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Comparative pH analysis of synthetic and natural cleaning agents: implications for eco-friendly and dermatological safety

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Abstract

Cleaning agents are essential for maintaining hygiene in domestic and industrial settings, and their pH plays a critical role in determining their safety and efficacy. This study analyzed the pH profiles of locally available synthetic (soaps, shampoos, and detergents) and natural cleaning agents (Aloe vera and Reetha) in dilute solutions to evaluate their implications for skin health and environmental safety. The results showed Neem Kanti Patanjali (NKP) and No. 1 soaps exhibited near-neutral to mildly alkaline pH (6.88–7.95), making them suitable for skin applications. Dove and Sunsilk (SS) shampoos have slightly acidic profiles (6.35–6.85), aligning with the scalp's natural pH. Detergents like Surf Excel and Ariel were strongly alkaline (8.16–8.59) suggesting effective cleaning but possibly being harsh on sensitive skin. Natural cleaning agents exhibited eco-friendly properties, with Aloe vera having a mildly acidic pH of 5.40–5.79, and Reetha being near neutral to slightly alkaline, with a pH of 7.36–7.74. In all samples, dilution reduced alkalinity or acidity, emphasizing the importance of using the correct concentrations. These findings highlight the need for pH-balanced formulations to ensure compatibility with human skin and minimize environmental harm. Future research should focus on optimizing product formulations for skin health, biodegradability, and ecological safety while promoting sustainable cleaning practices.

Keywords
Cleaning agent, Shampoo, pH behavior, Soap, Skin compatibility, Dermatological safety

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1 Introduction

Cleaning refers to washing clothes and dishes and maintaining personal hygiene to ensure a healthy, safe, and pleasant environment. It involves removing dirt, organic matter, salts, and visible soil from objects and surfaces using water, and various cleaning products [1,2]. Cleaning agents play a vital role in daily life, helping prevent the spread of pathogens in homes, healthcare settings, and industrial environments [3]. These agents are generally categorized as synthetic or natural and are available in liquids, powders, sprays, granules, or solids [2].

Understanding their pH behavior is critical, as cleaning agents are commonly used in aqueous solutions. The pH of a diluted cleaning agent influences its effectiveness, compatibility with human skin, and environmental impact [4]. For instance, acidic agents are effective for removing mineral deposits but may irritate the skin or harm ecosystems if improperly disposed of. Alkaline agents are suitable for cleaning grease and oils but may disrupt the natural pH of skin and pose environmental risks [5, 6]. In contrast, neutral agents tend to be milder, offering safer options for both skin and nature. Since human skin has a slightly acidic pH of 4.5 to 5.5, cleaning products with extreme pH levels can lead to skin issues such as irritation, dryness, or allergic reactions [7, 8].

Environmental concerns also arise from the discharge of cleaning solutions into water bodies, where altered pH levels can negatively affect aquatic organisms and soil microbiota [9, 10]. Therefore, evaluating the pH behavior of cleaning agents is essential to ensure both personal and environmental safety. Synthetic cleaning agents, such as soaps, shampoos, detergents, bleaches, and degreasers, are widely used due to their high efficacy and affordability [8]. These agents typically contain synthetic surfactants, petrochemicals, dyes, and fragrances, which enhance their cleaning power but may pose risks to health and the environment over time [1, 11]. Repeated exposure to such chemicals can lead to skin problems, particularly in individuals with sensitive skin. Moreover, synthetic cleaning waste can pollute water sources, disrupt aquatic ecosystems, and contribute to toxic build-up [12].

Natural cleaning agents, on the other hand, are formulated with eco-friendly ingredients such as baking soda, citric acid, vinegar, and essential oils. These products are generally safer for both human health and the environment because of their mild pH and biodegradable nature. Often marketed under the umbrella of "green cleaning", these agents emphasize not only safe ingredients but also sustainable manufacturing, packaging, and disposal practices [13]. As the demand for eco-conscious products increases, refining the formulation of natural cleaning agents is essential to ensure they remain effective and safe.

This research aims to analyze the pH behavior of nine synthetic and two natural cleaning agents in dilute solutions and assess their implications for skin health and environmental safety (Table 1). Comparing their pH profiles will help to promote sustainable cleaning practices, inform consumer choices, and guide the development of safer and more eco-friendly products.

