

Comparison Study of Non-Alcoholic Sanitizer and Alcohol Based Sanitizer

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Abstract

Hand sanitizer is the best choice to maintain the hand hygiene and stopping the spread of infectious diseases. The active ingredient in traditional hand sanitizers is usually alcohol, but worries about flammability, skin irritation, and possible abuse have prompted the creation and growing popularity of alcohol-free substitutes. The purpose of this review is to objectively assess the safety, effectiveness, and usefulness of alcohol-free hand sanitizers. To successfully eradicate germs, alcohol-free hand sanitizers rely on substitute active ingredients, such as triclosan, quaternary ammonium compounds, or benzalkonium chloride. Research evaluating the performance of alcohol-free sanitizers against their alcohol-based equivalents has yielded inconsistent findings; some have demonstrated that the two types of sanitizers are equally successful in lowering bacterial counts, while others have highlighted variations in the range and duration of action. Additionally, issues with microbial resistance and the durability of antimicrobial agents on skin have been brought up. Alcohol-free hand sanitizers depend on different active ingredients, like triclosan, quaternary ammonium compounds, or benzalkonium chloride, to effectively kill germs. Research evaluating the performance of alcohol-free sanitizers against their alcohol-based equivalents has yielded inconsistent findings; some have demonstrated that the two types of sanitizers are equally successful in lowering bacterial counts, while others have highlighted variations in the range and duration of action. Additionally, worries have been raised regarding the potential for bacterial resistance and the persistence of antimicrobial agent residue on skin. Safety concerns are quite important, especially when it comes to potential allergies and skin irritation. Formulations without alcohol tend to be less drying and irritating than those with alcohol, which makes them appropriate for daily use for people with sensitive skin. To ascertain the long-term consequences of consistent exposure to various active ingredients, more study is necessary. The practical ramifications encompass evaluations of affordability, usability, and accessibility. In places like hospitals, schools, and other sectors where alcohol-based products are prohibited or unwelcome, alcohol-free hand sanitizers are advantageous. Still, there are obstacles in the way of gaining broad acceptance and guaranteeing adherence to hand hygiene protocols. In comparison to conventional alcohol-based formulations, alcohol-free hand sanitizers show promise as a viable substitute, providing

similar effectiveness with maybe less safety risks. To clarify their long-term effects and adjust their formulation for optimal efficacy and consumer acceptance, more research is necessary.

Keywords: Hand hygiene, sanitizer, alcohol, infections, microbial resistance

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INTRODUCTION

Like eating food, washing your hands is also important. It is the best approach to stay healthy and avoid numerous medical conditions. Dust, microorganisms, and other particles can be removed with soap, daily lubrication and good health maintenance. Certain microorganisms, pesticides, and other chemical residues that remain on hands

can be eliminated more effectively with hand sanitizer. In hospitals, hand sanitizers act effectively when hands are in contact with pathogens but are not oily or dirty [1]. They are recognized as over-the-counter products that are important in lowering hand colonization with potentially infectious organisms [2].

Hand hygiene is defined by the Centers for Disease Control and Prevention (CDC) as the practice of regularly washing hands with soap and water, sanitizing hands, and utilizing antiseptic hand washes. Foams, gels, surgical hand antiseptics, and hand sanitizers with an alcohol foundation are examples of antiseptic hand rubs and hand sanitizers (ABHS). These days, hand sanitizers are utilized as disinfectants more often due to their accessibility, low water and time requirements, and demonstrated capacity to lower microbial load [3]. Even if your hands seem clean, the World Health Organization (WHO) recommends washing them with soap and water or alcohol. The World Health Organization suggest that wash your hands with soap and water or hand sanitizer that contains at least 60% alcohol at the suggested intervals of time (Figure 1) [4].



Figure 1. Various types of hand sanitizer dosage forms.

Over 460,280,168 people had been infected by the virus as of March 16, 2022, and there had been over 6,050,018 fatalities [5]. The fast-spreading virus caused an unprecedentedly quick response from the scientific community in response to the potentially very serious new health problem. There were no safe and effective pharmaceuticals licensed for the treatment of COVID-19, despite the scientific community's immediate response and the vast global efforts to address this health issue [5]. The COVID-19 pandemic is being managed using a variety of strategies, including immunizations as well as good hygiene practices such frequent handwashing and the use of hand sanitizers. Hand Sanitizers played a vital role during the pandemic to avoid the viruses like SARS-CoV-2 which were causing Coronavirus [6].

After the first American fatality from COVID-19, hand sanitizer sales in the US jumped by 300% in comparison to the same week previous year. The next week, the first week of March, had a 470% spike in hand sanitizer sales over the same period the previous year. That is in an industry where hand sanitizer products already bring in more than \$200 million in sales annually in the US [7].

HISTORY

Beforehand sanitizer was created, alcohol was recognized to have sterilizing qualities. The phrase 'al kohl' relates to the antimony, the source of alcohol, which was utilized to cure eye ailments 5,000 years ago by the ancient Egyptians. Later, you could read about medical professionals who used alcohol to cure wounds, including Claudius Galen (131–201 AD) [5]. Although alcohol's antibacterial properties were now known, there was no practical way to use it at home or on the road. Still, Lupe Hernandez, a California nursing student, found that alcohol could be given as a gel in 1966, and that led to the invention of hand sanitizer. Its application was restricted to medical settings until 1988, when businesses like Purell and Gojo started to sell it [8].

