Alcohol–based Hand Sanitizers amid COVID-19: Chemical Formulation, Analysis, Safety

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Abstract

Alcohol-based hand sanitizers (ABHSs) containing ethanol (EtOH) or isopropyl alcohol (IPA) to inactivate microorganisms help to prevent the spread of respiratory diseases. These products have become very popular during the COVID-19 pandemic. Apart from vaccines or other preventative antiseptic measures, the majority of consumers have relied on different types of ABHSs to disinfect their hands. As a result, there has been a global rush in the demand for these ABHSs and other antiseptic hygiene products. This has resulted in the formation of many new commercial sanitizer producers. There are around fifty companies of varying sizes that have been marketing their ABHSs in Bangladesh, most of which have only been manufacturing their products for the first time since the COVID-19 pandemic. To monitor the quality and components of these products, the Bangladesh Council of Scientific and Industrial Research (BCSIR) analyzed approximately 200 different hand sanitizer samples using GC–FID mass spectrometry. All samples were alcohol-based except for 3 which were alcohol-free aqueous hand sanitizers. Of the supplied formulated ABHSs, 80 samples were found to contain only IPA and 54 contained only EtOH. However, 28 samples were found to be contaminated with methanol (MeOH), 7 samples contained only MeOH and 18 samples contained both EtOH and IPA. This is the first study to explore the analysis of alcohol content in formulated ABHSs and their marketing status in Bangladesh, but the findings could be of use in other jurisdictions as similar issues have been raised in many parts of the world.

1. Introduction

Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) disease, a highly infectious respiratory disease known simply as COVID-19, was first identified in December, 2019 in Wuhan, China (Zhu et al., 2020). On March 11, 2020 the World Health Organization (WHO) declared COVID-19 to be a pandemic (Assefa et al. 2021). Since then, COVID-19 has spread rapidly over the world and became a global health crisis including causing widespread social, economic and resulting political problems (WHO, 2020; Li et al. 2020; Lai et al. 2020). Following its initial alarming spread, several rapidly formed variants were identified, including B.1.1.7 (Alpha), B.1.351 (Beta), P.1 (Gamma), and B.1.617.2 (Delta) (WHO, 2021). On November 26, 2021, the WHO announced the Omicron variant B.1.1.529, first identified less than three weeks earlier in South Africa (WHO, 2021). The Omicron variant has proven to be more contagious than previous variants of COVID-19 but appears to cause less severe illness than its predecessors. On the other hand, the Delta variant first detected in India in December 2020, is associated with more severe illness and increased transmissibility compared with the alpha variant, (Hart, 2022). The Centres for Disease Control and Prevention (CDC) designated both variants as “Variants of Concern” (CDC, 2022). These emerging variants reflect progressively higher effective reproduction numbers which allow novel variants to outcompete previously dominant strains in the face of disease control interventions. This has led to concerns of viral immune evasion and decreased vaccine effectiveness.

A pathogenic virus can be transmitted by infected persons even when they have no, or only mild symptoms (Chu et al., 2020; IPC, 2020). The SARS-CoV-2 virus has proven to be remarkably stable in a variety of environments and surfaces (van Doremalen et al 2020) in which humans can come into contact with by touching. Pathogenic infection in an individual can occur when hands contaminated with pathogenic viruses or bacteria touch the mucosa of a person's mouth, nose, or eyes. Hand washing/sanitizing therefore is one of the simplest, most important and cost-effective ways to prevent transmission and infection and one healthy. As a result, there has been a great surge in demand for hand sanitization products, as frequent hand-washing and sanitization was recommended by public health agencies across the world to prevent the COVID-19, primarily in less-affected countries before vaccines became or are available. The CDC recommends five steps (Fig. 1) that need to be taken when hand washing to be the most successful in preventing the spread of illness. Hand sanitizers are applied and rubbed over the surface of the hands to inactivate pathogenic microorganisms.

To meet the great demand, not only pharmaceutical companies, but other chemical industries, breweries, as well as perfumeries started to produce hand sanitizers using unconventional methods (Bomgardner et al., 2020). However, appropriate formulation and manufacturing directions are needed to ensure adequate quality of the formulated products. The most important factor in determining the efficacy of a hand sanitizer during the COVID-19 outbreak is its alcohol content. Alcohol-free hand rub products are not recommended by the CDC and WHO (Allen et al. 2020; Kampf et al. 2004; Todd et al., 2010) to prevent COVID-19 infection (Howes et al. 2020). Although hand washing using soap can effectively remove all types of pathogens hand-washing facilities are not always readily available in many work-place environments or public places. Hand sanitizers can however also effectively kill about 99.9% of germs (Alberto et al. 2020) and are most effective and convenient during frequent contact with individuals or goods, (CDC, 2019a; Hadaway, 2020). Generally, ABHSs remain more versatile, convenient, quick and can be less irritating than hand washing with soap and water (Edmonds et al. 2012). The convenience and portability of ABHSs has led their widespread availability, and ABHSs were recommended by WHO as alternative hand hygiene products in April 2020 (WHO, 2020).

The first case of Covid-19 was reported in Bangladesh on March 8, 2020. To date, according to WHO data more than 1.95 million cases and more than 29,000 deaths attributed to Covid-19 have been reported (https://covid19.who.int). In response to the Covid-19 public health concerns many companies and organizations in Bangladesh started to produce ABHSs. Consequently, in 2020 the Bangladesh Council of Scientific and Industrial Research (BCSIR) were receiving a high number of samples daily for alcohol content analysis and providing their analysis reports in a prescribed format. This report is of the findings from this BCSIR work which may help as a baseline data for further related studies and for the quality evaluation of ABHSs.

