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REVIEW ARTICLE

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The science behind wet wipes for infant skin: Ingredient review, safety, and efficacy

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Abstract

In the diapered area, the continuous exposure to excess moisture and irritants from urine and feces weakens the stratum corneum, making the skin more susceptible to irritation. The use of wet wipes for infants (baby wipes) is a common practice to clean skin after urine or a bowel movement, and this practice even extends to cleaning the hands and face, resulting in repeated daily use. Therefore, ensuring that baby wipes contain ingredients that are safe and mild on skin is important to help minimize skin irritation and discomfort. While disposable baby wipes have been shown to be effective and gentle at cleaning infant skin, even the skin of premature infants, there is growing public concern regarding their safety and tolerability. Not all products are made the same, as differences exist in manufacturing processes, ingredients, materials, safety, and quality testing. Therefore, it is important that healthcare professionals have accessible evidenced-based information on the safety and tolerability of common ingredients found in baby wipes to optimally educate their patients and families. Herein, we provide a review on best practices for ingredient selection, safety, and efficacy of baby wipes.

KEYWORDS

baby wipe, ingredients, preservatives, skin care, wet wipe

1 | INTRODUCTION

Skin irritation in the diapered region (commonly referred as diaper dermatitis) is one of the most common skin disorders found in infancy, with the highest incidence at 9-12 months of age.[1] Overhydration and prolonged exposure to urine and feces are known to be the main contributors to skin irritation in the diapered area.[2] However, an infant's diet, medications, underlying skin conditions, certain product ingredients, caretaker behavior, and practices such as infrequent diaper changes or ineffective cleaning can also influence the occurrence of diaper dermatitis. It has been reported that the diapering process can be a stressful event for an infant.[3] The presence of skin irritation can exacerbate this response, leading to increased pain and discomfort. Ensuring the diapered area is kept dry and clean and that products used do not adversely impact the skin can help minimize the occurrence of dermatitis in the diapered region and, in turn, provide comfort to the infant.

Rodriguez and Cunningham contributed equally to this work.

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Herein, we provide a review on best practices for ingredients selection, safety, and efficacy of baby wipes to help make more informed decisions when selecting products for infant diapered skin care.

2 | ANATOMY OF A BABY WIPE

A disposable baby wipe consists of three main components—the basesheet (the cloth that makes the wipe), the formulation (the ingredients in the solution that make the wipe wet and help with cleaning), and package, as shown in Figure 1. The packaging (not discussed here) and the basesheet are the most physically obvious components of a wipe. There are three types of basesheets with differences in composition which translates into differences in thickness, absorbency, and softness to touch. These differences can impact cleaning performance but the materials themselves are quite common—wood pulp, polypropylene, polyester, or combinations thereof.

Over the last two decades, significant advances have been made to baby wipes. More recently, efforts have been centered on the removal of ingredients with irritation or skin-sensitizing potential such as methylisothiazolinone (MI) and phenoxyethanol.[4] In fact, five clinical studies have demonstrated that the use of modern baby wipes is superior to using water and cloth to clean diapered skin (see Table 1). In 2016, a recommendation was made by the European Roundtable Meeting on Best Practice Healthy Infant Skin Care stating that a wet wipe for infant skin should contain pH buffers to maintain the slightly acidic pH of the skin, should be free of potential irritants, and should contain well-tolerated preservatives.[5]

2.1 | Formulation of baby wipes

Formulating a hypoallergenic, safe, gentle, and effective baby wipe can be challenging as the wipe must meet regulatory, safety, and performance measures while remaining aesthetically pleasing. It is preferred that baby wipes are formulated with a very large percentage of water. However, water alone is not enough to effectively remove water-insoluble residues from feces and prevent the growth of microorganisms or maintain a healthy skin pH. Thus, it is important that baby wipes also contain an extremely mild surfactant (detergent or cleanser) to lower surface tension for better cleaning, a preservation system to ensure product freshness before and during use, a pH adjusting (buffering) system to maintain a solution pH similar to infant skin, and, optionally, skin-benefiting ingredients that reduce frictional damage, replenish the skin lipids, etc A common misconception about baby wipes is that they contain drying alcohols such as ethanol and isopropanol. While ethanol and isopropanol can be found in some sanitizing wipes, these ingredients have not been used in branded baby wipes.

