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A Review: Hand Sanitizer

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Abstract: ***In the midst of worldwide health emergencies like the COVID-19 epidemic, hand sanitizers have become indispensable hygiene items. They provide quick antimicrobial action that aids in halting the spread of infectious pathogens, making them practical substitutes for soap and water. The kinds, formulation techniques, assessment criteria, and most current developments in hand sanitizers are all examined in this study. The efficacy, safety, and user acceptability of both herbal and alcohol-based formulations are examined. A variety of antimicrobial agents, additives, and regulatory requirements that are involved in formulation creation are also highlighted in the article. Additionally, cutting-edge strategies to improve effectiveness and lessen negative effects being explored, such as integrating herbal ingredients and nanotechnology. To evaluate overall quality, evaluation techniques including pH analysis, antimicrobial testing, and user input are used. Future developments including eco-friendly formulations, longer-lasting action, and sustainable packaging options are highlighted in the review's conclusion. For hand hygiene products to continue to develop, these advances are essential.***

Keywords: Hand sanitizer, Alcohol-based, Herbal hand rub, Antimicrobial efficacy, Gel formulation, Skin safety, WHO guidelines, COVID-19, Evaluation parameters, Future trends

I. INTRODUCTION

One of the most important aspects of public health is maintaining personal cleanliness. One of the best ways to stop the spread of infectious illnesses across different hygiene practices is to practice good hand hygiene. As lifestyles have changed and people's awareness of hygiene has increased, hand sanitizers have become a practical and efficient substitute for the conventional method of washing hands with soap and water, especially in places where water is limited or unavailable. In addition to revolutionizing personal cleanliness habits, the invention and broad usage of hand sanitizers has been essential in reducing infections in public areas, the food industry, and healthcare facilities[1-2]. The phrase "hand sanitizer" describes a mixture of antimicrobial compounds that assist lessen or get rid of bacteria on hands. These formulations are usually in liquid, gel, or foam form. These items are intended to destroy or deactivate viruses, bacteria, and some fungus. The majority of commercial hand sanitizers contain alcohol-based substances such ethanol, isopropyl alcohol, or n-propanol as their primary active components. To minimize dryness and irritation and increase user happiness, several formulas include skin-conditioning ingredients like glycerin, aloe vera, or essential oils in addition to alcohol[3-4]. The usage of hand sanitizers has become more commonplace in everyday life due to rising public health awareness, especially in the aftermath of worldwide pandemics like COVID-19. Once thought of as an adjunct to handwashing, these products are now the first line of defence against the transmission of infectious illnesses, particularly in situations where soap and water are not easily available. Over time, hand sanitizer formulations have changed dramatically. Modern formulations, which were formerly restricted to alcohol-based gels, now include moisturizers, essential oils, and herbal extracts to reduce skin irritation and improve antibacterial activity. For efficient germicidal activity, the World Health Organization (WHO) and the Centers for Disease Control and Prevention (CDC) advise using alcohol-based hand sanitizers that contain at least 60% ethanol or 70% isopropyl alcohol. They have veridical qualities against enveloped viruses like influenza and coronaviruses in addition to their bactericidal activities. However, problems including skin dryness, flammability, alcohol evaporation, and the development of resistance have sparked interest in alcohol-free substitutes that use substances like silver nanoparticles, benzalkonium chloride, and chozidine[3-4]. Consumer preference for natural, safer, and eco-friendly ingredients has led to an increase in demand for herbal hand sanitizers in recent years. Plant-based actives with well-established antibacterial and calming qualities, such neem, tulsi, aloe vera, and tea tree oil, are frequently included in these formulations. Because of the widespread use of hand sanitizers, ongoing research and development in formulation, delivery methods, and efficacy testing are crucial to guaranteeing consumer pleasure and public safety[4-5].

A. Historical Background

Alcohol has been used for ages as a disinfectant. Ethanol and other alcohols have long been known to have antibacterial qualities. Early societies cleaned wounds and practiced rudimentary cleanliness with wine and other alcoholic liquids. However, the 20th century saw the development of the modern idea of hand sanitizers.