2 Experimental

2.1 Materials

Four different types of cleaning agents such as commercial soaps, shampoos, detergents, and natural products, were selected in this study and purchased from local markets in Biratnagar, Nepal. The commercial soaps analyzed were Liril soap, Dettol soap, Neem Kanti Patanjali soap (NKP), and No. 1 soap (N1), while the shampoos included Head & Shoulders (HS), Clinic Plus (CP), Sunsilk (SS), and Dove. The detergents studied were Surf Excel (SE), Clean Add (CA), 2-in-1, and Ariel. Additionally, natural agents such as Aloe Vera gel (AVG) and Indian soapberry (Reetha) (ISB) were included to provide a broader perspective on cleaning performance and safety. Distilled water was used as the diluent to ensure consistent and uncontaminated conditions for the pH measurements. Figure 1 shows images of some commercial and natural cleaning agents studied. Analytical grade reagents and standard laboratory equipment were used throughout the study.

Figure 1: Cleaning agents under study.

2.2 Preparation of Sample Solutions

The preparation of different sample solutions was done using different techniques. Six different solutions for soaps and detergents were made by dissolving 0.2 gm and 0.25 gm of the samples, respectively, in 50 mL to 100 mL volumes of distilled water. These were prepared at room temperature with gentle stirring to ensure complete dissolution. For shampoos, 1.5 mL of each was diluted with distilled water to create volumes ranging from 25 to 75 mL and mixed gently to achieve a homogenous solution. Natural product sample solutions, such as Aloe Vera gel and Reetha (Indian soapberry), were made by dissolving 0.5 gm of each in 50–100 mL of distilled water while stirring to ensure uniform dispersion [14, 15].

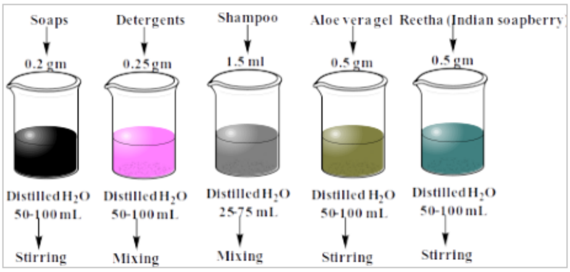

Figure 2: Preparation of sample solutions.

2.3 pH Measurement

A digital pH meter (MARS auto pH meter) was used to measure the pH of the prepared solutions. The meter was calibrated with standard buffer solutions at pH 4.0, 7.0, and 10.0 prior to each set of measurements. To prevent cross-contamination, the electrode was rinsed with distilled water and blotted dry before immersion in test solutions. The experiments were conducted at room temperature, and the pH readings were recorded after stabilization on the meter display. The pH of each sample was measured in triplicate, and the average values were calculated for analysis. Trends in alkalinity, acidity, and buffering capacity were revealed by tabulating the results, which were categorized according to sample types, including soap, shampoo, detergent, and natural products. Quality control procedures included making fresh solutions to prevent contamination or deterioration, cleaning glassware thoroughly with distilled water, and checking the accuracy pH meter on a regular basis. Table 1 lists the composition details and other pertinent data for every cleaning agent under study.