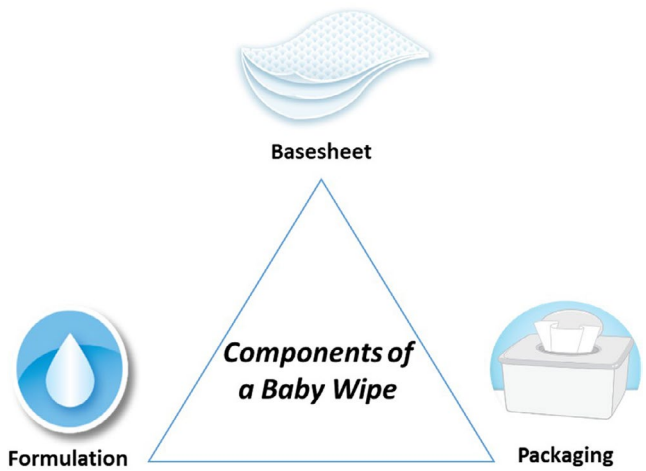

FIGURE 1 Main components of a baby wipe

2.2 | Ingredient classification and function

2.2.1 | Water

The water used in baby wipes should range from highly purified to reverse osmosis quality. The treatment process removes most of the salt content ($CaCO_3$ and $MgCO_3$, contributing to overall hardness) and other residual minerals that can serve as nutrients for microorganisms. Most water systems also employ ozone and ultraviolet light processing to sterilize the water before use. In addition, extensive filtration removes total dissolved solids and microbes. These intentional processes produce water that is of a higher quality than standard drinking water and some types of distilled water.

2.2.2 | Surfactants

Surfactants are the molecules within the formulation that provide cleaning action. Surfactants contain hydrophilic moieties attached to hydrophobic end chains. It is the hydrophobic end chains that bind to oily residue on the skin surface and help remove it. For baby wipes, it is important to use a surfactant that can adequately remove the oily molecules within feces without removing skin lipids, which can lead to skin barrier damage with repeated or prolonged use. For baby wipes, the surfactant fraction would not be expected to exceed 1% by weight of the formula and, in most cases, would be below 0.3% by weight.[6] This is in stark contrast to bottled baby products (body wash, shampoo, hand soap) where the surfactant concentration is typically between 5% and 20% by weight as dilution is expected upon use followed by rinsing.[6]

Surfactants are typically classified as anionic (negatively charged), cationic (positively charged), and non-ionic (no net charge). Generally, non-ionic surfactants are the mildest on skin; however, there are examples of suitable surfactants in all classifications. Table 2 contains a list of typical baby wipe surfactants along with maximum use concentrations and references to full reviews on their safety profile as concluded by the Cosmetic Ingredient Review (CIR), an independent expert panel consisting of dermatologists, toxicologists, academic researchers in

TABLE 1 Summary of literature comparing baby wipes with water and cloth

Reference	Subjects	Method	Results summary
Ehretsmann et al[12]	102 full-term infants	Investigator-blinded, parallel study comparing infants cleaned with a baby wipes vs water and cloth/implement	No difference is rash severity for genitals, the perianal area, and buttocks. Decrease in the severity of diaper rash in the intertriginous folds with the baby wipes group.
Lavender et al[33]	280 full-term healthy newborns	Infants randomized to have the diaper area cleaned with a baby wipes or cotton wool and water	Measured skin pH, water loss, hydration, and skin erythema. Found no differences between use of cotton wool and water and baby wipes.
Adam et al[34]	15 full-term infants	Infants randomized to cleaning diaper area with baby wipe or washcloth and water for 14 d	Buttocks skin pH of infants cleaned with water and cloth was significantly higher than untreated site. Infants cleaned with baby wipes showed the same buttocks skin pH as the untreated site.
Visscher et al[35]	130 preterm infants	Infants randomized to have their diaper area cleaned by a baby wipe or water and gauze.	Diapered skin erythema and pH were significantly lower, and barrier function was better in infants cleaned with one of the baby wipes tested as compared to water and gauze.
Odio et al[13]	82 full-term infants	Randomized, double blinded study comparing skin health attributes of infants cleaned with a baby wipe or water and washcloth for 8 d	Diapered skin erythema scores were statistically lower in the perianal region of subjects cleaned with baby wipes. No differences in skin barrier function were observed between the groups.
Garcia Bartels et al[36]	44 healthy full-term neonates	Randomized, prospective pilot study, comparing skin transepidermal water loss (TEWL), skin pH, hydration, interleukin 1α (IL-1α) and microbial colonization of infants cleaned with a baby wipe or water-moistened washcloth for 28 d	Significantly lower TEWL was found on the buttock in the group using baby wipes compared to water. No significant difference was observed in skin hydration, IL-1α, skin pH, and microbial colonization between the two care regimens.

medicinal and pharmaceutical sciences, industrial scientists, and representatives from the FDA and consumer groups.

