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Research Article

An Experimental Study on the Effectiveness of Cleaning and Cosmetic Products Using pH Sensors

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Abstract—This study delves into the innovative use of pH sensors to measure the residue left by cleaning and cosmetic products on surfaces and the resultant changes in surface pH values. Sensor technologies are a novel and critical tool in this context. The solubility of residues from cleaning and cosmetic products and the effectiveness of these products are directly related to pH values. This study underscores the increasing importance of pH sensors in the formulation development, efficacy evaluation, and user safety of cleaning and cosmetic products.

1. Introduction

pH sensors play a critical role in determining and optimizing the efficacy of cleaning and cosmetic products. The interactions of cleaning products with surfaces and cosmetic products with skin determine the performance and safety of these products. pH is an important parameter affecting products' chemical efficacy, suitability, and residue potential [1].

The effects of pH in cleaning products have been studied for a long time. The "Sinner Circle," developed by Sinner (1959), emphasizes the four fundamental factors determining cleaning efficacy: chemical action, mechanical action, temperature, and time, highlighting the importance of the relationship between these factors and pH. In surface cleaning products, pH is one of the most critical parameters for the dissolution of soils. Alkaline pH dissolves grease and protein-based soils, while acidic pH is effective against mineral-based soils [2–5]. The efficacy of products is also dependent on the chemical changes on the surface, as well as the potential for residue formation and compatibility with the surface [6].

pH in cosmetic products is critical for skin health. The natural pH level of human skin ranges from 4.5 to 5.5, and these values help protect the skin barrier [7, 8]. Products that do not have a pH value compatible with the body can cause degradation, irritation, and skin dryness [9, 10]. Optimizing pH supports skin health and enhances the stability of active ingredients [11, 12]. Recent studies have demonstrated that pH sensors are crucial in such analyses. Advanced pH sensors precisely measure the pH variations of residues left by cleaning products on surfaces and assess the compatibility of cosmetic products with the skin.

A study by Glass and Wright (2011) revealed that high-sensitivity pH sensors can accurately detect pH fluctuations during cleaning processes. Furthermore, pH sensors are instrumental in optimizing the efficacy of cleaning products and evaluating their performance across various surfaces [13–15]. Portable pH sensors offer a cost-effective solution for assessing efficacy in cleaning and cosmetic formulations [16, 17].

The importance of pH sensors is increasing in developing formulations, evaluating efficacy, and ensuring user safety in cleaning and cosmetic products. PH sensors analyze chemical residues in cleaning products, while cosmetic products measure skin compatibility and formulation stability [18].

In this comprehensive study, the effectiveness of cleaning products on various surfaces, their potential for residue formation, and the compatibility of cosmetic products with the skin have been thoroughly investigated using pH sensors. The study aims to enhance the performance of cleaning and cosmetic products based on the data obtained from pH sensors, as well as to optimize the safe use of these products and user satisfaction [19].

Additionally, this study aims to understand the role of pH levels on product performance and safety, depending on the type of surface used and the formulation. The practical implications of this understanding will provide a foundation for more informed product design and healthier consumer choices, thereby enlightening the industry and academia.

2. Experimental

The cleaning and pH measurement procedures for glass, porcelain, stainless steel, tile, concrete, and leather surfaces were carried out as follows: The surfaces used were cleaned of dirt and dust before the experiment. Subsequently, they were rinsed with ample water and adjusted to pH 7. The surfaces were soaked in hot water for 5 hours to ensure no contaminants remained and were then dried with a clean microfiber cloth. A specified amount of the cleaning product (0.1 g per cm^2) was evenly applied to each surface and allowed to sit for 30 minutes. At the end of the cleaning duration, the surfaces were rinsed again with ample water adjusted to pH 7. Finally, 1 kg of deionized water was weighed using a 0.000 precision scale adjusted to pH 7, and the glass, porcelain, stainless steel, tile, concrete, and leather were soaked in this water for 5 hours. At the end of the soaking period, the weight of the water that contacted the surfaces and the pH values were measured. pH measurements were conducted using a portable pH sensor with a precision of ±0.001. Each measurement was repeated three times, and the average values were recorded. The measurements were performed at a constant temperature of 23 °C. The washing process was carried out for three different durations: 15 minutes, 30 minutes, and 60 minutes. At the end of each duration, the surface pH changes and the residue amount were measured. This measurement was conducted to determine the waste on the surfaces and the pH changes of the soaked water. The weight of the water was adjusted to pH seven, and the pH changes were recorded. All measurements were repeated several times and documented in detail. Subsequently, these data were used to investigate the effect of the residue left by the cleaning products on pH changes.

