COVID

MDPI

Article

Alcohol-Based Hand Sanitizers Used for COVID-19 Prevention in the Informal Settlements of Cape Town, South Africa

Sisanda Dalasile [1,*], Elie Itoba Tombo [1], Benett Siyabonga Madonsela [1], Philani Perfect Mpungose [2], Ndumiso Mshicileli [3] and Makabongwe Menziwa [3]

[1] Department of Environmental and Occupational Studies, Faculty of Applied Sciences, Cape Peninsula University of Technology, Cape Town 8000, South Africa; itobatomboe@cput.ac.za (E.I.T.); madonselab@cput.ac.za (B.S.M.)
[2] Department of chemistry, Faculty of Applied Sciences, Cape Peninsula University of Technology, Bellville 7530, South Africa; mpungosep@cput.ac.za
[3] Department of Food Science and Technology, Cape Peninsula University of Technology, Cape Town 7535, South Africa; mshicilelin@cput.ac.za (N.M.); menziwam@cput.ac.za (M.M.)
* Correspondence: 211148199@mycput.ac.za

Abstract: The COVID-19 pandemic and other infectious diseases continue to threaten public health, particularly in densely populated informal settlements. Effective hand hygiene, supported by alcohol-based hand sanitizers (ABHS), plays a critical role in preventing disease transmission. This study assessed the quality, safety, and compliance of ABHS used in informal settlements around Cape Town. A total of 78 samples were collected from spaza shops, with 72 analyzed using gas chromatography with flame ionization detection. The results showed that 76% of ethanol-based sanitizers met compliance standards, while 24% did not. Isopropanol compliance (≥70%) was only observed in 36% of samples, with 64% failing to meet Centers for Disease Control and Prevention (CDC) guidelines. Overall, 74% of hand sanitizers complied with recommended alcohol concentrations by the U.S. Food and Drug Administration (FDA) and CDC, while 26% posed a health risk due to non-compliance. These findings emphasize the urgent need for stricter regulation and public education to ensure effective hand sanitizers are used, thereby reducing infection risks in vulnerable populations. The study aims to inform public health policies and improve regulatory standards.

Keywords: alcohol based-hand sanitizers; alcohol content; ethanol; isopropanol; informal settlements; COVID-19 prevention

Citation: Dalasile, S.; Itoba Tombo, E.; Madonsela, B.S.; Mpungose, P.P.; Mshicileli, N.; Menziwa, M. Alcohol-Based Hand Sanitizers Used for COVID-19 Prevention in the Informal Settlements of Cape Town, South Africa. *COVID* **2024**, *4*, 1655–1675. https://doi.org/10.3390/covid4100115

Academic Editor: Luigi Vimercati

Received: 18 September 2024
Revised: 8 October 2024
Accepted: 11 October 2024
Published: 14 October 2024

1. Introduction

Before the 1970s, most known viruses were recognized as human pathogens, with others such as *Escherichia coli* (*E. coli*) O157 only being discovered in the following decades [1]. Recently, there has been an increase in the discovery of pathogens, with the latest being the novel severe acute respiratory syndrome (SARS) coronavirus 2 strain (SARS-CoV-2) [2] known for causing the coronavirus disease of 2019 (COVID-19) [3]. As of now, seven Coronaviruses (CoVs) have been associated with infections in humans. There are four endemic CoVs present in humans worldwide (HCoV-OC43, HCoV-HKU1, HCoV-229E, and HCoV-NL63). These viruses frequently manifest as mild upper respiratory infections, showing symptoms akin to those of the common cold. They are spread through behaviors such as coughing and sneezing [4]. On the other hand, the three remaining viruses (SARS, MERS, and SARS-CoV-2) can cause serious respiratory infections with symptoms such as fever, cough, and difficulty breathing. According to Yin and Wunderink [5], this could result in more severe illnesses and, in certain instances, even life-threatening conditions. SARS-Cov-2 is the third coronavirus documented to have jumped from animals to humans [6]. Research on genetics has found similarities in sequences between SARS and

SARS-CoV-2, indicating that they both likely originated from bats [6]. SARS-CoV-2 leads to symptoms similar to the flu, such as fever and pneumonia [7].

As per the findings of Yang et al. [8] the lethal virus originated as a small-scale outbreak that involved several cases of pneumonia identified in Wuhan, China, in December 2019. Afterward, various groups of patients with this form of pneumonia were documented across the globe. It later expanded its presence to additional countries, such as South Africa. It has turned into a worldwide issue for public health because it impacted many continents (NICD, 2020). Later on, the COVID-19 outbreak was classified as a global pandemic by the World Health Organization (WHO) on 11 March 2020 [9]. As per the report from the Centre for Disease Control and Prevention in 2019, an outbreak happens when there are more cases of a disease than what is usually expected. A pandemic is described as a widespread epidemic that spans a large geographic region, transcends boundaries, impacts many individuals, and leads to notable mortality rates [10,11]. In order for a disease to be classified as a pandemic, it needs to be contagious [11]. Furthermore, an endemic is a disease outbreak persistently existing but confined to a specific region. A pandemic usually begins as an endemic, but due to the rapid spread of the disease, these endemics eventually turn into pandemics [12]. In accordance with these definitions, COVID-19 was declared a pandemic.

Since COVID-19 is a contagious illness, it is caused by viruses or bacteria that can be transmitted through contact with contaminated surfaces, bodily fluids, blood products, insect bites, or the air [13]. Following the identification of the virus in South Africa, a number of specific actions were implemented to limit its transmission. The Government imposed stringent lockdown restrictions, which involved the temporary closure of public spaces like schools, restaurants, and markets and the halt of public transportation services. The city's medical centers were also activated to offer prompt care to the impacted individuals, with multiple hospitals being built to handle the rising patient count. The government worked together with global health institutions to exchange information and resources in combating the virus. As stated by Dong et al. [14], it is thought that implementing specific measures can assist in slowing down the transmission of SARS-CoV-2. These measures consist of practices like maintaining social distancing, wearing masks, practicing proper hand hygiene, and avoiding close contact with sick individuals. By putting these actions into effect, nations can decrease the rate at which the virus spreads and avoid healthcare systems from being overloaded. Additionally, as mentioned in a study by Alshammari et al. [15], certain nations implemented pre-emptive actions to stop or slow down the transmission of SARS-CoV-2 prior to any reported cases. These actions involved checking passengers at airports, enforcing isolation requirements for individuals who had contact with the virus, and limiting travel to and from impacted regions. By putting these measures in place quickly, these nations managed to stop or slow down the spread of the virus and reduce the effect on their people.