2. Alcohol-based Hand Sanitizers: A Primary Resource To Prevent Covid Infection And Spread

The COVID-19 pandemic has brought unprecedented demands for health care products including various disinfectants and sanitizers whose roles have been extensively reviewed recently (Dhama et al 2021) Some of these disinfectants however, have unwanted environmental effects (Parveen et al, 2021). Among health care products alcohol-based hand sanitizer (ABHS) products have long been the common recommended means for maintaining good hand hygiene (Wolfe et al. 2017). In general, hand hygiene is a mainstay of infection prevention by preventing the transfer of pathogens via a person's hands, and is necessary to lessen the spreading of infection to the general public and healthcare workers (Kampf et al. 2004; Nhung et al. 2007). The most regularly used ABHS should have an alcohol concentration of 60 to 85% (Kramer et al. 2002) to ensure destroying up to 99.99% of microorganisms on hands; a sanitizer with 70% alcohol is reported to kill 99.9% of the microorganisms on hands (Rotter et al. 1999

The SARS-CoV-2 virus is a member of the *Coronaviridae* family (Fehr et al. 2015). It contains highly glycosylated spikes on the protein membrane in a crown-like arrangement (Andersen et al. 2020). These spikes can bind to the functional receptors of a host's respiratory cells, namely at the host angiotensin converting enzyme-2 (ACE-2) protein (Singh et al. 2020; Daniel et al., 2020; Lu et al., 2020). The possible mode of action of alcohol against the virus is shown in Fig. 2. Alcohols likely cause the disruption of microbial membrane and inhibits metabolism through the key mechanisms such as lipid membrane dissolution and protein denaturation (Wanderlingh et al., 2010; Golin et al. 2020).

Since alcohols possess both hydrophilic and lipophilic (hydrophobic) properties, these facilitate their penetration through the viral envelope. Membrane fluidity in the virus is altered when an alcohol comes in contact with the virus (Ingram et al. 1976). The polar alcohol oxygen atoms destabilize and denaturate the protein structures of the virus moiety weakening the lipophilic interactions between the non-polar residues. As a consequence, the internal affinity of the membrane for water increases (Wanderlingh et al. 2010). Whereas the "alcohol" i.e ethanol (EtOH) and isopropyl alcohol (IPA) component is the main antiseptic in an ABHS, depending on the type of the formulation, the excipients can include viscosity enhancers, emollients, buffers, preservatives, colorants and fragrances (Todd et al. 2010). It is however important to know that ABHSs are only effective when formulations are appropriate and are used correctly on hands (Hadaway et al. 2020).

3. Formulation Of Alcohol-based Hand Sanitizers (Abhss)

Two alcohols (EtOH, IPA) are used in ABHS products (Fig. 3). The performance of ABHS products is most commonly defined as a function of their alcohol content and several factors are important in determining efficacy. There are two major types of ABHS marketed: liquid hand rubs and hand gels. In Bangladesh, "hand sanitizers" are liquid formulated products (i.e. hand rub) and "gels" are semi-solid, or thick viscous products. Commercialized ABHS gel products available in the marketplace are thickened by using carbomer, while others contain cellulosic thickeners (Berardi et al., 2020b). Typical cellulosic gelling agents are hydroxyethyl cellulose (HEC), hydroxypropyl cellulose (HPC), hydroxypropyl methylcellulose (HPMC) and sodium carboxymethyl cellulose (CMC) which are the viscosity enhancers recommended by the Italian Society of Compounding Pharmacists (SIFAP, 2020) for the formulation of ABHS gels against COVID-19. In Brazil, the Agência Nacional de Vigilância Sanitária (ANVISA) has recommended that ABHSs should contain water, EtOH, carbomer980 and triethanolamine (ANVISA, 2012). Amines such as triethanolamine or aminomethyl propanol (AMP) or other bases are used as a neutralizing agent to adjust the pH of the ABHS. ANVISA requires the EtOH content to be at least 70% and the product must have antibacterial activity (ANVISA, 2010). Additionally, ABHSs may have other ingredients which perform a variety of functions, such as glycerol for example, which is added for skin care. The key considerations for ABHS manufacturers are the influence of these ingredients on product efficacy, safety and usage. Typically, biocidal products contain 60–80 % EtOH (Berardi et al., 2020b) and CDC recommended using an ABHS that contains at least 60 % alcohol.

The WHO recommended two hand rub formulations which have broad spectrum antimicrobial activity including efficacy against COVID-19 (Table 1). In many European countries, ABHS products have been established as a standard in hygienic hand disinfection (Kampf et al. 2004).

Table 1. WHO-recommended hand rub formulations (WHO, 2020).

Formulation 1	Formulation 2
• Ethanol 80% (v/v), • Glycerol 1.45% (v/v), • Hydrogen peroxide 0.125% (v/v).	• IPA75% (v/v), • Glycerol 1.45% (v/v), • Hydrogen peroxide 0.125% (v/v).

4. Analysis Of Alcohol-based Hand Sanitizers (Abhss) By Gc–fid

In Bangladesh, several irregular factories emerged amid the COVID-19 pandemic to produce ABHS products. Many of these factories had no quality-control testing facilities for the compositions of their formulated hand sanitizers. As the primary research body of the Bangladesh government, the BCSIR has been providing analytical services to these industries and has been analyzing the ABHSs supplied by these factories by GC–FID (Fig. 4) since the very beginning of the COVID-19 outbreak (April 2020). The methods employed for this report are described below.

Some methods such as the use of specific gravity measurements using alcoholmeters, hydrometers or pycnometers are used for the analysis of ethanol solutions (FDA, CDER, 2020). Mid-infrared (MIR) and near-infrared (NIR) spectroscopies associated with chemometrics are also useful to determine alcohol content in beverages, fuels and fermentation broths (FDA, CDER, 2020; Nascimento et al. 2017; Correia et al. 2018; Fonseca et al. 2020). The problem with these methods however, is that the viscosity of gels hinders the use of alcoholmeters and the other methods require specific expensive equipment or require destructive and/or time-consuming sample treatments.