But a recent search by historian Joyce Bedi of the Smithsonian Institution failed to find any records of Hernandez or proof of a 1960s U.S. patent for sanitizer with that name (Figure 2) [9].



Figure 2. Purell hand sanitizer advertisement.

TYPES OF HAND SANITIZER

The two types of hand sanitizer that are commonly available are alcohol-based and non-alcohol-based. One or more forms of alcohol, together with or without additional excipients and humectants, may be included in an ABHS that is applied to the hands to eliminate bacteria and temporarily stop their growth. Without the need for water or towel drying, ABHS may rapidly and efficiently eliminate microorganisms with a wide range of germicidal properties. However, there are a few drawbacks to ABHS's potency, including its brief antibacterial activity and poor resistance to various non-lipophilic viruses, bacterial spores, and protozoa (Figure 3) [10].

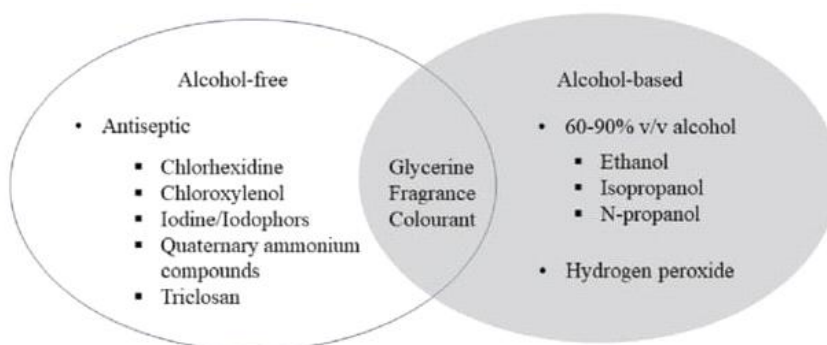


Figure 3. Types of hand sanitizer.

In contrast, NABHS or alcohol-free sanitizer uses substances that have antiseptic qualities to carry out the antimicrobial actions. The chemical functional groups of these substances determine their distinct modes of action and function. Compared to ABHS, they are generally safer for youngsters to use because they are nonflammable and are frequently used in low quantities [11].

Alcohol Based Hand Sanitizer

ABHS comes in three different dose forms: gel, liquid, and foam. Since each variety has unique qualities, research was done to determine how sensory attributes might affect how well users accept the product and, in turn, how they utilize it, which in turn affects compliance with hand hygiene regulations. Overall, the results demonstrated that although liquids left a high feeling of cleanliness and dried faster, gels and foams are more universally accepted than liquids, particularly in terms of handleability [12].

Direct contact between the alcohol solution and the target surface is made possible by ABHS, which comes in the shape of a spray that triggers stream aerosol solution. Nonetheless, there are several drawbacks to the sprays, such as flammability and patient inhalation of overspray. Ready-to-drink alcohol 'Hand Sanitizing Wipes (HSW)' are pre-wetted towelettes that are ready for topical disinfection usage and come in a sealed packet with disinfectants, antiseptics, surfactants, and other ingredients. The benefit of HSW is that it gets rid of potential pathogen transfers and contaminations caused by reusing towelettes. However, because the active chemicals may bind to the towelettes or degrade over time, the extended storage period may increase the likelihood that the antimicrobial/viricidal activity may be lost [13].

The World Health Organization defines an alcohol-based hand rub as a liquid, gel, or foam that contains alcohol and is applied to the hands with the intention of inactivating germs and/or temporarily halting their development. These treatments also contain other active ingredients, such as humectants and excipients, and may contain one or more forms of alcohol [14].

Various Preparation Techniques for alcohol based gel hand sanitizer

- a. Except for the thickening agent, all components are added and mixed simultaneously in the direct addition technique. The thickening agent is added when the ingredients have been mixed in the required amounts. To control the sanitizer's pH level and get it to a pH-neutral condition once the thickening agents are added, a neutralizing agent might need to be added. Changes to the process are dependent on the precise chemical makeup of the components, especially when the thickening agents and neutralizing agents are incompatible.
- b. The inverse addition process involves pre-wetting the thickener, typically with glycerol. After completing the previous step, the sanitizing ingredients are introduced gradually and blended meticulously. The name itself implies that this strategy is the opposite of the one mentioned above. This strategy is like the inclusion and requirements of neutralizing agents. Small-scale sanitizer manufacture is a good fit for this process.
- c. Other techniques: High-viscosity solutions exhibit a propensity to agglomerate. To mitigate this issue, we can employ the 'hot/cold' approach. This approach is unsuitable for components that contain ethanol. Ethanol and other volatile components are introduced into the gel after it is created using the hot cold approach, specifically during the cooling portion of the technique. To mitigate the drawbacks associated with the procedures, such as caking, it is possible to employ a mixture of such methods to prepare sanitizers. After the wet slurry is prepared, additional ingredients are incorporated using the processes employed in the addition procedure [15–17].

MECHANISM OF ACTION

As alcohols denature proteins in a generic way, they have been employed as disinfectants for one or more than one century, and the effectiveness of sanitizer has been well investigated. The purpose of hand sanitizers is to lessen the microorganisms that are linked to illnesses in hospital settings, namely the transient skin flora. They are typically picked up close contact with patients or from infected objects in the patient's immediate environment. The fate of the local skin flora is disregarded during this operation (Figure 4) [18].