Global organizations acknowledge that in the initial crucial phases of infectious disease outbreaks such as new flu strains, SARS, and Ebola, prioritizing hygiene is the primary line of defense before introducing larger interventions like vaccines [16]. The WHO and national disease control agencies have consistently stressed the significance of hand hygiene in efforts to minimize virus transmission. WHO guidelines suggest regular handwashing with soap and water after using the restroom, before meals, and after coughing and sneezing to uphold hand hygiene [16]. Studies by both Bloomfield et al. [1] and Warnes et al. [17] have demonstrated that respiratory hygiene measures can prevent the transmission of respiratory infections like colds and influenza. These measures include cleaning hands and surfaces after coughing. During the COVID-19 pandemic, the utilization of hand sanitizers became a prevalent approach for cleansing hands and surfaces. A report by Hammond et al. [18] indicated that incorporating alcohol-based gel hand sanitizer in the classroom as part of a hand hygiene program led to a notable reduction in elementary school absences due to illnesses from infections.

The heightened recognition of the significance of hand cleansing resulted in the incorporation of hand sanitizers into individuals' hygiene routines, even after the COVID-19 pandemic. As a result, the need for hand sanitizers stayed elevated for a prolonged period of time [2]. Nevertheless, the rise in the need for alcohol-based sanitizers caused shortages in the nation, with different companies such as chemical industries, breweries, and perfumeries manufacturing sanitizers—some of which were not authorized for use. As a result, the quality of alcohol-based hand sanitizers being made was affected. Pharmacists and other manufacturers need proper instructions to create a consistent and high-quality product to combat the spread of diseases like the current coronavirus pandemic. Typically, hand sanitizers contain ethanol, a type of alcohol.

The Coronavirus has garnered considerable focus because of the swift increase in global infection numbers. As of now, there is no cure available, so preventive measures like social distancing, mask-wearing, getting vaccinated, and using hand sanitizers with 70% alcohol content are advised to lower infection rates. Hand sanitizers with alcohol are specially created to eliminate infectious diseases and viral infections. Before the COVID-19 pandemic, masks were mainly used in public spaces and hospitals, but now, they have become the standard after the pandemic. Yet, there have been revelations and worries about the low quality of sanitizers. Recent reports have shown that almost 50% of hand sanitizers fail to meet the WHO regulation from 2020, which requires them to have at least 70% alcohol content. This presents an issue and hinders public health efforts in combatting the COVID-19 pandemic and other contagious diseases. Therefore, the current study evaluated the quality of alcohol-based hand sanitizers used for COVID-19 prevention in the informal settlements of Cape Town, South Africa. The current study addresses a crucial public health issue in informal settlements in South Africa, where the COVID-19 pandemic has worsened existing vulnerabilities. Moreover, it emphasizes the importance of education campaigns on public health issues and the use of ABHS in communities with less or non-existent healthcare infrastructures. The current study acknowledges that while there is a global emphasis on hand hygiene to prevent infectious diseases, there is limited research on the quality of alcohol-based hand sanitizers (ABHS) used in low-resource and informal settings. Most of the existing literature focuses on the efficacy of hand sanitizers in clinical and well-regulated environments, but few studies consider the challenges of quality control, regulatory oversight, and access to effective products in informal economies where vulnerable populations reside.

1.1. Description of the Study Area

The Cape Town metro area, situated in South Africa's Western Cape province, ranks as the second largest urban region, known for its dense population and bustling activity of people, goods, and services. It is known for its extensive growth, numerous commercial zones, and industrial districts, and is renowned globally for its stunning cities and ports [19]. As per Stats SA in 2022, Cape Town is home to around 4 million people, with a significant portion residing in 230 informal settlements containing roughly 140,000 informal homes. The map displayed various colored boundaries marking the informal settlements within the City of Cape Town. These communities are made up of groups of thin shacks/housing, ranging in size from a few shacks to thousands, refer to (Figure 1). The City of Cape Town organizes these groups of clusters, known as "pockets", to create informal settlements. It is crucial to mention that these informal settlements lack official legal recognition and are frequently set up without proper planning, building codes, or basic infrastructure and services. As a result, these settlements often suffer from inadequate living conditions, putting the health and safety of their residents at risk.

Figure 1. City of Cape Map, displaying Marikana, Masiphumelele, and Kosovo informal settlement locations (Google Earth Pro, 2023, v7.3.1).

1.2. Sample Sites

The research setting pertains to the location where data are gathered. In this study, data were collected from three sample sites that focused on informal settlements in underdeveloped countries, where population density and inadequate sanitation pose significant challenges during outbreaks. Sadly, the COVID-19 crisis led to the creation of additional informal settlements nationwide amid the devastating lockdown in March 2020. However, informal settlements are often viewed as illegal or criminal activities, rather than an act of housing desperation, and these areas are frequently associated with poverty. According to Austrian et al. [20], people in these industries are at the highest risk of becoming infected with COVID-19 because they do not have basic needs like proper housing, water, electricity, and sanitation and live in overcrowded conditions. Informal sectors involve informal business activities like street vending and "spaza" stores. Furthermore, self-quarantining in such settlements is impractical due to space constraints, violence, and overcrowding. A study by Gibson and Rush [21] confirmed that informal settlements were among the most adversely affected during COVID-19, as these densely populated areas made implementing social distancing measures difficult due to their density and layout. The three sample sites in question are Masiphumelele, Kosovo, and Marikana informal settlements, where the residents heavily rely on spaza shops. When the COVID-19 pandemic struck and the president announced the 21-day lockdown, informal shops were utilized. The high-density informal sectors pose significant challenges in implementing social distancing measures, making them susceptible to COVID-19 outbreaks.