2.1. pH and Residue Amount Results

Materials Used and Their Properties: Surfaces: Glass, porcelain, stainless steel, tile, concrete, leather

Cleaning Products: Dish detergent (neutral, pH 7.0), Degreaser (alkaline, pH 10.0), Limescale remover (acidic, pH 2.5), Hydrochloric acid (acidic, pH 1.5), Bleach (essential, pH 11.4), Shampoo (acidic, pH 5.5), Conditioner (acidic, pH 4.5)

Measurement Temperature: 23.0 °C,

Soaking Duration: 5 hours (in deionized water adjusted to pH 7.0),

Residue Amount Measurement: Calculated in mg/cm^2.

3. Results and Discussion

This study investigated the effects of cleaning and cosmetic products' pH values and residue potential on different surfaces. The findings indicate that the physical and chemical properties of surfaces play a significant role in the effectiveness and residue potential of the products.

The research results reveal that surface roughness, porosity, and chemical characteristics affect the residue left behind. Rough and porous surfaces retain more cleaning products and dirt, increasing the residue. For instance, surfaces such as wood and concrete elevate the residue potential of cleaning products. In contrast, smoother and flat surfaces like glass and stainless steel have been observed to leave less residue. This situation emphasizes the impact of the physical properties of surfaces on cleaning products.

The variation of pH changes according to surfaces and products can be explained by the chemical composition of the products and the interactions between the surfaces and the products. Acidic products limit pH changes by undergoing neutralization reactions on alkaline surfaces. On the other hand, alkaline products increase pH by reacting with organic matter. The concentration of the products and the duration of their presence on the surface are also significant factors affecting pH changes. These findings indicate that the pH values in the formulations of cleaning and cosmetic products should be carefully optimized.

Products such as degreasers, hydrochloric acid, and bleach have left more residue. This is related to their chemical compositions and application methods. Degreasers contain strong surfactants and organic solvents, which can leave insoluble residues on surfaces [3]. Bleach can react with organic matter on surfaces to form by-products such as chloramines. Additionally, the viscous nature of these products and inadequate rinsing are other factors that increase the amount of residue. This situation emphasizes the importance of rinsing to enhance the effectiveness of cleaning products.

The results presented in Table 1, Figures 1 and 2 were analyzed using an ANOVA test. The analysis found statistically significant differences in pH changes and residue amounts across different surfaces ($p<0.05$).

Figure 3 presents the results obtained for different washing durations. The findings indicate that the surface's residue decreases as the washing duration increases, while pH changes become more pronounced.

This study emphasizes the need to select cleaning and cosmetic products based on the type of surface and the importance of optimizing the pH values of the products for both effectiveness and safety. When cleaning products come into contact with the skin, pH compatibility is critical for maintaining skin health. Additionally, it has been concluded that users should make appropriate selections of cleaning products based on the surface type. The surface's physical and chemical properties directly affect the products' effectiveness. For example, degreasers have a higher potential to leave residue on stainless steel surfaces.

The findings of this study are consistent with the results reported by Glass and Wright (2011). Specifically, the sensitivity of pH sensors in evaluating the effectiveness of cleaning products has also been confirmed in this study [14].

As the washing duration increases, the surface's residue decreases, while pH changes become more pronounced. This indicates that viscous cleaning products, in particular, are rinsed more effectively over longer durations.

The pH values of cosmetic products also directly impact skin health. Ensuring the pH values of products such as shampoos and conditioners are compatible with the skin will help prevent dryness and irritation. Providing users with information on selecting products suitable for the type of surface and using pH-balanced cosmetic products will enhance the effectiveness of the products and protect skin health.

Manufacturers providing information on surface compatibility and pH values on product labels will assist users in making informed choices, enhance user satisfaction, and maximize the products' effectiveness.

Furthermore, these findings provide an important foundation for improving industry practices and raising user awareness. In the future, it is recommended to investigate the pH performance of products under different temperature and humidity conditions, evaluate a broader range of products, and explore consumer experiences. Such studies will increase the applicability of the current findings in a wider context.

Table 1. The pH and residue amount results

Surface	Cleaning Products	Initial pH	Final pH	Residue Amount (mg/cm^2)
Glass	Dishwashing detergent	7.00	7.05	0.05
Porcelain	Dishwashing detergent	7.00	7.08	0.06
Stainless Steel	Dishwashing detergent	7.00	7.10	0.10
Glass	Degreaser	7.00	7.30	0.15
Porcelain	Degreaser	7.00	7.35	0.22
Stainless Steel	Degreaser	7.00	7.45	0.34
Tile	Limescale remover	7.00	6.75	0.55
Concrete	Hydrochloric acid	7.00	6.50	0.60
Concrete	Bleach	7.00	7.40	0.42
Skin (Cowhide)	Shampoo	7.00	7.05	0.19
Skin (Cowhide)	Conditioner	7.00	7.10	0.36