When applied topically, alcohols have a fast germicidal effect but do not have long-term effects. However, the slow regrowth of bacteria on the skin after the application of alcohol-based hand antiseptics is likely due to the alcohol's sub-lethal effect on certain cutaneous bacteria (Figure 5) [19].

Alcohol-based sanitizers for medical use must have at least 70% alcohol by volume. Using alcohol-based hand sanitizers presents unique issues for healthcare personnel because they must wash their hands 100 times a day. An 85% alcohol gel applied topically to the skin for 15 seconds lowers bacterial infection by a factor of five. Use additional germicides, such as triclosan or chlorhexidine, to prolong the duration of protection.

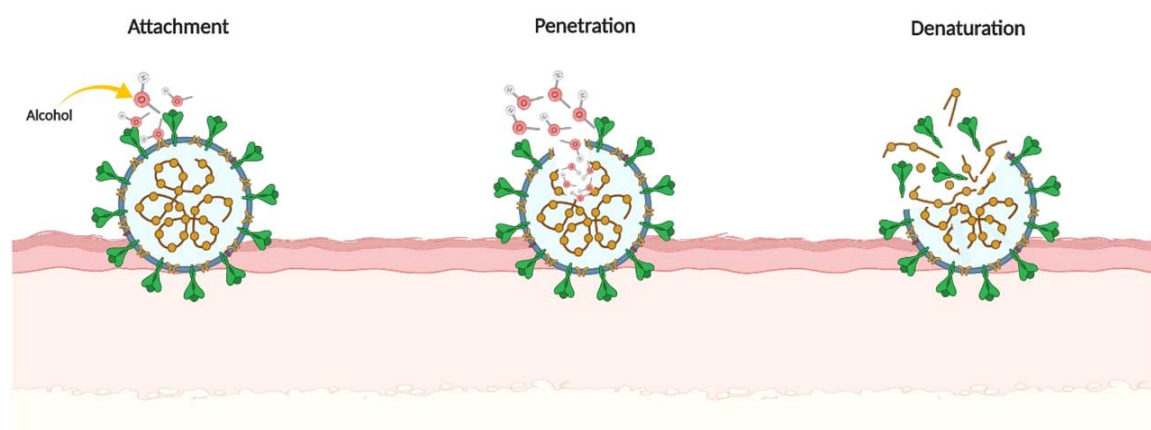


Figure 4. Virucidal action of hand sanitizer.

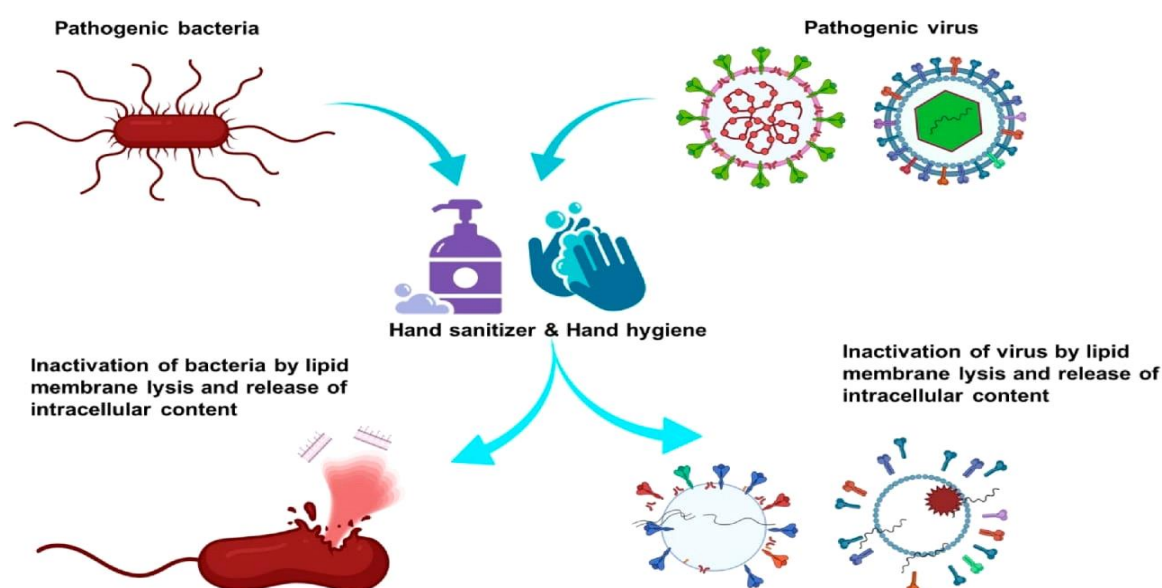


Figure 5. Bactericidal action of hand sanitizer.

DRAWBACKS OF ALCOHOL CONTAINING HAND SANITIZERS (ABHS)

ABHS is a Cause of Allergic Dermatitis

In ABHS, there are numerous possible allergens. Any of alcohol's constituents, such as thickeners, softeners, fragrances, or preservatives, might be the cause of this allergy. Exposure to certain allergens can cause local contact dermatitis, which manifests as red, painful, inflammatory hands with dry, cracked, and usually itchy skin. It can also cause urticaria syndrome [20]. An inflammatory skin reaction that is frequently brought on by external sources is contact dermatitis. ICD, which is frequently misdiagnosed, is the outcome of the stratum corneum being directly harmed by chemicals or other physical agents. Damage happens more quickly than the skin can heal itself. Irritating response, subjective or sensory, xerotic eczema, traumatic, pustular and acneiform, non-erythematous, cumulative, and traumiterative toxic are some of the several forms of ICD that have been documented [21, 22].

