Journal of Cosmetics, Dermatological Sciences and Applications, 2024, 14, 276-288
https://www.scirp.org/journal/jcdsa
ISSN Online: 2161-4512
ISSN Print: 2161-4105

Formulating Dead Sea Mud in Cosmetic Products, Its Effects on Skin, and the Underlying Biological Mechanism: A Review

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How to cite this paper: Ma'or, Z., Cohen, D. and Assis, A. (2024) Formulating Dead Sea Mud in Cosmetic Products, Its Effects on Skin, and the Underlying Biological Mechanism: A Review. *Journal of Cosmetics, Dermatological Sciences and Applications*, **14**, 276-288.
https://doi.org/10.4236/jcdsa.2024.143019

Received: August 12, 2024
Accepted: September 21, 2024
Published: September 24, 2024

Abstract

Research Background: The marketing of cosmetic products derived from Dead Sea (DS) mud has undergone significant evolution, transforming from simple souvenirs into a large-scale cosmetic industry offering a diverse array of products. DS mud is utilized both as pure mud for home spa treatments and as an active ingredient in cosmetic and cosmeceutical formulations. Its global appeal is largely due to its natural, health-oriented image, which aligns with consumer preferences and provides assurance regarding its use in skincare. **Research Objectives:** This review examines the published data related to the rationale for formulating DS mud in cosmetics, the biological and cosmetic effects of DS mud on the skin, and the speculated bio-mechanisms underlying these effects. **Methods:** We screened relevant literature on DS mud collected from the shores of the Dead Sea in Jordan and Israel. Publications on mineral muds excavated in different locations around the globe, as well as studies on the biological mechanisms of other DS minerals, were also reviewed as indications and supportive recommendations. Summarizing the vast collected data into a comprehensive review was undertaken to expose readers to the various aspects of DS mud in cosmetics. **Results:** The primary reason for formulating DS mud in skincare products is its deep cleansing and skin detoxification properties. Consequently, it is often incorporated into rinse-off masks, soaps, and scrubbing products. Additionally, DS mud is used in leave-on products and sheet masks. Cosmeceutical applications of DS mud, recommended for various skin conditions, offer complementary treatments to improve the quality of life for people with skin diseases. The physicochemical and biological effects of DS mud are driven by its rich mineral ion composition, including magnesium,

calcium, sodium, potassium, zinc, and strontium—elements known to improve skin barrier function, enhance hydration, and reduce inflammation. The high salt concentration induces moderate ionic osmotic stress, stimulating cellular growth and hydration pathways. Moreover, DS mud's anti-microbial properties further contribute to its therapeutic potential. Ongoing innovations in formulation techniques continue to expand the applications of DS mud, including blending it with other active ingredients, developing novel application methods, and refining manufacturing processes to improve product quality and efficacy. **Conclusions:** DS mud remains a valuable ingredient in modern skincare due to its rich mineral content and therapeutic properties. Ongoing research and technological advancements promise further innovations, reinforcing its status as a natural and effective component in the global cosmetics industry.

Keywords

Dead Sea, Mineral, Cosmetics, Mud, Health

1. Introduction

Evidence for the practice of mud materials by Homo sapiens was found in Ancient Egypt and Mesopotamia, suggesting that our forefathers recognized the medicinal powers of mud to treat skin inflammation [1] [2]. Additionally, documents from the first century BC provide evidence that Cleopatra, the Queen of Ancient Egypt, imported minerals from the Dead Sea, potentially for her personal care. The foundational perspective of Greek and Roman spa forefathers, merging therapeutic goals with the desire for pleasure and beauty, still influences modern spa mud treatments in modern spa facilities [3].

Fast forward to our modern age: in 1949, the term "pelotherapy" was officially adopted to refer to the use of mud as a therapeutic treatment. The term combines the Greek word "pelos", meaning mud, with "therapy" to highlight its medical healing purpose. Pelotherapy is considered an alternative and complementary medicine approach widely accepted alongside conventional medical treatments [4]. This special linkage of health and beauty, medicine and pleasure, may explain the evolution of the cosmetic and cosmeceutical business based on therapeutic muds [4].

