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Biochemical incompatibility: a critical and refutative review of the systemic impacts of alkaline hair straightening products.

Chemical incompatibility: a critical and refutative review of the systemic health impacts of alkaline hair relaxers

Biochemical incompatibility: a critical and refutative review on the systemic impacts of alkaline plates

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SUMMARY:
This research is configured as a critical and refutative narrative review on the biological safety of alkaline hair relaxers, based on the analytical triangulation of evidence from cosmetic chemistry, ultrastructural biology, toxicology, and...
Oncological epidemiology. The study analyzes the literature published between 2020 and 2026, based on the Bradford Hill framework (1965), for the determination of causal links. The results demonstrate that the aesthetic efficacy of these products depends on extreme alkalinity (pH 12-14) and the corrosive lanthionization process, reactions that trigger Post-Alkaline Hair Fragility and Trichoptilosis (PATHF) and Alkali-Induced Chemical Damage to the Hair Shaft (AICHSD). This local tissue disruption acts as an obligatory mechanical precursor for epidermal barrier erosion and chronic scalp inflammation, allowing deep transfollicular permeation of endocrine disruptors and carcinogenic contaminants into the systemic circulation. Epidemiological analysis, supported by the Sister Study and Black Women's Health Study cohorts, establishes a robust causal association between chronic chemical exposure and a linear increase in the incidence of hormone-dependent and extrauterine malignancies. It demonstrates that structural racism and the politics of respectability function as the psychosocial engine that directly governs the dose-response gradient and the biological temporality of aggression, forcing childhood initiation and high frequency of use. It concludes that the incompleteness of fine molecular knowledge does not justify regulatory inaction or state health omission in the face of vital risks concentrated in the Black population.

Keywords: Hair straightening agents, Systemic toxicity, Oncological epidemiology, Endocrine disruptors, Bradford Hill criteria.

ABSTRACT: This

study constitutes a critical, refutative narrative review of the biological safety of alkaline hair relaxers, grounded in the analytical triangulation of evidence from cosmetic chemistry, ultrastructural biology, systemic toxicology, and oncological epidemiology. The investigation analyzes literature published between 2020 and 2026, utilizing the Bradford Hill (1965) framework as a methodological matrix for causal determination. The results demonstrate that the aesthetic efficacy of these products depends on extreme alkalinity (pH 12-14) and the corrosive lanthionization process. These reactions trigger Post-Alkaline Trichoptilosis and Hair Fragility (PATHF) and Alkaline-Induced Chemical Hair Shaft Damage (AICHSD). This local tissue disruption serves as the mandatory mechanical precursor to epidermal barrier erosion and chronic scalp inflammation, enabling deep transfollicular permeation of endocrine-disrupting chemicals and carcinogenic contaminants into the systemic circulation. The epidemiological analysis, sustained by the Sister Study and Black Women's Health Study cohorts, establishes a robust causal association between chronic chemical exposure and a linear increase in the incidence of hormone-dependent and extrauterine malignancies. Furthermore, structural racism

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and the politics of respectability operate as the psychosocial mechanism that directly governs the dose-response gradient and the biological temporality of the aggression, forcing childhood initiation and high frequency of use. In conclusion, the incompleteness of fine molecular knowledge does not justify state regulatory inaction or sanitary omission in the face of vital risks that perpetuate racial health inequities.

Keywords: Hair relaxers, Systemic toxicity, Cancer epidemiology, Endocrine disruptors, Bradford Hill criteria.

1. Introduction

The chronic use of chemical relaxers and alkaline-based hair straighteners exceeds a mere individual aesthetic choice, becoming a serious and neglected issue. a determinant of impact on global public health (VAAH, 2024). The historical imposition of Eurocentric beauty standards act as a coercive force that drives consumption in mass of highly toxic substances, disproportionately exposing women to African ancestry is linked to epidemiological vulnerabilities and systemic pathologies. (IRUNGU et al., 2025; NEEDLE et al., 2024).

Large-scale prospective studies, such as the *Sister Study* and the *Black Women's Health Study. Studies* provide robust evidence of causal links between the frequent use of hair straighteners. and the development of hormone-dependent malignant neoplasms (breast, uterus and ovary) (CHANG et al., 2022; COOGAN et al., 2021). Recently, Bailey et al. (2026) expanded this debate, by identifying statistically significant associations between these products and extrauterine and non-reproductive neoplasms, such as pancreatic adenocarcinoma, cancer of Thyroid and non-Hodgkin lymphoma, highlighting a multisystemic oncological risk.

The central hypothesis of this investigation suggests that the continuous application of these Formulations in a severely corrosive pH environment promote the breakdown of defenses. local biological agents, allowing transdermal permeation and subsequent systemic absorption of Endocrine disruptors (EDCs) and carcinogens (GECZIK et al., 2023). From the perspective From a pathophysiological standpoint, this internal absorption is catalyzed by the very nature of the formulations. commercials that compromise the anatomical integrity of the skin barrier through levels of extreme alkalinity (BURNETT et al., 2021; VELASCO et al., 2022). In their research, Irungu et al. (2025, p. 10) point out that:

Although the pH values of the 22 relaxants analyzed were within the limits KEBS regulations, their extreme alkalinity makes them inherently corrosive, increasing the risk of scalp burns and irritation, particularly when using The product deviates from the recommended guidelines.

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This skin degradation is associated with lanthionization—which destroys disulfide bridges. and causes protein lysis of keratin (BARRETO et al., 2021) — transforming the scalp damaged and hypervascularized in a highly permeable entry route for xenobiotics and impurities in the bloodstream (VELASCO et al., 2022; NEEDLE et al., 2024).

Contemporary debate reveals a critical clinical and ethical *gap* regarding formulations. fraudulently marketed under marketing claims of being "gentle" or "for children's use" (IRUNGU et al., 2025). Mass spectrometry measurements demonstrate that variants Infants chronically maintain a pH around 12, a level capable of inducing erosion. epidermal and permanent cicatricial alopecia, demonstrating that industrial marketing omits the internal chemical reality of the products (IRUNGU et al., 2025; VELASCO et al., 2022).