Alcohol Alters the Skin pH and Changes the Skin Microflora

Additionally, alcohol alters the pH of the skin, which impacts the skin's naturally occurring microorganisms and raises the danger of two types of bacteria that are known to cause skin infections: staphylococci and gram-negative bacteria. Skin with a pH of less than 5.0 is in a better state than skin with a pH of more than 5.0, according to studies. This result is supported by measurements of biophysical factors such as barrier function, scaling, and moisturization. The impact of pH on the

adherence of local skin bacteria was also ascertained. An alkaline pH (8–9) encourages the microflora to move out from the skin, whereas an acidic pH (4–4.5) protects the bacterial flora that resides there linked to the skin [23].

AHBS in People with Skin Disease

Those who currently have skin disorders like psoriasis or eczema are more likely to experience problems while using AHBS. It must be their first preference to wash their hands with plain, fragrance-free water and soap. If they must use AHBS, they should always let the gel dry on their hands before applying on an enormous amount of moisturizer. They are often urged to wear gloves to protect their hands and lessen the frequency of hand cleaning. Misuse of alcohol has been connected, among other skin disorders, to the development of psoriasis, discoid eczema, and superficial infections [24]. Long-term alcohol abuse also increases the risk of cellulitis, necrotizing wound infections, and delayed wound healing.

Numerous theories exist on the etiology of these skin conditions, such as impaired immunity, malnourishment, hepatic dysfunction, or alcohol's impact on fat metabolism. Since both acute and chronic alcohol misuse affect immunity, dermatological illnesses with an immunological pathogenetic process can be explained by this mechanism [22, 23, 25–28].

Possible Long-term Health Effects of ABHS

Phthalates and parabens are two other potentially harmful ingredients typically found in alcohol-based hand sanitizers. Certain research has connected elevated exposure to phthalates with reduced testosterone levels and an increase in aberrant sperm. Additionally connected to poorer fertility outcomes, parabens may also raise the risk of cancer [23].

ABHS Can Result in Alcohol Intoxication

When the hands meet ABHS, the alcohol becomes absorbed through the skin. The primary metabolite of alcohol breakdown in the liver is acetaldehyde. This can be detected in the blood soon after using the product, although levels are usually very low. However, because they are unable to metabolize alcohol, those who have acetaldehyde dehydrogenase deficiency will be more vulnerable while using alcohol-based hand gel. Inflamed or broken skin is also likely to absorb alcohol more readily. In children, alcohol-based sanitizers can result in alcohol poisoning [23].

There have been reports of young people consuming alcohol gel and becoming intoxicated. The blood of healthcare professionals who use ABHS thirty times a day exhibits measurable levels of alcohol. Alcoholic hand gel inhalation can irritate the lungs, airways, and inside of nostrils.

Uncertainty of AHBS Used by Pregnant Women

The safety of AHBS used in pregnant women is unknown. Alcohol may harm the foetus, which is why this is a concern. Few studies have investigated measuring blood alcohol content after using these alcohol-based hand sanitizers. However, studies on the effects of breathing in hand sanitizer on skin ages 21 to 25 have shown that a little quantity of alcohol is absorbed and reaches the user's circulation.

The more times the hand sanitizer was used, the more alcohol was absorbed. This is troubling since, according to ACOG, 'even at low levels of exposure, adverse effects of prenatal alcohol exposure on child behavior at age 6 to 7 years are evident.' Therefore, it's unclear if using hand sanitizer frequently while pregnant is safe [29].

ABHS is Flammable

It should be noted that AHBS is flammable and should not be used near open flames, such as lighters and matches. Alcohol-based hand sanitizers contain a high percentage of alcohol, usually around 60–95%. This high alcohol content makes them flammable. Hand sanitizers with alcohol base also have the risk of burning hands if they meet open flame after being applied. Hand sanitizer should never be used

near an open flame. Due to its flammability, hand sanitizer can catch fire or explode when it meets an open flame. This is especially true for hand sanitizers that contain a high percentage of alcohol, as they can ignite at relatively low temperatures [30].

Increase in Antibiotic Resistance

An unfortunate side effect of using AHBS over time is an increase in antibiotic resistance. For example, a 2018 study found that the *Enterococcus faecium* bacteria, which is one of the main sources of hospital-acquired infections, is growing more resistant to antibiotic-associated health problems. Hospital disinfectants are already losing their ability to kill certain bacteria [3].

The problem of antibiotic resistance is not new. But the COVID-19 pandemic has raised the danger of antibiotic resistance, which was already killing 700,000 people year globally. Antibiotics are being prescribed to COVID patients in many hospitals, not to treat the virus itself, but rather for potential secondary bacterial infections. There were reports of 2.8 million antibiotic-resistant infections in 2018. This will only get worse if ABHS is used [21, 25, 31].

Child Risk Factor

Kids might lick hand sanitizers since they occasionally taste good and come in vibrant colors. Even while moderate alcohol use is usually safe, it's crucial to remember that young children are more vulnerable to alcohol poisoning than teenagers. In the user's writing, a particular source or reference is referenced. Alcohol-intoxicated young children are more vulnerable to liver problems. Recent studies have shown that newborns suffering from acidosis, apnea, and coma have been using hand sanitizers containing alcohol. US officials report that during the first half of 2020, 9504 youngsters younger than twelve years old met a disinfectant. The results suggested that alcohol use might be dangerous, even at very low levels [32].

