International Journal of Community Medicine and Public Health
Abdullah AR et al. Int J Community Med Public Health. 2025 Nov;12(11):5285-5295
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20253716

Review Article

Navigating the new norm: review of health risks associated with widespread disinfectant and hand sanitizer use

Amira Raudhah Abdullah[1]*, Liyana Azmi[1], Muhamad Afiq Aziz[2], Nur Waliyuddin Hanis Zainal Abidin[3], Muhammad Idham Jasmiad[4]

[1]Faculty of Medicine and Health Sciences, Universiti Sains Islam Malaysia, Persiaran Ilmu, Putra Nilai, Nilai, Negeri Sembilan, Malaysia
[2]Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia
[3]School of Health Sciences, Health Campus, Universiti Sains Malaysia, Kubang Kerian, Kelantan, Malaysia
[4]Department of Nursing, Fakulti Perubatan Universiti Kebangsaan Malaysia, Hospital Canselor Tuanku Muhriz, Cheras, Kuala Lumpur, Malaysia

Received: 27 August 2025
Accepted: 16 October 2025

***Correspondence:**
Dr. Amira Raudhah Abdullah,
E-mail: amiraraudhah@usim.edu.my

ABSTRACT

The COVID-19 pandemic led to increased global use of alcohol-based hand sanitizers (ABHS) and disinfectants as key infection control measures. While initially implemented as emergency measures, their continued and widespread use in healthcare and community settings has raised concerns regarding long-term safety and environmental impact. This systematic review aimed to evaluate the adverse health effects associated with ABHS and disinfectants beyond the pandemic phase. Following PRISMA guidelines, a comprehensive search of PubMed, Google Scholar and Scopus identified studies published between 2014 and 2025. Eleven studies met inclusion criteria, focusing on chemical composition, exposure routes and the toxicological outcomes. Evidence shows that dermal absorption, inhalation, ingestion and ocular contact are the main exposure pathways to ABHS and disinfectant. Meanwhile, reported health effects ranging from mild dermatitis to systemic toxicity. Chemicals such as methanol, quaternary ammonium compounds (QACs) and chlorine-based disinfectants were most often linked to respiratory problems, neurological effects, reproductive risks as well as pose risk as environmental contamination. Children, pregnant women, and healthcare workers were found to be especially vulnerable. Weak regulatory oversight during the pandemic contributed to the circulation of substandard or counterfeit products, adding to the risks. The ongoing high use of ABHS and disinfectants in 2025 underscores the importance of stronger regulations, clearer labelling, better quality control, and continuous public education. Moving forward, safer alternatives and sustainable hygiene practices are needed to maintain effective infection prevention while minimizing risks to health and the environment.

Keywords: Alcohol-based hand sanitizer, Disinfectant, Adverse effects, Chemical safety, Infection control

INTRODUCTION

Zoonotic viral infections remain a persistent public health threat, most recently illustrated by the emergence of SARS-CoV-2 in Wuhan, China.[1,2] The resulting Coronavirus Disease 2019 (COVID-19) pandemic rapidly escalated into a global health emergency, reshaping healthcare systems, economies and daily behaviour.[3] Although the acute phase has passed, its impact continues to influence public health strategies and individual behavior. Figure 1 shows the transmission of SARS-CoV-2 that can occurs mainly through respiratory droplets, aerosols and contact with contaminated surfaces.[4] These have highlighted the importance of airborne transmission control measures which has contributed to the current approaches to infection prevention. Therefore, the COVID-19 pandemic contributed to the long-term integration of hygiene practices, including regular hand hygiene using alcohol-based hand sanitizers (ABHS), disinfectant use and routine environmental cleaning which were initially introduced as emergency responses.[5]

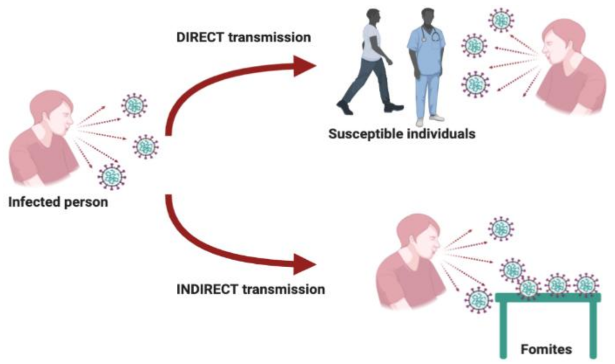

Figure 1: Schematic representation of the transmission pathways of SARS-CoV-2. Infected individuals release respiratory droplets and aerosols during activities such as coughing, sneezing, or speaking, which facilitate both direct person-to-person transmission and short-range airborne spread. Indirect transmission may occur via fomites, where viral particles deposited on contaminated surfaces or objects can infect susceptible individuals upon contact.

As of mid-2025, SARS-CoV-2 continues to circulate globally, with periodic increases in activity noted since 2024 particularly in the Eastern Mediterranean, South-East Asia and Western Pacific regions, while Africa, Europe and the Americas report lower number of cases.[6] Although the incidence of cases and deaths has declined compared to the pandemic period, recurrent outbreaks continue to underscore the importance of preventive hygiene measures. As a result, the use of ABHS and disinfectants remains as a practice across healthcare and community settings. While these products are effective in limiting transmission, sustained and extensive exposure has raised concerns regarding potential health risks and environmental effects. This review examines current evidence on the adverse outcomes of ABHS and disinfectants, with emphasis on their chemical composition, exposure routes and associated health impacts.