Beyond the oncological outcome, this biochemical iatrogenesis also affects the Female fertility. Investigations from the PRESTO cohort study documented a reduction. up to 29% increase in the estimated probability of conception per menstrual cycle in exposed women prolonged exposure to hair straighteners, creating a blatant "environmental inequality of beauty" (WISE et al., 2023; NEEDLE et al., 2024). Furthermore, the hidden chemical composition highly restricted substances under the generic terms of "fragrance" or "trade secret" (IRUNGU et al., 2025). Clandestine concentrations of free formaldehyde and ingredients of High reproductive hazards, such as lilial and phenolphthalein, have been detected in screenings. independent laboratories, allowing carcinogens to freely pass into organs. distant (SILVESTRE et al., 2020; BAILEY et al., 2026).

From this perspective, the age of onset emerges as a determining chronological factor in Modeling cumulative risk. Early initiation, socially imposed on children before the age of 10 years, extends the time window for indoor exposure to EDCs during plastic periods of hormonal development (WISE et al., 2023; NEEDLE et al., 2024). The consequences of this Chemical stress culminates in the early onset of menarche and the aggressive triggering of uterine myomatosis at maturity (OGUNSINA et al., 2025).

To give this research the necessary scientific edge, analysis and discussion The evidence gathered here will be entirely guided by the methodological framework of causality proposed by Austin Bradford Hill (1965). Moving away from merely Descriptive, this critical narrative review will apply, in a coordinated manner, the Strength of criteria. Association, Consistency, Biological Plausibility, Analogy, Temporality, and Gradient Biological (Dose-Response) (HILL, 1965). The central argument lies in demonstrating that the psychosocial pressures stemming from structural racism and the aesthetic demands for exclusion of

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The formal labor market (TAYLOR et al., 2023; VAAH, 2024) functions as the engine.
sociological factors dictate the internal biological dose and timing of aggression, forcing the
early initiation and high frequency of use (TAYLOR et al., 2023; CHANG et al., 2022).

2. Theoretical Framework

2.1 Bradford Hill's causality framework as a methodological matrix

To support this analysis, the Bradford Hill epidemiological framework was used.
(1965), which assists in the evaluation of causal links based on statistical associations. The author
It proposes nine fundamental criteria to guide scientific judgment, moving away from impressions.
subjective. Among them, the strength of the association and consistency (repetition of) stand out.
phenomenon) and the biological gradient (dose-response relationship) (HILL, 1965).

The framework also considers biological plausibility and coherence, although Hill
It should be noted that "what is biologically plausible depends on the biological knowledge of the day."
(HILL, 1965, p. 298, author's translation). This caveat is crucial for the study of
hair modifiers, whose mechanisms of contamination and endocrine disruption
They only became visible with the advancement of modern analytical techniques.

Clinically, the temporality requires that exposure to the cosmetic product precedes the pathology.
Hill emphasizes that his criteria are not rigid rules:

> None of my nine viewpoints can present indisputable evidence in favor of or
> against the hypothesis of cause and effect, and neither can be required as a sine qua non. What
> What they can do, with greater or lesser force, is help us decide on the fundamental question.
> — Is there any other way to explain the set of facts before us? (HILL, 1965, p.
> 299, author's translation)

Finally, the criterion of analogy allows us to infer systemic risks based on substances.
of similar chemical structure, while experimental evidence acts as a control.
definitive (the reduction of damage after the removal of the harmful agent). The author argues that the
The incompleteness of science should not delay preventive actions that the available knowledge already allows.
justifies (HILL, 1965). The integration of these criteria allows for a critical evaluation of the impact of
Cosmetic ingredients related to hair health and fiber.

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2.2 Dermal Permeation of Endocrine Disruptors in Cosmetics

The continuous presence of hygiene and cosmetic products in contemporary life generates prolonged chemical exposure. Among the most critical components are phthalates. (solvents) and parabens (preservatives), recognized for their potential to act as Endocrine disruptors interfere with hormonal signaling (GECZIK *et al.,* 2023). A Chronic absorption via percutaneous administration results in a daily internal dosage that challenges the metabolic capacity for purifying the body.

The study by Shen *et al.* (2007) analyzed 15 categories of cosmetics (such as perfumes, deodorants and lotions) and revealed a worrying scenario: only one sample presented total absence of these compounds. Most contained a combination of three or more types of phthalates or parabens, revealing a "chemical cocktail". This phenomenon demonstrates that the Biosafety measures should not evaluate isolated ingredients, as the synergistic action of mixtures is crucial. amplifies the potential for endocrine disruption in target tissues (SHEN *et al.,* 2007).

The concentrations detected varied widely, from 1.22 mg/kg to 5289 mg/kg. highlighting the disparity in quality control between brands (SHEN *et al.,* 2007). Residues of diethyl phthalate (DEP), dibutyl phthalate (DBP), methylparaben, and propylparaben were the most prevalent. Although the skin acts as a physical barrier, repeated application of *Leave-on* products facilitate dermal permeation. Velasco *et al.* (2022) These findings corroborate the lipophilic nature of certain compounds and the integrity of the skin barrier. They determine this rate of systemic penetration.

To accurately identify such risks, highly sensitive analytical methodologies are used. They are indispensable. The use of HPLC-DAD and GC-MS allows for the separation and quantification of molecules in complex cosmetic matrices, enabling toxicological evaluation. (SILVESTRE *et al.,* 2020). Furthermore, the interaction of these substances with hair follicles It adds complexity, potentially causing damage to internal physiology and structural changes in Hair fiber and its impact on scalp health.

Therefore, the transition to safe formulations requires a reassessment of current standards and Greater transparency in labeling. Recognition of estrogenic properties and The carcinogenic properties of certain parabens and phthalates are driving the search for alternative preservatives. that minimize unwanted permeability, balancing aesthetic effectiveness and safety. systemic (VELASCO *et al.,* 2022).

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2.3 Structural Impacts and Permeability of Hair Fiber and Scalp

The hair shaft has a complex organization (cuticle, cortex, and medulla) that defines Its resistance and permeability. The cuticle, the outermost layer, acts as a physical barrier. essential, but its integrity is constantly threatened by extrinsic factors and by chemical treatments. When this protection is compromised, there is an immediate increase in Fiber porosity, facilitating the diffusion of harmful substances into the cortex. (VELASCO *et al.,* 2022). This degradation removes the natural hydrophobicity of the yarn, transforming it into a porous conduit exposed to external agents.

