

Mercury in Skin Lightening Creams: A Comprehensive Review of Health Risks, Analytical Detection Methods, and Regulatory Legislations

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الزئبق في كريمات تفتيح البشرة: مراجعة شاملة للمخاطر الصحية، الطرق التحليلية للكشف، والتشريعات التنظيمية

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Abstract:

This research provides a comprehensive review addressing the use of mercury in skin-lightening creams, with a particular focus on the chemical and health risks resulting from its exposure, and the analytical methods employed for its detection specifically in these creams. It also examines the relevant regulatory legislations, including international efforts such as the Minamata Convention aimed at limiting the use of mercury in cosmetics. Evidence derived from studies indicates the direct or indirect continued use of mercury in numerous skin-lightening creams and other cosmetic products, posing a threat to public health, especially in countries experiencing weak regulatory oversight of these products.

Keywords: Mercury, Skin Lightening Creams, Health Risks, Analytical Methods, Regulatory legislations.

المخلص

يقدم هذا البحث مراجعة شاملة تتناول استخدام الزئبق في كريمات تفتيح البشرة، مع تركيز خاص على المخاطر الكيميائية والصحية الناتجة عن التعرض له، والطرق التحليلية المستخدمة في الكشف عنه تحديداً في هذه الكريمات. كما يدرس التشريعات التنظيمية ذات الصلة، بما في ذلك الجهود الدولية مثل اتفاقية ميناماتا التي تهدف إلى الحد من استخدام الزئبق في مستحضرات التجميل. تشير الأدلة المستمدة من الدراسات إلى الاستخدام المستمر المباشر أو غير المباشر للزئبق في العديد من كريمات تفتيح البشرة ومنتجات التجميل الأخرى، مما يشكل تهديداً للصحة العامة، خاصة في البلدان التي تعاني من ضعف الرقابة التنظيمية على هذه المنتجات.

الكلمات المفتاحية: الزئبق، كريمات تفتيح البشرة، المخاطر الصحية، الطرق التحليلية، التشريعات التنظيمية.

Introduction

Skin lightening is a term that refers to products marketed with the aim of reducing skin pigmentation (melanin) and unifying its color. These products include various names such as: skin whitening creams, dark circle removal creams, skin peeling creams, dark spot removers, and other products claimed to treat hyperpigmentation problems, melasma, freckles, wrinkles, and acne [1]. This type of cosmetic is commonly used in many countries around the world, with increasing demand in Africa, Asia, and the

Caribbean, and is used by both men and women. Skin lightening products are used for cosmetic purposes by reducing melanin production through the inhibition of the tyrosinase enzyme responsible for its synthesis. Inorganic mercury is considered one of the strongest inhibitors of this enzyme, which is why it is added to some of these products to prevent melanin formation and lighten skin tone, despite its serious health risks. It can be absorbed through the skin via sweat glands and hair follicles, which may lead to local skin damage, in addition to toxic effects on the kidneys and nervous system.

Chronic exposure to it leads to irritation, muscle weakness, and memory loss, and may lead to kidney failure. Due to these risks, the international community adopted the Minamata Convention in (2013), which prohibits the use of cosmetics with a mercury concentration exceeding 1 part per million [2]. This comprehensive review aims to clarify the use of mercury in skin lightening products, in terms of its mechanism, health risks, and detection methods, while highlighting relevant regulatory frameworks, thereby contributing to raising awareness and improving control.

The global proliferation of skin-lightening products, particularly in regions across Asia, Africa, Latin America, and the Middle East, has emerged as a pervasive public health and socio-cultural phenomenon. Rooted in deep-seated historical, aesthetic, and social constructs, the widespread use of skin-lightening creams is often driven by perceptions that lighter skin tones are associated with higher social status, beauty, and economic opportunity. However, the increased demand for these cosmetic formulations has led to the unchecked circulation of products containing hazardous substances—foremost among them, mercury, a heavy metal recognized for its potent toxicity and long-term bioaccumulative properties [3].