Evolving infection control measures post-COVID-19: hygiene and chemical use

In the early phase of the COVID-19 pandemic, countries worldwide adopted stringent infection-control measures, including lockdowns, travel restrictions, quarantines, physical distancing and universal masking.[7] To complement these broad public health directives, individual and collective hygiene protocols became foundational. While early population-level containment strategies, were effective in suppressing initial COVID-19 surges, the focus eventually shifted toward maintaining individual hygiene practices. The structural characteristics of SARS-CoV-2 made it highly susceptible to inactivation by alcohol-based formulations and other chemical or physical methods.[8,9] As a result, ABHS and chemical disinfectants became central to both healthcare and community-level prevention strategies. These stringent operational procedures were concurrently extended to public domains and daily routines. As of 2025, the continued circulation of SARS-CoV-2 and the resurgence of respiratory viruses globally highlight the ongoing importance of these hygiene practices. These practices have contributed to a marked increase in global consumption of hand sanitizers and disinfectants, raising concerns about long-term safety and environmental impact. The post-pandemic period provides an opportunity to re-evaluate their use and address risks related to chemical overexposure and sustainability.

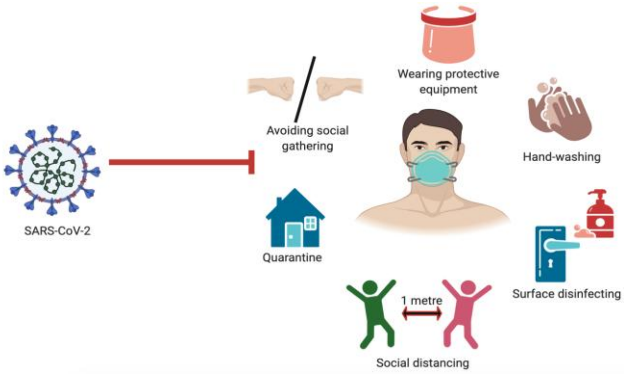

Figure 2: Strategies to prevent the spread of the SARS-CoV-2 virus. SARS-CoV-2 is mainly spread from human to human through droplets generated from an infected person. Wearing protective equipment such as a mask and face shield alone cannot protect an individual against respiratory viruses. Physical distancing in combination with hand hygiene should be applied to block virus transmission from spreading to others.

Alcohol-based hand sanitizers

Alcohol-based hand sanitizers (ABHS) typically contain ethanol, isopropanol, or n-propanol at concentrations of 60–95%, which are highly effective against enveloped viruses including SARS-CoV-2.[10,11] Their continued widespread use beyond the pandemic has raised concerns about long-term safety. Repeated exposure to ethanol or isopropanol can impair the skin barrier, while contaminants such as methanol, benzene and acetaldehyde have been detected in some commercial formulations, posing risks of systemic toxicity.[12-14] Although safer formulations such as low-VOC, fragrance-free and biodegradable products have been developed, evidence on their long-term safety remains limited. Table 1 summarizes the hazard classifications of commonly used ABHS ingredients and contaminants.

Table 1: Safety labelling and chemical classification for notable chemicals in hand sanitizers and disinfectants.

Chemical name	Classification code	Labelling		Product
		Signal word	Hazard pictogram	
Ethanol	Flam. Liq. 2	Danger		ABHS
Isopropyl alcohol/isopropanol	Flam. Liq. 2 Eye Irrit. 2 STOT SE 3	Danger		ABHS
Sodium hypochlorite	Skin Corr. 1B Eye Dam. 1 Aquatic Acute 1	Danger		Household bleach, commercial disinfectant, surface cleaners
Hydrogen peroxide	Ox. Liq. 1 Acute Tox. 4 (inh) Acute Tox. 4 (oral) Skin Corr. 1A Eye Dam. 1 STOT SE 3	Danger		ABHS, household bleach, commercial disinfectant, surface cleaners
Quaternary Ammonium (ammonium chloride)	Acute Tox. 4 (oral) Eye Irrit. 2	Warning		Household bleach, commercial disinfectant, surface cleaners
Quaternary Ammonium (Triethylene glycol)	Eye Dam. 1	Danger		Household bleach, commercial disinfectant, surface cleaners
Glutaraldehyde	Acute Tox. 2 (inh) Acute Tox. 3 (oral) Skin Corr. 1B Eye Dam. 1 STOT SE 3 Resp. Sens. 1 Skin Sens. 1 Aquatic Acute 1 Aquatic Chronic 2	Danger		Hospital grade disinfectant

Role of disinfectants in infection control

Disinfectants are chemicals commonly used on inanimate objects or surfaces commonly containing hydrogen peroxide, sodium hypochlorite, glutaraldehyde, quaternary ammonium compounds (QACs) or alcohols.[15] Their antimicrobial activity is achieved through oxidative damage or membrane disruption.[16] While effective for infection control, excessive use during the COVID-19 pandemic led to increased reports of acute effects such as skin irritation, mucosal injury and respiratory symptoms in poorly ventilated spaces.[17] Longer-term concerns include associations between occupational QAC exposure and respiratory illness and the accumulation of chemical residues in wastewater and indoor air.[18-20] Furthermore, aerosolized disinfectants released into the open environment may contribute to chemical pollution and generate toxic residues, posing additional ecological hazards.[21] By 2023, health authorities cautioned against some disinfection practices due to limited efficacy and documented health risks. While the use of ABHS and surface disinfectants remain important for infection prevention, their active compounds can cause adverse effects when misused or overapplied. Awareness of their chemical properties and hazard classifications are summarized in Table 1 which is essential to support responsible use in healthcare and community settings.

METHODS

A comprehensive literature search was conducted to identify relevant studies on the composition, safety profiles, the health implications of ABHS and disinfectants. Electronic databases searched included PubMed, Google Scholar, and Scopus covering publications from the year 2014 to 2025. Additional references were identified from the bibliographies of key articles and grey literature sources, including World Health Organization (WHO) guidelines and national regulatory documents. The primary keywords used were: "alcohol-based hand sanitizer," "disinfectant," "COVID-19," and "public health." Additionally, the reference lists of all included articles were manually screened to identify any further relevant studies. Search strategy was shown in Figure 3.