Unlike other areas of the body, the scalp exhibits permeability. accentuated due to the high density of hair follicles. These follicles function as channels. low resistance *(shunts),* allowing low molecular weight molecules to penetrate deeper and faster form (VELASCO *et al.,* 2022). This anatomical characteristic makes the The scalp is a critical route for the systemic absorption of cosmetic ingredients. shortening the transit time of xenobiotics to the subcutaneous vascular plexus.

Prolonged exposure to ultraviolet radiation and the use of products with an unsuitable pH. They modify the hair surface by promoting the lifting of the cuticle scales. This damage It generates microcracks that increase the vulnerability of the stem to chemical residues and pollutants. environmental factors, impairing the elasticity and water retention of the yarn (VELASCO *et al.,* 2022). In urban environments, the interaction between heavy metals present in pollution and the hair fiber It triggers severe oxidative processes that accelerate the wear and tear of hair proteins. (VELASCO *et al.,* 2022), reinforcing the need for formulations that act as a barrier. protective physics.

Porosity assessment is a vital clinical indicator for measuring the degradation of Fiber: Highly porous strands absorb liquids quickly but fail to retain moisture. (VELASCO *et al.,* 2022). This dynamic facilitates the entry of endocrine disruptors, which They can reach the bloodstream through the follicular openings. In parallel, Imbalances in the physiological pH of the scalp can trigger inflammatory processes. which increase skin permeability and susceptibility to allergens (VELASCO *et al.,* 2022), The use of sealing agents and conditioning polymers is recommended to contain this. unwanted penetration.

Therefore, Velasco et al. (2022) conclude that hair health is intrinsically linked to maintaining the integrity of the cuticular and follicular barriers.

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detailed understanding of the permeation mechanisms through the hair-scalp complex
Hair is essential for the development of new products to prioritize safety.
The user's biological makeup. Preventing hair structure degradation is the initial step in preventing this.
that the use of cosmetics becomes a route of systemic exposure to environmental risks and to
far-reaching biochemical iatrogenic effects.

3. Materials and Methods

The methodological architecture of this investigation is based on overcoming gaps.
Conceptual and terminological differences in the literature on hair modification. Given the insufficiency
Using informal terms like *"scab hair,"* this research adopts highly sophisticated nomenclature.
Clinical and dermatological rigor: Capillary fragility and post -*alkaline* trichoptilosis
Trichoptilosis and Hair Fragility (PATHF) and *Alkaline-Induced Chemical Hair Shaft Damage* (AICHSD).
The use of these
Nosological categories allow for a precise biophysical description of how chemical aggression occurs.
Severe alopecia alters the physiology of the hair follicle, destroys cuticular cohesion, and perpetuates a state of hyperplasia.
chronic inflammatory condition of the scalp (BARRETO et al., 2021; VELASCO et al., 2022).

To fulfill this scope, the study is structured as a critical narrative review and
refutative of a qualitative nature. This methodological design enables analytical triangulation.
from evidence drawn from multidisciplinary fields: cosmetic chemistry, biology
ultrastructural, dermal toxicology, reproductive endocrinology, and oncological epidemiology.
To safeguard the internal validity of causal inferences, document analysis was used.
strictly guided by the criteria of causality of Austin Bradford Hill (1965),
evaluating, in a coordinated manner, the strength of association, consistency, specificity,
temporality, analogy and pathophysiological plausibility of the findings (HILL, 1965; NEEDLE
et al., 2024).

The analytical *corpus* was based on the careful selection of 24 high-quality focal articles.
Relevance, published between 2020 and 2026 and indexed in high-relevance international databases.
impact. In the data screening, the preferred inclusion criterion was established as
Findings from the world's largest longitudinal cohorts of women's health: the *Sister study.*
The Black Women's Health *Study* (BWHS) and the *Black Women's Health Study* (BWHS) are the gold standard databases.
methodological approach in investigating the causal link between the regular use of chemical modifiers
and the triggering of hormone-dependent and extrauterine neoplasms, shielding the

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population inferences from this review against sampling errors (COOGAN et al., 2021; CHANG et al., 2022; BAILEY et al., 2026).

The analysis was organized and systematized into five thematic axes, distributed from following form1 :

- Pillar 1: Pathophysiology and Biophysical-Chemical Alterations
- Pillar 2: Epidemiological and Systemic Impacts on the Health of the Black Population
- Pillar 3: Psychosocial Determinants, Aesthetic Pressure, and the Dose-Response Gradient from Bradford Hill

4. Results and Discussion

4.1 Pillar 1: Pathophysiology and Biophysical-Chemical Alterations

The analysis of systemic damage requires the examination of the physicochemical properties that They govern the interaction between cosmetics and Afro-textured hair fibers. The anatomy of the hair strand. (cuticle, cortex and medulla) suffers severe damage due to the extreme alkalinity of the relaxants. commercial, which operate in pH ranges between 12 and 14 (BURNETT *et al.,* 2021; VELASCO *et al.,* 2022). The use of strong inorganic hydroxides — such as those of sodium, calcium, and potassium — aims to disrupt the macrostructural barriers of the wire, promoting the expansion of the shaft and the diffusive penetration of the hydroxyl ion into the cortex (BURNETT *et al.,* 2021). Biochemically, These substances are caustic agents with high dissociative power, capable of inducing necrosis by severe tissue liquefaction and corrosion under acute exposure (BURNETT *et al.,* 2021).

The molecular mechanism responsible for the permanent modification of hair curvature. This occurs through lanthionization, a nucleophilic substitution reaction in which the ion The hydroxyl group cleaves the disulfide bridges present in the helical structure of keratin (VELASCO). et al., 2022). In this process, the amino acid cystine, which originally confers rigidity, The elasticity and mechanical resilience of Afro hair is restored by losing a sulfur atom and being converted. irreversibly converted to lanthionine (BARRETO et al., 2021; GEORGE; POTLAPATI, 2021). A The lanthionine generated stabilizes the new straight configuration imposed on the hair strand; however, it performs this transition at the cost of severe mechanical weakening and protein loss massive and cumulative intracortical (BARRETO et al., 2021). This profound modification

[1] A complete table of articles can be found in the attachment.

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The structural difference is the dividing line that differentiates traditional alkaline relaxers from...
acid-based straightening procedures, since the hydroxides break down
permanently increases the elastic strength of the yarn, without depending on the subsequent application of heat.
for the initial activation of the bonds (PALMER; MCMICHAEL, 2024; VELASCO et al., 2022).