4.1 Experimental section:

Required solvents: EtOH (99.8%), butanol-1 (99.7%), methanol (99.9%), isopropyl alcohol (99.7%) and toluene (99.7%). Unless otherwise stated, all solvents were purchased from Active Fine Bangladesh, Alfa Aesar or Sigma-Aldrich and were used without further purification.

Method-1:

Sample preparation: a 4.0 mL hand sanitizer sample was added to a 100.0 mL volumetric flask to which 96 mL of MeOH was added, and the mixture was vortexed for 10 min, then, filtered through a 0.22 µm PTFE disc filter. The Standard preparation was prepared in the same way using 4.0 mL of the respective alcohol (MeOH or IPA) in 96 mL MeOH in a 100-mL volumetric flask. After vortexing for 10 min the prepared standard was filtered through 0.22 µm PTFE disc filter.

Calculation:

$$\text{Percentage of alcohol (\%)} = \frac{\text{Area of sample} \times \mathbf{D}}{\text{Area of standard}} \times \text{potency of standard}$$

Method-2:

We prepared the following five standard solutions for the alcohol (EtOH/IPA) analyses in ABHS

1. Internal standard stock solution (ISSS): 5.0 mL butanol-1 + 95 mL diluent (MeOH).
2. EtOH/IPA stock solution: 5.0 mL EtOH + 95.0 mL diluent (MeOH).
3. EtOH/IPA standard solution: 10.0 mL EtOH Stock Solution (B) + 10.0 mL ISSS (A) + 80.0 mL diluent (MeOH).
4. Internal standard solution (ISS): 5.0 mL ISSS (A) + 95.0 mL diluent (MeOH).
5. Test solution: 0.5 mL sample + 10.0 mL ISSS (A) + 89.5 mL diluent (MeOH).

Each mixture was vortexed and sonicated for 10 minutes and filtered through 0.22 µm PTFE disc filter.

Calculation:

$$\text{Percentage of alcohol (\%)} = \frac{R \times D}{R_1} \times \text{potency of standard}$$

R = Peak ratio of alcohol (EtOH/IPA) to butanol-1 for sample solution (E/D)

R_1 = Peak ratio of alcohol (EtOH/IPA) to butanol-1 for standard solution (C/D)

D = Dilution factor for sample solution.

Method-1 is more accurate in result than Method-2 and was less tedious and time consuming. Each method was validated by measuring known samples prepared in our laboratory. To ensure whether the supplied samples contained MeOH or not, injecting 0.5 µL of the liquid sample directly. For the gels, samples were diluted with toluene in a 1:5 ratio and then 0.5 µL samples analyzed under the same chromatographic conditions as all of the other samples tested.

The standard deviation and relative standard deviation were determined by the following formula:

Standard Deviation:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2}$$

$$\bar{x} = \frac{x_1 + x_2 + \cdots x_n}{n}$$

The relative standard deviation (RSD):

$$RSD = \frac{s}{|\bar{x}|} \times 100$$

Where,

S = Sample standard deviation

$x_1, \ldots\ldots, x_N$ = the sample data set

$\bar{x}$ = mean value of the sample data set

N = size of the sample data set

4.2 Chromatographic conditions:

The GC analyses were conducted with a Bruker (Germany), Model SCION 456-GC, connected with an FID detector and an auto injector. A BR-5/SCION-5 (30 m × 0.25 mm i.d.) fused silica capillary column with 5%-phenyl-methylpolysiloxane as stationary phase and 0.25 µm film thickness was employed under the following conditions: The GC oven temperature program: initial temperature 40 ºC held for 1 min, ramped at 100 ºC min^{-1} to 180 ºC with a total run time of 19 min. and Injection volume: 0.5 µL.; detector temp.: 250°C; injection mode: split ratio: 100; carrier gas: helium (1.5 mL/min); make-up gas: nitrogen (25 mL/min); combustion gas: air (300 mL/min).

4.3 Result and discussion

The names of the different hand rub products, their corresponding chemical and commercial names provided by the manufacturer are listed in Table S2 (SI) by code. Each sample was measured in triplicate and RSD values were observed in the range of 0.4-4 for the supplied samples. The GC chromatograms (Fig. S1–Fig. S8) and retention times are listed in supporting information (Table S1). For the standards for calibration, RSD values less than 2 were obtained. A total of 177 samples were analyzed in 2020 and 13 samples in 2021. Among the 190 samples analyzed, the majority (80) were found to be IPA-formulated products, 54 samples were ethanol-formulated and 7 samples were found to contain only MeOH. The mixed alcohols-containing samples (18) contained EtOH + IPA; 6 samples contained EtOH + MeOH; 13 samples had IPA + MeOH; 9 samples had ethanol + IPA + MeOH, and the rest (3 samples) contained no alcohol at all (Fig. 5). Among the samples, a total of 128 samples were hand rubs, 58 samples were in gel form, 3 samples were in spray form and 1 sample was from wipes (Fig. 6).

Among the 54 samples of EtOH-formulated ABHSs, 46 samples contained EtOH in the range of 60–90 % and 6 samples contained more than 90% EtOH (Fig. 8). Only 2 samples contained less than 60% EtOH. Among the 80 samples of IPA-formulated ABHSs, 70 samples contained IPA in the range of 60-90 % and 7 samples contained more than 90% IPA (Fig. 9).

During the period May, 2020 to July, 2020 there was a tremendous rush for hand sanitizers which was evident from the number of samples supplied by different companies for analysis (Fig. 7). After that, the rush decreased a little bit and this trend continued till the August, 2020–October, 2020 period but once again the demand for ABHSs began to increase and reached a peak in the November, 2020–January, 2021 period. After that, the volume of samples supplied from different companies decreased rapidly and surprisingly only 12 samples were analyzed in the period of February, 2021–Dececember, 2021.