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Although there is no official documentation, Lupe Hernandez, a nursing student from Bakersfield, California, is frequently given credit for creating the first alcohol-based hand sanitizer gel in 1966. In clinical and medical environments where hand cleanliness was crucial, the product became well-liked[5-6].

Due to growing knowledge of infection prevention and cleanliness, hand sanitizers did not become widely used until the 1990s. During pandemics and outbreaks like the SARS epidemic, the H1N1 virus, and—most importantly—the COVID-19 pandemic, their significance increased tremendously. The 2020 SARS-CoV-2 pandemic caused a worldwide spike in demand for alcohol-based hand sanitizers, which prompted mass manufacturing, changes to regulations, and formulation innovation[6-7].

B. Importance in Public Health

Hand sanitizers have become indispensable in hospitals, clinics, schools, offices, and transportation hubs. Healthcare-associated infections (HAIs) can be drastically reduced through proper hand hygiene. Moreover, in food processing and preparation areas, hand sanitizers help ensure safety and reduce the risk of foodborne illnesses. Public usage also contributes to a broader preventive effort against communicable diseases, reinforcing the community's role in public health. Hand sanitizers are now essential at clinics, hospitals, companies, schools, and transit hubs. By practicing good hand hygiene, healthcare-associated infections (HAIs) can be significantly decreased. Additionally, hand sanitizers assist maintain safety and lower the risk of foodborne infections in places where food is processed and prepared. The community's involvement in public health is further strengthened by the fact that public usage supports a larger preventative effort against communicable illnesses[8-9].

In circumstances when soap and water are not easily accessible, hand sanitizer is essential for preserving personal hygiene and halting the spread of infectious illnesses. In recent years, its significance has grown, especially during international health emergencies like the COVID-19 pandemic. Hand sanitizers, particularly those with an alcohol basis, offer a rapid and efficient way to get rid of a variety of pathogens, including as bacteria, viruses, and fungus. They are perfect for usage in public areas, offices, schools, and hospitals since they are portable and may be used right away.

Hand sanitizers are necessary for preserving cleanliness in everyday situations such as handling food, shopping, and commuting, even outside of clinical settings. By lowering the microbial burden on hands, they lessen the chance of cross-contamination and the transmission of infectious illnesses. Furthermore, current sanitizers now contain moisturizers and skin-soothing ingredients due to formulation advances, enabling repeated usage without irritating the skin.

Widespread usage of hand sanitizers not only protects personal health but also helps reduce infections in the community. They are advised by health officials across the world and are a crucial part of infection prevention strategies. Therefore, hand sanitizers are essential components of public health defence systems and are not only convenience items.

C. Classification of Hand Sanitizers

Based on their ingredients and mode of action, hand sanitizers can be divided into many general categories:

The most often used kind are alcohol-based hand sanitizers (ABHS), which contain 60–95% alcohol. Active substances like ethanol, isopropanol, or n-propanol break down cell membranes and denature proteins, which kills a variety of microorganisms. They don't leave any residue and act quickly.

Non-Alcohol-Based Hand Sanitizers: These products include iodine-based chemicals, triclosan, chlorhexidine gluconate, and Benzalkonium chloride as disinfectants. Although they could have long-lasting antibacterial effects, their extensive use has been constrained by worries about skin sensitization and antibiotic resistance.

Herbal and Natural Hand Sanitizers: Herbal sanitizers have become more popular as consumers' desire for sustainable and natural goods grows. Because of their calming and antibacterial qualities, ingredients including tea tree oil, tulsi, aloe vera, and neem are employed. Customers looking for eco-friendly and compassionate substitutes will find these goods appealing[9-10].