The intrinsic gravity of the active ingredients that make up these formulations.
The aesthetic appeal is evidenced by its close similarity to synthetic and commercial compounds.
distinctly industrial. Many of the alkaline agents used in relaxer creams,
Like guanidine and lithium hydroxides, they act as functional and reactive components.
present in highly aggressive household cleaning products, including drain cleaners.
sanitary piping and industrial bleaches (VAAH, 2024). This evident incompatibility
Biological degradation results in measurable protein degradation in the hair cortex, in comparison
with the behavior of virgin hair. Through Lowry's colorimetric method,
Laboratory investigations have quantified that exposure to hydroxides causes lysis.
significantly higher protein content than any other cosmetic treatment, degrading
both the cuticular envelope and the proteins associated with intermediate filaments, which
drastically reduces the tensile breaking strength of the fiber (VELASCO et al., 2022).

Surface morphological analyses performed by electron microscopy of
Scanning electron microscopy (SEM) images confirm the destructive nature of alkaline relaxants by revealing erosion.
complete physical appearance, longitudinal striations, and excessive scaling of the layers that form
the hair cuticle (VELASCO et al., 2022). Unlike acidic formulations, which tend
By polymerizing into a smooth, reflective biofilm on the stem, the hydroxides promote the
true dissolution of essential lipids from the cuticular cell membrane complex
(VELASCO et al., 2022). This ultrastructural degradation eliminates the hydrophobic capacity.
The hair's natural structure is altered, permanently preventing the cortex from retaining its hydration and moisture.
internal. As a direct consequence, the hair chronically assumes a constitution
porous, rigid, dry, and structurally fragile, clinically manifesting as extreme
proneness to breakage due to routine mechanical shear (VELASCO et al., 2022).

It is imperative to highlight the biochemical aggression perpetrated by these formulations.
Caustic properties are not limited to the inert boundaries of the capillary shaft; the highly corrosive nature of
Extreme pH simultaneously promotes cellular erosion of the epidermal barrier and
Recurrent manifestation of acute chemical burns on the scalp tissue
(GEORGE; POTLAPATI, 2021; IRUNGU et al., 2025). These dermatological lesions rupture
The cohesion of keratinocytes is disrupted and the protective stratum corneum is destroyed, drastically reducing the...

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resistance to skin penetration in the region. From this anatomical and physiological perspective, the leather hairy — which is already naturally characterized by abundant subcutaneous vascularization And because it has one of the highest densities of hair follicles in the human body — it has its own defenses. neutralized barriers, transforming into a highly permeable and free-flowing channel. for the direct systemic absorption of xenobiotic substances and industrial impurities (YOUSEFIAN; KREJCI, 2023; NEEDLE et al., 2024).

Validating a damaged scalp as a viable and hazardous route of exposure. Systemic exposure to xenobiotics finds support in serious precedents documented in the literature. contemporary cosmetic toxicology. A critical clinical outcome that illustrates this. deep transdermal permeation capacity is the renal toxicity associated with the use of hair modifiers in acidic formulations containing glyoxylic acid, commonly promoted in the market under the commercial appeal of "free from formaldehyde". In these scenarios Specifically, after penetrating the skin layer, glyoxylic acid reaches the bloodstream and It is metabolized in the liver parenchyma into oxalate, a compound that, when filtered and excreted... In the kidneys, it precipitates in the form of insoluble calcium oxalate crystals inside the... renal tubules, triggering severe episodes of acute renal failure due to nephropathy. obstructive (ROBERT et al., 2024; NEEDLE et al., 2024).

The evocation of this biological mechanism fulfills a central theoretical function in this investigation when applying the analogy criterion proposed in the causality framework of Bradford Hill (1965). Although alkaline relaxants operate via a chemical pathway entirely distinct from that observed in acidic straightening treatments — based on lanthionization by hydroxides and not by acid crosslinking—the clinical precedent of glyoxylic acid leaves It is an undisputed fact that the scalp barrier is permeable and unable to retain moisture. chemical compounds under cutaneous stress. By analogy, if dermal exposure to an acid Cosmetics are capable of inducing internal organ failure, chronic inflammatory aggression, and loss. of lipid integrity induced by extreme alkaline pH (BARRETO et al., 2021; VELASCO et al., 2022) operate as a primary facilitator for the unwanted absorption of other harmful substances, metallic contaminants such as lead and mercury, and byproducts carcinogens dissolved in the vehicle of commercial relaxers (PUTRA et al., 2022).

The severity of this scenario of local tissue vulnerability is substantially aggravated by the persistence of serious non-conformities and fraud in the production chain and Regulatory framework for the hair cosmetics sector. Laboratory testing of various hair straightening products. Different brands reveal an alarming discrepancy between the declared chemical composition.

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mandatory on labels and the actual ingredients identified in the product matrices.

A chronic example of this vulnerability is manifested in the hidden presence of formaldehyde; although the National Health Surveillance Agency (ANVISA) has prohibited the use of Formaldehyde has been used as an active straightening agent since 2009, and the compound remains detectable in a wide range of commercial samples (SILVESTRE et al., 2020; VELASCO et al., 2022). Qualitative investigations have demonstrated scenarios in which up to 100% of the products Samples taken from beauty salons showed the illegal presence of formaldehyde. deliberately omitted by manufacturers to circumvent sanctions and oversight from regulatory bodies. regulators (SILVESTRE et al., 2020).

The quantitative findings from these laboratory analyses highlight the risk. acute and chronic genotoxicity to which both users and beauty salon professionals are at risk. They are continuously exposed. While current health legislation tolerates a maximum limit. containing only 0.2% formaldehyde, acting strictly in the secondary function of a preservative. Microbiological analysis of the formula, chemical screenings identified absurd free concentrations. ranging between 3.5% and 14.5% of the total volume of the commercial product (SILVESTRE et al., 2020). This systematic adulteration is driven by the pursuit of economic advantages, given the low The operational cost of free formaldehyde and its ability to mimic an aesthetic result. High shine achieved through the rigid waterproofing of the hair fiber, a visual trick. deceptive that masks the massive inhalation and dermal absorption of a volatile carcinogen of class 1 (SILVESTRE et al., 2020).

