic safety education into routine prenatal care, strengthen product labelling regulations, enhance public awareness campaigns, and develop standardized clinical guidelines to improve maternal health literacy and minimize preventable fetal exposure to potentially harmful cosmetic chemicals during pregnancy.

Keywords: Cosmetic safety; Pregnancy; Antenatal women; Chemical ingredients; Fetal exposure; Health literacy; Parabens; Phthalates.

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Introduction

The modern consumer market exposes individuals to a diverse mixture of synthetic chemicals through daily routines. Among the various sources of chemical exposure, cosmetics and personal care products (PCPs) represent a consistent and intimate point of contact. Globally, women of reproductive age use an average of 9 to 12 distinct cosmetic products each day. This combination of body lotions, facial creams, hair treatments, perfumes, and decorative makeup exposes consumers to over a hundred unique chemical ingredients before they enter their workplace or home environment (Al-Saleh et al., 2019). This behavioral pattern does not cease upon the confirmation of pregnancy; rather, it often intensifies.

Gestation brings about profound, hormonally driven physiological alterations in skin elasticity, vascularity, and pigmentation. The rapid rise in circulating oestrogen, progesterone, and melanocyte-stimulating hormone (MSH) frequently induces localized hyperpigmentation, such as melasma ("the mask of pregnancy"), alongside gestational acne, pruritus, and striae gravidarum (stretch marks). These changes often lead pregnant women to seek out specialized skincare

formulations, anti-acne topicals, and skin-lightening agents (Belsito et al., 2021).

While the consumer market largely views commercially available cosmetics as inherently safe and dermatologically benign, a growing body of scientific literature raises concerns about the systemic absorption of active chemical constituents, preservatives, and stabilizers during critical embryological windows. The maternal-fetal interface, once viewed as an impermeable barrier protecting the fetus from environmental insults, is now understood to be highly vulnerable to exogenous xenobiotics. Due to their low molecular weight (< 500 Da) and highly lipophilic properties, many cosmetic ingredients can easily cross the placental syncytiotrophoblast layers via simple passive diffusion (Nohynek et al., 2010).

Once inside the fetal compartment, these chemicals encounter an immature metabolic environment. The fetal hepatic cytochrome P450 enzyme systems (such as CYP3A4 and CYP1A2) and renal clearance pathways are underdeveloped. This metabolic immaturity results in prolonged tissue accumulation and elevated toxic potential within the developing fetus (Pasanen et al., 2013).

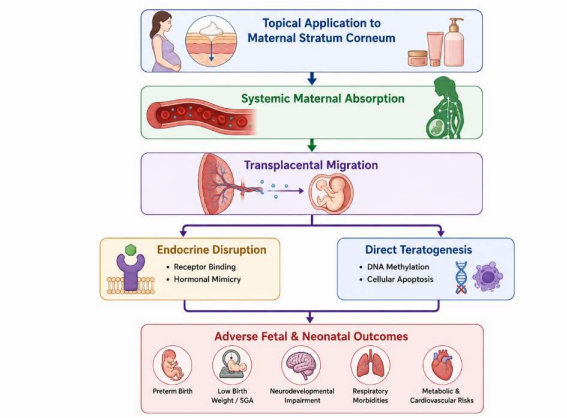

Figure 1: Flowchart illustrating the systemic migration and toxicological pathways of cosmetic chemicals through the maternal-fetal interface.

Despite these clear toxicological pathways, public health monitoring and structured clinical screening regarding cosmetic use during the antenatal period remain limited. Pregnant women are exposed to diverse mixtures of chemical classes, including known teratogens like synthetic retinoids, potent skin-lightening agents like hydroquinone, and a wide array of endocrine-disrupting chemicals (EDCs) such as phthalates, parabens, alkylphenols, and synthetic musk's (Vernet et al., 2019).

The primary barrier to protective behavioral adaptation is a widespread lack of clinical literacy and technical awareness. Most antenatal women demonstrate a general, abstract understanding that "environmental chemicals" could pose a risk to their pregnancy, yet they remain unable to decipher complex ingredient lists or identify dangerous compounds on standard commercial labels (Külahçı et al., 2022). This issue is further compounded by a historical lack of explicit advice from perinatal health professionals, leaving women dependent on unregulated digital marketing, social media influencers, and non-peer-reviewed beauty blogs for product safety guidance (Marie et al., 2016).

This comprehensive review systematically synthesizes current literature regarding the assessment of chemical ingredient knowledge among antenatal women, maps the underlying mechanisms of maternal-fetal toxicity, and proposes clinical and policy frameworks to optimize risk communication in prenatal care.

Methodology

To establish a robust foundation for this review, a comprehensive literature search was conducted across major electronic databases, including PubMed, Embase, Scopus, Web of Science, and Google Scholar, covering literature published up to mid-2026. The search strategy employed combinations of Medical Subject Headings (MeSH) terms and high-yield keywords, including: *"antenatal women"*, *"pregnancy"*, *"cosmetics"*, *"personal care products"*, *"chemical ingredients"*, *"knowledge assessment"*, *"adverse pregnancy outcomes"*, *"teratogenesis"*, and *"endocrine disruptors"*.

The selection criteria focused on original epidemiological cohorts, cross-sectional surveys evaluating maternal knowledge, in vivo and in vitro toxicological evaluations, and formal risk characterization profiles. Studies written in languages other than English without accessible official translations or those evaluating industrial workplace exposures unrelated to consumer cosmetics were excluded. A total of 48 peer-reviewed references were selected based on scientific rigor, methodological quality, and direct relevance to gestational consumer safety, forming the analytical basis of this review.

Detailed Classification of Chemical Ingredients in Cosmetics and Their Toxicological Mechanisms

The complexity of contemporary cosmetic chemistry poses a substantial challenge for consumers and clinicians trying to evaluate pregnancy safety. Formulations contain an array of synthetic molecules designed for preservation, emulsification, pigment deposition, and active therapy. When applied topically to the maternal skin, these ingredients interact with a changing biological

environment characterized by increased cutaneous blood flow, increased body surface area, and altered epidermal permeability.