1.2.1. Kosovo Informal Settlement

Kosovo (34°0′59.77″ S 18°35′16.12″ E) is a makeshift community situated in the Philippi neighborhood of Cape Town. Established in 1998, this informal settlement is just one of numerous in the area, offering a potential housing solution for individuals requiring temporary accommodation close to their original site, refer to Figure 1. This led to the first illegal land occupation and the formation of what is now known as the Kosovo settlement [22]. The distinctive name of the community, similar to numerous other informal settlements in the Cape region, is associated with a historical event during the war period in the Balkans [22]. The settlement is home to approximately 5500 people during the pandemic and has been promised relocation [23]. Like many other informal settlements, Kosovo lacks the necessary infrastructure and services, which leads to substandard living

conditions and limited access to resources [24]. The absence of essential amenities like sanitation, clean water, electricity, and waste disposal creates considerable health hazards for the inhabitants [22]. The settlement also lacks proper housing, with most residents living in makeshift structures constructed from scrap materials. Despite these difficulties, Kosovo and similar informal settlements are crucial in addressing the housing demands of low-income populations, especially in cities where inexpensive housing is lacking [22]. Many residents of informal settlements are unable to afford the high cost of rent in formal housing, and as such, informal settlements provide an affordable alternative [24]. To address the underlying causes of informal settlements, governments and organizations need to work together to provide adequate housing and basic services to all residents of these settlements.

1.2.2. Marikana Informal Settlement

The Marikana informal settlement (34°0′16.39″ S 18°36′36.03″ E) is situated in Philippi East Ward 35., Marikana was established through an illegal land invasion in November 2012, and although it was legally demolished, it was re-established through another land invasion on Freedom Day in April 2013 [25]. The settlement is named after the Marikana miners who died protesting for better wages in 2012 in Marikana, Rustenburg [25]. It is one of the biggest townships, about 7 km away from Cape Town International Airport and 20 km from the Cape Town city center. The informal dwelling is encountering a range of issues such as poverty and the absence of essential amenities [26]. The inhabitants have no access to proper sanitation facilities, and the water supply is limited, with very few communal taps. The settlement also suffers from a lack of electricity, with illegal connections to nearby Philippi township houses posing a safety risk to the community [27]. Additionally, the lack of a proper sewerage system presents significant health risks to the community. The inhabitants rely on makeshift sanitation facilities, which are unhygienic and pose a health hazard [27]. To worsen the situation, the settlement lacks a proper waste management system, leading to the accumulation of garbage and an environment that is conducive to diseases. The absence of basic infrastructure, such as roads, walkways, and street lighting, makes the settlement more vulnerable to crime and accidents. Despite these challenges, the community of the Marikana informal dwelling remains resilient and optimistic about the future.

1.2.3. Masiphumelele Informal Settlement

Masiphumelele (34°7′41.46″ S 18°22′25.76″ E) is a small town situated in the Western Cape region of South Africa located between Kommetjie, Capricorn Village, and Noordhoek [28], as shown in Figure 1 The settlement was established in 1992 as an informal settlement for people who had overflowed from the nearby Khayelitsha Township and a nearby squatter camp [29]. Originally, the community was planned for 750 families, but an increase in population led to the construction of thousands of makeshift shelters alongside the formal houses. Regrettably, this has resulted in worsened living conditions for the residents of the township [30]. The Masiphumelele population has grown to over 50,000 people and 23,000 households since the early 1990s. Foreign nationals also arrived in Masiphumelele, which has resulted in a diverse population from different parts of South Africa and Africa [29]. The community of Masiphumelele in the Western Cape is indeed not immune to the challenges brought about by overcrowding and delays in the provision of low-cost housing [30]. The poor access to housing in Masiphumelele leads to health risks, especially for children, pregnant women, and the elderly [30]. The City of Cape Town neglected to deal with the unsanitary conditions, leading to prevalent illnesses such as diarrhea and respiratory tract infections. Poverty, crime, and violence also affect the quality of life in Masiphumelele due to a shortage of land that is often privately owned [30]. Additionally, the absence of established sanitation facilities hinders efforts to manage the transmission of contagious illnesses, like COVID-19, among the population.

2. Materials and Methods

2.1. Sampling Size

The number of individuals included in a study to represent a population is known as the sample size, as defined by Tejada et al. [31]. Obtaining accurate, statistically significant data and successfully conducting your study heavily relies on having the appropriate sample size [31]. The sample size in this study was determined using a formula that factors in the number of samples 'n', the total number of shops 'N', and the margin of error 'e'. This computation was utilized to precisely depict the overall samples collected. The margin of error displays the extent of values that fall on either side of the sample statistic within a confidence interval, indicating the level of precision intended for the research. In this research, a 95% confidence level was utilized with a margin of error of 0.05 [32].

$n = N/(1 + Ne^2)$

$n = 180/(1 + (180)(0.05)^2)$

$n = 124$

Due to the lockdown restrictions and limitations imposed by the COVID-19 pandemic, we encountered challenges in collecting the expected number of samples from the Spaza shops in Masiphumelele informal settlements. This was primarily due to the closure of some Spaza shops and the absence of sanitizers at most shop entrances. In response to these obstacles, the researcher decided to include two additional locations to compensate and increase the sample size. As previously indicated, the reliability of the results is directly linked to the sample size. The hand sanitizer samples were gathered randomly from various Spaza shops, which are common grocery shopping areas for residents. In total, 78 samples were collected from the three locations, with Masiphumelele contributing 19 samples, Kosovo 15, and Marikana 44. In the study, 78 out of 124 samples (which is 60% of 124) were included, taking into account sample representativeness and resource constraints. Therefore, the sample size remains reliable, as a good maximum sample size is typically around 10% of the population. However, since the researcher has expanded the sampling sites, the population of sanitizers is currently unknown and out of all the spaza shops that were approached for the study, these were the only ones that agreed to participate. Despite efforts to get more spaza shops involved, these were the only ones who showed an interest in the study and were willing to take part in it.