Additionally, the dynamics of occupational and residential exposure are exacerbated by the presence of formaldehyde-releasing compounds and the resulting thermal instability own hair styling protocols. Under the subsequent application of mechanical heat. intense, such as the use of metalized heat presses operating at temperatures that reach or When temperatures exceed 200 degrees Celsius, these chemical bonds undergo immediate degradation, releasing Concentrated clouds of formaldehyde and acetaldehyde vapors directed into the breathing zone. of individuals (PALMER; MCMICHAEL, 2024; VELASCO et al., 2022). This phenomenon establishes a pattern of chronic inhalation exposure that directly correlates with Handling these cosmetic mixtures can lead to the development of digestive tract dysfunctions. respiratory tract and with an increased risk of developing malignant neoplasms of the respiratory tract. upper aerodigestive tract, such as nasopharyngeal carcinoma (PALMER; MCMICHAEL, 2024).

In summary, the biophysical-chemical evidence demonstrates the aesthetic effectiveness of Alkaline relaxants are inextricably linked to a severe biochemical incompatibility with the

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The human organism. Local structural damage — characterized by caustic corrosion of the leather.
Hairy hair, lipid dissolution, and protein bond disruption—it transcends superficial alteration.
and constitutes the essential pathophysiological precursor to the disruption of the cutaneous mechanical barrier.
Once this protective shield is overcome, transfollicular permeation and continuous systemic absorption occur.
Endocrine disruptors and carcinogens link routine hair management to outcomes.
serious chronic illnesses, directing this research towards mapping the
Epidemiological impacts on the health of the black population.

4.2 Pillar 2: Epidemiological and systemic impacts on the health of the Black population

The transition from local tissue iatrogenesis to chronic systemic toxicity stems from continuous exposure to endocrine disruptors (EDCs) and bioactive xenobiotics from hair relaxers. Exogenous substances, such as phthalates, parabens, and phenols, permeate the In ulcerated epithelial tissue, they mimic endogenous estrogen by binding to ERÿ receptors. and ERÿ (GECZIK *et al.,* 2023; MOORE, 2025). This transfollicular absorption disrupts the hormonal metabolism, raising circulating levels of mitogenic estrogens via the 16-ÿ- pathway. hydroxyl, specifically estriol and 16-epiestriol (GECZIK *et al.,* 2023). This clinical deviation It creates an environment of sustained estrogenic hyperstimulation, altering the hypothalamic-pituitary-hypo ... pituitary-gonadal axis and triggering alterations in the reproductive homeostasis of the exposed population. (MOORE, 2025).

This condition of chronic endocrine disruption manifests severe deleterious effects. regarding the chronology of development and biological maturation of the users, establishing a clear temporal gradient of vulnerability associated with early initiation. The application systematic use of caustic alkaline formulations during childhood and pre-adolescence, Frequently occurring before the age of 10, it correlates directly with the anticipation of menarche and with the premature development of secondary sexual characteristics (NEEDLE et (al., 2024; OGUNSINA et al., 2025). Repeated chemical stress and burns on the hide. hair follicles act as catalysts for this internal absorption in childhood, allowing the hair growth spikes to develop. serum EDCs intercept critical windows of biological plasticity and differentiation. tissue (GECZIK et al., 2023). This early interference necessitates reprogramming Epigenetics and physiology in female biology, extending the exposure time of organs. reproductive systems are subjected to steroid hormones throughout life, paving the way for... development of complex gynecological pathologies in adulthood (NEEDLE et al.,

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2024).

In the context of fertility and immediate reproductive health, the impact of iatrogenesis The biochemistry of alkaline relaxants translates into significant impairments in the ability to Conception in women of childbearing age. Robust longitudinal cohort study data. Prospective PRESTO studies show a linear and statistically significant reduction in Fertility rates among active users of hair straightening products (WISE et al., 2023). Women Those continuously exposed to these inputs show a 19% decrease in probability. Estimated chance of conception in each menstrual cycle (Fertilization Ratio, FR = 0.81) in comparison with those who have never adopted these aesthetic practices (WISE et al., 2023). When analyzed from the perspective of accumulated duration and internal dosage, subfertility It reaches even more critical levels: users who started using the applications before the barrier of At age 10, fertility rates decrease by 27% (RF = 0.73). while continued use for periods exceeding a decade depresses the probability pregnancy in 29% (RF = 0.71), consolidating the hypothesis that chronic accumulation of xenobiotics progressively damage endometrial signaling and ovarian homeostasis (WISE). et al., 2023; NEEDLE et al., 2024).

The proliferation of benign uterine tumor pathologies constitutes another aspect. epidemiological of high morbidity, directly linked to the chronic absorption of these formulations. The development of uterine leiomyomas (fibroids) presents associations of large magnitude and statistical strength associated with a history of exposure to chemical relaxants. (KITHIKII et al., 2025). Clinical surveys conducted in populations of ancestry African studies reveal that women exposed to inorganic hydroxides have absurdly high chances of developing cancer. higher risk of developing uterine fibroids, with probability ratios that can reach... a risk up to five times greater when compared to unexposed groups (OR = 5.12) (KITHIKII et al., 2025). Additionally, mathematical analyses based on fraction calculation attributable to the population, they estimate that a staggering three-fifths (59.2%) of all cases Surgical and clinical treatments for fibroids diagnosed in these communities would be fully would be avoided if there were a complete cessation and discontinuation of the use of caustic relaxants. (KITHIKII et al., 2025). The robustness of these findings is reinforced by cross-referencing data from The Sister Study, which unequivocally links the early and intensive use of hair straighteners to... Aggressive development of leiomyomas before the age of 36, requiring hysterectomies. premature births and chronic pelvic pain affect a significant portion of black women (OGUNSINA et al. al., 2025).

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The consolidation of chronic use of hair relaxers as a determining factor.
The most relevant epidemiological finding reaches its analytical peak when examining the oncological burden.
reproductive burden that falls, severely and disproportionately, on frequent users. Under the
Under the aegis of Bradford Hill's methodological framework (1965), the criterion of strength of association
This is undeniably evident in the results published by the largest global cohorts.
Women's health. Consolidated prospective data from the Sister Study reveal that women who
They frequently use chemical hair straighteners — operationally defined as a frequency
Applications made more than four times a year experience an exact mathematical doubling.
the risk of developing endometrial and uterine cancer throughout the period of
monitoring, exhibiting a risk ratio (HR) greater than 2.0 compared to the rate
of baseline incidence of non-users (CHANG et al., 2022). This increased cancer risk
Reproductive cancer extends in a manner analogous to ovarian cancer, revealing that the circulation of
Transdermal carcinogens affect, in a systemic and coordinated way, the entire gynecological tract
female higher education (CHANG et al., 2024).