The long list of various muds used in pelotherapy practices is generally divided into two major groups based on their origin: one major category is "organic mud", which includes muds with at least 50 percent (calculated as dry matter) of plant-origin substances, such as peat. The other major category is "mineral mud", which comprises volcanic mud, various soil-origin muds, and sea mineral muds, including the DS mud [4]-[7]. The Dead Sea, located at the lowest point on Earth, is reported as a popular source of active mineral ingredients [8]-[11]. The therapeutic benefits of DS mud and DS water have been demonstrated in controlled clinical studies to alleviate inflammatory skin disorders [8]-[11].

This review presents the related literature on DS mud in cosmetics. The reported cosmetic and therapeutic benefits of DS mud on the skin are described. Speculated theories regarding its mode of action, as mentioned in the literature, are also shared. Additionally, important facts related to mud-based cosmetic formulation, safety, and regulatory aspects are presented.

2. DS Mud as an Active Ingredient in the Cosmetic Markets

From a physicochemical perspective, DS mud is a suspension, mainly composed of two different phases: the external phase is saline interstitial water with a chemical composition corresponding to DS water, *i.e.* enriched with positive charged cations of Magnesium, Sodium, Calcium, and Potassium, balanced by negative charged anions of Chlorides and Bromides. The internal phase consists of solid particles, composed of various clay minerals: illite-smectite, kaolinite, illite, calcite, quartz, and small concentrations of chlorite, palygorskite, dolomite and halite, as described in Table 1 and Table 2 [12]-[14].

Table 1. Major and micro elemental analysis of the interstitial water, centrifuged from crude DS mud [14].

Marco-elements	Interstitial water (mg/L)
Cl + Br	140,000
Mg	28,250
Na	20,200
Ca	9800
K	9500
Sr	150
SO_4	<1000
Micro-elements	**Interstitial water (µg/L)**
Mn	9800
Ni	41.1
Cr	Undetected
Co	0.7
Cu	2.1
Zn	16.0

Table 2. Semi-quantitative mineralogical composition of the clay fraction (<2 µm particle size) of Dead Sea mineral mud (values in percentage by weight) [14].

Mineral	% by weight [14]
Illite-smectite phases	50 - 70
Kaolinite	10 - 20
Illite	10 - 15
Calcite	5 - 15
Quartz	1 - 5

Marketing of modern DS mud-based cosmetics began as a complementary take-home option, proposed to visitors at the Dead Sea spa resorts, and during the years, evolved from primitive "packed muds" souvenirs into a massive business [13]. DS mud is marketed as a pure mud for "spa at home" mud application and as an active ingredient formulated in cosmetic and cosmeceutical products [5] [13] [15]. The significant recognition of DS mud in today's markets can be attributed to its health-oriented, and authentic natural ingredient that aligns well with consumer beliefs and preferences [5] [8] [15] [16].

Deep cleansing and skin detox attributes are the main reasons for using DS mud in cosmetic products by individuals with healthy skin. Thus, DS mud is often formulated in rinse-off mud masks, in mud soaps, in shampoos, and skin scrubbing products [5] [15]. DS mud, is also formulated in cosmetic preparations that are directly massaged on skin surface. Inspired by the global success of Korean Beauty, DS mud sheet masks have been successfully marketed. In addition to its usage in rinse-off products, DS mud is also formulated into leave-on skincare products in limited concentrations [5] [15] [17].

Cosmeceutical DS mud-based preparations are reported to improve customers' quality of life, and as a complementary treatment for a wide range of symptoms, including mild to moderate severity levels of seborrheic dermatitis, psoriasis, atopic dermatitis, eczema, and acne-prone skin [5] [15]. Application of DS mud-containing products in such pathologies was reported to prevent skin flare-ups and attenuate the signs of inflammation [5] [13] [17] [18].

Cosmetic products, containing DS mud, are distributed today in the conservative channels, as consumer goods, mainly via department stores and pharmacies, virtual shops, and marketed as touristic souvenirs at the DS spa resorts [13] [15].