2.2.3 | Preservatives

As baby wipes contain a large amount of water, this can allow microorganism growth. To prevent contamination, various manufacturing and testing practices are followed by major suppliers. The use of preservatives ensures the product is not contaminated before the consumer begins using it, and that it maintains a reasonable shelf life for use. Ensuring a consistent product, free of pathogenic microorganisms, should be of the highest concern, especially when cleaning infants with compromised skin.

In the personal care industry, the default listing of preservative chemicals is maintained by the European Union (EU) and is known as Annex V.[7] Ingredients on this list are recognized for their antimicrobial action and listed with acceptable and safe usage concentrations. A subset of these chemicals applicable to baby wipes is shown in Table 3. Notably, many of the chemicals in Annex V are not allowed for use in children's products due to regulation at the state or country level. The US FDA does not maintain a list of approved preservatives but does have the authority to limit the use of ingredients in certain product classifications. After considering safety, allergenicity and irritation potential, the choice of preservative in a formulation depends on water solubility, effective concentration, pH compatibility, odor, and consumer expectation. A good example of regulatory and industrial response has been the removal of formaldehyde donating preservatives and MI from wipes and other leave-on products following many reports of contact dermatitis and sensitization in the diapered area and in other common areas of baby wipes use such as hands and face. Currently, it is rare to find this ingredient in mainstream baby wipes.[8]

In addition to known preservatives, many products employ additional ingredients that improve preservative performance, allowing for reduced concentration. These ingredients function primarily by improving penetration into microbial cells or chelation.

2.2.4 | pH adjustment

At birth, infant skin pH is neutral; within a few days of life, the acid mantle forms and skin pH has a significant drop to slightly acidic values around 5-5.5.[9] Maintaining the acid mantle of the skin ensures the skin barrier function remains intact.[10] This slightly acidic environment also serves to slow growth of microorganisms.[11] The adjustment of formulation pH serves two critical purposes—to match the pH of the surface of the skin and to prevent microbial growth in the formulation. Using baby wipes with a slightly acidic pH has been shown to maintain skin pH at healthy levels more effectively than water and cloth alone and to be well tolerated.[12-15] In a baby wipe formulation, a balanced pH can be accomplished through the use of

TABLE 2 Common surfactants found in mainstream baby wipes and associated safety information

Surfactant INCI name	Typical use concentration in wipes (% weight)	Human dermal safety assessment	Cosmetic ingredient review reference
Coco-glucoside, or Decyl glucoside, or Lauryl glucoside	<0.50% Cunningham (2008)[6]	Not a primary skin irritant or sensitizer up to 5% Not irritating in various ocular studies up to 1% Safe in present practices of use and concentrations when formulated to be non-irritating	Fiume et al[37]
Coco-betaine (note this is not the same chemical as cocoamidopropyl betaine)	<0.50% Cunningham (2008)[6]	Not a primary skin irritant or sensitizer even at high concentrations Some ocular irritation when used above 10% Safe in present practices of use and concentrations when formulated to be non-irritating	Burnett et al[38]
Bis-PEG/PPG-16/16 PEG/PPG-16/16 dimethicone	0.10%-0.45% Sheehan (2007)[39]	Not a primary skin irritant or sensitizer even at high concentrations Not an ocular irritant Safe in present practices of use and concentrations when formulated to be non-irritating	Bergfeld et al[40]
Polysorbate 20	<0.50% Cunningham (2008)[6]	Little or no irritation or sensitization in multiple tests of dermal or ocular exposure Safe in present practices of use and concentrations when formulated to be non-irritating	Anon [41]
PEG-40 hydrogenated castor oil	<0.80% Sheehan (2007)[39]	Little or no irritation or sensitization in multiple tests of dermal or ocular exposure Safe in present practices of use and concentrations when formulated to be non-irritating	Pang et al[42] Burnett et al[43]
Glyceryl stearate	1.0%-2.0% Cunningham (2012)[44]	Little or no irritation or sensitization in multiple tests of dermal or ocular exposure Safe in present practices of use and concentrations when formulated to be non-irritating	Anon[45] Johnson [46]
Glyceryl stearate citrate	0.5%-2.0% Cunningham (2012)[44]	Little or no irritation or sensitization in multiple tests of dermal or ocular exposure Safe in present practices of use and concentrations when formulated to be non-irritating	Johnson [47]
Sodium cocoamphoacetate or Disodium cocoamphodiacetate	<0.50% Cunningham (2008)[6]	Not a primary irritant or sensitizer at typical use concentrations to skin or eyes Safe in present practices of use and concentrations when formulated to be non-irritating	Anon [48] Andersen et al[20]

common organic acids (malic acid or citric acid) and conjugate bases (sodium citrate, sodium bicarbonate, sodium phosphate) to create a buffer system.