Table 1: Major chemical ingredients of the studied cleaning agents

S.N.	Category	Cleaning Agents	Manufacturer	Major Ingredients
1.	Soap	Liril Soap	Hindustan Unilever Ltd.	Sodium Palmate, Sodium Palm Kernelate, Water, Talc, Glycerin, Sorbitol, Perfume, Sodium C14-16 Olefin Sulfonate, Sodium Chloride, Sodium Sulfate, Lauric Acid, Titanium Dioxide, Tetrasodium Etidronate, Tetrasodium EDTA, Lime (*Citrus aurantifolia*) Extract, CI 74260, CI 11680
2.		Dettol	Reckitt Benckiser (India) Ltd.	Sodium Palmate, Sodium Palm Kernelate, Talc, Aqua, Glycerin, Parfum, Sodium Chloride, Sodium C14-16 Olefin Sulfonate, Menthol, Etidronic Acid, Tetrasodium Etidronate, Tetrasodium EDTA, Linalool, Sodium Hydroxide, Cymbopogon Flexuosus Oil, Citral, Camphor, Benzyl Salicylate, Limonene, Coumarin, CI77891, CI74160
3.		Neem Kanti Patanjali	Patanjali Foods Ltd.	Neem (*Azadirachta indica*), Manjistha (*Rubia cordifolia*), *Curcuma longa*, Tulsi (*Ocimum sanctum*), Giloy (*Tinospora cordifolia*), Amla (*Emblica officinalis*), Haldi (*Curcuma amada*), and Aloe Vera (*Aloe barbadensis*)
4.		No. 1 Soap	Godrej	Sodium Palmate, Sodium Palm Kernelate, Water, Perfume, Sodium Chloride, Sorbitol, Glycerin, Titanium Dioxide, Disodium EDTA, Propylene Glycol, PEG-8, Rosa Damascena Flower Water (Rose Water), Prunus Amygdalus Dulcis Oil, BHT, Citric Acid, CI 45100, CI 73360, CI 11680, CI 74160
5.	Shampoo	Head &Shoulders	Procter & Gamble Home Products Pvt. Ltd.	Sodium Lauryl Sulfate, Sodium Laureth Sulfate, Sodium Chloride, Glycol Distearate, Zinc Carbonate, Sodium Xylene Sulfonate, Cocamidopropyl Betaine, Dimethicone, Zinc Pyrithione, Menthol, Sodium Benzoate, Guar Hydroxypropyltrimonium Chloride, Hexyl Cinnamate, Linalool, Butylphenyl Methylpropional, Magnesium Carbonate Hydroxide, Ammonium Laureth Sulfate. Methylchloroisothiazolinone, Methylisothiazolinone
6.		Clinic Plus	Hindustan Unilever Ltd.	Sodium Laureth Sulphate, Dimethiconol (and) Tea-Dodecylbenzene Sulfonate, Cocoamidopropyl Betaine, Sodium Chloride, Perfume, Carbomer, Guarhydroxypropyltrimonium Chloride, Mica & Titanium Dioxide, Sodium Hydroxide, Lysine Monohydrochloride, Citric Acid, DMDM Hydantoin, PEG-45M, Disodium EDTA, Niacinamide, Egg Powder, Sodium Ascorbyl Phosphate, Methylchloroisothiazolinone and Methylisothiazolinone, Benzyl Salicylate, Hexylcinnamal, Limonene, Linalool
7.		Sunsilk	Hindustan Unilever Ltd.	Sodium Laureth Sulfate, Sodium Chloride, Cocamidopropyl Betaine, Dimethiconol (and) Teadodecylbenzenesulfonate (and)Laureth-23, Glycerin, Sodium Benzoate, Perfume, Guarhydroxypropyltrimonium Chloride, Disodium EDA, Benzophenone-4, Lysine Hydrochloride, Citric Acid, *Simmondsia chinensis* (Jojoba) Seed Oil, *Alliumcepa* (Onion) Bulbs Oil and *Helianthus annuus* (Sunflower) Seed Oil, Sodium Hydroxide
8.		Dove	Hindustan Unilever Ltd.	Sodium LaurethSulfate, Glycol Distearate, Cocamidopropyl Betaine, Sodium Chloride, Glycerin, Dimethiconol, Fragrance (Parfum), Sodium Benzoate, Citric Acid, Dimethiconeigluconolactone, Acrylates/Beheneth-25 Methacrylate Copolymer, Styrene/Acrylates Copolymer Guar Hydroxypropyltrimonium Chloride, Amodimethicone, Sodium Sulfate, Trehalose, Tea-Dodecylbenzenesulfonate, Disodium Edtaipeg-Umi Dipropylene Glycol, Hydrolyzed Keratin, Cio-40 Isoalkylamidopropylethyldimoniumethosulfatei Cetrimonium Chloride, Carrageenan, PPG-91 DMDM Hydantoin, Methylchloroisothiazolinone, Methylisothiazolinone, Mica (Cl 77019), Titanium Dioxide
9.	Detergents	Surf Excel	Hindustan Unilever Ltd.	Sodium Carbonate, Sodium Aluminosilicate, Sodium Perborate, and Enzymes
10.		Clean Add	N/A	Surfactants (like anionic and non-ionic), Builders (like phosphates or alternative builders), Enzymes, Bleach Actives, Optical Brighteners, and Fragrances
11.		2-in-1	N/A	Surfactants (like anionic and non-ionic), Builders (like phosphates or alternative builders), Enzymes, Bleach Actives, Optical Brighteners, and Fragrances
12.		Ariel	Procter & Gamble Home Products Pvt. Ltd.	Alcohol Ethoxylate, Alkyl (or Alcohol) Ethoxy Sulphate, Alkyl Sulphate, Amine Oxide, Carboxymethyl Cellulose, Citric Acid, Cyclodextrin, Diethyl Ester Dimethyl Ammonium Chloride, Ethanol, Ethylene Diamine Disuccinate, Hydrogen Peroxide, Linear Alkylbenzene Sulfonate, Mono Ethanol Amine, 2-Aminoethanol or Ethanolamine, Percarbonate, Polyethylene Glycols, Polyethylene Oxide or Polyoxyethylene, Polyvinyl Alcohol, Sodium Carbonate, Sodium Disilicate, Sodium Hypochlorite, Sodium Triphosphate, Tetra Acetyl Ethylene Diamine, Titanium and Titanium Dioxide, Zinc Phthalocyanine Sulphonate
13.	Natural cleaning agent	Aloe Vera Gel	N/A	*Aloe barbadensis*
14.		Indian Soapberry (Reetha)	N/A	*Sapindus mukorossi*