Retinoids (Vitamin A Derivatives)
Retinoids, which include topical tretinoin (all-trans-retinoic acid), retinol, retinyl palmitate, and retinaldehyde, are widely utilized in anti-aging serums, chemical peels, and acne therapies. Retinoic acid is an essential signaling molecule during embryogenesis, strictly regulating transcription via nuclear retinoic acid receptors (RARs) and retinoid X receptors (RXRs) to govern limb development, craniofacial organization, and cardiovascular patterning (Pasanen et al., 2013).

When exogenous retinoids are systemically absorbed, they disrupt this highly controlled internal concentration gradient. While oral isotretinoin is a well-established, classic human teratogen that causes a specific set of malformations known as "retinoic acid embryopathy," the safety profile of topical retinoids remains a subject of ongoing clinical caution. Topical application exhibits a relatively low systemic bioavailability, typically resting between 1% and 5% (Kaplan et al., 2015). However, factors such as an altered skin barrier, widespread body application, or concurrent use of chemical penetration enhancers can significantly elevate this absorption rate. Because of the catastrophic nature of retinoic acid-induced developmental anomalies, clinical consensus strongly recommends completely avoiding all formulations containing retinoids during pregnancy (Chien et al., 2016).

The molecular mechanism of retinoic acid embryopathy involves the dysregulation of *HOX* (Homeobox) genes, which guide the craniocaudal axis patterning in the early embryo. Excessive binding to RARs triggers premature apoptosis in cranial neural crest cells, leading to characteristic defects such as microtia, cleft palate, thymic aplasia, and transposition of the great vessels.

Hydroquinone
Hydroquinone (1,4-dihydroxybenzene) is a highly effective skin-lightening agent commonly used to treat localized hyperpigmentation disorders, including melasma. It functions by inhibiting the enzymatic activity of tyrosinase, thereby preventing the conversion of L-3,4-dihydroxyphenylalanine (L-DOPA) into melanin polymers within epidermal melanocytes (Andersen et al., 2010).

Unlike most other topically applied compounds, hydroquinone exhibits an exceptionally high dermal absorption rate, with up to 35% to 45% of the applied dose entering maternal systemic circulation (Al-Saleh et al., 2004). While epidemiological cohorts have not yet linked topical hydroquinone use to a definitive increase in major structural malformations, its high systemic load warrants substantial concern. The chemical's presence in maternal blood can lead to significant fetal exposure, increasing the biological burden on the fetus during critical periods of organic development.

Endocrine Disrupting Chemicals (EDCs): Phthalates and Parabens
Endocrine-disrupting chemicals represent a broad, structurally diverse class of synthetic compounds that interfere with normal endocrine signaling cascades. In cosmetic products, phthalates—most notably diethyl phthalate (DEP)—are widely used as solvents to stabilize synthetic fragrances and prevent brittleness in nail polishes (Vernet et al., 2019). Parabens (such as methylparaben, ethylparaben, propylparaben, and butylparaben) serve as cheap, highly effective antimicrobial preservatives across nearly all categories of liquid and cream-based cosmetics (Philippat et al., 2013).

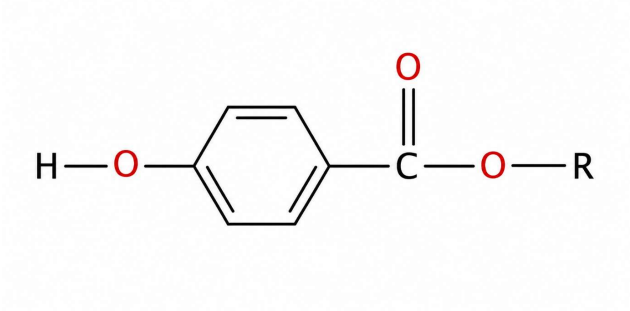

Figure 2: General chemical structure of parabens, where the alkyl chain length (R) directly correlates with increased lipophilicity and binding affinity to human oestrogen receptors.

The structural similarity of parabens to endogenous 17β-oestradiol allows them to bind directly to oestrogen receptors (ERα and ERβ), activating estrogenic transcriptional programs albeit with lower potency than natural hormones (Darbre et al., 2014). Phthalates exert a distinct anti-androgenic effect, suppressing the expression of genes involved in testicular steroidogenesis, such as the steroidogenic acute regulatory (StAR) protein (Buser et al., 2014).

During early fetal life, the precise balance of androgens and oestrogens drives sexual differentiation and reproductive tract organization. Even low-dose exposure to these compounds during critical gestational windows can disrupt this delicate endocrine balance, leading to reproductive modifications and altered developmental trajectories (Braun et al., 2013).

Triclosan and Organic UV Filters
Triclosan is a chlorinated aromatic compound used as a broad-spectrum antimicrobial agent in

medicated soaps, body washes, and toothpastes. Structurally resembling thyroid hormones, triclosan disrupts thyroid homeostasis by competitively binding to transport proteins and upregulating hepatic clearance pathways (Weatherly et al., 2017). Maternal thyroid hormones are critical for early fetal neurodevelopment, particularly during the first trimester when the fetus relies entirely on maternal thyroxine (T_4) for neocortical migration and organization (Pycke et al., 2014).

Organic (chemical) ultraviolet filters, including oxybenzone (benzophenone-3), octinoxate (octyl methoxycinnamate), and homosalate, are extensively used in sunscreens, daily moisturizers, and foundations. These compounds are highly lipophilic and exhibit significant dermal absorption. Once in systemic circulation, oxybenzone interacts with oestrogen and progesterone receptors, acting as an endocrine disruptor (Lim, 2025). Furthermore, placental passage of chemical UV filters can disrupt normal cellular differentiation and induce local oxidative stress in fetal tissues (Marie et al., 2016).