D. Regulatory Framework and Safety

Several national and international regulatory bodies oversee the production and distribution of hand sanitizers. The Food and Drug Administration (FDA) in the US regulates hand sanitizers as over-the-counter (OTC) pharmaceuticals. Guidelines for the use of ethanol and isopropanol during medical emergencies such as pandemics have been released by the European medicines agency (EMA) and other national regulatory agencies, Additionally, two standard formulations of hand sanitizers for use in community and clinical settings have been created by the WHO. These are commonly employed in low-resource environments and are based on ethanol 80% v/v and isopropyl alcohol 75% v/v. The proper use of hand sanitizers is essential to their safety. Toxicology may arise from overuse or unintentional consumption, especially in youngsters[11-12].

E. Market Trends and Global Demand

In recent years, the worldwide hand sanitizer market has grown at an exponential rate. Market research data state that the industry's worth jumped to almost USD 7 billion during the COVID-19 pandemic and was valued at over USD 2 billion in 2019. This quick growth has prompted new competitors, product diversity, and creative packaging and marketing approaches. For convenience, businesses have released versions with extra moisturizers, scents, herbal components and specially designed packaging The market for hand sanitizers is anticipated to continue growing moderately after the pandemic, propelled by consumer choice for portable hygiene products, institutional demand, and ongoing hygiene awareness. In response to environmental concerns, eco-friendly and sustainable formulas are also becoming more popular[13-14].

F. Innovation and Challenges

Long-lasting antimicrobial coatings, foam-based sanitizers, and dual-action solutions that combine skin nourishing and washing are examples of innovative hand sanitizer technologies. For increased efficacy, studies are also being done on herbal-antimicrobial mixes and nanotechnology-based ones. even with these developments, a number of issues still exist. Frequent use of alcohol-based products can cause dryness, irritation, and allergic responses in certain people. Additionally, certain individuals may become sensitive to the use of artificial perfumes and chemicals. Concerns over product quality and regulatory enforcement were also raised by the flood of inferior or counterfeit goods with insufficient alcohol content that hit the market during the epidemic.

Alcohol manufacturing, which may require non-renewable resources, and the environmental effects of single-use sanitizer bottles are two more growing concerns. Demands for biodegradable components, refillable packaging, and more environmentally friendly production methods are rising[15-16].

G. Role in Pandemic Preparedness

During medical situations, hand sanitizers have been shown to be an effective first line of defence. The lack of medical-grade hand sanitizers during the COVID-19 epidemic forced both public and commercial organizations to start mass manufacture. Manufacturers of cosmetics, distilleries, and breweries converted their spaces to satisfy the pressing need. The event highlighted the necessity of preparatory measures, such as developing public-private partnerships for quick reaction, expediting regulatory clearances, and storing basic hygiene supplies. Campaigns to educate people on the proper application and limits of hand sanitizers—such as the necessity of applying a sufficient amount, rubbing until dry, and avoiding usage on hands that are obviously soiled—were also crucial[17-18].

H. Educational and Behavioral Aspects

Availability is important, but effective use and public education are also crucial. Efficacy might be diminished by misconceptions such using too little product, using moist hands, or anticipating immediate benefits. According to behavioral research, perceived risk, accessibility, and understanding are important determinants of hand hygiene habits. Effective hand sanitizer use requires training for the general population, food workers, and healthcare professionals. Workplaces, public transportation, and schools are crucial venues for advancing hygiene instruction. Even outside of pandemic situations, including hand cleanliness into daily activities can create enduring habits that assist prevent the spread of illness[19-20].

II. LITERATURE SURVEY

1) *Kampf G., Kramer A. (2004). "Efficacy of Alcohol-Based Hand Disinfectants." Journal of Hospital Infection, 56(1): S13–S15*[21].

Aim: To evaluate the antimicrobial efficacy of alcohol-based hand rubs.

Methodology: Laboratory testing of ethanol and isopropanol against bacteria and viruses.

Findings: Alcohols at 60–95% concentration effectively inactivate a wide range of microorganisms; ethanol was more effective against viruses.