3. DS Mud Physicochemical-Biological Mode of Action

There is limited research on the activation mechanism of DS mud. However, we can gain insights into its biological mode of action by examining the well-documented biological effects of DS water, as both DS water and DS mud share high concentrations of mineral ions that influence known biological pathways. Based on this assumption, DS mud can be perceived as a semi-solid vehicle for DS water, which may provide a starting point for future comprehensive studies to better understand the broader biological effects of DS mud. Like DS water, the composition of DS mud is notably rich in magnesium, calcium, sodium, potassium, zinc, strontium, and bromides (**Table 1**). These minerals, particularly in their specific ratios, play key roles as major dissolved cations—such as Mg^{2+}, Ca^{2+}, Na^{+}, and K^{+}—that are known to influence signal transduction and cell metabolism [14]. Magnesium ions (Mg^{2+}) are the predominant cation in DS mud (**Table 1**) and have been shown to inhibit the antigen-presenting function of human epidermal Langerhans cells both *in vivo* and *in vitro* [19]. Skin exposure to a Mg^{2+}-rich DS salt solution or DS mud may improve skin barrier function, enhance skin hydration, and reduce

inflammation in conditions such as atopic dermatitis and dry skin [20]. Additionally, strontium, zinc, and potassium salts have been demonstrated to inhibit irritation and inflammation when applied topically [21].

Epidermal integrity crucially depends on the transport of lipids and hydrolytic enzymes through lamellar bodies, originating from granular cells. This process of lamellar body exocytosis, essential for barrier repair, is intricately regulated by ionic concentrations, notably calcium (Ca^{2+}). Previous research has demonstrated a distinct Ca^{2+} concentration gradient within the epidermis, peaking in the outer layers of the stratum granulosum. Upon acute disruption of the permeability barrier, this gradient diminishes but is reinstated during barrier recovery. Conditions like psoriasis disrupt this gradient, underscoring the interplay between barrier function and Ca^{2+} distribution [21] [22]. As a result of these physiological processes, Calcium ions (Ca^{2+}) are crucial for regulating various skin functions, including keratinocyte differentiation, skin barrier formation, and permeability barrier homeostasis [21] [22]. Furthermore, there is increasing evidence of the functional existence and involvement of various calcium channels that mediate calcium flux in keratinocytes. While the precise mechanisms of the biochemical effect of DS mud on skin cells require further research, some studies suggest that these minerals might influence cellular processes related to growth factors or gene expression, ultimately affecting cell proliferation. Strontium salts found in DS mud can effectively improve skin biometric parameters, and significantly reduce symptoms of irritant contact dermatitis [23]. The high salt concentration in DS mud can also expose the skin to a Moderate Ionic Osmotic Stress (MIOS). One study suggested that this high salt concentration creates mild osmotic stress on skin cells, potentially activating signaling pathways involved in cell growth and proliferation [24] [25]. Moreover, MIOS triggers skin cells to augment water content, leading to improved skin hydration and plumpness. Following MIOS activation, MAPK, or the PI3K/Akt pathway, could be involved, and these proteins are known to play a role in cell division and stimulating skin cell renewal [24] [26]. Another study suggested that human skin exposure to DS MIOS may induce the translocation of the Nrf2-Keap1 mechanism, thereby activating a phase II enzyme cascade, that exerts survival and anti-inflammatory effects [27].

As described in **Table 2**, DS mud is composed of various clay minerals [12] [28], and clay minerals have a high affinity to bind and absorb impurities. Therefore, it is used to adsorb impurities from skin surface [29]. This impurities-binding action simulates circulation and lymphatic flow and is believed to purify and detox the skin, cure wounds, soothe irritations, and deeply cleanse the skin [30] [31]. Clay minerals, used in aesthetic medicine and in cosmetic products, as active principles or excipients, and after drying slightly on the skin, are capable of aiding natural exfoliation and improving skin texture [30] [31].

The main speculated DS mud modes of actions are schematically described in **Figure 1**.