This article provides a comprehensive investigation into the multifaceted issue of mercury usage in skin-lightening products, examining its toxicological implications, analytical detection methodologies, and regulatory governance. Specifically, it explores: (1) the prevalence and rationale behind the inclusion of mercury compounds in cosmetic formulations; (2) the health risks associated with chronic exposure to mercury through dermal absorption, as documented in clinical and epidemiological studies; (3) a critical evaluation of analytical techniques employed for mercury detection in cosmetic matrices, highlighting their operational principles, strengths, and limitations; and (4) a review of international and national regulatory frameworks governing the use of mercury in cosmetics. The article concludes with a synthesis of key findings and recommendations aimed at informing public health policy, regulatory enforcement, and future research.

Mercury in Skin Lightening Products

Mercury is used in skin lightening products for its ability to inhibit melanin production. Mercury lightens skin tone by competing with copper ions in the tyrosinase enzyme, which is responsible for melanin production. The World Health Organization classifies mercury as one of the top ten chemicals of major public health concern. Mercury exists in three main forms: elemental (metallic), inorganic, and organic. Inorganic mercury is easily absorbed through the skin, making it the most common form used as an active ingredient in skin lightening creams. In contrast, some organic mercury compounds are used as preservatives in cosmetics. It is worth noting that mercury is a neurotoxic substance and its use is prohibited in the European Union and many African countries [4,5]. Multiple studies have revealed the widespread presence of mercury in skin lightening products. In Banjarnegara, Indonesia, mercury was found in some bleaching creams at concentrations ranging from 0.01814 to 0.91000 mg/kg [6]. A systematic review of analyses of hundreds of samples from different countries confirmed the presence of mercury at an average level of 0.49 micrograms/gram, indicating its global prevalence [7]. Moreover, in some regions like Katsina, Nigeria, all tested samples contained mercury at concentrations exceeding the safe limits recommended by the World Health Organization, ranging from 27.7 to 61.5 parts per million [8].

Health Risks Associated with Mercury Use

Mercury, the only liquid heavy metal at room temperature, can be absorbed through the respiratory and digestive systems, as well as the skin, leading to poisoning that primarily affects the kidneys and the central nervous system. Kidney damage often manifests as nephrotic syndrome [9]. Studies since 1818 have indicated its role in the appearance of protein in the urine as an early sign of its renal effects. Historically, mercurial diuretics and ointments were sources of exposure. However, skin-lightening creams containing mercury have emerged as a modern source of poisoning [10]. Mercury absorption through the skin increases with its concentration and skin moisture. After absorption, it spreads throughout the body and is primarily excreted via urine and feces, with renal excretion being predominant in chronic exposure with a half-life ranging from one to two months. The kidney is considered the primary target organ for the accumulation of inorganic mercury, causing proteinuria, tubular necrosis, and nephrotic syndrome. Symptoms may include a metallic taste, gingivitis, and nausea. Although its penetration of the blood-brain barrier is limited, prolonged exposure can lead to neurotoxicity [11]. Mercury exposure during pregnancy can cause serious effects on fetal neurological

and cognitive development and may be associated with a reduced IQ. Symptoms of poisoning include irritability, tremors, memory problems, and sensory changes [12]. Table (1) documents studies of poisoning cases resulting from the use of mercury-containing skin-lightening creams.

Table 1: illustrates documented studies of poisoning cases resulting from the use of mercury-containing skin-lightening creams.

Country	Key Findings	Health Risks	Reference
Trinidad and Tobago	16 out of 19 products had high mercury, 21% unsafe, 16% dangerous	Mercury poisoning, unidentified skin issues	[13]
Saudi Arabia	Clinical case of severe acne due to mercury cream, with call for awareness	Cystic acne, renal and neurological complications	[14]
Multiple Countries (22)	Review of 41 studies showing high and diverse mercury exposure effects	Multiple risks: kidney, skin, nervous system	[15]
Unspecified	Inhibits melanin synthesis, causes kidney diseases like membranous nephropathy	Nephrotoxicity, liver damage, neurotoxicity	[16]
Indonesia	Long-term use leads to dermatological, systemic, and psychological toxicity	Kidney damage, skin discoloration, psychological issues	[17]
United States	Mercury causes optic nerve damage and severe visual impairment	Toxic optic neuropathy, vision loss	[18]
Malaysia	Mercury levels exceed legal limits in local market, warning against products	Skin pigmentation damage, general health effects	[19]