N/A: Manufacturer information not available for natural products

3 Results and Discussion

The pH levels of various soaps, shampoos, detergents, and natural cleaning agents were measured in different volumes of distilled water to evaluate their pH behavior and compatibility with skin and fabric.

3.1 Soaps

The pH analysis of various soaps revealed distinct trends in alkalinity and neutrality upon dilution with distilled water. The pH of **Liril soap** decreased from 7.4 at 50 mL to 6.97 at 100 mL, transitioning from slightly alkaline to almost neutral, suggesting its mild nature. **Dettol soap** showed a reduction in pH from 7.28 to 6.68 as the water volume increased, aligning with its formulation for antibacterial activity at mildly acidic to neutral pH levels. **NKP soap** demonstrated a comparable behavior, with pH ranging from 7.31 to 6.88, suggesting its suitability for skincare due to its mild nature. **No. 1 soap**, initially more alkaline at 7.95, became closer to neutral at 6.78 after dilution, making it appropriate for general use. These findings demonstrate the varying degrees of alkalinity and neutrality of soaps, which can influence their compatibility with skin health and applications, depending on their pH behavior during dilution [11, 16–18]. It is therefore likely that dilution reduces the buffering capability of the solutions. The pH values for each soap with different amounts of distilled water are shown in Table 2, and Figure 3 provides a visual representation of these values.

Table 2: pH of different soaps at varying volumes of distilled water.

S.N.	Volume of distilled water (ml)	Mass of Soap (gm)	Liril	Dettol	No. 1	NKP
1	50	0.2	7.40	7.28	7.95	7.31
2	60	0.2	7.26	7.00	7.84	7.18
3	70	0.2	7.15	6.88	7.51	7.12
4	80	0.2	7.07	6.78	7.38	7.08
5	90	0.2	7.00	6.73	7.27	7.00
6	100	0.2	6.97	6.68	6.78	6.88

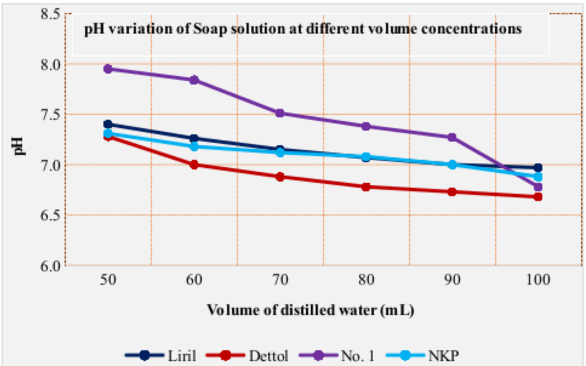

Figure 3: pH of different soaps at varying volumes of distilled water.

3.2 Shampoos

The pH of shampoos plays a crucial role in their effectiveness and compatibility with hair and scalp health. Head & Shoulders (HS) shampoo exhibited a pH range of 7.14 to 6.66, and supports its anti-dandruff properties, as slightly acidic formulations are kinder on the scalp. With an initial pH of 6.78 and a steady decline to 6.35, Clinic Plus exhibits mild acidity that is unlikely to be damaging to hair or the scalp. Sunsilk demonstrated minimal variation in pH (6.83 to 6.62), suggesting a stable formulation suitable for regular use. Dove demonstrated a steady drop in pH from 6.85 to 6.48, highlighting its standing as a mild and moisturizing product. These findings highlight the importance of pH-balanced formulations in maintaining scalp health and preventing hair damage, as excessively alkaline products can disrupt the natural structure of hair, and lead to issues like dryness and breakage [19, 20]. The pH information for each shampoo with different amounts of distilled water is shown in Table 3 and is graphically depicted in Figure 4.