Heavy Metals and Volatile Organic Solvents

Heavy metals, including lead, mercury, arsenic, cadmium, and nickel, are frequently detected as unintentional contaminants or intentional pigments in low-cost, unregulated cosmetics like lipsticks, eye shadows, and traditional kohl formulations (Al-Saleh et al., 2019). Lead acts as a potent neurotoxin that directly impairs synaptic plasticity by substituting for calcium ions within key neuronal signaling cascades (Gundacker et al., 2012). Inorganic and organic mercury species commonly found in illicit skin-whitening creams rapidly cross both the placental and blood-brain barriers, causing extensive oxidative stress, lipid peroxidation, and irreversible damage to the developing fetal central nervous system (Al-Saleh et al., 2004).

Volatile organic solvents, such as toluene and formaldehyde, are commonly used in nail treatments, nail polish removers, and chemical hair-straightening products. Formaldehyde is a known human carcinogen that cross-links DNA and proteins, disrupting normal cellular replication cycles. Toluene acts as a central nervous system depressant; when inhaled in high concentrations, it can induce "fetal solvent syndrome," characterized by microcephaly, distinct craniofacial dysmorphism, and profound developmental delays (Külahçı et al., 2022).

Epidemiological Evidence of Adverse Pregnancy and Fetal Outcomes

A substantial body of epidemiological evidence correlates elevated prenatal biomarkers of cosmetic ingredients with a range of adverse maternal, fetal, and neonatal health outcomes. The "cocktail effect"—simultaneous exposure to multiple sub-threshold chemical classes—further complicates risk profiles, as non-monotonic dose-response curves mean low-dose mixtures can exhibit synergistic toxicities that are difficult to predict through single-chemical testing (Peinado et al., 2021).

Structural Anomalies and Teratogenesis

The link between high-dose gestational chemical exposure and structural defects is well documented. Exposure to heavy metals and topical retinoids during organogenesis can alter early structural patterning. For instance, mercury exposure has been shown to disrupt standard cell migration and structural organization in the fetus, contributing to congenital abnormalities (Al-Saleh et al., 2004). Similarly, structural disruptions have been observed in cases of intense exposure to volatile organic solvents like toluene via inhalation, which can lead to craniofacial defects reminiscent of fetal alcohol syndrome (Külahçı et al., 2022).

Endocrine Disruption and Urogenital Alterations

Because fetal development is closely tied to precise endocrine signaling, exposure to EDCs during key gestational windows can lead to structural and functional alterations in reproductive systems.

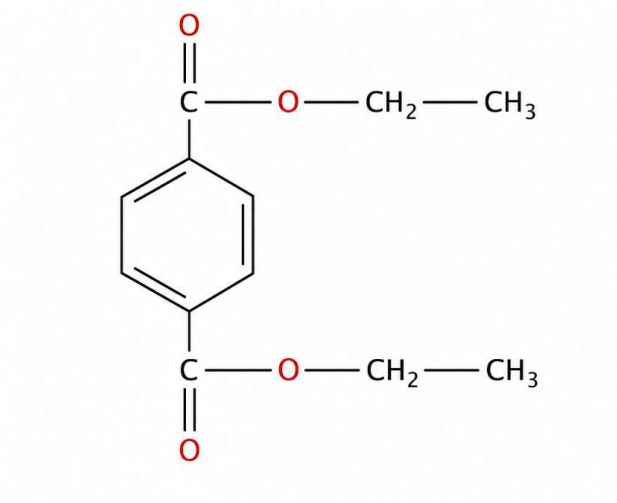

Figure 3: Chemical structure of Diethyl Phthalate (DEP), a common cosmetic plasticizer that exhibits anti-androgenic properties during male fetal reproductive tract development.

Prospective birth cohorts have established that high maternal urinary concentrations of phthalate metabolites, specifically monoethyl phthalate (MEP), during the first trimester are significantly associated with a shortened anogenital distance (AGD) in male neonates (Swan et al., 2015). The distance from the anus to the base of the penis is a reliable, sensitive marker of androgen action during the critical fetal programming window. A shortened

AGD indicates incomplete masculinization, often correlating with an increased risk of cryptorchidism (undescended testes) and hypospadias at birth, as well as impaired spermatogenesis later in adult life (Braun et al., 2013).

Birth Weight Modifications and Preterm Delivery

Gestational exposure to parabens and triclosan has been linked to altered fetal growth trajectories and shortened gestational duration. Studies measuring serial urinary concentrations of propylparaben and butylparaben during pregnancy have identified a distinct, sex-specific effect on fetal growth. Elevated maternal paraben levels frequently correlate with reduced birth weight and restricted head circumference in male neonates, whereas some female cohorts exhibit a paradoxical increase in birth weight, highlighting complex, sex-dependent endocrine interactions (Philippat et al., 2013).

Large-scale prospective cohort data have demonstrated that regular use of personal cosmetics during pregnancy significantly elevates the risk of the infant being born small for gestational age (SGA) (Li et al., 2019). This correlation exhibits a strong dose-response relationship, with high-frequency users (≥ 5 times per week) facing a much higher probability of delivering an SGA infant compared to non-users, likely driven by chemical accumulation impacting placental perfusion and nutrient transport (Li et al., 2019). Furthermore, women in the highest quartile of urinary phthalate and paraben excretion experience a significantly elevated risk of spontaneous preterm birth before 37 weeks of gestation, potentially driven by chemical-induced placental inflammation and oxidative stress at the maternal-fetal interface (Ferguson et al., 2014).

Neurodevelopmental and Long-Term Metabolic Consequences

The impacts of prenatal chemical exposure often extend far beyond the immediate neonatal period, manifesting as long-term neurodevelopmental and metabolic disorders.