Premature infants (especially extremely premature infants) or infants with a compromised skin barrier are more susceptible to the penetration of irritants and infection. Consideration should be given to developing a documented protocol for managing and maintaining healthy diapered skin for this vulnerable population. The Association of Women's Health, Obstetric, and Neonatal Nurses has established evidence-based clinical practice skin care guidelines for preterm and healthy infants as an informational resource for nursing practice based on current research and recognized authorities.[16]

2.2.5 | Skin benefit agents

This is the broadest category of baby wipe ingredients, used to improve the overall aesthetics of the wipe, help minimize friction against the skin, or provide moisturization benefits, among others. The most common ingredients are butoxy PEG-4 PG-amodimethicone,[17] xanthan

TABLE 3 Preservatives listed on EU Annex V that are or have been associated with baby wipes[7]

Preservative	Maximum approved concentration (% weight)[39]	Typical use concentration in wipes (% weight)	Approval status	Human dermal safety assessment	Cosmetic ingredient review reference
Sodium Benzoate (Benzoic Acid)	0.50% (acid form)	<0.45%	Approved at this level for leave-on products, including wipes Last updated 25-Oct-2010	Not a sensitizer Safe for use up to 5%	Nair[49] Johnson et al[50]
Potassium Sorbate (Sorbic Acid)	0.60% (acid form)	<0.50%	All products Last updated 16-Oct-2010	Not irritating or sensitizing up to 0.5%	Andersen et al[20] Anon[51]
Phenoxyethanol	1.00%	<0.70%	All products Last updated 16-Oct-2010	Neither a primary irritant or sensitizer	Andersen et al[52]
Methylisothiazolinone	0.0015%	Not used or allowed	Not allowed in leave-on or wipes Rinse-off products only Last updated 14-Sep-2017	Strong sensitization potential Not recommended for leave-on products	Burnett et al[53]

gum,[18] glycerin,[19] and behenyl alcohol.[20] Various botanicals and vitamins are added including *Aloe Barbadensis*, *Chamomilla Recutita*, and vitamin E derivatives. A full review is beyond the scope of this review but as these botanical ingredients contain many chemicals and can have seasonal variability when they are harvested, it is important that their presence be carefully monitored.[4,8] Skin benefit agents serve as market differentiators and meet the needs of their consumer group. Full safety profiles of these and many other cosmetic product ingredients are available via the searchable database maintained by Cosmetic Ingredient Review (https://www.cir-safety.org/ingredients).

3 | MICROBIOLOGICAL TESTING OF BABY WIPES

A critical part of ensuring baby wipes are safe and effective to clean infant skin is following specific microbiological quality standards prior to product distribution. As is the case with most non-sterile formulated personal care products, baby wipes require specific analyses to ensure they (1) do not contain harmful or high levels of microbes following manufacturing and (2) can control the growth of microbes introduced during use. Non-profit scientific organizations, such as the United States Pharmacopeia (USP) and the European Pharmacopeia (EP), have published guidelines on the preferred approaches for completing these analyses.

Prior to releasing baby wipes for sale to consumers, an evaluation of the final product should be completed for the presence and level of microbes within the product. For example, the USP recommends that methods used in the release of non-sterile products have data available that demonstrates the ability for methods to successfully recover and quantify *Staphylococcus aureus*, *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Candida albicans*, and *Aspergillus brasiliensis*.[21]

Any products that have a water activity level of >0.90 are susceptible to the growth of microbes in the product as this is the minimum level of water required for bacteria and fungi to grow.[22-24] As such, products at or exceeding this level of water, such as wipes, should include a preservative to prevent the growth of microbes that may be introduced post-manufacturing. A likely route of post-manufacturing product contamination is while dispensing the product during use,[25] a reason why packaging is a key component. In this scenario, transient or normal flora from a wipes' user can transfer from the hands onto the stack of wipes in the product package. To assure a baby wipe product is effectively preserved and able to overcome this type of contamination, a confirmatory lab test must be utilized to ensure microbial growth will not occur during normal product use. Specifically, the test should involve adding a defined number of diverse organisms (at a minimum those recommended by USP/EP but others may be added) to a defined quantity of product and then monitoring the survival and/or growth of the added organisms over time.[26] This test is commonly utilized on product that has been freshly made and on product aged under ambient or accelerated (high temperature, high relative humidity) conditions. While there is no universally applied approach in how this test is conducted for wipes, many manufacturers utilize USP and/or EP guidance as the basis for establishing their method and acceptance criteria.