Inclusion criteria

Studies were eligible for inclusion if they met the following criteria: 1) published systematic reviews, meta-analyses, observational studies and experimental studies that investigate the health and safety of hand sanitizers and disinfectants, 2) focused on chemical composition, antimicrobial efficacy, toxicological effects, or regulatory standards related to ABHS and/or disinfectants, 3) studies involving the general population, occupational groups (e.g., healthcare workers), and vulnerable populations (e.g., children) were included, 4) the studies must be relevant to the context of the COVID-19 pandemic and its aftermath, reflecting the increased use and associated public health issues and 5) available in English.

Exclusion criteria

Articles were excluded if they were: 1) opinion without supporting evidence, 2) studies focused solely on the efficacy of these products without mentioning health risks or safety were excluded, 3) studies on other sanitizing agents or methods not discussed in the manuscript, 4) articles that are in other languages than English and 5) any duplicate studies were excluded to prevent data redundancy.

Any dispute about whether an article fits the inclusion criteria, such as study type, chemical function, pathogenesis of exposure, and safety, was resolved by discussion.

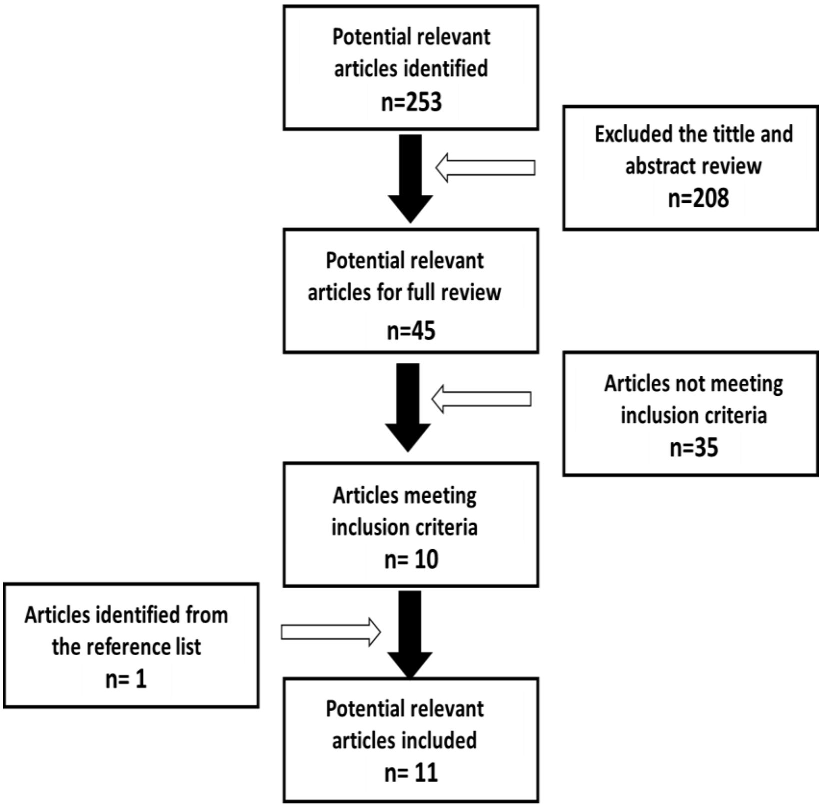

Figure 3: Literature selection for systematic review.

RESULTS

This section presents the key findings from the systematic review regarding the exposure routes and adverse health effects associated with the widespread use of ABHS and disinfectants. The literature search yielded an initial 253 records from PubMed, Scopus, and Google Scholar. Our comprehensive literature search identified twelve studies published between 2014 and 2025 that met the inclusion criteria, following the removal of duplicates and a rigorous two-stage screening process. The characteristics of these studies and their key findings related to hand sanitizers and disinfectants are summarized in Table 2. The analysis of the included studies as shown in Table 2 revealed that the primary routes of exposure were dermal contact, inhalation and accidental ingestion, with varying levels of associated health risks. The findings consistently demonstrated a range of adverse effects, ranging from localized outcomes such as irritant and allergic contact dermatitis to severe systemic toxicities. Specific chemical agents, including methanol, QACs and chlorine-based disinfectants were frequently implicated in more serious adverse health effects.

Table 2: Exposure routes and adverse effects of ABHS and disinfectant.