2.2. Collection of Alcohol-Based Hand Sanitisers

A total of 78 hand sanitizers (73 liquid and 5 gel) were randomly collected at entrance points of various spaza shops, (informal convenience shop businesses) hardware stores, and by street vendors located around three different informal communities in the City of Cape Town Municipality representing different income groups. Their brands were not recorded because this information was not visible, there was no labeling on the dispensers or the dispensers might have been refilled with a product not specified on the label. The samples were used to gather fundamental data such as the name and whereabouts of the store/spaza shops. Additionally, a set of homemade hand sanitizers, prepared based on the WHO's recommendations for daily use by staff or individuals, was also gathered. These sanitizers were collected directly from the container using 1.5-mL sterile Eppendorf tubes and then transferred into 10 mL glass vials. The first batch of sanitizer samples was collected in Masiphumelele and Kosovo informal settlements between April to November 2021 while the second batch was collected in Marikana informal settlements between January and June 2022. For the purpose of determining the alcohol content and compliance with labeling requirements, all hand sanitizers of different types and brands were chosen and tested. Each hand sanitizer was assigned a unique sample identifier code, ranging from HS1_site 1 to HS1_site 2 and HS1_site 3, which were collected from local shops and supermarkets in Masiphumelele, Marikana, and Kosovo informal settlements.

2.3. Formulation and Distribution of Sanitiser Samples Collected for Analysis

The samples consisted of seventy-three (73) liquids and five (5) gels, Gel hand sanitizers were only found in Masiphumelele informal settlements (site 1); the other two sites used liquid hand sanitizers. Out of the 78 samples, only 72 were analyzed (Figure 2).

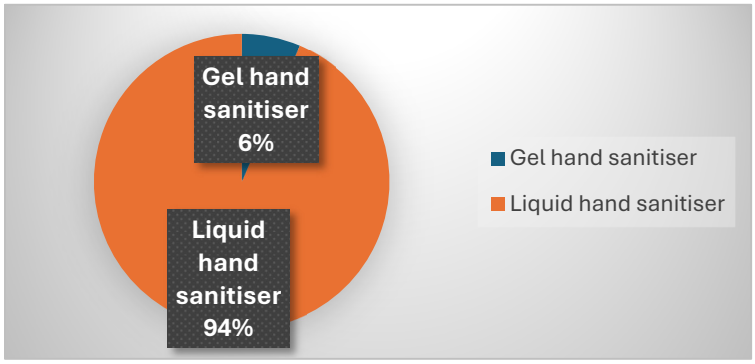

Figure 2. A pie chart of hand sanitizers collected around Cape Town's informal settlements, comprising gels and liquids.

2.4. Common Active Ingredients in Hand Sanitiser

The research observed that ethanol was the most common alcohol present, constituting 74% (Figure 3) of the total alcohol content. Following ethanol, isopropanol was found to make up the remaining 26% of the alcohol content.

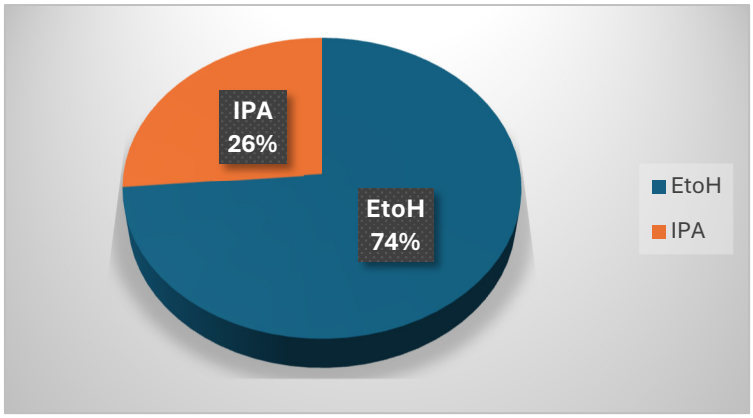

Figure 3. Common active ingredients in hand sanitizers collected around Cape Town's informal settlements, comprising of gels and liquids.

2.5. Equipment and Instruments Used for Sampling and Analysis of Hand Sanitisers

All sampling tools (such as 1.5-mL sterile Eppendorf, 10 mL glass vials, scoops, and bags) were made of non-contaminating substances and rinsed with distilled water prior to and following every sampling event. Following the collection of samples, the vial lids were securely fastened to offer an extra safeguard against evaporation and leakage while being transported. Next, the samples were promptly placed in a cooler, transferred to the lab, and kept at 20 °C until additional testing. Later on, all of these samples were examined as part of this inquiry. The Agilent 7890A Gas Chromatograph with a Flame Ionization Detector (7890A GC-FID) was one of the tools and devices used. Measurements and transfers were conducted by utilizing Eppendorf Pipets along with pipet tips. Conical tubes were used as receptacles for the ultimately diluted mixtures of hand sanitizers. A 100 mL beaker was used for measuring solvents and solutions. The sanitizers in these samples were collected from various spaza shops. The purpose of collecting the samples was to assess their efficiency, standards, and security. The information gathered from these

samples will be assessed to establish if they meet the necessary standards and regulations. The assessment will aid in pinpointing any possible hazards or concerns linked to the utilization of these sanitizers and will offer valuable insights to enhance the quality and safety of the products.

2.6. Hand Sanitiser Samples Collected for Analysis

Figure 4 below depicts the collected hand sanitizer samples for analysis.

Figure 4. Sanitizer samples collected for analysis.

