

Physicochemical Analysis of Clays and Sand Mud from the Estuaries of the Saloum Islands in Senegal for Cosmetic Applications

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Abstract: Cosmetics are defined as any substance or mixture intended to be applied to the external parts of the human body (epidermis, hair and scalp, nails, lips, and external genitalia) or with the teeth and oral mucosa for the purpose, exclusively or primarily, of cleaning, perfuming, altering their appearance, protecting them, keeping them in good condition, or correcting body odors. To assess and verify the compliance of clays from Senegalese inlets, which are frequently used in cosmetic applications, a comprehensive chemical analysis was conducted. Major and trace chemical elements (Cl⁻, F, K, Ca, Mg, SO₄²⁻, Fe, NO₃⁻, HCO₃⁻, CO₃²⁻, Mn, Cu, Zn, As, Cd, Cr, Pb, and Hg) were determined by atomic absorption for three samples: mud, sand, and estuarine clay. The results show that the clay complies with cosmetic standard (EC (European Community)) 1223/2009, allowing for its use in the cosmetics industry.

Key words: Clay, sand mud, chemical analysis, cosmetics.

1. Introduction

Cosmetics is a multidisciplinary field that combines basic and applied sciences, drawing on concepts from biology, chemistry, biochemistry, formulation, physiology, sociology, neurosensory sciences, pharmacy, and more... [1, 2]. Initially, improving aesthetic appearance was the primary goal in the marketing of cosmetic products. Today, consumer enthusiasm for natural and health-beneficial products is a reality. Consequently, effective products that not only enhance the skin's appearance but also promote its health have become the new demand among consumers, who are increasingly concerned about the origin, quality, and manufacturing processes of these products.

Clays and sand muds from estuaries are versatile materials with numerous applications in the medical, cosmetic, industrial, and water treatment sectors,

among others. They are widely used in various industries [3-10].

Interest in the use of clays is growing, as they contain abundant and inexpensive materials that, when disposed of, do not harm the environment [11].

Since the early days of the cosmetics industry, natural ingredients have played a central role. The use of clays for beauty care dates back to prehistoric times, when they were already used for therapeutic purposes [12-14].

To be suitable for pharmaceutical or cosmetic applications, clays must meet several chemical (stability, purity, chemical inertness), physical (texture, water content, particle size), and toxicological criteria (toxicity, safety, and microbiological purity) [15-18].

In particular, they must have no or very low toxicity, in accordance with EC Regulation (European Community)

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No. 1223/2009, which consolidates Directives 76/768/EEC and 2001/58/EC.

Clays and clay minerals are widely used in the pharmaceutical and cosmetic industries. In pharmaceuticals, they serve as excipients acting as disintegrates, carriers and release agents for active ingredients, binders, and diluents as well as emulsifiers, thickeners, and anti-caking agents. As active ingredients, they are used as antacids, gastrointestinal protectants, antidiarrheals, and dermatological protectants. In cosmetics, clays are found in creams, powders, and emulsions [12], [19, 20].

Minerals are solids with defined compositions and structures. They are essential for biochemical and biological functions and are not derived from living organisms, so the human body cannot synthesize them. Their role as cofactors or coenzymes is essential for the proper functioning and optimal appearance of the skin. The minerals most commonly used in the cosmetics industry are Zn (zinc), Cu (copper), and Se (selenium), as they possess outstanding properties for maintaining skin health [21]. They are essential for the functioning of the human body; they help the skin defend itself against oxidative stress caused by UV rays and have the ability to reverse the effects of this radiation by activating antioxidant enzymes (glutathione peroxidase, thioredoxin reductase) [22, 23].

This study aims to provide scientific information on the use of cosmetic clays and to assess potential health risks. A material intended for cosmetic and pharmaceutical use must have low or no toxicity. The presence of certain elements, even in trace amounts, can pose a significant potential threat to human health.

2. Material and Methods

Currently, the development of new cosmetic products that meet consumer demand relies on the inclusion of minerals and biologically active molecules, such as antioxidants. Indeed, these substances can serve a dual purpose: first, they act as ingredients that help mitigate the oxidation of other compounds present, and second, they serve as effective components that

promote cellular renewal or repair [21]. Antioxidants can be classified into four groups: vitamins, polyphenols, carotenoids, and minerals [22].

In this study, an in-depth physicochemical analysis was conducted to determine the composition of minerals and chemical elements

2.1 Material

Samples were collected from the coastal waters off the Saloum Islands, specifically at the beach of the Hôtel Palétuviers in Toubacouta, Fatick Region, Senegal.