The huge demand of ABHS caused a few dishonest producers to emerge, disregarding proper manufacturing practices and often producing hand sanitizers that did not meet the specifications required for destruction of the pathogen, which gave the users a false sense of protection. Again, since MeOH is cheaper than the EtOH or IPA, dishonest and new producers could have substituted MeOH for greater profit or without knowledge of ABHS formulation guidelines.

5. Marketing Status Of Alcohol-based Hand Sanitizers: Bangladesh

Like other countries, Bangladesh is also facing curative emergency health rules amid the COVID-19 pandemic and the role of hand sanitizers is one of the essentials along with proper mask-wearing and social distancing needed to control the spread of infection in the population. Presently, different ABHSs are to be found throughout Bangladesh whereas before the sudden outbreak of this pandemic, the hand sanitizer market was dormant. After the appearance of the first COVID-19 case in the country an overwhelming demand ensued for hand sanitizers following the public health experts recommendations. The quest for hand sanitizers was intense in the capital city, Dhaka, as was evidenced by the rush in formulated ABHS samples manufactured by different known and unknown producers which were submitted for quality testing in our laboratory (Fig. 5). Previous to 2020 no ABHs samples had been analyzed in our laboratory. The rush in ABHS products for submitted for quality testing obliged the analysis to be conducted during the country lockdown. Based on the public demands, the hand sanitizer producers in Bangladesh have concentrated significantly on the packaging of the sanitizers to make it cheaply available to everyone.

About 50 manufacturers in Bangladesh are currently engaged in the production of ABHSs . Drug manufacturers and small-scale chemicals and cosmetics producers are the main sources of hand sanitizers for the city as well as for the country at large. Most of them are manufacturing hand sanitizers based on Formulations 1 and 2 of the WHO guidelines, in which EtOH or IPA is the main active ingredient (WHO Guide, 2020). According to market research from Nielsen, the sale of hand sanitizers skyrocketed by 300% and 470% in the last week of February and in the first week of March 2020, respectively, in comparison to the same time in the previous year in USA (Huddleston et al. 2020). Similarly, in Italy–one of the most affected countries by COVID-19 sales of hand sanitizers in supermarkets were augmented by 561% during the first three weeks of the pandemic (24th February-15th March 2020) compared to the previous year (Ufficio Studi Coop, 2020).

6. Precautions To Be Considered For The Use Of Alcohol–based Hand Sanitizers: Safety Concerns

Although the focus of most concern regarding ABHS performance has been the alcohol concentration, added ingredients and auxiliary factors also play a role in thier efficacy, safety and long-term utility. The main safety concerns at the consumer level with commercialized ABHS products are their flammability, ingestion (accidental or intentional) and dermatological. A case of an individual who suffered burns from exposing his hands which were wet with sanitizer to a flame illustrates this potential risk (O'Leary et al. 2011). It is therefore obligatory to provide appropriate cautions concerning flammability on product labels. ABHS, especially in liquid or gel packaged containers have some ingestion risks (Gormley et al. 2012). As well, ABHS products adulterated with MeOH are especially concerning due to its toxicity. The intentional misuse of MeOH-containing ABHS as a substitute for ethanolic beverages has led to serious adverse health consequences and deaths (Yip et al. 2020). This highlights the importance of manufacturers to ensure that they have adequate quality controls to prevent such adulterated products from reaching the marketplace. Tragically, hundreds of deaths and numerous cases of loss of sight was reported in Iran in 2020 when individuals unknowingly consumed ABHS contaminated with MeOH (Delirrad et al. 2020). Deaths related following use of MeOH-contaminated ABHS were also reported in the Southwest United States in the summer of 2020 (Yip et al. 2020; Holzmana et al. 2021). MeOH is metabolized to formic acid (Dear et al. 2020; Kraut et al. 2007), and can cause blindness, renal damage, coma, seizures and death. Thus, it is imperative for ABHS manufacturers to avoid using MeOH, or methylated spirits containing MeOH (Dear et al. 2020).

Regular application of ABHS products may cause skin irritation and allergy problems (Jakasa et al. 2018). With irritated or damaged skin, alcohols may cause a burning sensation. Recently, a 12 year-old child felt severe irritation in his hands following the over-application of a 70% isopropanol-based hand sanitizer (Inder et al. 2020). EtOH is also capable of causing contact dermatitis, although the causative chemical may be either the alcohol or associated impurities or an aldehyde metabolite (Ophaswongse et al. 1994). Most ABHSs are colored and had specific flavors whose nature and concentrations are not known. Such incorporations of coloring and flavoring agents may not be suitable for some consumers due to their possible allergic sensitivities (WHO Guide, 2020). Emollients such as myristyl alcohol, glycerol, dexpanthenol, levomenol, hydrogen peroxide and lanolin alcohol etc. used in some ABHS may also have adverse skin effects. For example, tocopherol, various fragrances, propylene glycol, benzoates, and cetylstearyl alcohol are common potential allergens in ABHS (Voller et al. 2020). Fragrances can sometimes cause contact allergies (Johansen et al. 2003). While some fragrance compounds may weaken the sensitizers, metabolism or oxidation of the parent compounds may produce potent allergens (Bråred et al. 2016). Packaging of ABHSs for marketing and storing are also of safety concerns. High EtOH concentrations alone are sufficient to degrade container liners and trigger corrosion of aluminum, eventually leading to failure of the can wall and leakage of liquid to the exterior environment (Thomson et al. 2020).

The use of formulations containing highly concentrated sodium chlorite has increased in recent years due to unsupported claims of efficacy in treating several medical conditions, now including COVID-19 (Hulshof et al. 2019). Fatal ingestion of sodium chlorite ($NaClO_2$) used as hand sanitizer containing a 28% solution of sodium chlorite during the COVID-19 pandemic has been reported in the USA (Lebin et al. 2021). A CDC survey showed nearly half of adult respondents were unaware hand sanitizers should be kept out of children's reach (Gharpure et al. 2020). Since ABHRs are considered as non-prescribed drugs, appropriate regulatory control should be in place over the distribution of these products.