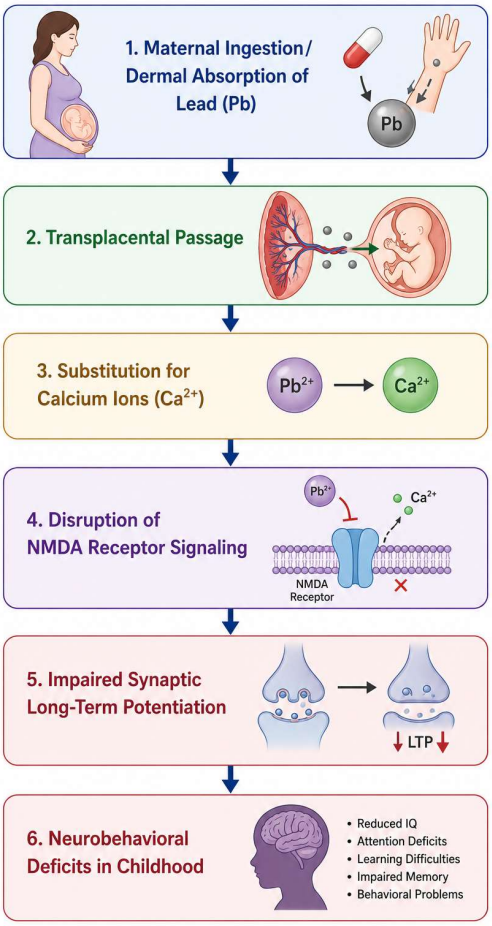

Figure 4: Conceptual diagram demonstrating the biochemical mechanism by which prenatal lead exposure disrupts synaptic development in the fetal brain.

Lead exposure, even at low systemic levels previously considered safe (< 5 µg/dL), interferes with N-methyl-D-aspartate (NMDA) receptor stability and downstream calcium-dependent signaling cascades, resulting in permanent neurodevelopmental deficits, lower intelligence quotients (IQ), and behavioral disorders in early childhood (Gundacker et al., 2012). Recent assessments also raise concerns regarding common cosmetic ingredients like parabens, phthalates, and benzophenones, which cross the blood-brain and placental barriers to trigger microglial inflammation and oxidative stress, potentially increasing vulnerability to congenital enteric neuropathies and neurodevelopmental conditions like autism spectrum disorders (Jones et al., 2024).

Concurrently, prenatal exposure to persistent EDCs can disrupt metabolic programming. In utero exposure to specific parabens has been strongly linked to rapid, dysregulated weight gain during infancy and a significantly higher risk of developing

childhood obesity and insulin resistance, suggesting that early chemical exposure can alter metabolic homeostasis across the lifespan (Lees et al., 2017).

Global Assessment of Knowledge and Risk Perception Among Antenatal Women

Despite clear toxicological mechanisms and supporting epidemiological data, surveys assessing chemical ingredient awareness among antenatal women consistently reveal a substantial gap in public health literacy.

The Dissonance Between Risk Perception and Behavioral Change

Epidemiological surveys show a striking contradiction in consumer behaviour: pregnant women express high general concern about environmental hazards but maintain high, unchanged usage of complex cosmetic products. In a multi-centre study, approximately 55% of pregnant respondents classified cosmetic use as a potential risk to fetal health, and 65% explicitly stated they desired professional advice on the topic (Marie et al., 2016). However, few women report making any specific behavioral modifications, such as reducing product use or switching to verified pregnancy-safe alternatives. This gap highlights a critical public health failure: while risk awareness is present, women lack the actionable information required to translate concern into safe consumer choices.

Inability to Interpret Product Ingredient Labels

The primary factor driving this behavioral gap is an inability to understand cosmetic product labels. Modern ingredient lists utilize the International Nomenclature of Cosmetic Ingredients (INCI) system, which lists compounds by their scientific or botanical names rather than common terms.

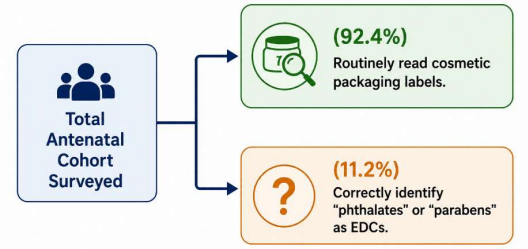

Figure 5: Graphic detailing the sharp drop-off between general label readership and true toxicological literacy among pregnant consumers.

Cross-sectional data show that while 92.4% of antenatal women report checking packaging labels before purchase, only 11.2% can successfully identify terms like "phthalates," "parabens," or "formaldehyde" as endocrine disruptors or chemical hazards (Külahçı et al., 2022). Most consumers rely heavily on uncertified marketing buzzwords such as *"natural"*, *"organic"*, *"hypoallergenic"*, or *"dermatologist-tested"*. These terms are often used loosely for greenwashing, as they lack standard regulatory definitions or mandatory safety verification, leading consumers into a false sense of security regarding product safety.

Predictors of Knowledge: Education, Socioeconomic Status, and Parity

The level of cosmetic chemical awareness among antenatal women is highly stratified by key socio-demographic factors. Statistical analyses across multiple cross-sectional cohorts show that a higher educational level and a background in health-related fields are the strongest predictors of accurate chemical risk identification ($p < 0.001$) (Marie et al., 2016). Conversely, low-income antenatal women living in rural or peri-urban areas display the lowest knowledge scores. This vulnerability is often compounded by limited access to premium organic alternatives and an increased reliance on low-cost, unregulated counterfeit cosmetics, which carry a higher risk of heavy metal contamination.

Parity also influences awareness: multiparous women generally score higher than primigravidas, suggesting that extended exposure to the healthcare system over multiple pregnancies can incrementally improve health literacy (Barrett et al., 2014).

Reliance on Unregulated Information Channels

Another major driver of low chemical literacy is where pregnant women obtain their information. Studies indicate that over 70% of antenatal women prioritize peer recommendations, beauty blogs, and commercial social media platforms over formal medical counseling for skincare decisions (Marie et al., 2016). These digital spaces frequently promote products based on aesthetic trends and commercial partnerships rather than scientific safety profiles. As a result, pregnant women remain largely unaware of real, evidence-backed chemical hazards while simultaneously over-worrying about safe or inert ingredients, leading to widespread confusion and ineffective behavioral choices.

The Crucial Role of Healthcare Professionals and Obstetric Counseling

Perinatal healthcare providers—including obstetricians, gynaecologists, midwives, and community pharmacists—occupy a critical position to bridge the consumer knowledge gap and promote safer behavioral choices.