2.7. Analytical System and Operating Conditions for Gas Chromatography Analysis

The conditions for the Agilent 7890A Gas Chromatograph with Flame Ionization Detector (7890 GC-FID) used in this study are shown in Table 1. The carrier gas utilized in the research was nitrogen, and the column employed was the HP88 type (100 m × 250 µm, 0.250 µm). The oven temperature of the gas chromatograph was set at 50 °C initially for five minutes and then increased by 30 °C per minute for three minutes. The specimens were introduced in split mode with a split ratio of 100:1. The temperature for the flame ionization detector was adjusted to 250 °C.

Table 1. GC-FID analytical conditions for analysis of alcohol content in hand sanitizers.

Analytical System and Conditions	
Column type	HP88, (100 m × 250 µm, 0.250 µm)
Injection temperature	250 °C
Injection volume	1 µ (split; 100:1)
Carrier gas	Nitrogen
Column flow rate	0.96 mL min^{-1}
Oven Temperature (holding time) programming	50 °C (5 min), 30 °C/min to 230 °C (3 min)
Total run time	40 min

2.8. Preparation and Evaluation of Calibration Standards for Ethanol and Isopropanol Analysis

The external calibration curve for ethanol and isopropanol was created by diluting the stock solution with deionized water over a 0–100% range of ethanol and isopropanol. The standards were each placed in a 2 mL headspace vial, sealed, and thoroughly mixed using a vortex mixer. The criteria were promptly loaded onto the headspace autosampler tray for analysis and displaying six measurement graphs. In total, 1 mL of ethanol and 1 mL of isopropanol were combined and subsequently examined in order to evaluate the method. The ethanol or isopropanol external calibration curve was used to measure the alcohol content, as these are the two main alcohols suggested by the WHO for ABHRs. The calibration graph covered a range of 0% to 100% (v/v) and was plotted with alcohol concentration percentages (0, 20, 40, 60, 80, and 100%) versus GC peak areas (refer to Figure 5).

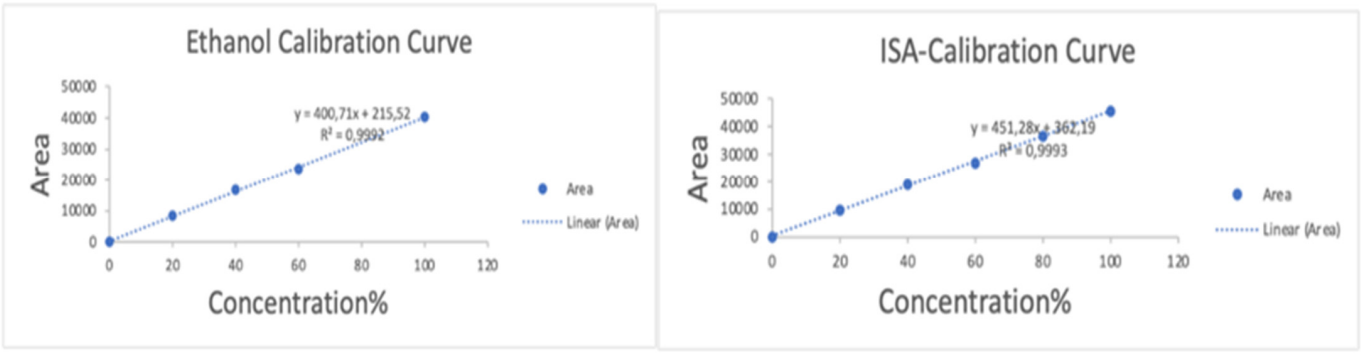

Figure 5. Calibration curves for isopropanol and ethanol indicate the accuracy of detection (R^2) and the regression parameters of the line y = mx + c.

2.9. Preparation of Hand Sanitiser Samples

Liquid hand sanitizers were transferred from 10 mL glass vials to 2 mL autosampler vials using a pipette. The vial was then capped, and the contents were thoroughly mixed on a vortex mixer before analysis.

3. Results and Discussion

The study analyzed 78 samples of hand sanitizer from various brands to determine the concentration of ethanol and isopropyl alcohol. The results of these parameters are presented in Table 2 below. Each sample was given a unique code based on the sample site and shop number. Different batches of sanitizers were labeled as HS1_Site1, HS1_Site2, and HS1_Site3. To determine the concentration of either ethanol or isopropanol, the equation of the trend line y = mx + c was used. In this equation, 'y' represents the measured peak intensity of alcohol, 'm' represents the gradient, 'x' represents the unknown concentration of alcohol, and 'c' represents the intercept.

Table 2. Determination of either ethanol or isopropanol concentration using the below calculation.

Parameters/Variables	x = (y − c)/m	Values
y-intercept	C	362.19
gradient or slope	M	451.28
Peak Area	Y	14,140.2
Concentration %	[x]	30

Alcohol-based hand sanitizers for SARS-CoV-2 and similar viruses or any communicable diseases should contain at least 60% ethanol or 70% isopropanol according to CDC recommendations. The tables below display the quantified values for 72 commercial sanitizer samples. The findings indicate that ethanol constitutes a significant majority of the total alcohol content, precisely 74%. This is an important observation as ethanol is commonly utilized in various applications. On the other hand, isopropanol, which is another type of alcohol commonly used as a disinfectant and solvent, accounts for the remaining 26% of the total alcohol content. Shockingly, 70% of hand sanitizer products containing isopropanol do not meet the 70% of the required alcohol content. Whereas, only 77% of Ethanol samples meet the required standards. Moreover, all five gel sanitizers were not quantified, and one liquid hand sanitizer did not demonstrate any peaks for either ethanol or isopropanol. However, ethanol was the most dominant in all three sites whereas isopropanol was only detected in site 1 (Masiphumelele) and site 2 (Marikana).