The samples were stored in a cool, dark place under conditions that met the standards for physicochemical analysis.

2.2 Method

Atomic absorption spectroscopy was used for the analyses. This is a highly accurate and particularly sensitive analytical method used to determine the concentration of minerals and heavy metals in solution. The protocol was implemented in accordance with European Regulation No. 1223/2009 on cosmetic products.

3. Results and Discussion

3.1 Hydrogen Potential (pH)

The three samples (mud, sand, and clay) have a pH close to neutral, which is generally suitable for cosmetic and medical applications. More specifically, the pH of the mud collected from the estuary is 7.34, that of the sand is 7.45, and that of the clay is 7.25.

3.2 Heavy Metals

The trace metals detected by atomic absorption are listed in Table 1. To interpret the trace elements present in the clays in relation to European Union Regulation (EC) No. 1223/2009 on cosmetic products, it is necessary to compare the heavy metal concentrations in the three samples with the limits set by this regulation. Fortunately, all samples (sludge, sand, and clay) are

Table 1. Concentrations of chemical elements in the samples (silt, sand, and clay) compared to the European Cosmetics Regulation (EC) No. 1223/2009.

Elements	Mud	Sand	Clay	Limit (CE) (mg l ⁻¹)
Arsenic (As)	0.00	0.00	0.00	1-3
Cadmium (Cd)	0.37	0.29	0.24	3
Chromium (Cr)	0.18	0.14	0.18	-
Copper (Cu)	4.32	3.77	3.84	-
Manganese (Mn)	0.32	0.30	0.33	-
Mercury (Hg)	0.00	0.00	0.00	1
Lead (Pb)	0.10	0.13	0.09	10
Zinc (Zn)	4.69	3.27	3.48	-

essentially free of toxic elements such as As (arsenic) and Hg (mercury). However, they contain low levels of Cd (cadmium) and Pb (lead). Limits for other heavy metals such as Cr (chromium), Cu (copper), Mn (manganese), and Zn (zinc) are not specified by the standard.

Future studies should determine whether these potentially toxic elements are readily exchangeable or strongly bound to mineral structures.

The results show that the analyzed samples of mud, sand, and clay comply with the limits, and these samples can be considered safe for use in cosmetics in accordance with this standard.

Zinc is an element with therapeutic and regenerative properties for the skin due to its ability to penetrate the outer layers of the skin; it can also reach the dermis and the bloodstream. To optimize zinc concentrations in the skin, thereby helping to protect it against environmental factors, topical application of this component is necessary [24]. Zinc is a fundamental factor in the activity of numerous antioxidant enzymes, such as SOD (superoxide dismutase), which plays a key role in neutralizing superoxide radicals. Zinc also ensures the stability of the cell membrane and thus plays an important role in cell division and differentiation processes. Zinc ensures the longevity of keratinocytes and regulates sebum production, thereby reducing skin breakouts [22].

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3.3 The Chemical Elements

The results of the major chemical analysis of the three samples (silt, sand, and clay), obtained by atomic absorption spectrometry, are presented (Table 2). The chloride concentration in the silt is extremely high compared to the sand and clay samples. The clay has a concentration of 1.85 mg/L, which is relatively low. Fluoride concentrations are low in all samples, with a value of 0.02 mg/L for the clay. Sulfate concentrations are similar between the sand and clay, with a value of 0.12 mg/L.

Clay has a calcium concentration of 0.68 mg/L, the highest of the three samples, and a magnesium concentration of 15.30 ppm, also the highest. The

Table 2. Concentrations of chemical elements in samples (silt, sand, and clay) intended for cosmetic and industrial applications.

Elements	Mud	Sand	Clay
Chloride (Cl ⁻)	147,925	1.70	1.85
Fluor (F ⁻)	0.04	0.07	0.02
Sulfate (SO ₄ ²⁻)	0.08	0.12	0.12
Calcium (Ca ²⁺)	0.23	0.65	0.68
Magnesium (Mg)	12.00	13.40	15.30
Sodium (Na ⁺)	20.75	18.88	15.98
Potassium (K ⁺)	0.18	0.24	0.26
Iron (Fe ²⁺)	0.33	0.63	0.63
TH	2100	-	-
Carbonates (CO ₃ ²⁻)	<0.01	-	-
Bicarbonates (HCO ₃ ⁻)	4.34	-	-
Nitrates (NO ₃ ⁻)	8.26	-	-

sodium concentration in clay is 15.98 ppm, lower than the concentrations found in silt and sand. The potassium concentration is 0.26 ppm, while the iron concentration is 0.63 ppm, similar to that of the sand. Nitrates and bicarbonates are detected only in the mud, while carbonates are not detected in any of the samples (<0.01 mg/L).