Chemicals	Types of products	Exposure routes	Adverse effects	Key findings	Reference
Hand sanitizer					
Methanol, ethyl acetate, acetaldehyde	ABHS (healthcare and household)	Dermal, inhalation, accidental ingestion	Methanol poisoning (blindness, death), skin dryness and barrier damage from ethyl acetate, carcinogenic/teratogenic risks from acetaldehyde.	ABHS formulated with technical-grade ethanol were temporarily permitted during COVID-19; though general dermal and inhalation risks were low, contaminants such as methanol, ethyl acetate, and acetaldehyde posed the highest health risks, leading to recalls and stricter regulatory oversight.	Tse et al[22]
70 % Isopropyl alcohol	ABHS	Dermal	Contact dermatitis	Reported case of child developed itching, dryness, and redness of the hands due to frequent use of 70% isopropyl in ABHS causing allergic contact dermatitis.	Inder et al[23]
Ethanol / Isopropanol vapors	ABHS	Inhalation	Skin irritation, eye discomfort, potential respiratory exposure from elevated vapor levels.	Real-time monitoring showed indoor alcohol vapor concentrations spiking up to ~46,000 ppb/g sample during hand-rub use. Surveyed residents reported frequent sanitizer use (≥5 times/day in 34%) with high prevalence of skin irritation (79%) and eye discomfort (18%), indicating potential long-term risks in poorly ventilated environments.	Lo et al[24]
n-propanol and isopropanol	ABHS	Dermal and inhalation.	Irritant contact dermatitis with frequent use.	The systematic review showed that n-propanol and isopropanol can cause skin irritation, with the severity influenced by concentration, frequency of use, and skin condition.	Taser et al[25]
62% ethanol	ABHS	Dermal, inhalation, ocular	Intoxication (drowsiness, eye irritation, nausea, vomiting, abdominal pain) and eye irritation	Chronic occupational exposure to ABHS in healthcare workers was detectable through biomarkers such as ethyl glucuronide, ethyl sulphate, and acetone in the urine sample indicating potential systemic absorption.	Mansour et al[26]
75% ethanol	ABHS	Dermal, inhalation, accidental ingestion	Chronic toxicity (visual disturbances, impaired vision, organ damage); Severe toxicity (coma, seizures, death, permanent blindness, CNS damage).	A 4-year-old child accidentally ingested ethanol at kindergarten and presented with blood alcohol concentration of 224.7 mg/dL, exceeding toxic levels and causing central nervous system depression. Children exposed to ethanol-containing substances, including hand sanitizers, may develop ethanol intoxication, as illustrated by clinical case reports.	Hon et al[27]
Methanol	ABHS	Derma, inhalation accidental ingestion and ocular	Skin irritation, alcohol poisoning (especially in children), and severe methanol poisoning from contaminated products, which can cause blindness and death.	Case series in Southeast Asia documented ongoing methanol poisoning from counterfeit hand sanitizers. Methanol poisoning cases were linked to contaminated hand sanitizers, identified through FDA investigations.	Konkel et al[28]
Disinfectant					
Trihalomethanes (THM) by-products of	Chlorine-based disinfectants	Dermal, inhalation, and ingestion during household cleaning (via	Increased risk of bladder cancer, colorectal cancer, adverse	Children and their mothers showed elevated urinary THM levels following routine household cleaning with chlorine-based	Andra et al[29]

Continued.

Chemicals	Types of products	Exposure routes	Adverse effects	Key findings	Reference
sodium hypochlorite	(household cleaning agents)	contaminated food/water, dermal absorption, or vapor inhalation)	pregnancy outcomes, congenital anomalies, and birth defects.	disinfectants, demonstrating significant passive exposure through domestic activities.	
Combination of QACs: Alkyl dimethyl benzyl ammonium chloride (ADBAC) and didecyl dimethyl ammonium chloride (DDAC)	QAC-based disinfectants	Inhalation	Risk of fertility impairment, contact dermatitis, asthma, ocular inflammation, membrane damage	In vivo studies showed that mice exposed to QACs for six months developed severe reproductive defects, decreased fertility, longer pregnancy intervals, and significant morbidities.	Melin et al[30]
QACs	Household and healthcare disinfectants	Dermal, inhalation	Respiratory symptoms (asthma), dermatitis and reproductive risks.	Narrative review highlighted that increased QAC use poses long-term human and environmental risks, including mitochondrial dysfunction, oxidative stress, and aquatic ecotoxicity; UV-C technology was proposed as a safer non-chemical alternative.	Ng et al[31]
Glutaraldehyde, hydrogen peroxide, alcohol, and QACs	Hospital-grade disinfectants	Inhalation	Respiratory irritation, chronic respiratory illness (COPD)	Epidemiological study of US female nurses found a significant association between long-term occupational exposure to disinfectants and increased incidence of chronic obstructive pulmonary disease (COPD).	Dumas et al[32]

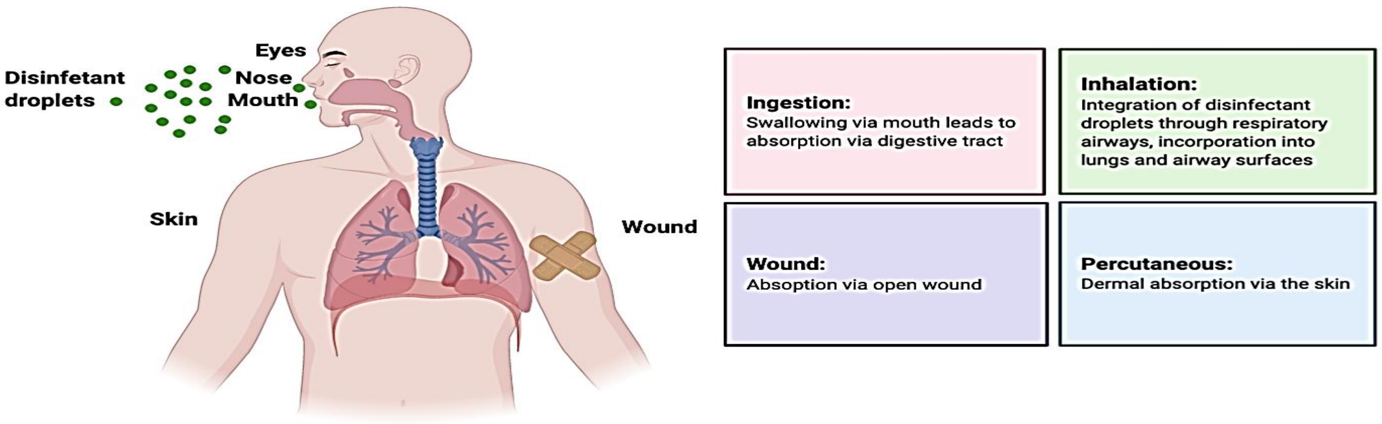

Figure 4: Potential routes of human exposure to chemicals. An individual may come into contact with disinfectant droplets through inhalation, ingestion, skin and open wound absorption including eyes.