3.1. Determining and Measuring Alcohol Levels

Isopropanol and ethanol are the two types of alcohol that were measured in hand sanitizer samples. The research revealed that 77% of alcohol-based hand sanitizers (ABHS)

contained more than 60% ethanol, which is the amount recommended by the World Health Organization (WHO). However, the remaining 23% of ABHS did not comply with the regulations regarding the percentage of alcohol present. The study also showed that most IPA samples had very low concentrations, indicating that the sanitizer collected at entrance shops in Masiphumelele and Marikana informal settlements might have been ineffective in preventing the transmission of SARS-CoV-2 and other infectious diseases. These results are alarming, as community settings heavily rely on these small spazas, which are not providing adequate protection. This is unfortunate, as informal settlements also struggled to employ social distancing during the pandemic due to these community settings being densely populated, making it hard to enforce social distancing. Alcohol concentrations ranging from 60% to 95% have been deemed effective and safe for disinfection by regulatory organizations such as the US FDA, CDC, and WHO [33]. In hand sanitizers, ethanol and isopropanol were the two most commonly used alcohols, with ethanol consisting of 53 samples and isopropanol constituting 19 samples. Ethanol is generally preferred in ABHS preparations due to its superior virucidal activity and skin tolerance when compared to isopropanol, as supported by Jing et al. [34]. However, IPA was only detected in Masiphumelele and Marikana, making ethanol the dominant alcohol in all three sites.

3.2. Masiphumelele Alcohol Concentration

The alcohol concentration analysis results for hand sanitizer samples collected from Masiphumelele (site 1) are presented in Table 3 and Figure 6. Out of the 13 samples analyzed, 77% contained ethanol, with concentrations ranging from 60% to 98%. Conversely, the remaining 23% of samples exhibited lower concentrations of isopropanol, ranging from 3% to 49%.

Table 3. The alcohol concentration at Masiphumelele found in hand sanitizer samples.

Hand Sanitiser Sample	Formulation	Ethanol Concentration (% *v*/*v*)	Isopropanol Concentration (% *v*/*v*)	Total Alcohol Concentration (% *v*/*v*)	Compliance to CDC Recommendations
HS_1	Liquid	0	12	12	No
HS_2	Liquid	0	16	16	No
HS_3	Liquid	0	30	30	No
HS_4	Liquid	67	0	67	Yes
HS_5	Liquid	74	0	74	Yes
HS_6	Liquid	71	0	71	Yes
HS_7	Liquid	68	0	68	Yes
HS_8	Liquid	72	0	72	Yes
HS_9	Liquid	74	0	74	Yes
HS_10	Liquid	73	0	73	Yes
HS_11	Liquid	70	0	70	Yes
HS_12	Liquid	76	0	76	Yes
HS_13	Liquid	68	0	68	Yes

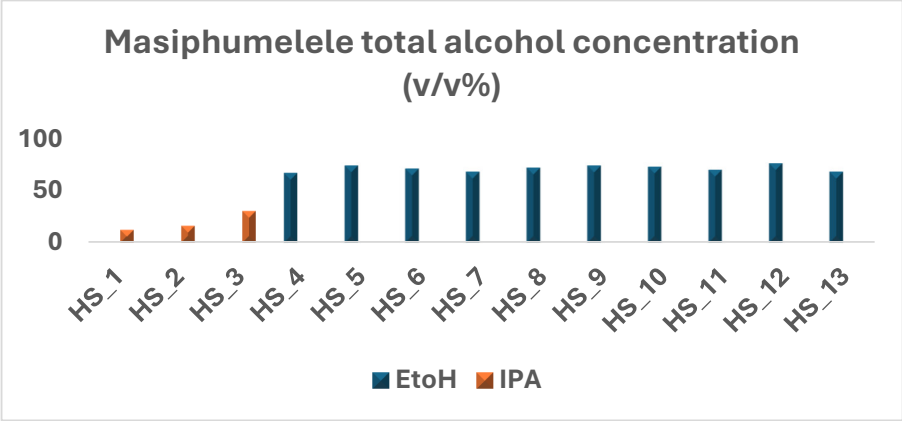

Figure 6. Graph with a total alcohol concentration at Masiphumelele informal settlement.

3.3. Alcohol Concentration and Effectiveness

Out of the 13 sanitizer samples collected in Masiphumelele, 77% contained ethanol within the recommended range of 60–79%, indicating adequate protection against COVID-19. These findings suggest a proactive approach by the community to ensuring public health during the pandemic. However, it was observed that the majority of compliant sanitizers contained ethanol, while most isopropanol samples were non-compliant. Studies have demonstrated that hand sanitizers with higher alcohol concentrations are more effective in combating viruses. Therefore, the presence of compliant ethanol-based sanitizers in Masiphumelele is encouraging. However, the lower concentrations of isopropanol in some samples may lead to reduced effectiveness and potential skin irritation, as reported. It has been found that ethanol is the most prevalent alcohol in the study, further supporting its effectiveness against viruses. Thus, the dominance of ethanol-based sanitizers in Masiphumelele aligns with existing research on effective hand hygiene practices. The findings from Masiphumelele highlight the importance of adequate alcohol concentration in hand sanitizers for effective virus prevention. The prevalence of compliant ethanol-based sanitizers indicates a proactive approach by the community to safeguarding public health. However, efforts to address the lower concentrations of isopropanol in some samples are warranted to ensure optimal effectiveness and minimize skin irritation risks.

3.4. Compliance with the Regulated 60% Alcohol-Based Hand Sanitisers Concentration

The importance and effectiveness of alcohol-based hand sanitizers in preventing healthcare-associated infections have been well-documented in numerous studies, even prior to the COVID-19 pandemic. However, achieving compliance with regulatory standards remains an ongoing challenge, particularly as the WHO permitted companies to manufacture sanitizers during the pandemic. The majority of the hand sanitizer products analyzed in Masiphumelele were found to meet the alcohol content requirements. However, significant gaps were observed in sanitizer samples containing isopropanol. Overall, compliance with regulatory standards was calculated at 77%, with ethanol-based samples demonstrating a higher compliance rate of 76%. Conversely, a lower level of compliance was observed for isopropanol samples, with an overall non-compliance rate of 23%. The lowest compliance percentage recorded was 3%. Figure 7 illustrates that the majority of sanitizers met the regulatory requirements set by the WHO and South African National Standards (SANS). This indicates that the community in Masiphumelele was adequately protected against the COVID-19 virus and other infectious diseases, as effective hand hygiene practices were being implemented.