The data presented in Table 1 highlights a growing body of documented evidence linking the use of mercury-containing skin-lightening creams to a wide range of adverse health effects and toxicological outcomes across various countries. These findings underscore the urgent need for regulatory action, public health education, and market surveillance, particularly in regions where these products are readily available and insufficiently controlled. In Trinidad and Tobago, an alarming 84% of tested products (16 out of 19) were found to contain dangerously high mercury levels, with 21% classified as unsafe and 16% considered highly dangerous. This reflects both widespread product contamination and a significant public health threat. Reported health issues included mercury poisoning and unidentified skin disorders, illustrating the challenges of clinical diagnosis due to nonspecific symptoms [13]. A clinical case in Saudi Arabia further emphasizes the severity of individual health impacts, where the use of a mercury-laden cream resulted in severe cystic acne, alongside renal and neurological complications. This case led to a call for greater public awareness and medical vigilance in recognizing mercury-related dermatological presentations [14].

A broader meta-analysis encompassing 22 countries and 41 studies revealed multiple systemic risks, including impacts on the kidneys, skin, and nervous system. Such wide-ranging data point to the global nature of the problem, affecting both developed and developing nations, and highlight the scale of human exposure to mercury through seemingly innocuous cosmetic products [15]. Additional evidence from unspecified regions sheds light on mercury's biochemical mechanisms, particularly its role in inhibiting melanin synthesis—a key reason for its inclusion in skin-lightening products. However, this inhibition comes at the cost of serious health consequences such as nephrotoxicity, liver impairment, and neurotoxicity, underscoring the trade-off between cosmetic effects and systemic toxicity [16].

In Indonesia, long-term exposure to mercury through these creams has been shown to cause dermatological, systemic, and psychological damage. Reported outcomes include kidney dysfunction, skin discoloration, and mental health disturbances, indicating that the damage is not confined to the skin but extends to multiple organ systems and mental well-being [17]. The United States has reported cases where mercury exposure from cosmetic products led to toxic optic neuropathy, resulting in irreversible visual impairment. This stark outcome further challenges the perception of skin-lightening creams as low-risk cosmetics and raises questions about gaps in regulatory oversight even in high-income countries [18]. Finally, in Malaysia, mercury levels in several local products exceeded legally permissible limits, prompting warnings to consumers. Documented health risks include skin pigmentation damage and generalized toxic effects, reinforcing the urgent need for stronger

enforcement of safety standards and consumer protection measures [19]. In conclusion, the data collectively expose the widespread and multi-dimensional health hazards of mercury-based skin-lightening products. They also highlight the inadequacy of existing regulations in many regions and the pressing need for internationally coordinated interventions, including public awareness campaigns, clinical screening protocols, and stricter import controls to mitigate this persistent public health issue.

Analytical Methods for Detecting Mercury in Skin-Lightening Creams

Detecting mercury in skin-lightening creams is a problem of paramount importance and risk due to its toxic hazards. Consequently, various analytical methods have been developed to detect and quantify mercury in these products. Table (2) illustrates these different analytical methods, highlighting the respective advantages and limitations of each, in addition to mentioning the scientific studies that confirm their effectiveness in the analysis of mercury in skin-lightening creams.

Table 2: The analytical methods, their respective advantages and limitations, and the scientific studies supporting their use for the detection of mercury in skin-lightening creams.

Method	Advantages	Limitations	Reference
XRF	Portable, rapid analysis, minimal sample preparation	Less accurate for heterogeneous samples	[20,21]
TXRF	High sensitivity, accurate for complex matrices	Requires sample preparation, less portable	[21]
ICP-MS	High sensitivity, accurate, and reliable	Expensive, complex, requires sample preparation	[21,22]
CV-AAS	Cost-effective, accurate for homogeneous samples	Requires sample preparation, not suitable for field analysis	[23,24,25]
FAAS	Simple, cost-effective	Less sensitive compared to CV-AAS and ICP-MS	[26,27]
FIAS	Fast, minimal sample preparation	Limited availability of instrumentation	[28]
HPLC	High resolution, suitable for complex matrices	Primarily used for hydroquinone detection, less common for mercury	[23]

Table 2 presents a comparative overview of analytical techniques utilized for the detection of mercury in skin-lightening creams, emphasizing each method's advantages, limitations, and supporting scientific references. This table serves as a valuable resource for selecting suitable methods based on analytical context—such as accuracy, sensitivity, cost, portability, and field applicability. XRF offers the benefits of portability, rapid on-site analysis, and minimal sample preparation, making it especially useful for preliminary screening and regulatory enforcement in field conditions. However, its performance is less accurate for heterogeneous samples, which may compromise result reliability when testing products with complex matrices or uneven mercury distribution [20,21].