Table 3: pH of different shampoos at varying volumes of distilled water.

S.N.	Volume of distilled water (ml)	Volume of Shampoo (ml)	HS	CP	SS	Dove
1	25	1.5	7.14	6.78	6.83	6.85
2	35	1.5	7.10	6.65	6.80	6.78
3	45	1.5	7.05	6.60	6.75	6.69
4	55	1.5	7.00	6.54	6.72	6.63
5	65	1.5	6.85	6.48	6.70	6.54
6	75	1.5	6.66	6.35	6.62	6.48

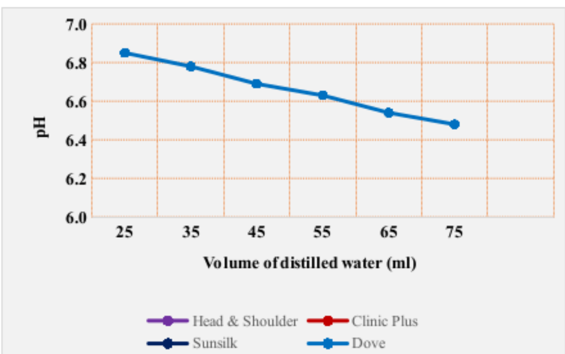

Figure 4: pH of different shampoos at varying volumes of distilled water .

3.3 Detergents

The pH analysis of four detergents, such as Surf Excel, Clean Add, 2-in-1, and Ariel, were found to have a uniformly alkaline pH, which makes them suitable for removing tough stains. Surf Excel and 2-in-1 detergents exhibited identical pH ranges from 8.59 to 8.19, highlighting their strong alkaline properties. Similar patterns were seen in Clean Add, where pH levels marginally dropped from 8.56 to 8.20. The alkaline profile of Ariel detergent was maintained, although its range was somewhat smaller, ranging from 8.42 to 8.16. These pH values align with the general characteristics of laundry detergents, which are formulated to be alkaline for efficient cleaning of dirt, grease, and oils. However, because high-pH solutions are harsh, improper rinsing may eventually cause fabric damage, even though their alkalinity guarantees effective stain removal [21]. The pH values for each detergent with different amounts of distilled water are shown in Table 4 and are visually represented in Figure 5.

Table 4: pH of different detergents at varying volumes of distilled water.

S.N.	Volume of distilled water (ml)	Mass of Detergent (gm)	Surf Excel	Ariel	2 in 1	Clean Add
1	20	0.25	8.51	8.42	8.59	8.56
2	30	0.25	8.45	8.35	8.49	8.48
3	40	0.25	8.40	8.30	8.38	8.43
4	50	0.25	8.35	8.25	8.33	8.39
5	60	0.25	8.21	8.19	8.24	8.23
6	70	0.25	8.18	8.16	8.19	8.20

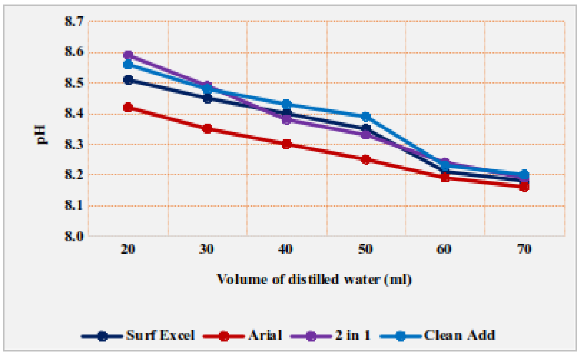

Figure 5: pH of different detergents at varying volumes of distilled water.

3.4 Natural Cleaning Agents

The pH levels of natural agents such as Aloe Vera and Indian Soapberry (Reetha) have been studied to understand their suitability for various applications. Aloe Vera exhibits a mildly acidic nature, with its pH increasing from 5.40 at 50 mL to 5.79 at 100 mL. The natural pH of human skin, which normally falls between 4.5 and 5.5, is closely matched by this mild acidity, making it advantageous for skincare and calming applications. On the other hand, Indian Soapberry (Reetha) shows a near neutral pH profile, varying from 7.74 to 7.36. This neutrality makes Reetha suitable for use as a natural cleaning agent for both skin and fabric, as it is less likely to cause irritation or disrupt the skin's natural pH balance [22–24]. Table 5 summarizes the pH data for these natural agents in different volumes of distilled water, and Figure 6 shows the data graphically, giving a thorough overview of their characteristics.