The performance of the preservative system is one of the most important factors that go into determining the expiration date on the package. Baby wipes that do not have a proper preservative system should have a much shorter expiration date (or period after opening) as the product does not have a means to prevent microbial growth post-manufacturing. This is especially critical when the dispensing of the wipes requires significant contact by human hands, that is, transfer of normal flora into the package. Wipes should not be used outside of the printed expiration dating on the package and should be stored as directed by the labeling on the package.

4 | SAFETY TESTING OF BABY WIPES

Baby wipe safety profiles should include both the individual ingredients and the whole product. Dermal reactions may be either irritant

or allergic. Since often baby wipes are also used around the face, the potential for eye irritation should also be considered. Currently, safety testing can be accomplished via animal test models, non-animal in vitro test models, and clinical human subject testing. It is the latter two options that have gained preference when appropriate.

Human subject testing occurs after the ingredient, formulation assessment is complete, and it is determined safety risks are unlikely. Tests of this nature are routinely executed under the control of Good Clinical Practices (GCPs) to demonstrate tolerance and confirm their purported use. It should be stressed that testing involving human subjects is used to confirm cosmetic products are safe and not to determine if hazards exist. As baby wipes are used for cleaning the skin, dermal irritation and allergic reactions are of primary importance, as well as eye irritation. Common methods used to assess the tolerability of wipes are shown in Table 4. While these tests will have protocols defined by the testing laboratories and study sponsors, the basis of their design is from the scientific literature. As the studies are human subject tests, the subjects enrolled can vary based upon the objectives and study design. For example, products which are designed for sensitive skin may enroll subjects with sensitive skin.

The repeated insult patch test confirms the test article does not induce allergy in naïve subjects.[27,28] The cumulative irritation test assesses the irritation potential of the test article after repeated, prolonged exposure, typically 5-21 days, to the same application site.[29-31] Phototoxicity/ photoallergy confirms the test article does not produce irritant or allergenic effects after exposure to UV light.[32] An ocular installation test confirms a lack of eye irritation, measures tear formation, and assesses subjective burning or stinging. Safety-in-use can assess overall product suitability consistent with the intended use based on the study design. Collectively, the ingredient safety profile, a thorough assessment by a suitably trained professional, and confirmatory safety testing assure continued product and consumer safety.

5 | CONCLUSION

In the diapered area, overhydration and presence of irritants from urine and feces are main contributors to skin irritation. Ensuring effective removal of residues from urine and feces, maintaining gentle contact with skin, using products that are free from potential irritants and contaminants and that can support the acid mantle of the skin can help promote skin health. In recent years, significant advances have been made to the development of baby wipes, including removal of ingredients with irritation or allergenicity potential. In fact, several clinical studies have demonstrated that properly formulated baby wipes can be superior to the use of water and cloth, even on premature skin. However, consideration should be given to developing a documented protocol for managing and maintaining healthy diapered skin on extremely premature infants, or infants with an underlying skin condition. When caring for infant skin, it is important to understand all the factors that can contribute to skin irritation and potentially result in dermatitis, as well as being selective about the diapering products used on infant skin. It is important to note that not all baby wipes are made the same. Ingredients in baby wipes should be carefully selected by industry professionals based on their safety profile, allergenicity, and tolerability. Furthermore, wipes manufacturing processes should adhere to quality guidelines established by recognized scientific organizations to ensure the wipes are not contaminated before or after use. In addition, safety testing must be performed considering the unique features of infant skin to ensure tolerability, low irritation potential, and skin sensitivity to the product.