Breast cancer outcomes also present epidemiological characteristics.
alarming, revealing a close correlation with the phenotypic and racial profile of the main
consumers of these inputs. Detailed investigations conducted within the scope of Black
The Women's Health Study (BWHS) found that the intense and prolonged use of relaxants
Hair follicles made with strong alkaline compounds (lye/sodium hydroxide) increase the risk of
development of estrogen receptor-positive breast carcinoma, specifically
the ERÿ, up to 37% (HR = 1.37) (COOGAN et al., 2021). This finding is particularly
prominent among women who reported an application frequency equal to or greater than 7 times.
per year or who had a biological history of exposure exceeding 15 uninterrupted years.
(COOGAN et al., 2021). The parallel replication of this risk gradient in the Sister Study, which
It documented a 30% increase in the overall incidence of breast cancer among regular users.
confers upon the causal link the status of inter-cohort methodological consistency, demonstrating that
The induction of malignancy in breast and uterine tissues transcends geographic variations.
isolated (WHITE et al., 2021; EBERLE et al., 2023).

The boundaries of contemporary oncology epidemiology have expanded.
substantially in the last publication window, demonstrating that the genotoxic potential and
The mutagenic nature of xenobiotics absorbed via the scalp has the capacity to induce
Systemic cancer that crosses the barriers of estrogen-dependent organs. The study
large-scale prospective study conducted by Bailey et al. (2026), by rigorously following

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A multifocal sample of 46,287 women showed positive statistical associations.
and unforeseen links exist between the chronic use of hair straighteners and the emergence of malignant neoplasms in organs.
Non-reproducing species with high lethality. Quantitative data indicate that the history of exposure
exposure to these chemicals significantly increases the risk of developing cancer.
thyroid (HR = 1.71) and non-Hodgkin lymphoma (HR = 1.62) (BAILEY et al., 2026). The finding
Most startling, however, was the focus on the incidence of pancreatic adenocarcinoma, which
It exhibited an overwhelming Hazard Ratio of 2.66 among frequent users, indicating that the
Chemical compounds of interest (CoCs) and absorbed contaminants exert an action
A cytotoxic and systemic inflammatory disease that damages the deep glandular parenchyma and the system.
lymphoreticular in a silent and chronic way (BAILEY et al., 2026).

The biological plausibility and molecular coherence of this broad spectrum of
Extrauterine carcinogenicity rests on the kinetics of the compounds that make up the vehicle.
The industrial market for relaxers, including those falsely labeled as protective or anti-aging.
mild (no-lye). Highly volatile and reactive inputs, such as free formaldehyde and...
byproducts generated by chemical releasers interact directly with the cells of
host after transfollicular permeation, facilitated by microlesions of corrosive pH
(IRUNGU et al., 2025). Once in the circulation and deep tissues, these chemical agents
They promote the cleavage of DNA strands, the formation of aberrant protein adducts, and the triggering of reactions.
of systemic inflammatory cascades mediated by severe oxidative stress (NEEDLE et al.,
2024). This continuous mutagenic aggression on tissues with a high rate of mitotic replication.
provides the necessary mechanistic anchoring to validate the observed high Hazard Ratios.
in epidemiological cohorts, removing any assumption that the empirical data are
resulting from bias or mere statistical chance (GEORGE; POTLAPATI, 2021).

The gravity and scope of this epidemiological situation are taking on even more pronounced dimensions.
Dramatic situations arise when literature begins to reveal the existence of iatrogenic effects.
Transgenerational and life-threatening risks extending to the offspring of users. Evidence
Recent scientific studies indicate that systemic permeation of toxins occurs during gestational windows.
Criticisms indicate that exposure goes beyond the placental barrier, exposing the fetus to severe genotoxic risks
even before birth (PEÑALOZA-DAGUER et al., 2024). Intrauterine maternal exposure
solvents, free formaldehyde, acetaldehyde and perchloroethylene — routinely detected as
adulterants or preservatives in the critical mass of hair straightening products — is strongly associated with
early development of leukemias in childhood and the increased incidence of tumors
Wilms (infantile nephroblastoma) (GEORGE; POTLAPATI, 2021; PEÑALOZA-DAGUER et

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al., 2024). This risk transfer from mother to child elevates the status of chemical hair straightening.
A seemingly harmless cosmetic decision has become a serious and avoidable vector of iatrogenic harm.
transgenerational issues in public health, requiring immediate preventive medicine interventions and
prenatal counseling (GEORGE; POTLAPATI, 2021).

The definitive establishment of the use of alkaline relaxants as a racial determinant-
The most important oncological problem lies in the alarming epidemiological disparity in
The prevalence and intensity of exposure vary among different ethnic groups. While the
The prevalence of chemical hair straightening use among white women of European descent is
statistically marginal, fluctuating around only 1.3% of the gynecological population, the
Global and national estimates reveal that the use of relaxants among Black women is...
African ancestry reaches endemic epidemiological levels, placing itself in a way
chronic in between 75% and 95% of the population samples analyzed (BAILEY et al., 2026;
IRUNGU et al., 2025; WILLIAMS; WOOLERY-LLOYD, 2020). This immense asymmetry in
Consumption of dangerous compounds ensures that the biological burden derived from hormonal disruption is met.
mediated by ERÿ and ERÿ receptors and extrauterine carcinogenesis falls in a way
concentrated and disproportionate on the bodies of Black women, turning a practice
aesthetic coercion within a blatant racial inequality in health and mortality rates due to
cancer (IRUNGU et al., 2025).

The perpetuation and market protection of this large-scale risk scenario are
severely aggravated by a chronic pattern of regulatory fraud and institutional failures of
Inspection and deliberate omissions in industrial labeling. Laboratory analyses by
Mass spectrometry results consistently reveal very low agreement between the
actual measured chemical composition and ingredients declared on product labels
targeted at a black audience, with massive omissions of endocrine disruptors and...
disguised insertion of formaldehyde in self-declared safe formulations (IRUNGU et al.,
2025). In addition to this, the barriers to protecting the lay consumer collapse at the point of
sales: field investigations have shown that approximately 68% of hair straighteners and
highly caustic alkaline relaxants (pH > 12), despite boasting in their
The restrictive warning "for professional use in salons only" is found on the packaging.
widely available for free purchase by laypeople on supermarket shelves and
retail pharmacies, allowing for home applications without any equipment.
for protection or mitigation of burns (IRUNGU et al., 2025; WISE et al., 2023).