7. Antimicrobial Resistivity As A Result Of The Use Of Alcohol-based Hand Sanitizers

Although the WHO-recommended vaccines and preventive measures against COVID-19 has advanced considerably, the spread of COVID-19 due to new variants is still increasing. Nevertheless, in developing countries especially, keeping hand hygiene using soap and water or ABHSs plays an essential role (WHO, 2019). The alcohols present in the ABHS formulations triggers bactericidal action through denaturation of microbial proteins (Paulson et al. 1999) however, rising concerns about the prevalence of inappropriate and excessive use of ABHSs and substandard products in the marketplace creates an ongoing additional concern. These can cause frequent microbial exposure to low doses or substandard concentrations of alcohol which can lead to making the pathogens ineffective and lead to the development of further mutations (Berardi et al. 2020; Mahmood et al. 2020; Jairoun et al. 2021). Prolonged exposure of susceptible resident bacteria on human hands can also generate a progressive stepwise accumulation of natural mutations and emergence of alcoholic tolerance in microbes. In the near future, these developments can become a serious challenge to the use ABHSs.

8. Limitation

There are limitations in our study; the alcohol content of only the formulated ABHSs provided by producers or others such as interested people, law enforcers, journalists etc for quality test were measured in this study and the antimicrobial activity of these samples were not determined. Only codes for each sample instead of the producers or brand name (SI, Table S3) are reported.

9. Conclusion And Recommendation

The novel COVID-19 pandemic is unlike anything the modern world has ever experienced and is affecting daily life. ABHSs are very inexpensive and effective in limiting microbial transmission during routine work, travel, journeys or in the workplace. The fear of the pandemic resulted in a huge demand for hand sanitizers, producing severe shortages and the use of ABHSs increased exponentially 2020. In the rush to meet the demand, instances of products lacking adequate quality control appeared in the marketplace. Quality control and quality assurance is very important for commercially-available sanitizers to ensure consumers' health care. In this work, a simple GC-FID technique was used to determine the alcohol content in formulated ABHSs appearing in Bangladesh. Some of the formulated ABHS products supplied by the producers for quality test were adulterated by MeOH or contained only MeOH as the main alcohol, or contained varying mixtures of EtOH and IPA. Even though ABHSs are easy to formulate, they must only be used after proper testing of their contents have been conducted and their producers should follow strict standard operational procedures to produce standardized products. Inappropriate use and prevalence of imperfect ABHSs can also lead to the potential for stepwise accumulation of alcohol-resistant mutations and consumers should be aware of the quality and storage of ABHS products.

This study reinforces the need for constant vigilance by responsible authorities to ensure that the marketed products have the required quality. Furthermore, the quality concern of ABHSs pointed out in this study may attract attention of regulatory agencies as well as producers to take appropriate measures to safeguard the public health. The GC technique described herein can be employed by regulators and industries to ensure product quality controls.

Declarations

Supplementary Information The online version contains supplementary material available at https:/

Authorship contribution

Md. Monarul Islam: Conceptualization, Investigation, Data curation, Formal analysis, Writing-original draft. Khondoker Shahin Ahmed, Md. Rezaul Karim, Bikash Dev Nath, Shyama Prosad Moulick, Rashedul Islam, Sharkar Md. Mahmudul Hassan: Investigation, Data curation, Formal analysis. Md. Hemayet Hossain, Mohammad Moniruzzaman: Methodology, Supervision. Md. Sarwar Jahan, Md. Aftab Ali Shaikh: Supervision, Funding acquisition, Review & editing. Paris E. Georghiou: Review & editing.

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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate Not applicable

Consent for publication Not applicable

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Supplementary Table

Supplementary Table S3 is not available with this version

Figures

Figure 1

Clean hands poster by CDC.

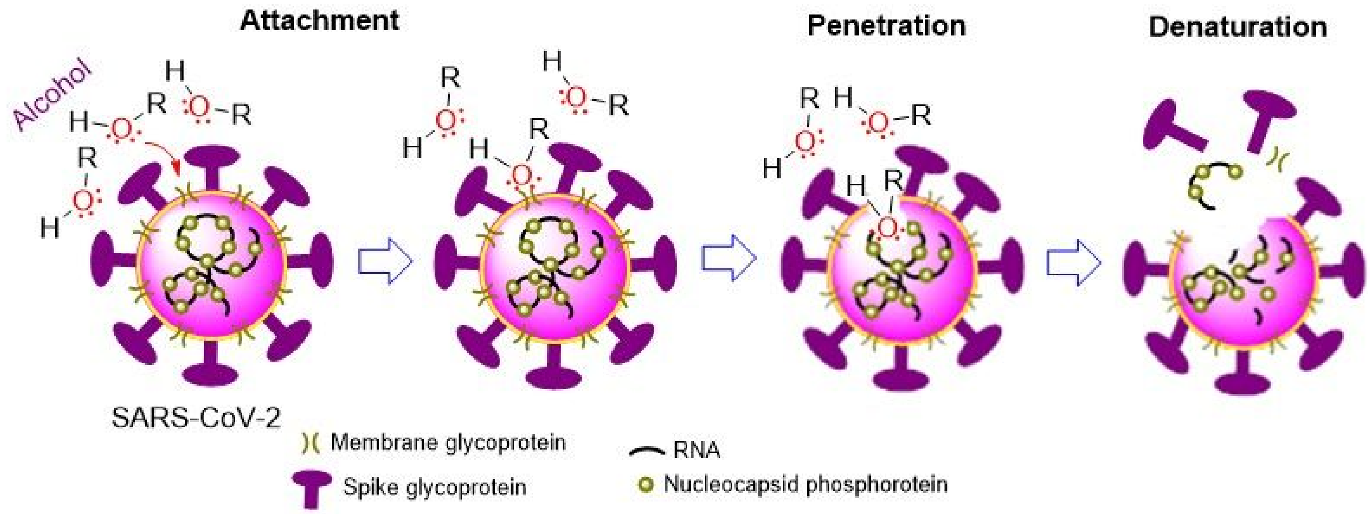

Figure 2

Plausible interaction to inhibit pathogens growth by ABHS.