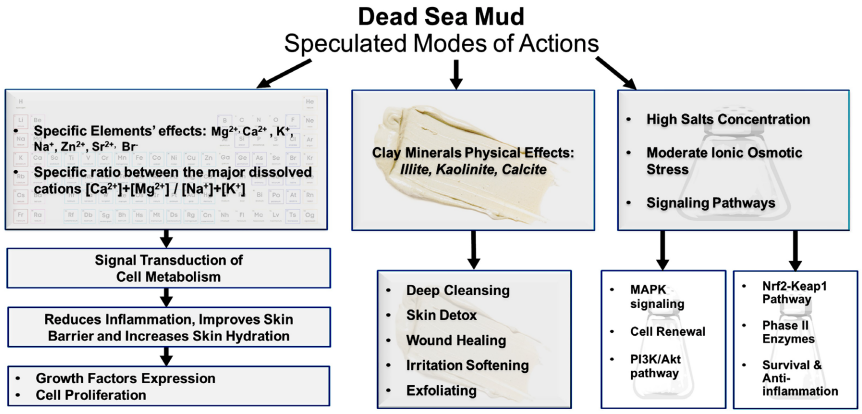

Figure 1. A scheme of the different speculating DS mud's mode of actions.

4. Formulating DS Mud in Cosmetic and Cosmeceutical Products

In a recent publication, practiced techniques for blending DS mud within various cosmetic formulae are shared [15]. DS mud fluidic homogeneity is hard to stabilize, since the dispersed mud grains tend to settle down, due to their higher density, leading to a solid-liquid phase separation. Attenuation of this natural sedimentation process could be achieved via adding anti-flocculants, or by adding super water absorbing agents which neutralize excess water. Another way to overcome DS mud sedimentation is by particle size reduction of the solid mud grains, increasing the viscosity of the fluidic mud [15].

Cosmetic items, based on DS mud, are categorized according to their application skin area, distinguishing between facial and body products, due to the different sensitivity, with small sub-categories as hand, scalp and hair items [15].

Formulation of a new mud-based product is reported to also consider customer's skin type and the desired beauty activity. Generally, pure DS mud is considered too aggressive for facial application and for sensitive and dry skin [15].

Incorporating skin-calming agents, such as aloe vera, allantoin, panthenol, and chamomile, enables safe and effective use for facial applications. Additional modifications to DS mud applications include supplementing DS mud's inherent ingredients such as metal silicate and carbonate clays [15] [29].

The adhesive texture of Dead Sea mud allows it to remain as a natural mask, adhering well to the skin's surface for a relatively long application time (5 - 10 minutes). The pleasant texture of DS mud, due to its fine grain size, is believed to be absorbed by the skin, helping the user relax while the active ingredients work effectively to improve skin smoothness [18] [32] [33].

5. Regulatory and Safety Aspects of DS Mud

According to the literature, DS mud is generally considered safe for the healthy population, based on the long historical experience of DS mud treatments in spa and health resorts [5] [15]. Despite the well-established therapeutic effects of DS

mud, when defined as a cosmetic ingredient, any claim for healing properties of DS mud is illegal, and the labelled purpose for use, is limited to beautifying the skin or improving its appearance [32]. According to the International Nomenclature of Cosmetic Ingredients (INCI), DS mud may be listed as "Silt", "Clay", "Maris Limmus Extract" or "Sea Silt" [15]. DS mud-based cosmetic manufacturers are responsible for avoiding mistaken and misleading assumptions that the mud-based cosmeceutical products could substitute medical treatments [15] [32] [34]. According to the European Commission (EC) regulation, cosmeceutical products are defined as cosmetics, and consequently, are no different from cosmetic items [32] [34] [35]. However, while formulated in skincare products, the safety of DS mud, should be assessed, like all cosmetic ingredients, addressing potential chemical hazardous, and microbial contaminations [15]. Therefore, risks of skin exposure to hazardous chemicals were studied. Heavy metals were reported to be found in mud from specific geographic locations [36]. Samples of DS mud were collected by Elkhateeb from nine different sites along the shore of the DS lake. The heavy metal concentrations measured in all DS mud samples were negligible, verifying that topical application of DS mud-containing products is free of risks [13] [37] [38]. From the list of elements prevalent in DS mud, transition metals, mainly nickel, chrome, barium, manganese, strontium, iron, zinc, and copper, are considered as potential risks to customers' health. Nickel and [37] [39] chrome are the main risk hazards in DS mud, especially if above the safety level. Therefore, their potential systemic and local toxicities were assessed, based on margin of safety calculations [36]. It was concluded that DS mud is safe for human health with respect to systemic toxicity, related to nickel and chrome, even under worst-case scenario and extreme conditions. Topical application of DS mud is safe for individuals who are non-sensitized to nickel and chrome [36]. The actual level of skin exposure to these two metals is rather low, since both metals tend to remain attached to DS mud solid clay components, and not easily released to the constituting aquatic solution [36] [40]. Abdel-Fattah analyzed the levels of toxic metals, in crude DS mud and in mud-based cosmetic products. He found that toxic metals' levels in the cosmetic products, are significantly lower than those found in samples of crude DS mud, due to dilution. Neither direct contact with the skin, nor inhalation of the dried DS mud, presents a substantial risk of the toxic metals to human health from either crude mud or mud-based cosmetics [40]. In another report, the risk of skin irritation, triggered by salts, was evaluated, using laser doppler flowmetry. The skin flux, temperature change and microcirculation were determined before and after the application of DS mud-based products and pure DS mud samples. Despite their high salt contents, all types of DS mud preparations did not cause detectable microcirculatory effects or any skin temperature changes. This is supported by experts' evaluation of DS mud as mild to skin and a non-irritating substance [40]. Radioactivity risks related to DS mud were considered since contamination of the radionuclides ^{238}U, ^{226}Ra, ^{232}Th, and ^{40}K, were reported in other types of mud. The existing levels of the radionuclides mentioned above