2) *Boyce J.M., Pittet D. (2002). "Guideline for Hand Hygiene in Health-Care Settings." MMWR Recommendations and Reports, 51(RR-16): 1–44*[22].

Aim: To provide updated guidelines for hand hygiene in clinical environments.

Methodology: Literature review and clinical data analysis.

Findings: Alcohol-based hand sanitizers are more effective and faster than soap and water for routine hand antisepsis.

3) *World Health Organization (2009). "WHO Guidelines on Hand Hygiene in Health Care." Geneva: WHO Press*[23].
Aim: To standardize global practices for hand hygiene.
Methodology: Evidence-based guideline development from global health data.
Findings: WHO recommended two alcohol-based formulations suitable for both developed and resource-limited settings.

4) *Girard R., et al. (2012). "Hand Hygiene in Non-Clinical Settings." Infection Control and Hospital Epidemiology, 33(4): 335–338*[24].
Aim: To explore hand Sanitizer use in schools and public areas.
Methodology: Observational and survey studies.
Findings: Proper use of hand sanitizers reduced absenteeism due to illness among students and employees.

5) *Suchomel M., et al. (2013). "Alcohols for Skin Antisepsis." Journal of Antimicrobial Chemotherapy, 68(5): 1005–1010*[25].
Aim: To compare different alcohols in skin antisepsis.
Methodology: Comparative efficacy testing of ethanol, isopropanol, and propanol.
Findings: Ethanol was more effective against non-enveloped viruses; isopropanol showed superior antibacterial action.

6) *Kramer A., et al. (2002). "Limited Efficacy of Alcohol-Based Hand Sanitizers against Spores." Journal of Clinical Microbiology, 40(4): 1343–1345*[26].
Aim: To test sanitizer efficacy against spore-forming bacteria.
Methodology: Laboratory tests with *Clostridium difficile* spores.
Findings: Alcohol-based hand sanitizers had limited effect on spores; washing with soap and water was superior.

7) *Sickbert-Bennett E.E., et al. (2005). "Comparative Efficacy of Hand Hygiene Agents." American Journal of Infection Control, 33(2): 67–77*[27].
Aim: To compare antimicrobial activity of various hand hygiene products.
Methodology: In vivo microbial reduction tests.
Findings: Ethanol-based gels showed the highest microbial kill rates, especially against Gram-negative bacteria.

8) *Mukherjee P.K., et al. (2017). "Antifungal Activity of Alcohol-Based Sanitizers." Journal of Medical Microbiology, 66(4): 520–528*[28].
Aim: To study efficacy of sanitizers on yeast and mold species.
Methodology: In vitro antifungal testing.
Findings: Hand sanitizers inhibited growth of *Candida albicans* and *Aspergillus niger*, though less effective against spore forms.

9) *Nair S.S., et al. (2021). "Formulation and Evaluation of Herbal Hand Sanitizer." International Journal of Pharmacy and Pharmaceutical Sciences, 13(3): 45–50*[29].
Aim: To develop an herbal-based alternative sanitizer.
Methodology: Extracts of neem and tulsi were formulated and tested.
Findings: Herbal hand sanitizer showed effective antibacterial properties and was safe for regular use.

10) *Golin A.P., Choi D., Ghahary A. (2020). "Hand Sanitizers: A Review of Ingredients, Mechanisms, and Efficacy." American Journal of Infection Control, 48(9): 1062–1067*[30].
Aim: To analyze current formulations of hand sanitizers.
Methodology: Systematic review of commercial sanitizer ingredients and effectiveness.
Findings: Alcohol-based products are the most effective, while non-alcoholic alternatives require more evidence.

III. FORMULATION

1) Usually made as gels, sprays, or liquids, hand sanitizers mostly contain alcohol or herbal components as the active antibacterial agent.
2) According to WHO recommendations, the most widely used alcohols are ethanol and isopropyl alcohol in concentrations between 60% and 95% v/v.