DISCUSSION

Routes of exposure for ABHS and disinfectants

Sanitizing chemicals can enter the body through four main routes: dermal absorption, inhalation, ingestion, and ocular contact (Figure 4). Understanding these pathways is essential to characterize the extent of exposure in different populations and settings, which forms the basis for evaluating toxicological risks. Dermal exposure is the most common route, especially during frequent ABHS use. Alcohols such as ethanol, isopropanol and n-propanol are readily absorbed through the skin.[33] The degree of absorption depends on factors including concentration, frequency of use, surface area of application and individual skin condition.[25] Bessonneau and Thomas (2012) demonstrated that isopropanol-containing ABHS enhances dermal absorption.[34] Excessive use has been linked to elevated urinary ethanol metabolites which suggest systemic absorption.[26] Healthcare workers, who may apply sanitizers multiple times per shift, and children, who have thinner skin, and a higher surface area-to-volume ratio may be especially vulnerable.[22]

Inhalation exposure occurs due to volatile properties of alcohol and disinfectants. For example, chemical such as QACs or chlorine-based products can aerosolize during spraying or wiping. Indoor use, especially in poorly ventilated environments can lead to measurable vapor concentrations.[24,34] Inhalation of aerosolized disinfectants such as QACs, glutaraldehyde and chlorine-based products has been linked to respiratory symptoms and with chronic exposure it may be associated with respiratory morbidity.[32] Children, pregnant women, and occupationally exposed workers represent high-risk groups. Ingestion exposure is typically accidental but has been widely documented, particularly in children. Ingestion events range from small accidental ingestions at home to cases of intentional misuse during the pandemic.[27,28] Although less frequent than dermal or inhalation exposure, ingestion carries the highest acute risk of systemic uptake. Lastly, ocular exposure may occur mainly through accidental splashes, sprays or hand-to-eye transfer after sanitizer application. Such exposures are common in both healthcare and domestic environments and can affect children due to their frequent hand-to-face contact.[24]

Overall, evidence indicates that repeated ABHS use can lead to detectable systemic absorption, reflected by elevated urinary ethanol metabolites and non-lethal blood ethanol levels in frequent users.[35,36] In pregnancy, even low ethanol doses are of concern as ethanol can freely crosses the placenta and may cause fetal harm.[37,38] In the end, understanding the routes of exposure for ABHS application is crucial to provide protection and information to the public, especially in high-risk populations. For disinfectants, inhalation remains the predominant exposure route. Frequent or improper use can result in unnecessary chemical uptake, with volatile compounds such as QACs and chlorine by-products associated with oxidative stress, cellular damage, and long-term respiratory risks.[29,30,32,39,40] Domestic exposures have also been reported in children, underscoring the risk of passive inhalation during household cleaning. These findings highlight the importance of safe handling, proper ventilation and public awareness, particularly in high-use community settings. Therefore, understanding the multiple exposure pathways of ABHS and disinfectants is crucial for effective risk communication, formulation improvements, and protection of high-risk populations.

Toxicological concern of ABHS and disinfectants

Currently, ABHS and disinfectants continue to be widely used, not only in healthcare facilities but also in schools, workplaces, indoor playgrounds and households. It has been properly documented and reported that hand sanitizers and disinfectants contain harmful chemicals that may cause adverse side effects if used too frequently and incorrectly.[38,41] The variety of ABHS made available in the market contains various mixtures of chemical compositions and excipients. Repeated and high concentration exposure to the main components of ABHS may lead to a range of health hazards. The most common side effect of ABHS over-usage is contact dermatitis or skin irritation.[23,42,43] Ethanol continues to be the primary alcohol used in ABHS due to its potent virucidal properties and relatively favourable skin tolerance. Both the CDC and WHO recommend 60–95% ethanol formulations as safe and effective.[44] However, ethanol toxicities from frequent inhalation or ingestion may lead to toxicity and produce symptoms such as drowsiness, eye irritation, nausea vomiting and abdominal pain.[26,42] On its own, ethanol is classified as type-2 flammable substance. Other alcohols used in ABHS include isopropanol or isopropyl alcohol, which is also classified as type-2 flammable substance. According to Turner et al, ABHS containing isopropyl alcohol have higher dermal absorption higher dermal compared with ethanol. Dermal absorption of isopropyl alcohol may induce side effects including headaches, dizziness, hypoglycaemia, abdominal pain, nausea and vomiting.[42]

Disinfectant use in public and community environments has persisted beyond the pandemic, with routine application in schools, offices and transport hubs becoming normalized. This continued reliance has heightened concern about unintended exposures, particularly since many disinfectants contain chemical classes already linked with adverse health outcomes (Table 2). QACs, among the most widely used agents, are increasingly recognized as respiratory irritants.[31] Epidemiological studies and occupational health reports associate repeated inhalation exposure to QAC aerosols with asthma exacerbations, chronic cough, and reduced lung function in both cleaning workers and individuals exposed in public facilities.[18] These findings are consistent with the acute respiratory symptoms listed in Table 2 and suggest that prolonged environmental exposure may contribute to chronic disease risk. Chlorine-based disinfectants, particularly sodium hypochlorite, also align with toxicological outcomes presented in Table 2, including skin corrosion, ocular injury and respiratory irritation. When used in poorly ventilated areas or mixed with acids, sodium hypochlorite can generate chlorine gas, producing acute toxic effects such as eye and lung injury.[45] Moreover, chlorination by-products, including trihalomethanes (THMs), have been associated with elevated risks of bladder cancer, congenital anomalies and adverse pregnancy outcomes in population studies.[46-48] These findings reinforce the chronic toxicity concerns summarized in Table 2, highlighting both short-term and long-term risks linked with common household and institutional cleaning practices.