Directions to Use Hand Sanitizers

The efficacy of ABHS is also affected by the application technique. There are no strict guidelines, although it's usually advised to rub both hands until they're dry. Several studies have indicated that to effectively kill bacteria, a single application of hand sanitizer need have amounts ranging from 1.1 to 3 mL, despite the FDA's recommendation of 2.4 mL [26]. To achieve maximal germ killing and effectiveness, hand sanitizers must be used for the ideal amount of time, during which the user must rub the sanitizer over their hands until it dries. For optimal germ-fighting effectiveness, the government and public health groups advise rubbing hands with sanitizer for at least 20 seconds. According to several studies, using hand sanitizer incorrectly could be caused by a lack of understanding about good hand hygiene. This is because not all the hands and palms were completely coated with the hand sanitizer, which means that live germs may still be on hands even after application [27].

ALCOHOL FREE HAND SANITIZERS (AFHS)

Herbal Hand Sanitizer

Various essential oils (EOs), glycerin, vitamin E, and aloe vera were some of the natural components utilized to make the AFHS formulations that were assessed. Because these substances are widely available in the market, they are also conveniently accessible. Because of its inherent moisturizing and antibacterial qualities, as well as its ability to suppress bacterial strains, aloe vera gel was selected as the carrier for the hand sanitizer [33]. The purpose of these AFHS gels is to prevent the spread of co-infections during pandemics. After the gels for hand sanitizer were created, the formulations were characterized and evaluated in terms of their rheological behavior, gel spreadability, pH measurement, and organoleptic qualities [34]. To investigate the antibacterial efficacy of AFHS gels, a microbiological test zone of inhibition was conducted against several bacterial strains and *Candida albicans* yeast. Ultimately, an acceptability test was carried out to evaluate the safety of the manufactured hand gels by identifying any potential negative effects on human skin, such as skin irritation and skin redness (Figure 6) [33–44].

One potential way to solve the toxicity issue is to adapt different hand sanitizer recipes based on plant and natural resources. Alcohol-based hand rubs can be substituted with recognized medicinal plants that have antiviral and disinfecting qualities during COVID-19. Broad-spectrum antiviral properties of several plants have been documented and published up to this point [43].

To produce a strong antimicrobial hand sanitizer, keep the alcohol to aloe vera ratio at 2:1. To kill most bacteria, the alcohol percentage must not be minimum 60% present in it [41]. Essential oils are not very concentrated or volatile enough in a skin product because they lose their antibacterial efficacy when they get wet. They do not provide enough protection on their own, but when combined with an efficient alcohol-based sanitizer, they might provide a nice scent and a bit more defense [40].

All common microorganisms on the surface of inanimate objects were reliably eliminated by Herbal Hand Sanitizer. The superior antibacterial efficacy of Herbal Hand Sanitizer suggests that, in addition to alcohol, *Coriandrum sativum* and *Azadirachta indica* play a complementary function. Considering this, herbal hand sanitizer appears to be an available treatment against nosocomial illnesses caused by the most prevalent microbes [42].

Chemical-Based Hand Sanitizer

Most hand sanitizers that are currently on the market without alcohol contain benzalkonium chloride (BZK), also known as quaternary ammonium. It is non-flammable, non-irritating, non-sticky, odorless, non-damaging to surfaces. Hand sanitizers containing BZK are relatively non-toxic due to low concentrations of 0.12–2% [45].

Benzalkonium Chloride can be used in the place of Alcohol. Much lower amounts of benzalkonium chloride can be utilized, and it does not provide you with that familiar ‘burn’ that comes from using alcohol hand sanitizer. Healthcare professionals and other individuals who frequently must sanitize their hands may find it simpler to live with, and it may even improve compliance to prescribed hand sanitizing practices [36].

The efficacy of benzalkonium chloride hand sanitizers was evaluated in comparison with a 70% ethanolic hand sanitizer over the course of one week. The results show that benzalkonium chloride hand sanitizers are more effective at lowering healthcare workers’ fingertip levels of *Staphylococcus aureus* [46].

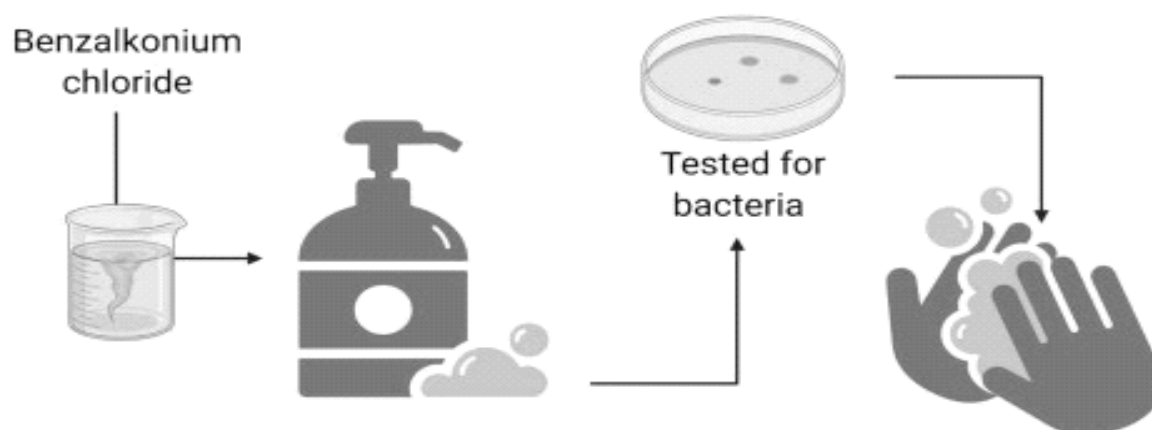


Figure 6. Alcohol free hand sanitizer.