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3) Typically, a formulation could include hydrogen peroxide (0.125%) to inactivate spores, glycerin (1.45%) as a humectant to avoid skin dryness, ethanol (80%), and filtered water to regulate the volume.
4) Because of their calming and antibacterial qualities, extracts from plants including neem, tulsi, aloe vera, and tea tree oil are used in herbal formulations. The gel consistency can be achieved by using xanthan gum or Carbopol.
5) Additional antibacterial action and scent can be achieved by adding essential oils. The right pH balance, usually between 6.0 and 7.0, guarantees skin compatibility.
6) To preserve microbiological quality and stability during storage and use, the components are combined in a sterile environment[31-32].

IV. EVALUATION TEST

1) The physicochemical characteristics, antibacterial effectiveness, and user acceptance of hand sanitizers are all evaluated.
2) Testing for appearance, color, odour, pH, viscosity, spreadability, and drying time are examples of physicochemical testing. A pH between 5.5 and 7.0 is ideal for skin, and viscosity makes application simple.
3) User compliance is impacted by drying time and spreadability. Using common microbial strains including E. coli, S. aureus, and Candida albicans, antimicrobial effectiveness is evaluated in vitro using techniques like the agar diffusion test, minimum inhibitory concentration (MIC), and time-kill experiments.
4) Commonly used hand-rub effectiveness techniques include ASTM E2315 and EN 1500, which are WHO-recommended. Phytochemical screening and stability testing under different circumstances (temperature, light) are crucial for herbal formulations. Tests for skin irritation and sensitization guarantee human safety.
5) Consumer comments on sensory qualities like stickiness, aroma, and general contentment can shed light on how usable a product is.
6) All things considered, these tests guarantee that the formulation is safe, effective, and suitable for regular hand washing[33-34].