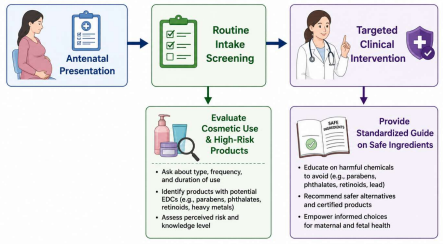

Figure 6: Proposed workflow for integrating cosmetic chemical risk screening into routine antenatal care.

Current Deficiencies in Clinical Risk Communication

Despite their position of trust, healthcare professionals rarely incorporate cosmetic safety into routine prenatal counseling. Surveys show that fewer than 10% of obstetricians and midwives routinely discuss personal care product safety during initial antenatal visits, typically prioritizing nutrition, lifestyle modifications, and medication safety instead (Barrett et al., 2014). This omission is rarely due to indifference; rather, it stems from a lack of formal training in environmental toxicology within medical curricula, brief consultation windows, and an absence of standardized, evidence-based clinical guidelines detailing cosmetic ingredient risks. Consequently, a vital opportunity to provide preventive counseling is routinely missed.

Evidence-Based Alternatives for Gestational Dermatoses

To counsel patients effectively, clinicians must be equipped to recommend safe, evidence-based alternatives for common gestational skin conditions, enabling women to manage their symptoms without exposing the fetus to unnecessary chemical risks. By providing structured guidelines, clinicians can help patients navigate cosmetic use safely while maintaining effective dermatological care.

Comparative Data Tables

To systematically analyse the scientific data underlying cosmetic chemical exposure during gestation, the following reference tables present cross-sectional metrics on product usage, maternal knowledge parameters, clinical recommendations, and epidemiological outcomes.

This below table contrasts the utilization rates of primary personal care products before and during pregnancy based on regional multi-Center cohort findings (Marie et al., 2016; Li et al., 2019).

Table 1: Prevalence and Frequency of Cosmetic Product Categories Among Antenatal Women

Cosmetic Category	Pre-Pregnancy Prevalence (%)	Gestational Prevalence (%)	Mean Frequency (Times/Week)	Primary Chemical Load of Concern
Facial Moisturizers	88.5%	84.2%	11.4	Parabens, Phthalates, Oxybenzone
Rinse-off Cleansers	94.1%	93.8%	14.0	Triclosan, Sodium Laury l Sulphate, Parabens
Nail Polish / Lacquer	62.4%	24.1%	0.8	Toluene, Formaldehyde, Dibutyl Phthalate
Lipsticks & Balms	76.8%	58.3%	8.5	Lead, Cadmium, Synthetic Pigments
Skin Whitening	34.5%	22.8%	6.2	Hydroquinone, Mercury, Cortic

Cosmetic Category	Pre-Pregnancy Prevalence (%)	Gestational Prevalence (%)	Mean Frequency (Times/Week)	Primary Chemical Load of Concern
Creams				osteroids
Hair Dyes & Straighteners	48.2%	15.3%	0.3	Formaldehyde, Ammonia, p-Phenylenediamine
Foundations & Makeup	74.0%	61.8%	5.4	Parabens, Heavy Metal Contaminants, Talc

This below table details the percentage of surveyed antenatal women who accurately identified common cosmetic chemicals and correctly classified their safety risk profiles (Barrett et al., 2014; Külahçı et al., 2022).

Table 2: Assessment of Ingredient Identification and Safety Knowledge Parameters

Chemical Ingredient (INCI Name)	Heard of Ingredient (%)	Correctly Identified Function (%)	Recognized Gestational Risk (%)	Primary Source of Knowledge
Retinol / Tretinoin	68.4%	54.2%	41.6%	Social media / Magazines
Parabens (Methyl/Propyl)	42.1%	12.3%	14.8%	Internet Blogs
Phthalates (DEP)	18.5%	4.1%	7.3%	Academic/Medical (Rare)
Hydroquinone	31.2%	26.4%	19.5%	Word of Mouth
Oxybenzone (Benzophenone-3)	12.4%	2.0%	3.5%	Product Label Only
Triclosan	22.8%	9.5%	8.1%	News Media
Lead / Heavy	89.6%	15.0%	74.2%	Television / General

Chemical Ingredient (INCI Name)	Heard of Ingredient (%)	Correctly Identified Function (%)	Recognized Gestational Risk (%)	Primary Source of Knowledge
Metals				Awareness

This table summarizes the adjusted odds ratios (aOR) and statistical significance of adverse pregnancy outcomes tied to prenatal exposure biomarkers (Philippat et al., 2013; Ferguson et al., 2014; Li et al., 2019).

Table 3: Summary of Adverse Maternal-Fetal Epidemiological Outcomes

Chemical Biomarker Evaluated	Exposure Metric Evaluated	Primary Fetal/Neonatal Adverse Outcome	Adjusted Odds Ratio (aOR / 95% CI)	Statistical Significance (p-value)
High Frequency Cosmetic Use	Use ≥ 5 times/week vs. non-use	Small for Gestational Age (SGA)	1.83 (1.25 – 2.69)	$p < 0.01$
Urinary Monoethyl Phthalate	Highest vs. Lowest Quartile	Spontaneous Preterm Birth	1.54 (1.12 – 2.11)	$p < 0.05$
Urinary Propylparaben	Maternal 3rd Trimester Concentration	Decreased Birth Weight (Male infants)	-64.2g change per unit log	$p < 0.01$
Maternal Blood Lead (Pb)	Maternal Blood Level ≥ 5 µg/dL	Cognitive Performance Deficits at 2yrs	2.14 (1.42 – 3.22)	$p < 0.001$
Urinary Triclosan	Medicated Soap Dermal Application	Altered Neonatal Head Circumference	-0.18cm change per quartile	$p < 0.05$

This below matrix outlines specific active ingredients that are contraindicated during gestation alongside validated alternatives and their clinical mechanisms (Chien et al., 2016; Lim, 2025).