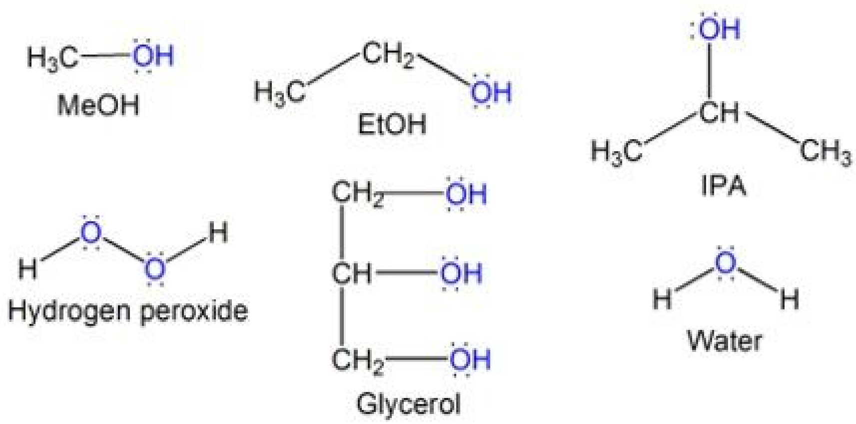

Figure 3

Structures of alcohol and some other ingredients in ABHSs.

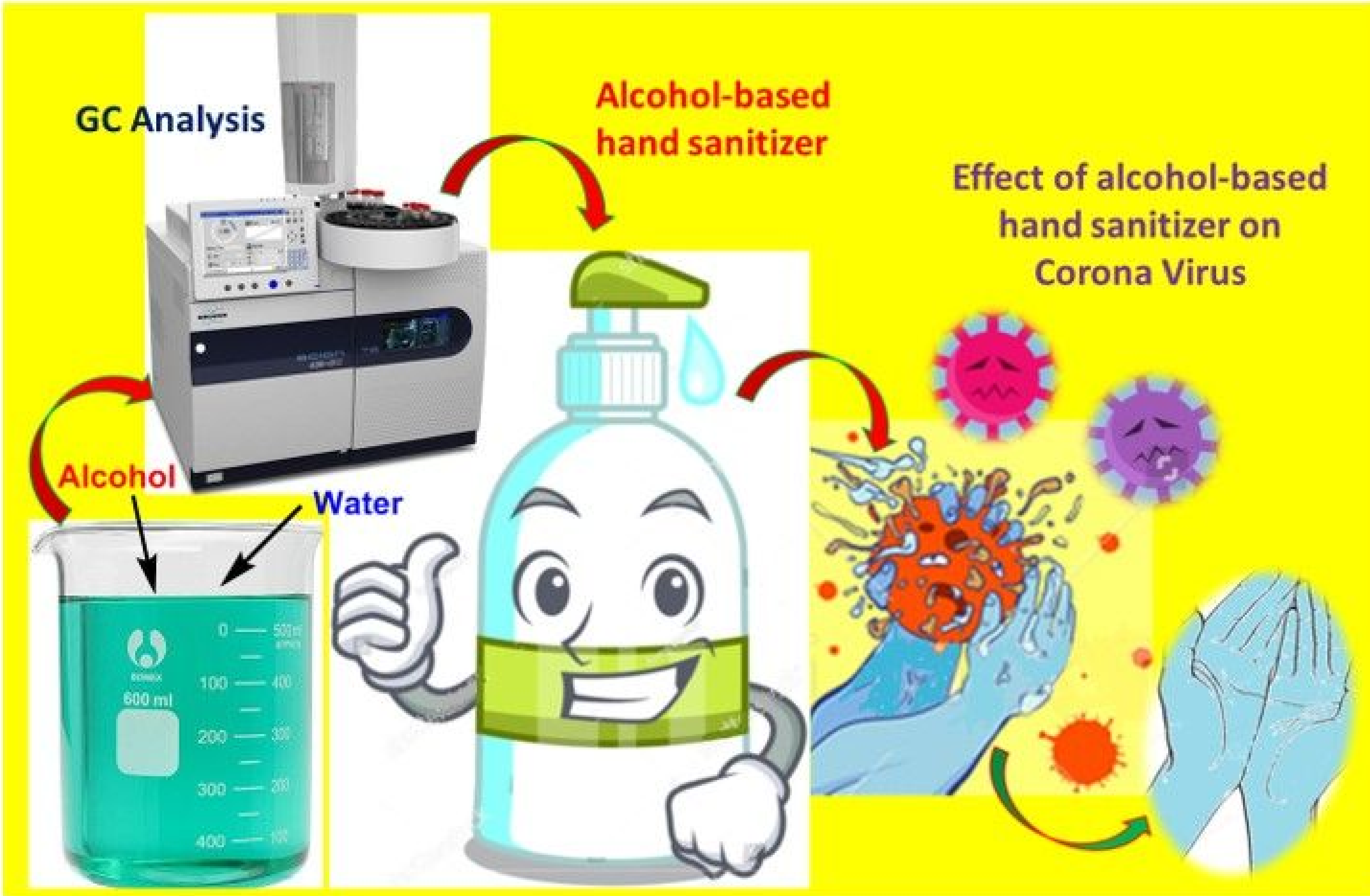

Figure 4

Schematic presentation of analysis of ABHS by GC and the effect of the sanitizer on COVID.