were measured in DS mud samples, confirming that the tested radiological compounds are below background or detection limits, presenting no health or environmental radioactivity-related risk issue [15] [36] [41] [42]. Mud microbial contamination is scarcely reported in scientific publications. However, due to clay's high surface area and free water availability, muds are relatively susceptible to microbial contaminations [14] [15]. Moreover, DS mud is not aseptic, even when collected from nature and is further exposed to microbial contamination during industrial processing. After its excavation and addition of solubilizing water, mud is mixed to obtain a homogeneous fluidic substance for napping out big particles [15]. Therefore, to ensure consumers' safety along with the product's shelf life, and in addition to the reported anti-microbial properties of DS mud, appropriate preservation methods were established [15]. According to the literature, the most common method for protecting commercial DS mud from microbial contamination is incorporating a preservative system onto the natural mud. This approach aims to use an effective preservation system with minimal undesired skin and environmental impacts, taking into consideration regulatory aspects, and customer concerns [15]. Sterilization methodologies, such as gamma irradiation, chlorination, and ozonation, are alternative ways to preserve DS muds, which are applied by some manufacturers. However, their efficacy is limited to the manufacturing time, while lacking residual protection for future product contamination [15].

6. Innovations in DS Mud Cosmetics

Innovative products and technologies involving DS mud, positioned as a traditional natural ingredient have been described:

A) Blending special active ingredients along with DS mud. In one publication, DS mud is reported to be blended with magnetized strontium hexaferrite, and this patented cosmetic combination was clinically proven to have an extra moisturizing effect [41] [43].

B) New modes of application of DS mud to skin surface. Portugal-Cohen described a leave-on mud (Dermud™), a patented technology, significantly attenuates the UVB-related biological damage to skin [17]. Another study reports a new mode of application of DS mud by smearing on a non-woven fabric, as opposed to the classical skin application mode. In another case, a body mudpack was invented for home use for application after heating in a microwave. This new mud technology was proven to effectively release body pains and reduce rheumatic symptoms [42].

C) A new protocol for manufacturing mud-based products, incorporating a special "maturation process" is a significant innovative method for DS mud cosmetic. This consists of producing mud with more precisely defined characteristics. Reported protocols workable steps include: 1) Washing the mud with water to reduce sodium salts content; 2) Ensuring environmentally friendly products by following strict "clean beauty" guidelines and avoiding addition of foreign chemicals during processing; 3) Attempts to achieve a homogeneous sub-micron grain

size, using a super grinding machine; and 4) Selecting specific mining locations, such as the bottom of the DS lake for "deep-sea" DS mud, or the delta of the Jordan River for "holy DS mud" [15].

D) Changing the recognized "muddy" texture, introducing a new skin feel for DS mud. Innovative approaches such as: 1) Using fluidic mud extract, obtained via centrifugation 2) Encapsulation or entrapped DS mud that enables mud-based formulae, avoiding unpleasant look and smell 3) Creation of mud globules, organized as a sticky DS mud ball, and 4) Formulation of mud powder obtained via controlled water expel mud technologies, for self-preparations of mud-bath for Do-It-Yourself (DIY) products at home [15] [44].