Given the collapse of current cosmetic safety models and the magnitude of

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Given the documented damage, the application of the precautionary principle derived from [the relevant legal principle] becomes urgent.
Bradford Hill's thought (1965). According to Hill's maxim, the incompleteness of
Fine molecular knowledge about a pathology does not justify regulatory inaction nor...
Postponement of preventive measures when public health is under vital threat (HILL, 1965).
The robustness of this epidemiological data demands a drastic paradigm shift.
regulatory, making it imperative to investigate the sociological drivers that maintain this chain of
active exposure. This need directs the present investigation to the analysis of the determinants.
psychosocial factors that perpetuate this iatrogenic effect in the black population.

4.3 Pillar 3: Psychosocial determinants, aesthetic pressure, and the dose gradient. Bradford Hill's response

The consolidation of chronic use of alkaline relaxants as a determinant of health.
Public discourse demands rejecting sociological variables as mere cultural appendages. Under the
Bradford Hill's framework (1965), the biological exposure behavior of
Consumer behavior does not stem from individual or frivolous aesthetic choices, but is governed by
structural racial and gender pressures (VAAH, 2024). The introduction of these determinants
Psychosocial factors underpin the criteria of Biological Gradient (Dose-Response) and of
Temporality, demonstrating that structural racism functions as the primary driving force that
determines the internal dosage and chronicity of exposure to carcinogens and endocrine disruptors.
endocrine disorders in the black population (VAAH, 2024).

The causal link between psychosocial suffering and systemic oncological damage lays bare the
its roots in the colonial legacy of transatlantic slavery, a period in which the classification
The pejorative term for Afro-textured hair, such as "woolly," served as a mark of inferiority.
biological and deliberate dehumanization to legitimize exploitation (VAAH, 2024). This
Phenotypic violence established and crystallized Eurocentric beauty ideals as the norm.
universal values of humanity, civility, cleanliness, and social acceptability, pushing aside the textures.
natural hair of black women to an area of chronic stigmatization and pathologization
Aesthetics (Tate, 2021; Johnson et al., 2022). As a historical survival strategy.
Physical, economic, and psychological factors, altering the structure of the thread emerged as an attempt
an imperative to mitigate social rejection, establishing, from the outset, an indissoluble bond
between racially based oppression and the need to subject the body to chemical agents.
corrosives (VAAH, 2024).

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In contemporary times, this matrix of aesthetic oppression has been reconfigured under the called the policy of respectability, an institutionalized code of conduct that requires Marginalized groups face strict phenotypic conformity as a condition for access. and permanence in spaces of power, education and socioeconomic advancement (VAAH, 2024). Sociological investigations focused on labor dynamics demonstrate that discrimination Hair texture-based behavior in the workplace acts as an active exclusion barrier. where straight, polished hair is rigidly associated with decorum and professionalism, whereas that curly and natural hair is summarily labeled as unkempt or not professionals (TAYLOR et al., 2023). This formal exclusion forces women of ancestry Africans are looking to chemically modify their biology as a mandatory prerequisite. for corporate eligibility, prioritizing aesthetic conformity over their own safety. vital (TAYLOR et al., 2023; NEEDLE et al., 2024).

It is precisely the intensity of this institutional and corporate coercion that underlies Bradford Hill's Biological Gradient (Dose-Response) criterion, acting as a vector that It determines the frequency of application and, consequently, the internal dose of toxins accumulated. throughout life (VAAH, 2024). The concrete fear of exclusion from the formal labor market and Continuous hypervigilance regarding aesthetics induces a state of chronic hair anxiety that prevents Discontinuing the use of the product dictates a strict application schedule, which frequently reaches or exceeds the barrier of four to seven annual interventions (TAYLOR et al., 2023; COOGAN et al., 2021). From a molecular perspective, this regularity of exposure at short intervals it prevents cell regeneration of the scalp and ensures that the portals transfollicular entry points remain permanently open, promoting repeated peaks. and linear endocrine disruptors in the systemic circulation (GECZIK et al., 2023; IRUNGU et al., 2025).

In this way, a perfect statistical and biological parallel is established, in which the Structural racism, as mapped by sociology, dictates the slope of the dose-response curve. documented by epidemiology (VAAH, 2024). The reproductive cancer risk, which doubles for endometrial cancer at frequencies greater than four applications per year (CHANG et al., 2022) and increases by 37% for ER+ breast cancer in intensive use regimens. (COOGAN et al., 2021), it is no longer seen as a biological fatality or a correlation Spurious. The need to maintain the smooth standard demanded by corporate whiteness. forces the black consumer to submit to the carcinogenic dose necessary to trigger the reaction. from aberrant cell proliferation and the formation of DNA adducts, transforming oppression

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social in a direct and quantifiable racial-oncological determinant (TAYLOR et al., 2023; BAILEY et al., 2026).

Additionally, psychosocial variables provide the necessary theoretical support. to validate Hill's criterion of temporality, correlating the chronology of social pressure with the biological windows of extreme reproductive vulnerability. The imposition of ideals Eurocentric perspectives significantly impact the life trajectories of Black women. early onset, manifesting itself in childhood and pre-adolescence through family socialization and school (TATE, 2021; JOHNSON et al., 2022). Under pressure to safeguard children from racial stigma and to facilitate the daily handling of tightly coiled wires in a society that If rejected, mothers are induced to start applying alkaline relaxants at younger ages. less than 10 years (NEEDLE et al., 2024; OGUNSINA et al., 2025). From the point of view physiologically, this early onset coincides with critical stages of biological maturation and Endocrine tissue differentiation, allowing for local chemical aggression and absorption. transdermal phthalates occur decades before adult hormonal stabilization (GECZIK et al., 2023).

This chronological anticipation of exposure acts as a determinant of the severity of subsequent gynecological pathologies, since it prolongs the cumulative exposure time. from the reproductive organs to xenobiotics with estrogenic activity throughout the entire course of user's life (NEEDLE et al., 2024). The epidemiological evidence linking the use From childhood hair straightening treatments to the early onset of menarche (OGUNSINA et al., 2025), to a 27% reduction in fertility rates (WISE et al., 2023) and the aggressive emergence of uterine leiomyomas before the age of 36 (OGUNSINA et al., 2025) find their logical explanation in the fact that childhood represents a window of maximum biological vulnerability, where the The organism exhibits a reduced capacity for metabolic detoxification and greater susceptibility to genotoxic mutations (NEEDLE et al., 2024). The temporality of social aggression dictates, therefore, the precocity and aggressiveness of the pathological clinical outcome (VAAH, 2024).