Table 5:pH of different natural agents at varying volumes of distilled water.

S.N.	Volume of distilled water (ml)	Mass of Soap (gm)	pH (Aloe vera)	pH (Reetha)
1	50	0.5	5.40	7.74
2	60	0.5	5.43	7.66
3	70	0.5	5.48	7.58
4	80	0.5	5.59	7.49
5	90	0.5	5.65	7.42
6	100	0.5	5.79	7.36

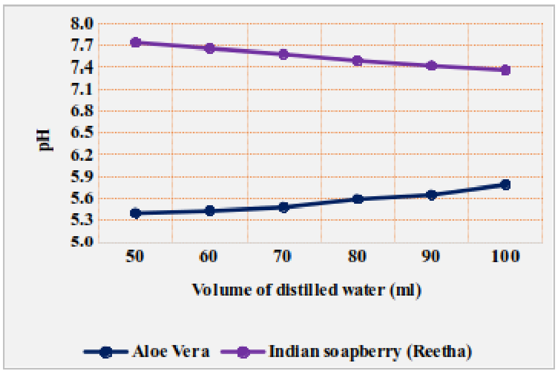

Figure 6: pH of different natural agents at varying volumes of distilled water.

4 General Discussion

The study highlights the critical role of pH in determining the suitability and safety of personal care and cleaning products. The majority of soaps and shampoos have a pH that is close to neutral to slightly acidic, which is in line with the skin's normal pH range of 5.4 to 5.9. This makes them appropriate for use on the skin and scalp [25]. In contrast, detergents are strongly alkaline, reflecting their primary purpose of cleaning fabrics but necessitating thorough rinsing to avoid irritation or damage from residual traces [26]. Dilution with distilled water consistently lowered the pH across all tested samples, likely due to the reduced concentration of acidic or alkaline ions. Among personal care products, items like Neem Kanti Patanjali soap, Dove shampoo, and Aloe Vera demonstrated mild pH levels, minimizing the risk of disrupting the skin's acid mantle. Furthermore, detergents' strong alkalinity makes them potentially harmful to sensitive skin if they are not properly rinsed out of fabrics [27]. Natural cleaning agents such as Reetha and Aloe Vera were found to have pH profiles suitable for eco-friendly and non-damaging cleaning applications, offering a sustainable alternative to synthetic products. This research highlights the importance of understanding pH profiles to optimize product applications and ensure user safety. It also emphasizes that maintaining a pH balance close to natural skin levels is essential for preventing issues such as dryness, irritation, or disruption of the skin's natural barrier. By tailoring formulations to appropriate pH levels, manufacturers can enhance product efficacy while minimizing adverse effects on users and the environment.

5 Conclusion

The compatibility of soaps, shampoos, detergents, and natural products with skin and hair health is highlighted by the study of their pH levels. Most of the soaps tested ranged from neutral to mildly alkaline and were influenced by the volume of distilled water used during preparation. Liril soap had a pH of 7.4 to 6.97, indicating mild alkalinity suitable for cleaning without harsh effects. Dettol soap showed a slightly lower pH range (7.28 to 6.68), making it more skin-friendly. Neem Kanti Patanjali and No.1 soaps also displayed mild alkalinity, supporting their cleaning efficacy while maintaining skin compatibility. Shampoos such as Head & Shoulders, Clinic Plus, Sunsilk, and Dove had pH values from slightly acidic to neutral, aligning with the natural scalp pH (5.4–5.9). This balance is vital for maintaining hair health and preventing dryness or irritation. In contrast, detergents like Surf Excel and Ariel exhibited higher alkaline pH values (8.59 to 8.16), reflecting their strong cleaning action but potentially harsh effects on sensitive skin. Natural products showed varied profiles: Aloe vera was acidic (pH 5.40–5.79), aligning with the skin's natural acidity and aiding hydration and healing, while Reetha ranged from neutral to mildly alkaline pH (7.74–7.36), and offering gentle cleaning properties. The study underscores the importance of selecting products with pH levels compatible with skin and hair health to avoid irritation or disruption of the acid mantle, a protective layer critical for maintaining hydration and bacterial balance.

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