Switching to alcohol-free hand sanitizer is logistically simple as well.

Before 2020, it was already in use. However, it appears that during this pandemic, non-alcohol-based hand sanitizers were abandoned by the government, which claimed that the novelty of the virus and the

particular laboratory conditions needed to conduct tests on it indicated that ‘we don’t know that this work.’ Based on its proven efficacy against lipid-encased viruses, such as COVID-19, the researchers reasoned that benzalkonium chloride would be a suitable disinfectant for the coronavirus [37, 47, 48].

ADVANTAGES OF AFHS IN COMPARISON TO ABHS

- *Non-flammable:* One of the most concerning aspects of alcohol-based hand sanitizers from a safety perspective is the possibility of misuse or accidental damage. People have burned themselves multiple times when sanitizer is misused, especially children who are unaware of the risks involved in touching someone with an open flame while using it. Because of this risk, several public spaces have transitioned to using alcohol-free hand sanitizers, especially for usage in patient rooms, hallways, and public areas [35–39].
- *Improve skin condition:* Since drying hands is one of the main negative effects of alcohol-based hand sanitizers, especially after frequent usage, any alcohol-free hand sanitizer will always have a greater chance of being kind to your skin. In contrast, alcohol-free hand sanitizers typically contain some oil or aloe gel to assist maintain and enhance skin condition. In the case of oil-based sanitizers, this helps moisturize dry hands [35–39].
- *Residual protection:* Once the concentration of alcohol-based hand sanitizers falls below a certain level, they lose their effectiveness. An alcohol-based sanitizer only provides protection to the extent that you can feel it on your skin; once it evaporates, the protection is gone. On the other hand, hand sanitizers without alcohol, especially those that contain essential oils, enable their antibacterial properties to penetrate the skin, resulting in a deeper and prolonged cleansing action [35–39, 49].
- *Natural and pleasant odor:* There’s no mistaking the distinct smell of alcohol, which many find repulsive. To make hand sanitizer smell acceptable enough to use, several compounds called esters are frequently added to the product. As consumers grow increasingly conscious of the risks, several alcohol-free sanitizers are turning to natural chemicals instead of perfumes and artificial smells to improve their scent and draw in customers. Finally, essential oils have their own distinct natural aromas that go well with them. Our special formulations combine functionality with fragrance to give you the best of both worlds [35–39, 50].
- *Potential for reduced development of antimicrobial resistance:* While research is still being done, some studies indicate that using alcohol-free active components in place of alcohol-based sanitizers on a regular basis may reduce the danger of contributing to the emergence of antimicrobial resistance [35–39]. It is crucial to remember that selecting between alcohol-based and alcohol-free hand sanitizers is dependent on several variables, such as the user’s unique needs, the environment in which it will be used, and personal preferences. People should select the hand sanitizer formulation that best suits their needs and priorities for hand hygiene, since each variety has pros and downsides of its own.

DRAWBACK OF ALCOHOL-FREE HAND SANITIZER

The fact that non-alcohol hand sanitizers typically arrive in a foamy shape could be a potential disadvantage. Although the user usually has a more enjoyable experience as a result, the dispenser does need to have a certain foaming mechanism. This can make converting from a non-foaming system cost prohibitive as it would need new hardware to be installed.

Despite some clear benefits, non-alcohol hand sanitizer products have yet to gain real traction in the health market. Health groups continue to support alcohol-based gels, which is why many in the field view them as a more trustworthy alternative. It’s not that these organizations don’t recognize the effectiveness of benzalkonium-based solutions. The term ‘alcohol-free’ or ‘non-alcohol’ could apply to any number of products on the market. It is a broad term that makes it impossible for agencies like the CDC and WHO to endorse [45].

CONCLUSION

Ultimately, a comparison of alcohol-based and alcohol-free hand sanitizers reveals a complicated environment with advantages and considerations for every formulation. To maintain hand hygiene and

stop the spread of infectious diseases, both kinds are required. Alcohol-based hand sanitizers, which are typically composed of ethanol or isopropanol, have been shown to be rapid and efficient against a variety of pathogens. Since they are particularly effective against bacteria, viruses, and fungus, they are the recommended choice in healthcare settings and situations where rapid and strong microbiological kill rates are essential. However, it is important to consider issues like skin irritation, dryness, and the possibility of alcohol being absorbed by the system, mostly for those with sensitive skin or specific medical conditions. On the other hand, alcohol-free hand sanitizers often contain different antibacterial agents.