TABLE 4 Common methods used to test tolerability of diaper wipes

Test	End points
Repeated insult patch test (RIPT)	Allergy, irritation
Cumulative irritation test (CIT)	Irritation
Phototoxicity/photoallergy (PT/PA)	Photoallergy (UV-induced), irritation
Ocular installation	Eye irritation
Safety-in-use	Suitability

CONFLICT OF INTEREST

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REFERENCES

1. Ward DB, Fleischer AB, Feldman SR, Krowchuk DP. Characterization of diaper dermatitis in the United States. *Arch Pediatr Adolesc Med*. 2000;154:943.
2. Gregorio J, Rodriguez K. Diaper dermatitis in infant skin: causes and mitigation. *Neonatal Intensive Care*. 2017;30:38-40.
3. Comaru T, Miura E. Postural support improves distress and pain during diaper change in preterm infants. *J Perinatol*. 2009;29:504-507.
4. Dumycz K, Kunkiel K, Feleszko W. Cosmetics for neonates and infants: haptens in products' composition. *Clin Transl Allergy*. 2019;9:15.
5. Blume-Peytavi U, Lavender T, Jenerowicz D, et al. Recommendations from a European roundtable meeting on best practice healthy infant skin care. *Pediatr Dermatol*. 2016;33:311-321.
6. Cunningham C, Mundschau S, Seidling J, Wenzel S. Baby care. In: Schlossman M, ed. *The Chemistry and Manufacture of Cosmetics*, 2nd edn, vol. 2. Chicago: Allured; 2008:1063-1154.
7. Annex V, list of preservatives allowed in cosmetics. European Commission. http://data.europa.eu/euodp/en/data/dataset/cosmetic-ingredient-database-list-of-preservatives-allowed-in-cosmetic-products. Published 2017. Last accessed November 21, 2019.
8. Yu J, Treat J, Chaney K, Brod B. Potential allergens in disposable diaper wipes, topical diaper preparations, and disposable diapers. *Dermatitis*. 2016;27:110-118.
9. Visscher MO, Chatterjee R, Munson KA, Pickens WL, Hoath SB. Changes in diapered and nondiapered infant skin over the first month of life. *Pediatr Dermatol*. 2000;17:45-51.
10. Rippke F, Schreiner V, Schwanitz H-J. The acidic milieu of the horny layer: new findings on the physiology and pathophysiology of skin pH. *Am J Clin Dermatol*. 2002;3:261-272.