Products such as honey and ghassoul, a clay mineral, are used as basic ingredients in cosmetics due to their composition, particularly their content of trace elements and minerals.

The minerals and trace elements primarily found in honey include potassium salts, calcium, sodium, copper, manganese, chlorine, sulfur, silicon, and iron. These compounds are among the elements that give honey its unique properties, which are beneficial for the skin. Honey is used as a cosmetic ingredient due to its nourishing, mildly astringent, and brightening properties. It is also recommended for treating acne thanks to its antiseptic and healing effects. Honey is also suggested for reducing the appearance of wrinkles. Studies have shown that, in fact, the processes involved in the loss of skin firmness and the appearance of wrinkles during aging share similarities with wound-healing mechanisms in terms of biological targets. To address these targets and promote the repair of aged or sun-exposed skin, cosmetologists have developed and offered a blend of

honey selected through DNA chip screening, combined with royal jelly of French origin [26].

Ghassoul is an organic mineral clay sourced from the Desert Mountains of the Moroccan Atlas, consisting primarily of stevenite, a clay mineral composed mainly of magnesium silicate. Among the main constituents of ghassoul are: the elements SiO₂ and MgO (SiO₂ + MgO ≥ 70%), with low levels of Al₂O₃, CaO, Fe₂O₃, FeO, TiO₂, Na₂O, K₂O, MnO, P₂O₅, and traces of various minerals and trace elements (Ag: silver; As: arsenic; Ba: barium; Be: beryllium; Bi: bismuth; Cd: cadmium; Ce: cerium; Co: cobalt; Cr: chromium; Cu: copper; Li: lithium; Mo: molybdenum; Nb: niobium; Ni: nickel; Pb: lead; Sb: antimony; Sr: strontium; V: vanadium; Y: yttrium; Zn: zinc; Hg: mercury). Thanks to its rich composition, ghassoul has become a key ingredient in cosmetology and dermatology. As a base ingredient, it is incorporated into the manufacture of numerous dermatological products, such as face creams and acne treatments. It is also used as a base component in the cosmetics industry for the production of shampoos, body washes, soaps, and face and body creams.

The chemical composition of the samples, which is similar to that of ghassoul, justifies its use in cosmetics. Its high mineral and trace element content gives it significant absorption power and CEC (cation exchange capacity) [27].

4. Conclusion

This study contributes to the promotion of our natural resources, and the results obtained confirm traditional practices.

The organic cosmetics market is booming, with steady growth reflecting consumers' interest in more natural products. This trend is particularly evident in the development of products that address specific hormonal needs.

Conventional cosmetics, which often use synthetic ingredients, raise several health and environmental concerns.

In conclusion, clay has potential for use in cosmetic products, but further efforts are needed to bring it into compliance with pharmaceutical standards.