Table 4: Clinical Guidance and Ingredient Recommendations for Prenatal Care

Gestational Condition	Contraindicated Ingredient	Mechanism of Maternal-Fetal Risk	Validated Safe Alternative	Clinical Mechanism of Alternative
Gestational Acne	Topical Tretinoin / Retinol	Disruption of RXR/RAR embryological transcription factors	**Azelaic Acid (15-20%)**	Topical anti-inflammatory and antimicrobial with low dermal absorption
Melasma & Pigmentation	Hydroquinone	High dermal absorption (up to 45%); potential cytotoxicity	**Vitamin C / Niacinamide**	Tyrosinase inhibition and melanosome transfer blockade
Ultraviolet Protection	Oxybenzone / Octinoxate	Estrogenic endocrine disruption; high systemic bioaccumulation	**Zinc Oxide / Titanium Dioxide**	Physical mineral barrier that reflects UV without systemic absorption
Chemical Exfoliation	High-dose Salicylic Acid (> 2%)	Salicylate accumulation risk; potential structural toxicity	**Glycolic Acid / Lactic Acid**	Alpha-hydroxy acids with safe epidermal clearance profiles

This below table summarizes knowledge score distributions based on demographic variables across surveyed antenatal populations (Barrett et al., 2014; Marie et al., 2016).

Table 5: Sociodemographic Predictors of Chemical Literacy and Cosmetic Safety Awareness

Demographic Variable	Sample Sub-Category	Mean Knowledge Score (Scale 0-100)	Odds Ratio for Low Literacy (95% CI)	Statistical Significance (p-value)
Educational Level	Post-Graduate Degree	74.2	1.00 (Reference)	—
	Secondary School or Less	28.5	4.62 (2.81 – 7.59)	$p < 0.001$
Maternal Age	≥ 35 Years Old	58.4	1.00 (Reference)	—
	< 25 Years Old	39.1	2.11 (1.34 – 3.32)	$p < 0.01$
Locality	Urban / Metropolitan	62.1	1.00 (Reference)	—
	Rural / Agricultural	34.7	3.18 (1.95 – 5.18)	$p < 0.001$
Parity	Multiparous (≥ 2 deliveries)	56.3	1.00 (Reference)	—
Status	Primigravida (First pregnancy)	42.8	1.74 (1.12 – 2.70)	$p < 0.05$

Comprehensive Structural Action Plan for Clinical Practice

To systematically bridge the gap between high cosmetic utilization and low toxicological awareness, clinical institutions should implement an integrated strategy. This protocol moves from initial intake screening to continuous education, ensuring environmental chemical risk assessment becomes a standard component of routine antenatal care.

Clinical Implementation Protocols

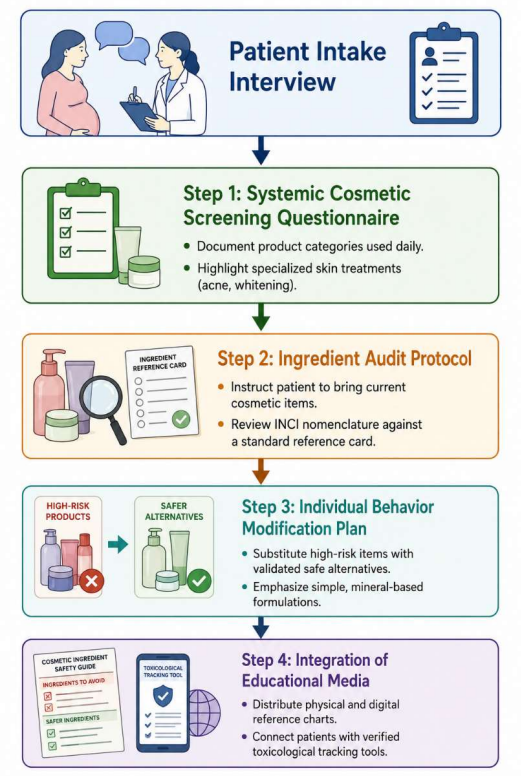

Figure 7: Diagram detailing the structured workflow for cosmetic chemical safety integration within antenatal clinics.

Step-by-Step Clinical Workflow

Step 1: Systemic Cosmetic Screening Questionnaire

- **Action:** During the first antenatal intake visit (typically weeks 4 to 8 of gestation), the triage nurse or midwife administers a standardized questionnaire alongside standard medical and dietary histories.
- **Scope:** The form logs the estimated number of daily cosmetics used, specific product types (e.g., waterproof makeup, skin-lightening creams, chemical sunscreens), and any history of professional salon chemical treatments.
- **Objective:** To flag high-frequency users or those utilizing high-risk cosmetic categories early in organogenesis.

Step 2: Ingredient Audit Protocol

- **Action:** If a patient is identified as a high-frequency consumer or user of high-risk items, the provider initiates an ingredient audit during the first obstetric consultation.
- **Execution:** The patient is asked to bring their daily skincare items to the clinic or use an electronic app to cross-reference their ingredient lists. The clinician compares the product's INCI labels against a reference card highlighting contraindicated compounds (e.g., retinoids, hydroquinone, parabens, chemical UV filters).
- **Objective:** To identify and remove specific chemical hazards from the patient's daily routine.

Step 3: Individual Behaviour Modification Plan

- **Action:** The clinician collaborates with the patient to establish an individualized behavioral plan, replacing high-risk formulations with verified safe alternatives.
- **Guidance:** For example, a patient using chemical anti-aging creams is transitioned to basic moisturizers containing hyaluronic acid or glycerine, and a user of chemical sunscreens is switched to micronized zinc oxide formulations.
- **Objective:** To reduce systemic chemical absorption while addressing the patient's dermatological needs.

Step 4: Integration of Educational Media

- **Action:** Clinics distribute physical infocards and provide QR access to updated public digital databases (such as the Environmental Working Group's SkinDeep database or institutional regulatory safety trackers).
- **Reinforcement:** These resources are reviewed at subsequent prenatal checkups (weeks 20 and 28) to maintain safe consumer habits and answer any questions regarding new products.
- **Objective:** To improve long-term consumer health literacy and empower self-directed, safe product selections.