V. FUTURE SCOPE OF STUDY

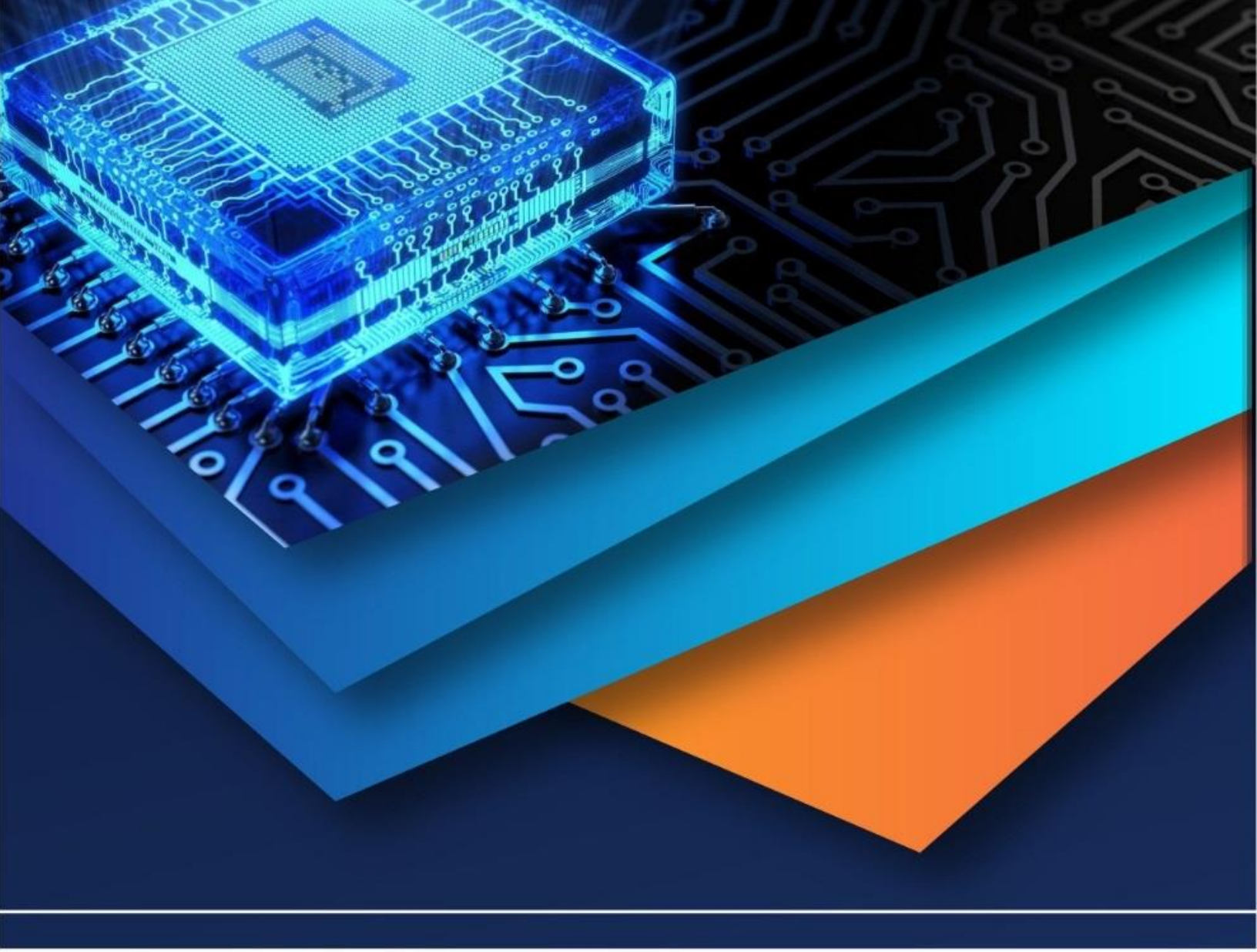
Research on hand sanitizers will focus on creating safer, more environmentally friendly, and more potent formulations by combining chemicals based on nanotechnology and herbs. Demand for non-alcoholic but just as effective sanitizers is rising as worries about alcohol-induced skin irritation and flammability rise. Innovative products including bio-polymeric gels, smart dispensers, and encapsulated essential oils present encouraging opportunities. Additionally, investigating hand sanitizers that have moisturizing and long-lasting antimicrobial properties might improve customer compliance. Environmental objectives might be further aligned with research on sustainable ingredient procurement and biodegradable packaging. In both public and medical settings, ongoing research will aid in addressing microbial resistance and enhancing cleanliness[35-36]. The creation of safer, more environmentally friendly, and very efficient formulations is the focus of future hand sanitizer research. Novel components beyond conventional alcohol-based formulations, such as herbal and bio-based antimicrobials that are eco-friendly and skin-friendly, must be investigated as antimicrobial resistance becomes a greater problem. Furthermore, extended-release formulations, clever delivery methods, and sanitizers based on nanotechnology provide encouraging paths for long-term protection. Additionally, more study is required to determine how long-term sanitizer use affects skin microbiota and overall health. The next generation of hand hygiene products will be shaped by developments in biodegradable packaging, regulatory improvments, and effectiveness against new infections[35-36]. Future research might also concentrate on incorporating AI and IoT technology into sanitizer dispensers to track hygienic compliance in public areas and hospitals in real time. Research on customized sanitizer's according to skin types, environment, and microbiological exposure might improve user comfort and efficacy, encouraging wider acceptance and regular use across the world.

VI. CONCLUSION

They offer a rapid and efficient way to practice hand hygiene, hand sanitizers are essential for preventing infections. Since of their broad-spectrum antibacterial action, alcohol-based formulations continue to be the gold standard, but herbal-based substitutes are becoming more popular since they are sustainable and kind to skin. Their efficacy, safety, and consumer appeal are guaranteed by proper formulation and assessment. To solve problems including skin irritation, germ resistance, and environmental concerns, more research and innovation are required. The creation of more sophisticated, environmentally friendly, and multipurpose hand sanitizers will continue to be a key topic of study in the pharmaceutical and cosmetic sciences due to rising demand and awareness.

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