11. Lambert RJW. A new model for the effect of pH on microbial growth: an extension of the Gamma hypothesis. *J Appl Microbiol*. 2011;110:61-68.
12. Ehretsmann C, Schaefer P, Adam R. Cutaneous tolerance of baby wipes by infants with atopic dermatitis, and comparison of the mildness of baby wipe and water in infant skin. *J Eur Acad Dermatology Venereol*. 2001;15(Supplement 1):16-21.
13. Odio M, Streicher-Scott J, Hansen RC. Disposable baby wipes: efficacy and skin mildness. *DermatolNurs*. 2001;13: 107-112, 117–118, 121.
14. Priestley GC, MeVittie E, Aldridge RD. Changes in skin pH after the use of baby wipes. *Pediatr Dermatol*. 1996;13:14-17.
15. Baranda L, González-Amaro R, Torres-Alvarez B, Alvarez C, Ramírez V. Correlation between pH and irritant effect of cleansers marketed for dry skin. *Int J Dermatol*. 2002;41:494-499.
16. Brandon D, Hill CM, Heimall L, et al. Neonatal Skin Care: Evidence Based Clinical Practice Guideline. 4th ed. Association of Women's Health Obstetrics and Neonatal Nurses; 2018.
17. Nair B. Final report on the safety assessment of Stearoxy Dimethicone, Dimethicone, Methicone, Amino Bispropyl Dimethicone, Aminopropyl Dimethicone, Amodimethicone, Amodimethicone Hydroxystearate, Behenoxy Dimethicone, C24-28 Alkyl Methicone, C30-45 Alkyl Methicone, C30-45 Alkyl Dimethicone, Cetearyl Methicone, Cetyl Dimethicone, Dimethoxysilyl Ethylenediaminopropyl Dimethicone, Hexyl Methicone, Hydroxypropyldimethicone, Stearamidopropyl Dimethicone, Stearyl Dimethicone, Stearyl Methicone, and Vinyldimethicone. *Int J Toxicol*. 2003;22(Suppl 2):11-35.
18. Fiume MM, Heldreth B, Bergfeld WF, et al. Safety assessment of microbial polysaccharide gums as used in cosmetics. *Int J Toxicol*. 2016;35(1_suppl):5S-49S.
19. Becker LC, Berfeld WF, Belsito DV, et al. Safety assessment of glycerin as used in cosmetics. *Int J Toxicol*. 2019;38(3_suppl):6S-22S.
20. Andersen FA. Reviewed by the Cosmetic Ingredient Review Expert Panel. Annual review of cosmetic ingredient safety assessments: 2005/2006. *Int J Toxicol*. 2008;27(1_suppl):77-142.
21. United States Pharmacopeial Convention. Chapter 51: Antimicrobial effectiveness testing. In: *United States Pharmacopeia 36 - National Formulary 31*. Rockville, MD: United States Pharmacopeia; 2012:54-55, 885–889.
22. Brown AD. Microbial water stress. *Bacteriol Rev*. 1976;40:803-846.
23. Manzoni S, Schimel JP, Porporato A. Responses of soil microbial communities to water stress: results from a meta-analysis. *Ecology*. 2012;93:930-938.
24. Moyano FE, Manzoni S, Chenu C. Responses of soil heterotrophic respiration to moisture availability: An exploration of processes and models. *Soil Biol Biochem*. 2013;59:72-85. https://doi.org/10.1016/j.soilbio.2013.01.002.
25. Cremieux A, Cupferman S, Lens C. Method for evaluation of the efficacy of antimicrobial preservatives in cosmetic wet wipes. *Int J Cosmet Sci*. 2005;27:223-236.
26. United States Pharmacopeial Convention. Chapter 61: Microbial examination of nonsterile products: microbial enumeration tests. In: *United States Pharmacopeia 36 - National Formulary 31*. Rockville, MD: United States Pharmacopeia; 2012.
27. Hardy J. Allergy, hypersensitivity and cosmetics. *J Soc Cosmet Chem*. 1973;24:423-468.
28. Giovacchini RP, Calandra JC. Old and new issues in the safety evaluation of cosmetics and toiletries. *CRC Crit Rev Toxicol*. 1972;1:361-378.
29. Lanman B, Elvers W, Howard C.The role of human patch testing in a product development program. In: Proceedings: Joint Conference on Cosmetic Sciences. Washington DC: Toilet Goods Association; 1968:135-145.
30. Richard SB, James PB. A reappraisal of the 21-day cumulative irritation test in man. *J Toxicol Cutan Ocul Toxicol*. 1982;1:109-115.
31. Kligman AM, Wooding WM. A method for the measurement and evaluation of irritants on human skin. *J Invest Dermatol*. 1967;49:78-94.
32. Harbor L, Baer R, Bickers D. Technique of evaluation of phototoxicity and photoallergy in biologic systems, including man with particular emphasis on immunologic aspects. In: Fitzpatrick T, Pathak M, Harber L, Seiji M, Kukita A, eds. *Sunlight and Man*. Tokyo: University of Tokyo Press; 1974:515-528.
33. Lavender T, Furber C, Campbell M, et al. Effect on skin hydration of using baby wipes to clean the napkin area of newborn babies: assessor-blinded randomised controlled equivalence trial. *BMC Pediatr*. 2012;12:59.
34. Adam R, Schnetz B, Mathey P, Pericoi M, de Prost Y. Clinical demonstration of skin mildness and suitability for sensitive infant skin of a new baby wipe. *Pediatr Dermatol*. 2009;26:506-513.
35. Visscher M, Odio M, Taylor T, et al. Skin care in the NICU patient: effects of wipes versus cloth and water on stratum corneum integrity. *Neonatology*. 2009;96:226-234.
36. Garcia Bartels N, Massoudy L, Scheufele R, et al. Standardized diaper care regimen: a prospective, randomized pilot study on skin barrier function and epidermal IL-1α in newborns. *Pediatr Dermatol*. 2012;29:270-276.
37. Fiume MM, Heldreth B, Bergfeld WF, et al. Safety assessment of decyl glucoside and other alkyl glucosides as used in cosmetics. *Int J Toxicol*. 2013;32(5_suppl):22S-48S.
38. Burnett CL, Bergfeld WF, Belsito DV, et al. Safety assessment of alkyl betaines as used in cosmetics. *Int J Toxicol*. 2018;37(1_suppl):28S-46S.
39. US Patent 9,315,929. Sheehan AA. Non-wovens with high interfacial pore size and method of making same. 2007.
40. Bergfeld W, Belsito D, Hill R, et al. Safety assessment of polyoxyalkylene siloxane copolymers, alkyl-polyoxyalkylene siloxane copolymers, and related ingredients as used in cosmetics. Washington DC; 2014.
41. No authors listed. Final report on the safety assessment of polysorbates 20, 21, 40, 60, 61, 65, 80, 81, and 85. *J Am Coll Toxicol*. 1984;3:1-82.
42. Pang SNJ. Reviewed by the Cosmetic Ingredient Review Expert Panel. Final report on the safety assessment of PEG-30,-33,-35,-36, and -40 castor oil and PEG-30 and-40 hydrogenated castor oil. *Int J Toxicol*. 1997;16(3):269-306.
43. Burnett CL, Heldreth B, Bergfeld WF, et al. Safety assessment of PEGylated oils as used in cosmetics. *Int J Toxicol*. 2014;33(4_suppl):13S-39S.
44. US Patent 9,393,197. Cunningham CT, Seidling JR, Kroll LM, Mundschau SA. Stable emulsion for prevention of skin irritation and articles using same. 2012.
45. No authors listed. Final report on the safety assessment of glyceryl stearate and glyceryl stearate/SE. *J Am Coll Toxicol*. 1982;1:169-192.
46. Johnson W. Reviewed by the Cosmetic Ingredient Review Expert Panel. Final report of the amended safety assessment of Glyceryl Laurate, Glyceryl Laurate SE, Glyceryl Laurate/Oleate, Glyceryl Adipate, Glyceryl Alginate, Glyceryl Arachidate, Glyceryl Arachidonate, Glyceryl Behenate, Glyceryl Caprate, Glyceryl Caprylate, Glyceryl Caprylate/Caprate, Glyceryl Citrate/Lactate/Linoleate/Oleate, Glyceryl Cocoate, Glyceryl Collagenate, Glyceryl Erucate, Glyceryl Hydrogenated Rosinate, Glyceryl Hydrogenated Soyate, Glyceryl Hydroxystearate, Glyceryl Isopalmitate, Glyceryl Isostearate, Glyceryl Isostearate/Myristate, Glyceryl Isostearates, Glyceryl Lanolate, Glyceryl Linoleate, Glyceryl Linolenate, Glyceryl Montanate, Glyceryl Myristate, Glyceryl Isotridecanoate/Stearate/Adipate, Glyceryl Oleate SE, Glyceryl Oleate/Elaidate, Glyceryl Palmitate, Glyceryl Palmitate/Stearate, Glyceryl Palmitoleate, Glyceryl Pentadecanoate, Glyceryl Polyacrylate, Glyceryl Rosinate, Glyceryl Sesquioleate, Glyceryl/Sorbitol