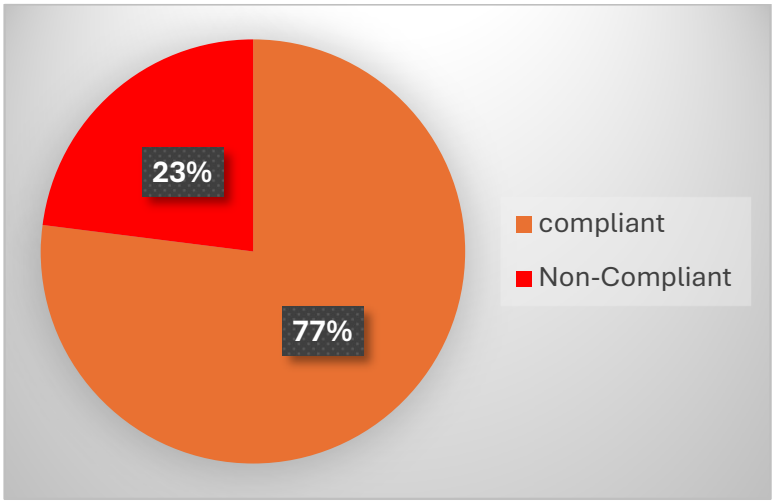

Figure 7. Overall compliance for Masiphumelele.

3.5. Marikana Alcohol Concentration

As illustrated in Figure 8 and detailed in Table 4 below, 64% of the hand sanitizer samples collected in Marikana contained ethanol, while the remaining 36% contained isopropanol. Ethanol emerged as the predominant sanitizer formulation used in the Marikana informal settlement, with a majority of the samples meeting the international and national standards set.

Table 4. The alcohol concentration at Marikana found in hand sanitizer samples.

Hand Sanitiser Sample	Formulation	Ethanol Concentration (% *v*/*v*)	Isopropanol Concentration (% *v*/*v*)	Total Alcohol Concentration (% *v*/*v*)	Compliance to CDC Recommendations
HS_1	Liquid	0	18	18	No
HS_2	Liquid	0	49	49	No
HS_3	Liquid	0	73	73	Yes
HS_4	Liquid	0	15	15	No
HS_5	Liquid	0	16	16	No
HS_6	Liquid	68	0	68	Yes
HS_7	Liquid	0	13	13	No
HS_8	Liquid	0	27	27	No
HS_9	Liquid	0	73	73	Yes
HS_10	Liquid	0	62	62	No
HS_11	Liquid	0	77	77	Yes
HS_12	Liquid	80	0	80	Yes
HS_13	Liquid	70	0	70	Yes
HS_14	Liquid	76	0	76	Yes
HS_15	Liquid	70	0	70	Yes
HS_16	Liquid	0	8	8	No
HS_17	Liquid	76	0	76	Yes
HS_18	Liquid	83	0	83	Yes
HS_19	Liquid	74	0	74	Yes
HS_20	Liquid	0	70	70	Yes
HS_21	Liquid	70	0	70	Yes
HS_22	Liquid	0	68	68	No
HS_23	Liquid	97	0	97	Yes
HS_24	Liquid	76	0	76	Yes
HS_25	Liquid	75	0	75	Yes
HS_26	Liquid	13	0	13	No
HS_27	Liquid	74	0	74	Yes
HS_28	Liquid	75	0	75	Yes
HS_29	Liquid	76	0	76	Yes
HS_30	Liquid	64	0	64	Yes
HS_31	Liquid	48	0	48	No
HS_32	Liquid	75	0	75	Yes
HS_33	Liquid	0	70	70	Yes
HS_34	Liquid	0	28	28	No
HS_35	Liquid	75	0	75	Yes
HS_36	Liquid	75	0	75	Yes
HS_37	Liquid	71	0	71	Yes
HS_38	Liquid	0	53	53	No
HS_39	Liquid	48	0	48	No
HS_40	Liquid	57	0	57	No
HS_41	Liquid	87	0	87	Yes
HS_42	Liquid	63	0	63	Yes
HS_43	Liquid	69	0	69	Yes
HS_44	Liquid	71	0	71	Yes

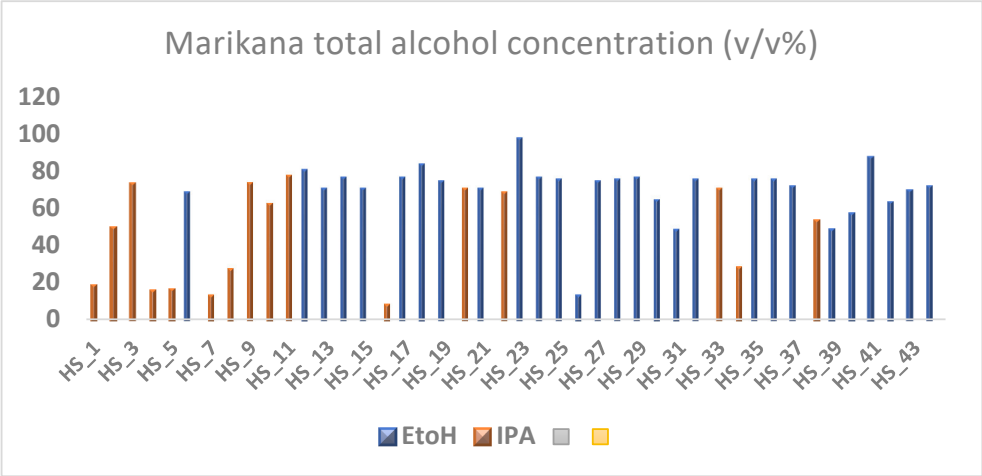

Figure 8. Graph with a total alcohol concentration at the Marikana informal settlement.