Taken together, the current body of evidence indicates that disinfectants remain essential for infection control but require cautious use, especially in non-healthcare public settings where daily disinfection may not always be necessary. The evidence presented in Table 2 underscores the importance of limiting exposures by avoiding excessive spraying or misting, ensuring adequate ventilation, and encouraging substitution with safer, low-volatility products when available. Strengthening labelling, product standardization, and user education will be critical to reduce unnecessary health risks while preserving the benefits of surface disinfection in 2025 and beyond.

Health and safety issues with product handling and quality control

The initial phase of the COVID-19 pandemic saw a dramatic surge in demand for disinfectants and ABHS, leading to a critical gap in product quality control. As manufacturers try to meet this demand, cases of improper production and the presence of prohibited chemicals became a significant concern.[49,50] This issue raised concern with a disturbing case of methanol-contaminated ABHS ingestion that resulted in fatalities in Arizona and New Mexico.[51] Regulatory bodies have since acted. For example, the U.S. Food and Drug Administration (FDA) has banned several active ingredients benzalkonium chloride (BAC), ethyl alcohol, and isopropyl alcohol from certain consumer hand sanitizers, pending further safety and effectiveness data.[52] This highlights an ongoing effort to ensure these chemicals are recognized as safe and effective for consumer use. To safeguard consumers, all chemical products, including hand sanitizers, must be accompanied by a Material Safety Data Sheet (MSDS). This document, which outlines a product's physical and chemical properties, toxicity and safe handling procedures, is vital for managing chemical hazards, spills, and over-exposure.[53]

However, during the pandemic, many products entered the market without MSDS documentation or proper labelling that urges regulators to strengthen enforcement and quality control worldwide.[54] Suppliers are responsible for ensuring accurate classification, labelling, packaging and chemical inventory before release. Correct labelling is critical for safe handling and storage: flammable sanitizers should be kept in cool, ventilated areas away from ignition sources, while toxic or corrosive disinfectants must be separated from incompatible materials to prevent accidental exposure.[55] Beyond labelling, personal protective equipment (PPE) such as gloves, goggles, and respirators is recommended for workers with high exposure risk, including cleaning personnel and healthcare staff, to reduce dermal, ocular and respiratory contact.[56] Apart from that, additional concern on the improper disposal of these chemicals should also take into accounts as these may produce radicals in the environment that in return may harm the community.[57] The extensive use of sanitizing chemicals highlights the need for a unified approach to global safety standards, rigorous quality control, and continuous health and environmental surveillance to prevent their associated risks from outweighing their protective benefits.

Raising public awareness

The pandemic has shown that more than anything, the best defence against this disease are people who follow and understand the importance of the enforced rules.[58] Public awareness is a critical determinant of both the efficacy and safety of infection prevention measures. In the aftermath of pandemic, ABHS and disinfectants have shifted from emergency interventions to routine hygiene practices, underscoring the need for continued education on their proper use While the efficacy of these products is well-documented, widespread and often inappropriate practices persist. These include excessive use, unsafe storage, and the use of uncertified products, all of which elevate the risks of chemical exposure and environmental contamination.

To address these challenges, public awareness campaigns must be sustained and enhanced. A central focus of this education should be to empower consumers to verify that products contain legitimate chemical ingredients and are accompanied by a MSDS. It is vital that regulatory authorities worldwide continue to monitor the market for counterfeit and unapproved products to safeguard public health. Furthermore, public health organizations should provide clear, accessible guidelines on safe hygiene practices that balance the necessity of infection control with the responsible use of these chemical agents. This ongoing education is crucial to empowering individuals to make informed choices that protect both their health and the environment.[53]

CONCLUSION

The COVID-19 pandemic has fundamentally reshaped global hygiene practices, with a sustained increase in the use of alcohol-based hand sanitizers and disinfectants. While these products are indispensable for infection control, their widespread and often unmonitored use has introduced a new set of public health challenges. This review highlights the toxicological and health risks associated with frequent and improper use of these chemical agents, including a range of adverse health effects from dermatological issues to more severe systemic, respiratory, and neurological problems. The pandemic also exposed critical gaps in product quality control, leading to the proliferation of counterfeit products and a lack of proper labelling, which compounded risks for both the public and occupational groups. Furthermore, the improper disposal of these chemicals contributes to environmental contamination and may foster antimicrobial resistance. In this new normal, effective disease prevention must be balanced with a comprehensive approach to safety, necessitating rigorous regulation, public education, reinforced occupational safety standards, and sustainable practices to ensure that the benefits of widespread chemical sanitization continue to outweigh the associated health and environmental risks.

ACKNOWLEDGEMENTS

The authors would like to express our gratitude to an anonymous reviewer for the critical reading and insightful suggestions for this review.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: Not required