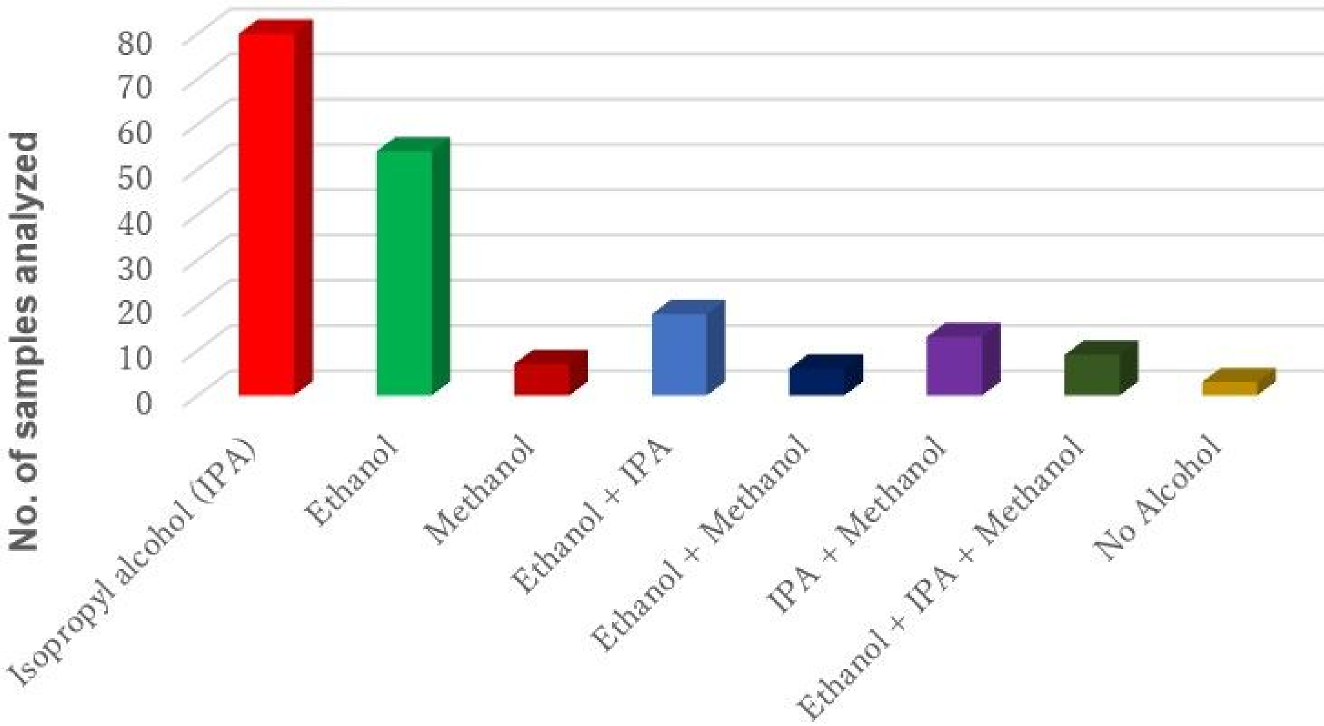

Figure 5

Comparative analysis of different alcohols found in the supplied ABSHs.

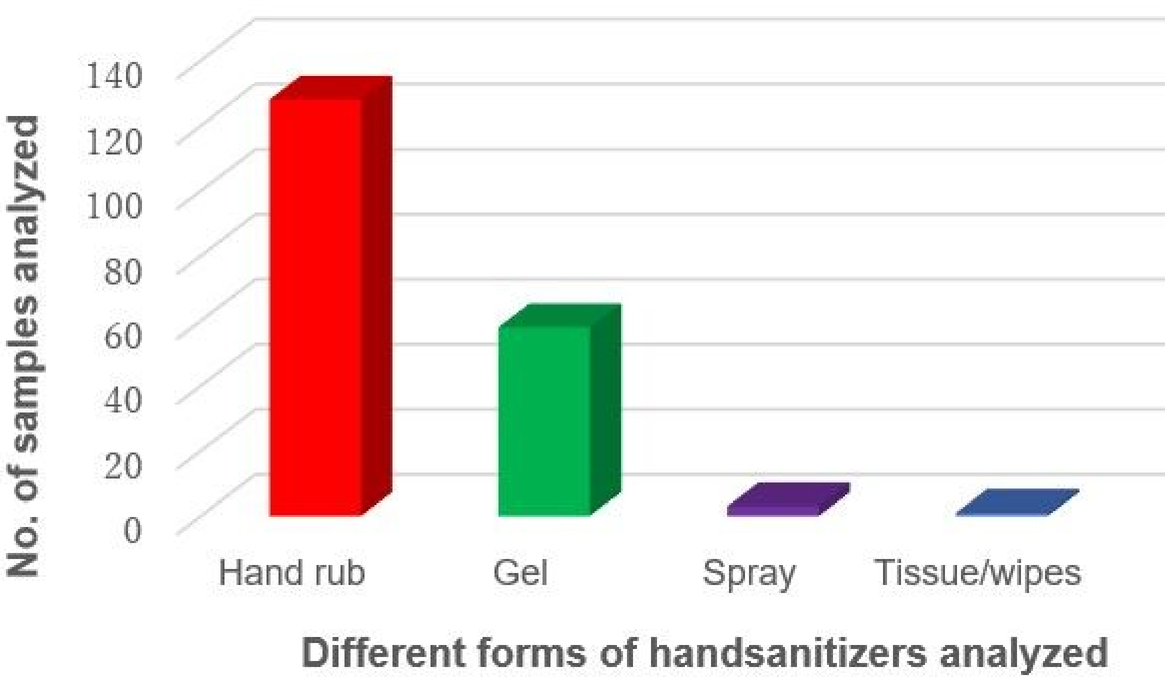

Figure 6

Different forms of ABHSs formulated products analyzed at BCSIR.