In addition to the listed above innovative approaches, there is novelty in marketing concepts. Examples include personalized DS mud-based products, tailored to individual needs, fragrance-free natural dermo-cosmetic formulations, and DIY spa-at-home sets, all featuring DS mud. These strategies aim to rejuvenate and modernize the perception of "old-fashioned"/"classic" DS mud products, thereby broadening their appeal and enhancing market relevance [15] [39] [44].

7. Discussion, Conclusions and Future Perspectives

From its documented origins in ancient history to its recognition as a therapeutic agent in modern dermatology, DS mud has become a significant natural active ingredient. Its unique mineral composition—including magnesium, calcium, sodium, potassium, zinc, and strontium—and the specific ratios between its major dissolved cations (Mg^{2+}, Ca^{2+}, Na^{+}, and K^{+}) may be responsible for DS mud's reputed therapeutic benefits, such as reducing inflammation, improving skin barrier function, and contributing to its skin-smoothing and moisturizing properties. Controlled studies support DS mud's efficacy in treating various skin conditions, from acne to eczema, highlighting its role in both beauty and skin health. Moreover, innovations in formulation have expanded its use beyond traditional mud masks to include leave-on products and specialized treatments, catering to diverse consumer needs and preferences. While the exact mechanisms of DS mud's activation remain unclear, existing research on the biological effects of DS mineral water provides valuable insights. The prevalent high concentration of minerals in DS mud influences various skin functions. Magnesium ions, predominant in DS water and mud are reported to improve skin barrier function, enhance hydration, and reduce inflammation [20]. Calcium ions regulate skin functions, including keratinocyte differentiation and barrier homeostasis [45], while strontium and zinc salts are known to help reduce skin irritation and inflammation [46]. Additionally, the high mineral concentration further enhances its therapeutic potential, particularly in treating acne [14]. The rich mineral composition can also induce Moderate Ionic Osmotic Stress (MIOS), potentially activating cell growth and hydration pathways and activating Nrf2-Keap1 mechanism [27]. On top of that, its clay minerals draw impurities and supply moisture from the deep skin layers, promoting circulation, wound healing, and exfoliation [29]. Regulatory oversight ensures the safety and

integrity of DS mud-based cosmetics, emphasizing their cosmetic rather than medicinal purpose, despite their well-documented therapeutic effects. This distinction is crucial in maintaining consumer trust and regulatory compliance. Recently, researchers have recognized the importance of the skin microbiome in maintaining skin health [16]. In a report by Ma'or *et al.* and in a report by Abu-Zurayk *et al.*, DS mud was shown to exhibit anti-microbial effects, including the inhibition of potential skin pathogens, which may partially explain its anti-acne properties [14] [16]. However, further research using up-to-date technologies is needed to fully understand DS mud's role in the skin microbiome.

In summary, ongoing research and technological advancements will pave the way for further innovations. As a natural, mineral-rich resource with scientifically proven skin benefits, DS mud continues to inspire skincare innovations and underscores the connection between health, beauty, and nature.

Acknowledgements

We would like to express our deepest gratitude to AHAVA Dead Sea Laboratories R&D scientists, for their invaluable contributions to this work. We also thank the support and good collaboration of Skin Lab of the Hebrew University of Jerusalem and the Skin Research Institute of the Dead Sea & Arava Science Center. Our appreciation is given to Dr. Miriam Oron and Dr. Gadi Cohen for reviewing and improving the quality of this manuscript.

Conflicts of Interest

The authors certify that they have no affiliation with, or involvement in any organization or entity, with any financial interest, or non-financial interest, in the subject matter or materials discussed in this manuscript. Z.M is Co-Chief Science Officer of Fosun Cosmetic Group and the Head of Dead Sea Hub. D.C is Managing the Ahava Skin Biotechnology and Biochemistry Research Lab. A.A is the Chief Researcher of AHAVA Dead Sea Lab. All three authors are also listed as researchers of the Dead Sea & Arava Science Center.

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