REFERENCES

1. Singh P, Potlia I, Malhotra S, Dubey H, Chauhan H. Hand sanitizer an alternative to hand washing—a review of literature. *J Adv Oral Res*. 2020;11(2):137–42.
2. Kumar S, Das A. Hand sanitizers: Science and rationale. *Indian J Dermatol Venereol Leprol*. 2021;87(2):309–14.
3. Srinivasan S, Cui H, Gao Z, Liu M, Lu S, Mkandawire W, et al. Structural genomics of SARS-CoV-2 indicates evolutionary conserved functional regions of viral proteins. *Viruses*. 2020;12(4):360.
4. Duane B, Pilling J, Saget S, Ashley P, Pinhas AR, Lyne A. Hand hygiene with hand sanitizer versus handwashing: what are the planetary health consequences? *Environ Sci Pollut Res Int*. 2022;29(32):48736–47.
5. Glowicz JB, Landon E, Sickbert-Bennett EE, Aiello AE, Dekay K, Hoffmann KK, et al. SHEA/IDSA/APIC practice recommendation: Strategies to prevent healthcare-associated infections through hand hygiene: 2022 update. *Infect Control Hosp Epidemiol*. 2023;44(3):355–76.
6. Marumure J, Makuvura Z, Alufasi R, Chapungu L, Gufe C. Effectiveness of hand sanitizers in the prevention of COVID-19 and related public health concerns: A review. *Cogent Public Health*. 2022;9(1):2060904.
7. Huddleston JT. The history of hand sanitizer—how the coronavirus staple went from mechanic shops to consumer shelves [Internet]. 2020. Available from: <https://www.cnbc.com/2020/03/27/coronavirus-the-history-of-hand-sanitizer-and-why-its-important.html>
8. Bedi J. Lupe Hernandez and the invention of hand sanitizer. Lemelson Center Study Invention Innov [Internet]. 2020. Available from: <https://invention.si.edu/lupe-hernandez-and-invention-hand-sanitizer>
9. Gold NA, Mirza TM, Avva U. Alcohol Sanitizer. In: StatPearls [Internet]. StatPearls Publishing; 2023. Available from: <https://pubmed.ncbi.nlm.nih.gov/30020626/>
10. Greenaway RE, Ormandy K, Fellows C, Hollowood T. Impact of hand sanitizer format (gel/foam/liquid) and dose amount on its sensory properties and acceptability for improving hand hygiene compliance. *J Hosp Infect*. 2018;100(2):195–201.
11. Song X, Vossebein L, Zille A. Efficacy of disinfectant-impregnated wipes used for surface disinfection in hospitals: a review. *Antimicrob Resist Infect Control*. 2019;8:1–4.
12. World Health Organization. WHO guidelines on hand hygiene in health care. First global patient safety challenge: Clean care is safer care [Internet]. 2009. Available from: <https://pubmed.ncbi.nlm.nih.gov/23805438/>
13. Block SS, editor. Disinfection, sterilization, and preservation. Philadelphia: Lippincott Williams & Wilkins; 2001.
14. Lilly HA, Lowbury EJ, Wilkins MD, Zaggy A. Delayed antimicrobial effects of skin disinfection by alcohol. *Epidemiol Infect*. 1979;82(3):497–500.
15. MacGibeny MA, Wassef C. Preventing adverse cutaneous reactions from amplified hygiene practices during the COVID-19 pandemic: How dermatologists can help through anticipatory guidance. *Arch Dermatol Res*. 2021;313(6):501–3.
16. Pandey S. Has the increased use of hand sanitizers during the pandemic impacted antimicrobial resistance? *Microbiol Soc*. 2021.
17. O'Donoghue M, Ho JM, Pittet D, Suen LK. Acceptability and tolerability of alcohol-based hand hygiene products for elderly residents in long-term care: A crossover study. *Antimicrob Resist Infect Control*. 2019;8:1–10.