Figure 7

Month-wise analysis of the samples.

Figure 8

Percentage of ethanol in ethanol containing hand sanitizers

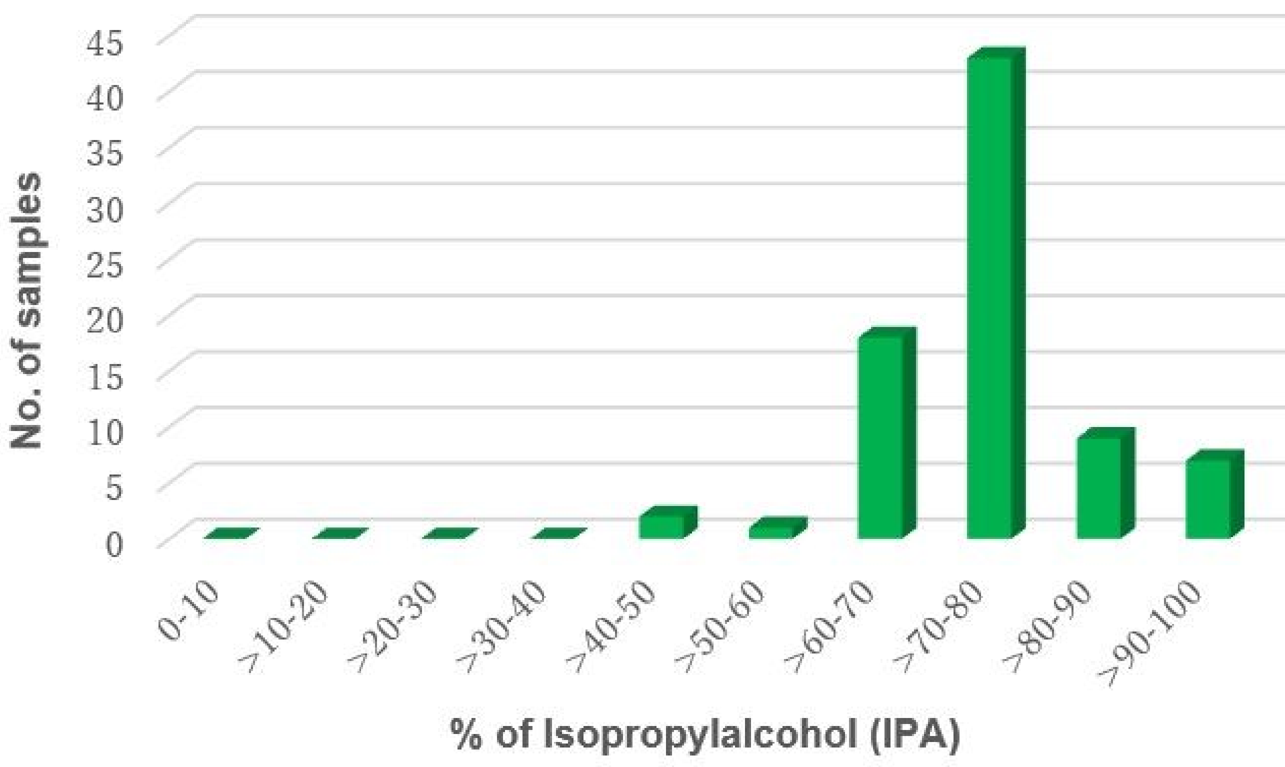

Figure 9

Percentage of IPA in IPA containing hand sanitizers

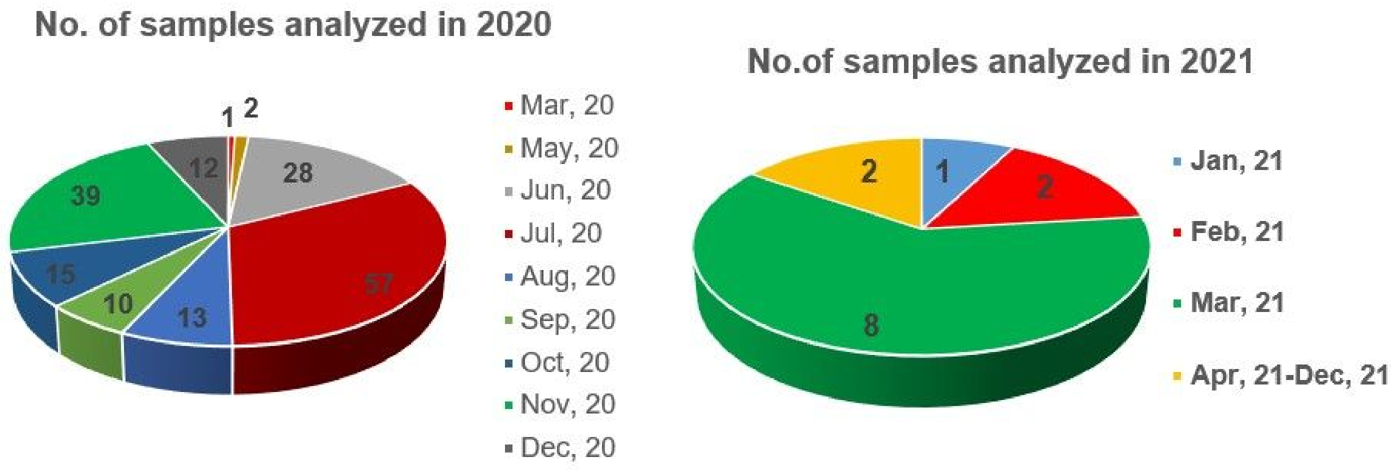

Figure 10

Month wise ABHSs sample analysis data.

Supplementary Files

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