Regulatory Frameworks and Public Health Implications

Managing the risks associated with cosmetic chemical exposure during pregnancy requires robust regulatory frameworks and proactive public health strategies alongside individual clinical counseling.

Regional Disparities in Cosmetic Chemical Regulation

Cosmetic ingredient safety is governed by vastly different regulatory structures worldwide, resulting in highly variable safety standards across

international markets. The European Union, operating under Regulation (EC) No 1223/2009, takes a strict, precautionary approach to consumer safety. The EU framework bans over 1,300 unique chemical compounds from use in cosmetics due to documented carcinogenic, mutagenic, or reproductive toxicity (CMR) profiles (Belsito et al., 2021).

In contrast, other regulatory frameworks historically employ a less restrictive approach, placing the primary burden of ingredient safety verification directly onto cosmetic manufacturers. This regulatory variation makes it challenging to maintain uniform safety standards in a globalized e-commerce market, where pregnant consumers can easily purchase unverified, poorly regulated products online.

The Global Challenge of Counterfeit and Adulterated Products

A major threat to maternal-fetal health is the widespread availability of counterfeit and adulterated cosmetics, which bypass international regulatory checks entirely. Illegal skin-lightening creams and low-cost makeup items frequently contain toxic concentrations of mercury or lead to maximize performance while minimizing manufacturing costs (Al-Saleh et al., 2019). These products are often distributed through unregulated digital marketplaces or local informal stores. Because these formulations completely omit hazardous ingredients from their packaging labels, consumers have no way of identifying the risk, frequently resulting in severe, accidental heavy metal toxicity during pregnancy (Gundacker et al., 2012).

Public Health Interventions and Structural Solutions

To address these systemic vulnerabilities, public health agencies must deploy broad, multifaceted interventions:

- **Mandatory Labelling Reform:** Regulatory bodies should mandate clear, consumer-friendly labelling on cosmetic packaging, requiring explicit warning icons or text for ingredients known to pose reproductive or developmental risks, like the clear warnings found on pharmaceuticals.
- **Broad Public Awareness Campaigns:** Public health authorities should launch targeted educational campaigns through community health centers, antenatal clinics, and digital platforms to improve consumer literacy regarding ingredient safety during pregnancy.
- **Integration into Prenatal Care:** Standardized cosmetic risk screenings should be formally integrated into routine obstetric intake protocols, ensuring that every pregnant woman receives evidence-based guidance early in gestation.

Implementing these structural changes can significantly lower environmental chemical exposure, protecting maternal well-being and safeguarding fetal development.

Direct Structural Comparison of Global Cosmetic Safety Frameworks

To further explore how regulatory policy translates into consumer protection, the following cross-comparative matrix evaluates how different major international jurisdictions classify, monitor, and restrict high-risk cosmetic compounds during the antenatal period.

This below table outlines the varying methodologies used by major regulatory agencies worldwide to manage hazardous or endocrine-disrupting cosmetic ingredients.

Table 6: Global Regulatory Comparison of Cosmetic Safety Frameworks

Jurisdiction & Agency	Core Regulatory Approach	Prohibited / Restricted Compounds	Premarket Approval Requirements	Stance on Endocrine Disrupting Chemicals (EDCs)	Labelling Regulations & Special Warnings
European Union	**Precautionary Pri**	Over 1,300 chemica	Mandatory registrati	High-risk parabens	All nanomaterial

Jurisdiction & Agency	Core Regulatory Approach	Prohibited / Restricted Compounds	Premarket Approval Requirements	Stance on Endocrine Disrupting Chemicals (EDCs)	Labelling Regulations & Special Warnings
(EU) *European Chemicals Agency (ECHA) / Regulation (EC) No 1223/2009*	**nciple** Prioritizes consumer safety by proactively banning substances suspected of toxicity	l compounds are banned under Annex II due to CMR (Carcinogenic, Mutagenic, or Repro du	on via the Cosmetic Products Notification Portal (CPNP) before market launch; requires a comprehens	(e.g., Propylparaben, Butylparaben) are strictly limited; specific substances like lilial are fully ban	s must be explicitly noted on labels; full INCI compliance is required; no specific warning sy
United States (US) *Food and Drug Administrati*	**Post-Market Surveillance & Enforcement**	Historically fewer than 15 specific ingredients are ful	Product registration and ingredient listing are mandatory,	Phthalates and parabens remain widely permitted in co	Fragrances can be listed under a blanket term, thou

Jurisdiction & Agency	Core Regulatory Approach	Prohibited / Restricted Compounds	Premarket Approval Requirements	Stance on Endocrine Disrupting Chemicals (EDCs)	Labelling Regulations & Special Warnings
on (FDA) / MoCRA (2022/2026 update)	Relies primarily on retrospective safety data; recent updates grant expanded authority to enforce ma	ly banned; individual states (e.g., California) enforce additional prohibitions on specific toxins.	but individual premarket product-by-product safety approval is not required for standard cosmetics.	nvention al formulations, though safety evaluations continue under recent cosmetic modernization	gh updates require allergen disclosure; no distinct maternal safety label is legally enforced.
Japan *Ministry of Health, Labour and Welfare (MHLW) /*	**Dual-Category Classification** Splits formulations into sta	Strictly controls lists for active constituents, preservatives, and UV	Quasi-drugs require formal premarket review and approval of effi	Maintains conservative concentration thresholds for common chem	Active ingredients in quasi-drugs must be highlighted clearl