The psychological impact of this continuous coercive mechanism culminates in internalization. The profound stigma and consequent rejection of one's own phenotype lead to severe conditions. of identity suffering and weakening of self-concept (JENKINS, 2022). When they subjected to aesthetic standards that are biologically unattainable without resorting to interventions. Due to caustic and erosive chemicals, Black women suffer a disruption in the formation of a positive racial identity, which unfolds into a state of learned helplessness in the face of of the dominant beauty standards (JENKINS, 2022; MWAKIBETE, 2021). The perception

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internalized belief that the natural texture of their hair is inherently inadequate or ugly
It traps the consumer in a vicious cycle of biochemical dependence, in which suffering
The mental framework generated by prejudice acts as the psychological cement that perpetuates exposure to agents that cause gynecological and systemic cancer (TATE, 2021; WISE et al., 2023).

Overcoming this scenario of mass iatrogenesis fundamentally requires, interventions that dismantle the link between the need for economic survival and the Forced chemical submission. From a legal protection perspective, the emergence of legislation such as The CROWN Act aims to explicitly criminalize hair discrimination based on texture. school environments and institutional workplaces, acting directly at the root of the problem. Corporate pressure (TAYLOR et al., 2023; NEEDLE et al., 2024). By removing punishment From institutional to black natural biology, these legal guarantees are indispensable to reduce population rates of hair anxiety and to grant women the security institutional measures are necessary to interrupt the regimen of use of life-threatening substances. breaking the upward slope of the dose-response curve (NEEDLE et al., 2024; OGUNSINA et al., 2025).

Simultaneously, at the clinical and psychotherapeutic levels, approaches based on Racial literacy and PsychoHairstyle emerge as essential tools for deconstruction. from learned defenselessness to promoting the unlearning of aesthetic norms. oppressive (JENKINS, 2022). By treating hair management and transition as access portals These clinical approaches, focused on mental health and identity strengthening, help the patient to... Breaking with internalized phenotypic self-rejection (JENKINS, 2022). The recovery of dignity. Identity and acceptance of the hair's natural texture work, in practical medical terms... preventive, such as a mental health intervention that prevents the introduction of carcinogens. in the organism, demonstrating that psychological healing and biological protection occur through coordinated and simultaneous form (JENKINS, 2022; VAAH, 2024).

In conclusion, the integration of psychosocial determinants in this critical review It solidifies the causal link of alkaline relaxants by connecting the sociology of structural racism. to the biology of systemic carcinogenesis. From the perspective of Bradford Hill (1965), to observe that the Eurocentric labor market demands dictate the timing and dose gradient. The answer to this statement removes any margin of uncertainty and constitutes a cause. unequivocal for regulatory and public health action. The incompleteness of knowledge Fine molecular physics cannot serve as a shield for inaction by the state or industry in the face of vital risks are so racially concentrated, making the protection of integrity urgent.

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biological and identity dignity of women of African descent (HILL, 1965; VAAH, 2024).

Final Considerations

The analytical triangulation of multidisciplinary evidence consolidates the incompatibility. biochemistry between alkaline hair relaxers and human biological integrity. A Applying the Bradford Hill framework (1965) enhances the statistical associations of cohorts. *The Sister Study* and *the Black Women's Health Study* have reached the level of robust causal link. This is evident. that chronic exposure to these industrial formulations promotes a severe increase in incidence of hormone-dependent neoplasms with high lethality (ER+ breast carcinomas, endometrium, uterus, and ovary), extending to adenocarcinomas of the pancreas and thyroid. (BAILEY et al., 2026; CHANG et al., 2022; COOGAN et al., 2021; HILL, 1965).

The elucidation of the biophysical-chemical mechanisms reveals that capillary straightening requires extreme alkalinity (pH 12-14) and the corrosive process of lanthionization, which generates lysis irreversible cortical protein damage (BARRETO et al., 2021; VELASCO et al., 2022). This damage Chemical reactions culminate in cellular erosion of the epidermal barrier and acute burns (GEORGE; POTLAPATI, 2021). Lipid and inflammatory breakdown acts as the precursor mandatory pathophysiological process for the breakdown of the dermal barrier, converting the scalp hypervascularized in a free-flow channel for transfollicular permeation and absorption. deep systemic exposure to endocrine disruptors and carcinogenic contaminants (SILVESTRE et al., 2020; IRUNGU et al., 2025).

The main distinguishing feature of this investigation is demonstrating that structural racism and The politics of respectability act as the primary epidemiological engine that governs the Bradford Hill's Biological Gradient (Dose-Response) and Temporality criteria (1965). The mandatory requirement for phenotypic conformity to mitigate workplace discrimination generates chronic hair anxiety that requires frequent application (ÿ 4 times per year), what determines the upward curve of the oncological dose-response (COOGAN et al., 2021; TAYLOR et al., 2023). Similarly, stigma anticipates biological exposure in childhood, Intercepting a critical vulnerability window that prolongs latency time. inflammatory and promotes the early onset of uterine fibroids, subfertility and malignancies in adulthood (NEEDLE et al., 2024; OGUNSINA et al., 2025; WISE et al., 2023).

Ultimately, the incompleteness of fine molecular knowledge does not confer upon

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Scientists or health authorities have the freedom to ignore robust evidence.
existing epidemiological data does not authorize the postponement of urgent preventive measures.
(HILL, 1965). It becomes imperative that the State and regulatory agencies adopt a stance
interventionist and precautionary medical approach. This should materialize in the strengthening of
Protective legislation inspired by the *CROWN Act* to dismantle institutional punishment.
Black biology, punishing labeling fraud, and promoting biotechnological alternatives.
safe cell modeling (COSTA, 2021; NEEDLE et al., 2024). Only by breaking the
A causal link between psychosocial oppression and internal dosage of xenobiotics will be possible.
to guarantee vital protection, reproductive justice, and the identity dignity of women of
African ancestry (HILL, 1965; VAAH, 2024).

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