REFERENCES

1. Zhu N, Zhang D, Wang W, Li X, Yang B, Song J, et al. A novel coronavirus from patients with pneumonia in China, 2019. N Engl J Med. 2020;382(8):727-33.
2. Chan FJ-W, Yuan S, Kok H-K, To KK-W, Chu H, Yang J, et al. A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster. The lancet, 2020;395(10223):514-23.
3. WHO. Coronavirus Disease 2019 (COVID019) Situation Report; November 2020.
4. van Doremalen N, Bushmaker T, Morris DH, Holbrook MG, Gamble A, Williamson BN, et al. Aerosol and surface stability of HCoV-19 (SARS-CoV-2) compared to SARS-CoV-1. N Engl J Med. 2020;382:1564-7.
5. Ali AS, Yohannes MW, Tesfahun T. Hygiene Behavior and COVID-19 Pandemic: Opportunities of COVID-19-Imposed Changes in Hygiene Behavior. Inquiry. 2023;60:469580231218421.
6. WHO. Disease Outbreak News: Update on SARS-CoV-2 variants and global epidemiological situation 2025. Available from: https://www.who.int/emergencies/disease-outbreak-news/item/2025-DON572. Accessed on 02 May 2025.
7. Scala A, Flori A, Spelta A, Brugnoli E, Cinelli M, Quattrociocch W, et al. Time, space and social interactions: Exit mechanisms for the COVID-19 epidemics. Scientific reports, 2020;10(1):1-12.
8. Yunoki M, Urayama T, Yamamoto I, Abe S, Ikuta K. Heat sensitivity of a SARS-associated coronavirus introduced into plasma products. Vox Sang. 2004;87(4):302-3.
9. Gröner A, Broumis C, Fang R, Nowak T, Popp B, Schäfer W, et al., Effective inactivation of a wide range of viruses by pasteurization. Transfusion, 2018;58(1):41-51.
10. Gold N, Avva U. StatPearls Publishing; 2018. Alcohol Sanitizer; 2020.
11. Kratzel A, Todt D, V'kovski P, Steiner S, Gultom ML, Thao TTN, Ebert N, et al. Efficient inactivation of SARS-CoV-2 by WHO-recommended hand rub formulations and alcohols. BioRxiv; 2020.
12. El-Mahdy MH, Makeen NM, Khrid ZA, Modawi KM, Sayegh MA, Hamrani AH, et al., An online survey on the association between the use of alcohol-based hand sanitizer and dermatitis in the Jizan Population. 2025;14(2):533-40.
13. Mawazi SM, Ann J, Othman N, Khan J, Alolayan SO, Al thagfan SS, et al. A review of moisturizers; history, preparation, characterization and applications. 2022;9(3):61.
14. Cheng CA, Tsai SW. Presence and Dermal Exposure to Benzene and Acetaldehyde in Hand Sanitizers Available in Taiwan. Toxics, 2025;13(7).
15. McDonnell G, Russell AD. Antiseptics and disinfectants: activity, action, and resistance. Clinical microbiology reviews, 1999;12(1):147-79.
16. Linley E, Denyer SP, McDonnell G, Simons C, Maillard JY. Use of hydrogen peroxide as a biocide: new consideration of its mechanisms of biocidal action. Journal of antimicrobial Chemotherapy. 2012;67(7):1589-96.
17. Ghafoor D, Khan Z, Khan A, Ualiyeva D, Zaman N. Excessive use of disinfectants against COVID-19 posing a potential threat to living beings. Curr Res Toxicol. 2021;2:159-68.
18. Frantz ALJT. Sciences, Chronic quaternary ammonium compound exposure during the COVID-19 pandemic and the impact on human health. 2023;15(3):199-206.
19. Barber OW. Hartmann, and Technology, Benzalkonium chloride: A systematic review of its environmental entry through wastewater treatment, potential impact, and mitigation strategies. 2022;52(15):2691-719.
20. Jahn LG, Tang M, Blomdahl D, Bhattacharyya N, Abue P, Novoselac A, et al. Volatile organic compound (VOC) emissions from the usage of benzalkonium chloride and other disinfectants based on quaternary ammonium compounds. Environmental Science: Atmospheres. 2023;3(2):363-73.
21. Biswal M, Kanaujia R, Angrup A, Ray P, Singh SM. Disinfection tunnels: potentially counterproductive in the context of a prolonged pandemic of COVID-19. Public Health, 2020;183:48.
22. Tse TJ, Purdy SK, Shen J, Nelson FB. Mustafa R, Wiens DJ, et al. Toxicology of alcohol-based hand

rubs formulated with technical-grade ethanol. Toxicology Reports. 2021;8:785-92.