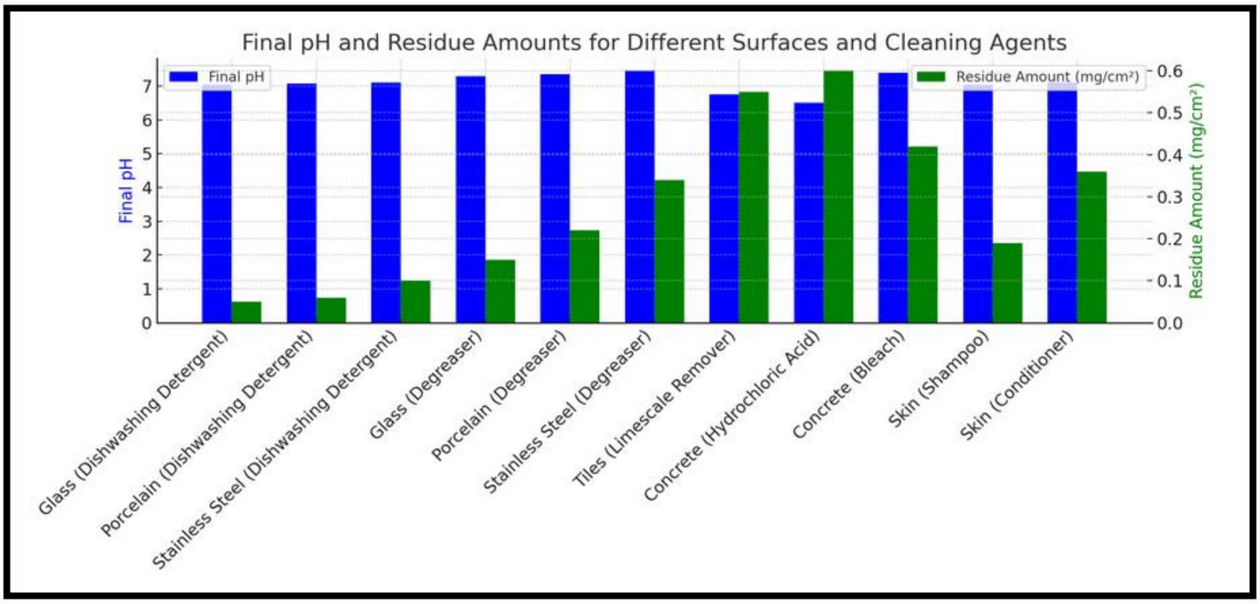

Figure 1. Final pH and residue amounts on various surfaces after application of cleaning and cosmetic products.