References

- [1] Véronique, N.-R., and Bonté, F. 2008. "Chimie et cosmétiques." *Actualité chimique*, No. 323-324: 10-12.
- [2] Regulation (EC) No. 1223/2009 of the European Parliament and of the Council of 30 November 2009 on Cosmetic Products.
- [3] Grim, R. E. 1962. *Applied Clay Mineralogy*. New York: McGraw-Hill.
- [4] Van Olphen, H. 1977. *An Introduction to Clay Colloid Chemistry* (2nd ed.). New York: Wiley.
- [5] Jepson, W. B. 1984. "Kaolins: Their Properties and Uses." *Philos. Trans. R. Soc. Lond. A* 311: 411-32.
- [6] Murray, H. H. 1986. "Clays." *Ullmann's Encyclopedia of Industrial Chemistry*, Vol. A7. Weinheim: VCH, pp. 109-36.
- [7] Murray, H. H. 1999. "Applied Clay Mineralogy Today and Tomorrow." *Clay Miner.* 34: 39-49.
- [8] Murray, H. H. 2000. "Traditional and New Applications for Kaolin, Smectite, and Palygorskite: A General Overview." *Appl. Clay Sci.* 17: 207-21.
- [9] Murray, H. H. 2003. "Clays in Industry." In *A Clay Odyssey. Proceedings of the 12th International Clay Conference*, edited by Dominguez, E. A., Mas, G. R., Cravero, F. Elsevier, Amsterdam, pp. 3-14.
- [10] Harvey, C. C., and Murray, H. H. 1993. "The Geology, Mineralogy and Exploitation of Halloysite Clays of Northland, New Zealand." In *Kaolin Genesis and Utilization*, edited by Murray, H. H., Bundy, W. M., and Harvey, C. C. Provo: The Clay Minerals Society.
- [11] Bergaya, F., Theng, B. K. G., and Lagaly, G., 2006. *Handbook of Clay Science*. Amsterdam: Elsevier.
- [12] Carretero, M. I. 2002. "Clay Minerals and Their Beneficial Effects upon Human Health." *A Review. Appl. Clay Sci.* 21: 155-63.
- [13] Carretero, M. I., Gomes, C. S. F., and Tateo, F. 2006. "Chapter 11.5 Clays and Human Health." In *Developments in Clay Science*. Volume 1. Amsterdam, The Netherlands: Elsevier, pp. 717-41.
- [14] Rautureau, M., Figueiredo Gomes, C. D. S., Liewig, N., and Katouzian-Safadi, M. 2017. *Clays and Health*. Cham, Switzerland: Springer International Publishing. ISBN:978-3-319-42883-3.
- [15] López-Galindo, A., and Viseras, C. 2004. "Pharmaceutical and Cosmetic Applications of Clays." In *Clay Surfaces. Fundamentals and Applications*, edited by Wypych, F., and Satyanarayana, K. G. Amsterdam: Elsevier, pp. 267-89.
- [16] López-Galindo, A., Viseras, C., and Cerezo, P. 2007. "Compositional, Technical and Safety Specifications of Clays to Be Used as Pharmaceutical and Cosmetic Products." *Appl. Clay Sci.* 36: 51-63.
- [17] Tateo, F., and Summa, V. 2007. "Element Mobility in Clays for Healing Use." *Appl. Clay Sci.* 36: 64-76.
- [18] Viseras, C., Aguzzi, C., Cerezo, P., and Lopez-Galindo, A. 2007. "Uses of Clay Minerals in Semisolid Health Care and Therapeutic Products." *Appl. Clay Sci.* 36: 37-50.
- [19] Viseras, C., Cultrone, G., Cerezo, P., Aguzzi, C., Baschini, M., Valle, J., and López, A. 2006. "Characterization of Northern Patagonian Bentonites for Pharmaceutical Use." *Appl. Clay Sci.* 31: 272-81. 13.
- [20] Carretero, M. I., Gomes, C. S. F., and Tateo, F. 2013. "Clays, Drugs and Human Health." In *Handbook of Clay Science (2nd ed., Part B: Techniques and Applications)*, edited by Bergaya, F., and Lagaly, G. The Netherlands: Elsevier, pp. 711-64.
- [21] Delaporte, A. 2024. "Conception de capsules naturelles innovantes et compréhension des interactions au sein de matrices cosmétiques (Caps4Skin)." Thèse, Université Le Havre Normandie.
- [22] Michalak, M., Pierzak, M., Kręcis, B., and Suliga, E. 2021. "Bioactive Compounds for Skin Health: A Review." *Nutrients* 13 (1): 203. ISSN:2072-6643. doi:10.3390/nu13010203.
- [23] Bjørklund, G., Shanida, M., Lysiuk, R., Antonyak, H., Klishch, I., Shanida, V., and Peana, M. 2022. "Selenium: An Antioxidant with a Critical Role in Anti-Aging." *Molecules* 27 (19): 6613. ISSN:1420-3049. doi:10.3390/molecules27196613.
- [24] Rostan, E. F., DeBuys, H. V., Madey, D. L., and Pinnell, S. R. 2002. "Evidence Supporting Zinc as an Important Antioxidant for Skin." *International Journal of Dermatology* 41 (9): 606-11. ISSN:0011-9059. doi:10.1046/j.1365-4362.2002.01567.x.

- [25] Pickart, L., and Margolina, A. 2018. "Skin Regenerative and Anti-Cancer Actions of Copper Peptides." *Cosmetics* 5 (2): 29. ISSN:2079-9284. doi:10.3390/cosmetics5020029.
- [26] Bonté, F., Rossant, A., Archambault, J. C., and Desmoulière, A. 2011. "Miels et plantes: De la thérapeutique à la cosmétique." *La phytothérapie européenne*, No. 63: 22-28.
- [27] Belamine, M. 2012. "Le Ghassoul, propriétés cosmétiques et thérapeutiques." Thèse, Université Mohammed V, Rabat, Maroc.