18. Glowicz JB, Landon E, Sickbert-Bennett EE, Aiello AE, Dekay K, Hoffmann KK, et al. SHEA/IDSA/APIC practice recommendation: Strategies to prevent healthcare-associated infections through hand hygiene: 2022 update. *Infect Control Hosp Epidemiol*. 2023;44(3):355–76.
19. Sandoval CJ, Cain PA, Diamond SF, Love JC, Smith SE, Nabipour S, et al. Legal education during the COVID-19 pandemic: Put health, safety, and equity first. *Santa Clara Law Rev*. 2020;61:367–94.
20. Fu L, Le T, Liu Z, Wang L, Guo H, Yang J, et al. Different efficacies of common disinfection methods against *Candida auris* and other *Candida* species. *J Infect Public Health*. 2020;13(5):730–6.
21. Sanitizer AB. Hand sanitizer use out and about. [Internet]. 2021. Available from: <https://www.cdc.gov/handwashing/show-me-the-science-hand-sanitizer.html>
22. Kramer A, Below H, Bieber N, Kampf G, Toma CD, Huebner NO, et al. Quantity of ethanol absorption after excessive hand disinfection using three commercially available hand rubs is minimal and below toxic levels for humans. *BMC Infect Dis*. 2007;7:1–2.
23. Fire Safety Support. Is hand sanitizer flammable? [Internet]. Available from: <https://www.ehs.washington.edu/system/files/resources/hand-sanitizer-fire-safety.pdf>
24. Allan M, Lièvre M, Laurenson-Schafer H, de Barros S, Jinnai Y, Andrews S, et al. The World Health Organization COVID-19 surveillance database. *Int J Equity Health*. 2022;21(Suppl 3):167.
25. Saha T, Khadka P, Das SC. Alcohol-based hand sanitizer—composition, proper use, and precautions. *Germes*. 2021;11(3):408.
26. Pope V, Ousley L. Irritant contact dermatitis caused by hand sanitizer use and handwashing during the COVID-19 pandemic. *Consultant*. 2020;60(7).
27. Lachenmeier DW. Safety evaluation of topical applications of ethanol on the skin and inside the oral cavity. *J Occup Med Toxicol*. 2008;3:1–6.
28. Booq RY, Alshehri AA, Almughem FA, Zaidan NM, Aburayan WS, Bakr AA, et al. Formulation and evaluation of alcohol-free hand sanitizer gels to prevent the spread of infections during pandemics. *Int J Environ Res Public Health*. 2021;18(12):6252.
29. Ogilvie BH, Solis-Leal A, Lopez JB, Poole BD, Robison RA, Berges BK. Alcohol-free hand sanitizer and other quaternary ammonium disinfectants quickly and effectively inactivate SARS-CoV-2. *J Hosp Infect*. 2021;108:142–5.
30. Kampf G, Todt D, Pfaender S, Steinmann E. Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *J Hosp Infect*. 2020;104(3):246–51.
31. Santos C. Reported adverse health effects in children from ingestion of alcohol-based hand sanitizers—United States, 2011–2014. *MMWR Morb Mortal Wkly Rep*. 2017;66.
32. Diepgen TL, Coenraads PJ. The epidemiology of occupational contact dermatitis. *Int Arch Occup Environ Health*. 1999;72:496–506.
33. Jing JL, Pei Yi T, Bose RJ, McCarthy JR, Tharmalingam N, Madheswaran T. Hand sanitizers: A review on formulation aspects, adverse effects, and regulations. *Int J Environ Res Public Health*. 2020;17(9):3326.
34. Singh D, Joshi K, Samuel A, Patra J, Mahindroo N. Alcohol-based hand sanitizers as first line of defence against SARS-CoV-2: A review of biology, chemistry, and formulations. *Epidemiol Infect*. 2020;148.
35. Merchel Piovesan Pereira B, Tagkopoulos I. Benzalkonium chlorides: Uses, regulatory status, and microbial resistance. *Appl Environ Microbiol*. 2019;85(13).
36. Chin AW, Chu JT, Perera MR, Hui KP, Yen HL, Chan MC, et al. Stability of SARS-CoV-2 in different environmental conditions. *Lancet Microbe*. 2020;1(1).
37. Lindberg S. How to make your own hand sanitizer. [Internet]. 2020. Available from: <https://www.healthline.com/health/how-to-make-hand-sanitizer>
38. Kolhapure SA. Evaluation of the antimicrobial efficacy and safety of PureHands herbal hand sanitizer in hand hygiene and on inanimate objects. *Antiseptic*. 2004;101(2):55–7.
39. Alghamdi HA. A need to combat COVID-19; herbal disinfection techniques, formulations and preparations of human health-friendly hand sanitizers. *Saudi J Biol Sci*. 2021;28(7):3943–7.

40. Chang A. Cleaning and disinfectant chemical exposures and temporal associations with COVID-19—National poison data system, United States, January 1, 2020–March 31, 2020. *MMWR Morb Mortal Wkly Rep.* 2020;69.
41. Ganjhu RK, Mudgal PP, Maity H, Dowarha D, Devadiga S, Nag S, et al. Herbal plants and plant preparations as remedial approach for viral diseases. *Virusdisease.* 2015;26:225–36.
42. Hammer KA, Carson CF, Riley TV. Antimicrobial activity of essential oils and other plant extracts. *J Appl Microbiol.* 1999;86(6):985–90.
43. Aodah AH, Bakr AA, Booq RY, Rahman MJ, Alzahrani DA, Alsulami KA, et al. Preparation and evaluation of benzalkonium chloride hand sanitizer as a potential alternative for alcohol-based hand gels. *Saudi Pharm J.* 2021;29(8):807–14.
44. Mowry JB, Spyker DA, Brooks DE, McMillan N, Schauben JL. 2014 annual report of the American Association of Poison Control Centers' National Poison Data System (NPDS): 32nd annual report. *Clin Toxicol (Phila).* 2015;53(10):962–1147.
45. Golin AP, Choi D, Ghahary A. Hand sanitizers: A review of ingredients, mechanisms of action, modes of delivery, and efficacy against coronaviruses. *Am J Infect Control.* 2020;48(9):1062–7.
46. Berardi A, Perinelli DR, Merchant HA, Bisharat L, Basheti IA, Bonacucina G, et al. Hand sanitisers amid COVID-19: A critical review of alcohol-based products on the market and formulation approaches to respond to increasing demand. *Int J Pharm.* 2020;584:119431.
47. Lai CC, Shih TP, Ko WC, Tang HJ, Hsueh PR. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and coronavirus disease-2019 (COVID-19): The epidemic and the challenges. *Int J Antimicrob Agents.* 2020;55(3):105924.
48. World Health Organization. Guide to local production: WHO-recommended handrub formulations. World Health Organization; 2010.
49. Prajapati P, Desai H, Chandarana C. Hand sanitizers as a preventive measure in COVID-19 pandemic: Its characteristics and harmful effects. *J Egypt Public Health Assoc.* 2022;97(1):6.
50. Ascenzi JM. Handbook of disinfectants and antiseptics. CRC Press; 1995.