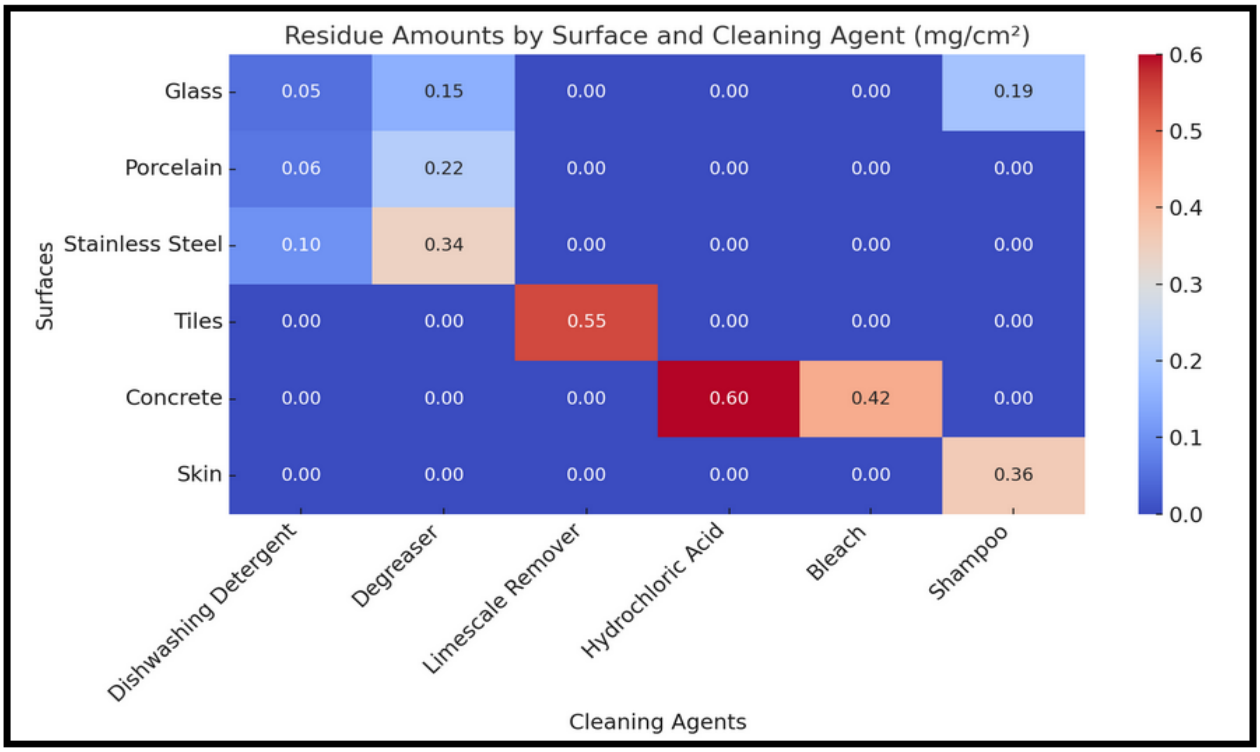

Figure 2. Heatmap of residue amounts by surface and cleaning products (mg/cm²)

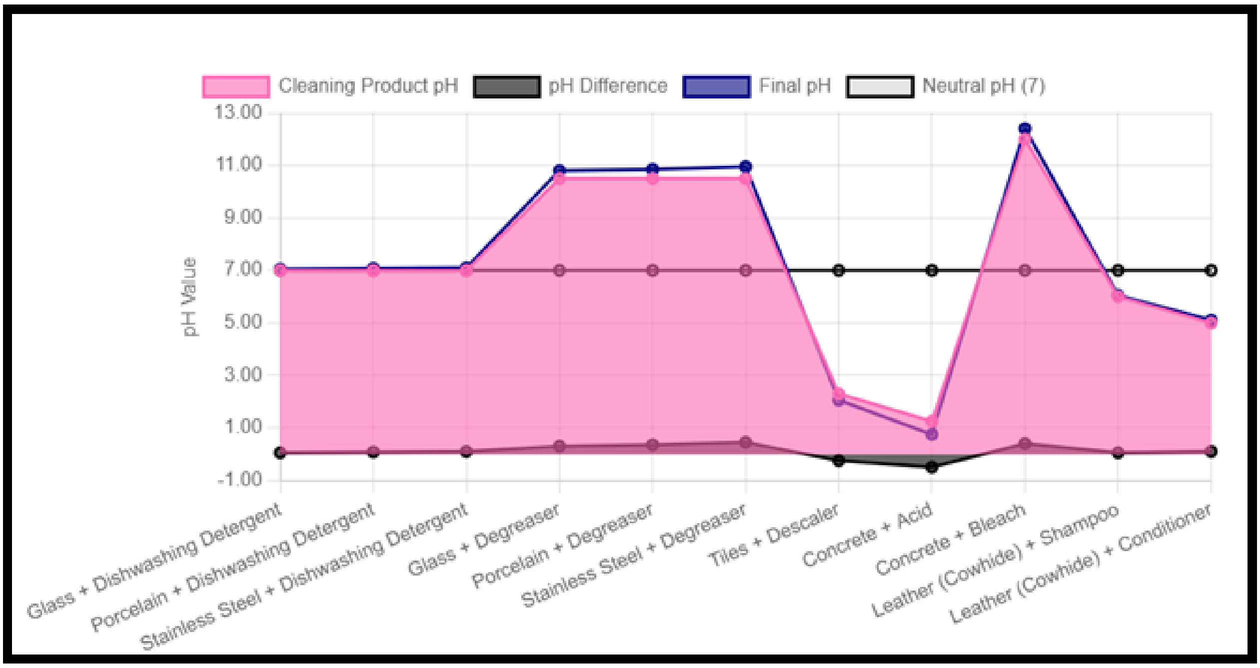

Figure 3. Comparison of cleaning product ph values and measured pH differences

4. Conclusion

This study has thoroughly examined the role of pH sensors in evaluating the effectiveness of cleaning and cosmetic products. The findings reveal the impact of pH values on the residue potential of cleaning products on surfaces and the compatibility of cosmetic products with the skin. Optimizing the pH value of cleaning products is critical for both effectiveness and user satisfaction. Future research will involve a more comprehensive investigation of the interactions between different surface types and pH values. Additionally, developing pH sensors and expanding their application areas will contribute to advancements in research in this field.

Conflicts of Interest

The authors declare that there is no conflict of interest for this article.

Authors' Contributions

Yakup Budak: Design of the study, conducting experiments, and article writing. **Fatih Yasar:** Data analysis.

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