Oleate/Hydroxystearate, Glyceryl Stearate/Acetate, Glyceryl Stearate/Maleate, Glyceryl Tallowate, Glyceryl Thiopropionate, and Glyceryl Undecylenate. *Int J Toxicol*. 2004;23(2_suppl):55-94.
47. Johnson W. Reviewed by the Cosmetic Ingredient Review Expert Panel. Amended final report on the safety assessment of glyceryl dilaurate, glyceryl diarachidate, glyceryl dibehenate, glyceryl dierucate, glyceryl dihydroxystearate, glyceryl diisopalmitate, glyceryl diisostearate, glyceryl dilinoleate, glyceryl dimyristate, glyceryl dioleate, glyceryl diricinoleate, glyceryl dipalmitate, glyceryl dipalmitoleate, glyceryl distearate, glyceryl palmitate lactate, glyceryl stearate citrate, glyceryl stearate lactate, and glyceryl stearate succinate. *Int J Toxicol*. 2007;26(3_suppl):1-30.
48. No authors listed. Final report on the safety assessment of cocoamphoacetate, cocoamphopropionate, cocoamphodiacetate, and cocoamphodipropionate. *J Am Coll Toxicol*. 1990;9:121-142.
49. Nair B. Final report on the safety assessment of benzyl alcohol, benzoic acid, and sodium benzoate. *Int J Toxicol*. 2001;20(3_suppl):23-50. https://doi.org/10.1080/10915810152630729
50. Johnson W, Bergfeld WF, Belsito DV, et al. Safety assessment of benzyl alcohol, benzoic acid and its salts, and benzyl benzoate. *Int J Toxicol*. 2017;36(3_suppl):5S-30S.
51. No authors listed. Final report on the safety assessment of sorbic acid and potassium sorbate. *J Am Coll Toxicol*. 1988;7:837-880.
52. Andersen FA. Annual review of cosmetic ingredient safety assessments: 2007–2010. *Int J Toxicol*. 2011;30(5_suppl):73S-127S.
53. Burnett CL, Boyer I, Bergfeld WF, et al. Amended safety assessment of methylisothiazolinone as used in cosmetics. *Int J Toxicol*. 2019;38(1_suppl):70S-84S.

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