Jurisdiction & Agency	Core Regulatory Approach	Prohibited / Restricted Compounds	Premarket Approval Requirements	Stance on Endocrine Disrupting Chemicals (EDCs)	Labelling Regulations & Special Warnings
Pharmaceuticals and Medical Devices Act	ndard cosmetics and "Quasi-drugs" (medicated skin treatments with active therapeutic claims).	filters; hydroquinone is permitted but subject to concentration limitations.	cacy and safety metrics; standard cosmetics require simple notification protocols.	ical preservatives and alkylphenols to limit consumer exposure.	y on packaging; full label disclosure applies across both consumer tiers.
Canada *Health Canada / Cosmetic Regulations under Food and Drugs Act*	**Active Risk Assessment** Utilizes a dynamic, regularly updated "Cosmetic Ingredient Ho	Banned list mirrors many EU standards; restricts formaldehyde, specific retinoids, and heavy metals	Requires mandatory submission of a detailed Cosmetic Notification Form within 10 days of a product	Continually evaluates potential EDCs under the Canadian Environmental Protection Act (CEPA);	Hotlist ingredients must adhere to specific inner-label instructions or warnings if concentrat

Jurisdiction & Agency	Core Regulatory Approach	Prohibited / Restricted Compounds	Premarket Approval Requirements	Stance on Endocrine Disrupting Chemicals (EDCs)	Labelling Regulations & Special Warnings
	tlist" to communicate restrictions and bans quickly to producers.	via a rapid-response regulatory registry.	entering the commercial market.	limits mercury and heavy metal content tightly.	ion thresholds approach the maximum limits.

Molecular and Cellular Impacts on the Placental Syncytiotrophoblast

Understanding the specific biological impacts of cosmetic ingredients requires evaluating how these chemicals interact with the cellular architecture of the placenta. The syncytiotrophoblast layer forms the continuous, multi-nucleated epithelial coverage of the placental villi, acting as the primary immunological, metabolic, and physical border separating maternal blood from fetal capillaries.

Disruption of ABC Transporter Glycoproteins

The syncytiotrophoblast depends heavily on ATP-binding cassette (ABC) efflux transporters, most notably P-glycoprotein (P-gp, encoded by ABCB1) and Breast Cancer Resistance Protein (BCRP, encoded by ABCG2). These energy-dependent pumps actively return exogenous xenobiotics and heavy metals back into maternal circulation, serving as an active defence mechanism against fetal exposure.

Toxicological models reveal that several common cosmetic components, particularly synthetic musk's (such as galaxolide and tonalide) and specific organic UV filters (like octinoxate), can act as competitive inhibitors or transcriptional suppressors of these ABC transporters. By binding directly to the active transport pockets or downregulating their expression, these chemicals compromise the placenta's efflux capacity. This reduction allows unrelated environmental toxins, heavy metals, and therapeutic drugs to accumulate within the fetal compartment at concentrations that would normally be prevented by functioning transporter systems.

Induction of Oxidative Stress and Trophoblast Apoptosis

Peroxisome proliferator-activated receptors (PPARs)and the nuclear factor erythroid 2-related factor 2 (Nrf2) pathway regulate cellular homeostasis and antioxidant defences within placental tissues. When exposed to elevated levels of heavy metal contaminants (such as lead or cadmium) or skin-lightening ingredients (like hydroquinone), the syncytiotrophoblast experiences a major increase in reactive oxygen species (ROS).

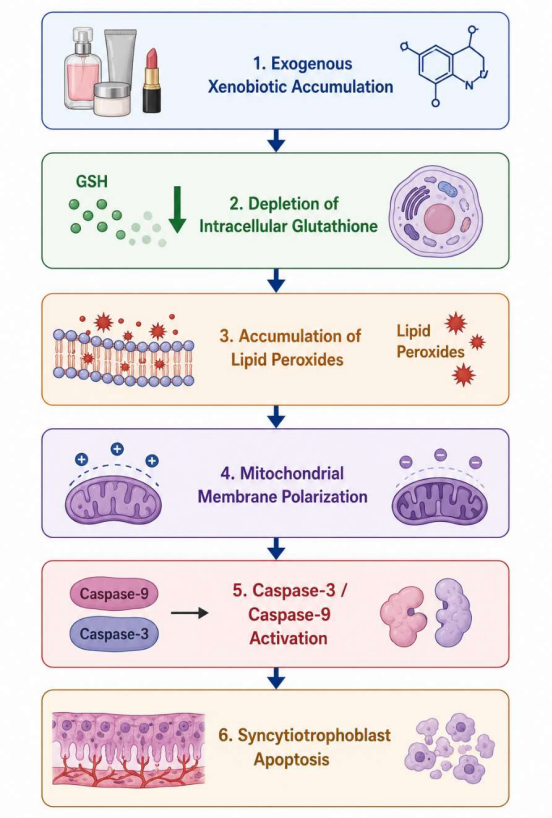

Figure 8: Cellular cascade leading to premature apoptosis in placental barrier cells due to chemical-induced oxidative stress.

This oxidative signaling downregulates syncytin-1 expression, an essential protein that drives the fusion of underlying cytotrophoblasts into the continuous syncytiotrophoblast layer. The resulting reduction in cell fusion disrupts structural integrity, increasing placental permeability and leading to micro-infarctions, localized inflammation, and a higher risk of placental insufficiency, which can manifest clinically as restricted fetal growth or preeclampsia.

Conclusion

This comprehensive review underscores a critical public health issue: antenatal women maintain high utilization of cosmetic products during pregnancy while lacking the fundamental chemical literacy needed to identify ingredients that pose a risk to fetal development. Epidemiological and toxicological data confirm that synthetic retinoids, hydroquinone, heavy metals, and various endocrine-disrupting chemicals can cross the placental barrier, with potential links to structural malformations, altered fetal growth, and long-term neurodevelopmental deficits.

Addressing this gap requires a coordinated response from clinical, regulatory, and public health sectors. Future research should prioritize large-scale, longitudinal birth cohorts utilizing advanced biomonitoring techniques to map the low-dose, cumulative effects of mixed chemical exposures during pregnancy. Concurrently, professional obstetric and gynecological societies must establish standardized clinical guidelines and educational tools to help prenatal providers deliver clear, actionable safety counseling. By combining stricter market regulations, improved product labelling, and active clinical guidance, public health systems can effectively reduce preventable environmental exposures and optimize health outcomes for both mothers and their children.

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