TXRF exhibits high sensitivity and precision, making it well-suited for the detection of mercury in complex cosmetic formulations. Nevertheless, its reliance on rigorous sample preparation and limited portability makes it less practical for rapid or field-based testing. It is more appropriate for laboratory-based confirmatory analysis [21]. ICP-MS is considered a gold standard for trace metal analysis due to its exceptional sensitivity, reliability, and quantitative accuracy. It can detect mercury at very low concentrations and is suitable for multi-elemental analysis. However, its high cost, operational complexity, and need for specialized facilities and sample preparation limit its routine use in low-resource settings [21,22]. CV-AAS is a cost-effective and accurate method for mercury detection in homogeneous samples. While it offers acceptable sensitivity for many applications, it also requires sample preparation and is not suitable for field-based analysis, which limits its utility in rapid screening programs [23,24,25]. FAAS stands out for its simplicity and cost-effectiveness, which has historically made it a popular choice in basic laboratory settings. However, its sensitivity is inferior to both CV-AAS and ICP-MS, making it less suitable for detecting trace levels of mercury in cosmetics, especially when regulatory thresholds are extremely low [26,27]. FIAS provides rapid analysis and requires minimal sample preparation, making it a potential candidate for high-throughput screening. However, the limited availability of specialized instrumentation hinders its widespread adoption, particularly in developing countries where mercury-containing creams are prevalent [28-23].

Regulatory legislations concerning mercury in skin-lightening creams

Recent studies underscore the significance of stringent regulations for mercury in skin-lightening creams due to its well-known health risks. Despite the Minamata Convention setting a permissible

mercury level of 1 microgram per gram, numerous products significantly exceed this limit. Countries such as the European Union, North America, the Philippines, and several African nations have banned mercury in these products; however, they remain widely accessible [29]. Nations like Saudi Arabia and Indonesia face challenges in enforcing regulations and ensuring compliance, influenced by cultural factors and the ease of online and social media sales [22,30,31]. Cosmetic vigilance, or the monitoring of cosmetic products for safety, is crucial for identifying and mitigating risks associated with heavy metals in cosmetics [32]. While regulations exist, their implementation varies considerably between countries and regions, indicating a lack of global consistency in enforcement, which necessitates international cooperation and stronger surveillance systems to safeguard public health.

Conclusion

This comprehensive review has elucidated the critical public health concerns associated with the continued use of mercury in skin-lightening creams, highlighting its toxicological severity and systemic health risks. Prolonged exposure to mercury, even in trace amounts, has been consistently linked to renal dysfunction, neurotoxicity, dermatological disorders, and other chronic conditions, underscoring the urgent need for effective risk mitigation strategies. While mercury may yield short-term cosmetic effects by inhibiting melanin synthesis, its long-term health consequences significantly outweigh any perceived aesthetic benefits. Given the gravity of these findings, there is a compelling imperative to advance and enforce strict regulatory measures governing the production, distribution, and sale of mercury-containing cosmetic products. In parallel, the development and standardization of highly sensitive and reliable analytical techniques are essential to accurately detect mercury in cosmetic matrices, especially those circulating through informal markets and online platforms. Furthermore, strengthening international regulatory coherence, enhancing cosmetic surveillance systems, and promoting public awareness campaigns are vital steps toward safeguarding consumer health. In sum, addressing the mercury crisis in skin-lightening products requires a multidisciplinary and coordinated global response, integrating scientific research, regulatory enforcement, public health policy, and education. Only through such comprehensive efforts can we ensure the elimination of hazardous substances from cosmetic products and uphold the fundamental right to safe and non-toxic consumer goods.

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