23. Inder D, Kumar P. Isopropyl alcohol (70%)-based hand sanitizer-induced contact dermatitis: A case report amid Covid-19. Indian Journal of Case Reports, 2020;14:403-5.
24. Lo C-M, Han J, Zuo J, Law S-K, Tang K-Y, Lau Y-L, Fung YT, et al. Real-Time Measurement of Alcohol Vapours Released from Alcohol-Based Hand Disinfectants and User Habits Study of Hong Kong Residents in the Pandemic of COVID-19. 2022;13(3):272.
25. Tasar RC, Wiegand, Elsner P. How irritant are n-propanol and isopropanol? - A systematic review. Contact Dermatitis. 2021;84(1):1-14.
26. Mansour G, El-Rafey D. Ethyl Glucuronide, Ethyl Sulfate and Acetone as Biomarkers for Alcohol Based Hand Sanitizers Chronic Exposure in Health Care Workers. Ain Shams Journal of Forensic Medicine and Clinical Toxicology, 2019;33(2):80-91.
27. Hon KL, Kc Leung A, Cheung E, Lee B, Mc Tsang M, Torres AR. An overview of exposure to ethanol-containing substances and ethanol intoxication in children based on three illustrated cases. Drugs in Context, 2018:7:212512.
28. Konkel K, Burkhart K, Chenge C, Lee R, Theresa Michele T, Mentari E, et al. Methanol poisonings from contaminated hand sanitizers identified by the United States Food and Drug Administration. Clin Toxicol (Phila). 2023;61(12):1065-7.
29. Andra SS, Charisiadis P, Karakitsios S, Sarigiannis DA, Makris KC. Passive exposures of children to volatile trihalomethanes during domestic cleaning activities of their parents. Environmental research. 2015;136:187-95.
30. Melin VE. Exposure to common quaternary ammonium disinfectants decreases fertility in mice. Reproductive Toxicology. 2014;50:163-70.
31. Ng M, Mont M, Bonutti P. Clinical and Environmental Harms of Quaternary Ammonium Disinfectants and the Promise of Ultraviolet-C (UV-C) Alternatives: A Narrative Review. Cureus, 2025;12:17.
32. Dumas O. Association of occupational exposure to disinfectants with incidence of chronic obstructive pulmonary disease among US female nurses. JAMA network open. 2019;2(10): p. e1913563-e1913563.
33. MacLean. Inhalation of alcohol vapor: measurement and implications. Alcoholism: Clinical and Experimental Research. 2017;41(2):238-50.
34. Bessonneau V, Thomas O. Assessment of exposure to alcohol vapor from alcohol-based hand rubs. International journal of environmental research and public health. 2012;9(3):868-79.
35. Reisfield GM. Ethyl glucuronide, ethyl sulfate, and ethanol in urine after sustained exposure to an ethanol-based hand sanitizer. Journal of analytical toxicology. 2011;35(2):85-91.
36. Kramer A. Quantity of ethanol absorption after excessive hand disinfection using three commercially available hand rubs is minimal and below toxic levels for humans. BMC Infectious Diseases. 2007;7(1):117.
37. Garcia-Bournissen F. Exposure to alcohol-containing medications during pregnancy. Canadian family physician Medecin de famille canadien, 2006;52(9):1067-68.
38. Evans VA, Orris P. The use of alcohol-based hand sanitizers by pregnant health care workers. Journal of occupational and environmental medicine, 2012;54(1):3.
39. Dumas O, Le Moual N. Damaging effects of household cleaning products on the lungs. Expert Review of Respiratory Medicine. 2020;14(1):1-4.
40. Peck B. Spectrum of sodium hypochlorite toxicity in man—also a concern for nephrologists. Nephrology Dialysis Transplantation Plus, 2011;4(4):231-5.
41. Beiu C. Frequent Hand Washing for COVID-19 Prevention Can Cause Hand Dermatitis: Management Tips. Cureus, 2020;12(4).
42. Turner PB, Saeed, Kelsey M.Dermal absorption of isopropyl alcohol from a commercial hand rub: implications for its use in hand decontamination. Journal of Hospital Infection. 2004;56(4):287-90.
43. Forrester MB. Characteristics of hand sanitizer ingestions by adolescents reported to poison centers. 2015;27(1):69.
44. Berardi A. Hand sanitisers amid CoViD-19: A critical review of alcohol-based products on the market and formulation approaches to respond to increasing demand. International journal of pharmaceutics, 2020;12:119431.
45. Chung I. Health effects of sodium hypochlorite: review of published case reports. Environ Anal Health Toxicol, 2022;37(1):e2022006-0.
46. Beane Freeman LE. Bladder cancer and water disinfection by-product exposures through multiple routes: a population-based case–control study (new England, USA). Environmental health perspectives, 2017;125(6):067010.
47. Righi E. Trihalomethanes, chlorite, chlorate in drinking water and risk of congenital anomalies: a population-based case-control study in Northern Italy. Environmental Research. 2012;116:66-73.
48. King WD. Exposure assessment in epidemiologic studies of adverse pregnancy outcomes and disinfection byproducts. Journal of Exposure Science & Environmental Epidemiology. 2004;14(6):466-72.
49. Chan AP, Chan TY. Methanol as an unlisted ingredient in supposedly alcohol-based hand rub can pose serious health risk. International journal of environmental research and public health, 2018;15(7):1440.
50. FDA Finalizes Rule on OTC Hand Sanitizers | RAPS. Regul. Focus; 2020. Available at: https://www.raps.org/news-and-articles. Accessed on 23 January 2024.

51. Yip L. Serious adverse health events, including death, associated with ingesting alcohol-based hand sanitizers containing methanol—Arizona and New Mexico, may–June 2020. Morbidity and Mortality Weekly Report. 2020;69(32):1070.
52. Nicol AM. Accuracy, comprehensibility, and use of material safety data sheets: a review. American journal of industrial medicine, 2008;51(11):861-76.
53. Jairoun AA, Al-Hemyari SS, Shahwan M. The pandemic of COVID-19 and its implications for the purity and authenticity of alcohol-based hand sanitizers: The health risks associated with falsified sanitizers and recommendations for regulatory and public health bodies. Research in Social and Administrative Pharmacy. 2021;17(1):2050-1.
54. Department of Occupational Safety and Health Malaysia. (2004). Guidelines on Occupational Safety and Health (Notification of Accident, Dangerous Occurrence, Occupational Poisoning and Occupational Disease) Regulations 2004 (NADOPOD). Available at: https://intranet.dosh.gov.my/index.php/competent-person-form/occupational-health/regulation-2-1/guidelines/general/599-06-guidelines-on-occupational-safety-and-health-notification-of-accident-dangerous-occurance-occupational-poisoning-occupational-disease-regulations-2004-nadopod-2005?path=regulation-2-1%2Fguidelines%2Fgeneral. Accessed on 1 August 2025.
55. Gazette MFG. Occupational Safety and Health (Classification, Labelling and Safety Datasheet on Hazardous Chemical Regulation 2013), O.S.a.H. Malaysia, Editor., Attorney General's Chamber Malaysia; 2013.
56. Malaysia AGC of. Occupational safety and health (Classification, labelling and safety data sheet of hazardous chemicals) regulations 2013. Fed Gov Gaz; 2013.
57. Fazzo L, Minichilli F, Santoro M, Ceccarini A, Della Seta M, Bianchi F, et al. Hazardous waste and health impact: a systematic review of the scientific literature. Environmental Health, 2017;16(1):1-11.
58. Clements JM. Knowledge and behaviors toward COVID-19 among US residents during the early days of the pandemic: cross-sectional online questionnaire. JMIR public health and surveillance, 2020;6(2):e19161.

Cite this article as: Abdullah AR, Azmi L, Aziz MA, Abidin NWHZ, Jasmiad MI. Navigating the new norm: review of health risks associated with widespread disinfectant and hand sanitizer use. Int J Community Med Public Health 2025;12:5285-95.