3.6. Alcohol Concentration and Effectiveness

Table 4 reveals that 64% of the samples contained ethanol, while 36% contained isopropanol, indicating a preference for ethanol-based sanitizers in Marikana. The majority of samples met the standards set by the WHO for alcohol concentration (60–95%), indicating effectiveness in combating the spread of the virus. However, one sample analyzed from Marikana contained an exceptionally high alcohol concentration of 97%. This finding is concerning, as excessively high alcohol concentrations may not effectively denature the virus. The importance of a balanced mixture of water and alcohol in hand sanitizers is fundamental to achieve effective protein denaturation of viruses. High alcohol concentrations above 95% without water may not effectively kill pathogens, as water is required for protein denaturation. Furthermore, hand sanitizers containing ethanol met the regulatory standards set by the FDA and SANS (60% ethanol), indicating compliance with international and national guidelines. This suggests that the majority of individuals in Marikana were using ethanol-based sanitizers and were adequately protected against the virus. These findings highlighted the importance of monitoring and regulating alcohol concentrations in hand sanitizers to ensure their effectiveness in preventing disease transmission. Future efforts should focus on promoting the use of sanitizers with balanced alcohol concentrations and educating communities on proper hand hygiene practices.

3.7. Compliance with the Regulated 60% Alcohol-Based Hand Sanitisers Concentration

Figure 9 depicts the compliance of hand sanitizer samples collected from Marikana with the regulated 60% alcohol-based concentration.

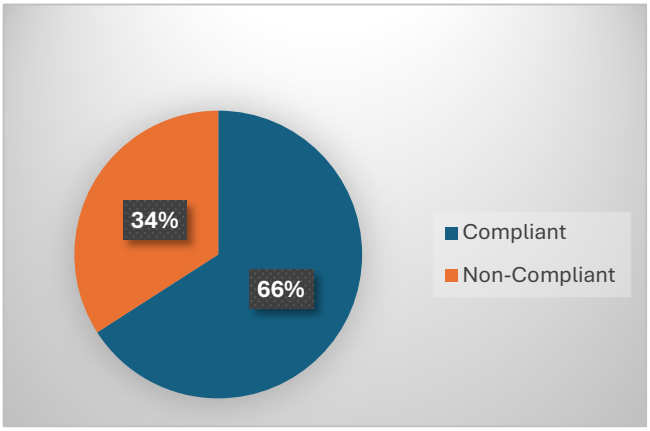

Figure 9. Overall compliance for Marikana.

3.8. Overall Compliance for Marikana

This figure illustrates that 66% of the sanitizer samples met the requirement for a 60% alcohol-based concentration, while 34% did not comply. This indicates that a significant portion of the hand sanitizer samples analyzed did not meet the minimum alcohol concentration required for effective germ-killing and virus protection. Non-compliant sanitizers may pose a risk to public health by potentially failing to adequately sanitize hands and prevent the transmission of viruses and bacteria.

3.9. Ethanol and Isopropanol Compliance

This figure shows the compliance rates specifically for ethanol and isopropanol-based hand sanitizers (Figure 10). It indicates that the majority of ethanol-based sanitizers were compliant with regulated concentrations, while a smaller proportion of isopropanol-based sanitizers met the requirements. This suggests that ethanol-based sanitizers were more consistently compliant with regulatory standards compared to isopropanol-based alternatives. The findings suggest that during the COVID-19 pandemic, local store owners in Marikana adhered to regulations and ensured that ethanol-based hand sanitizers, which are more prevalent in the area, were compliant with regulatory standards. However, attention should be given to the compliance of isopropanol-based sanitizers, as they play a significant role in hand hygiene practices and public health outcomes. It is important to note that hand hygiene compliance can be influenced by factors such as the visibility and accessibility of hand sanitizer dispensers, particularly at entrance points [35]. Therefore, efforts to improve the availability and visibility of hand sanitizer dispensers may further enhance hand hygiene practices in public spaces like spaza shops.

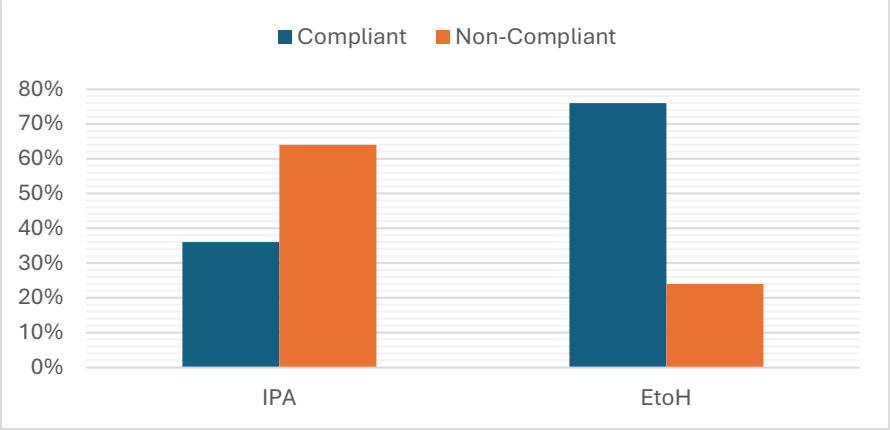

Figure 10. Ethanol and isopropanol compliance.

3.10. Kosovo Alcohol Concentration Levels

The analysis of hand sanitizer samples collected from Kosovo revealed concerning findings regarding ethanol concentration and compliance with regulatory standards. The analysis of all the collected samples revealed the presence of ethanol in each one. Furthermore, among the 15 sanitizers subjected to testing, 53% were found to exceed the recommended standard set by the World Health Organization (WHO) of 60–95%. Conversely, the remaining 47% fell below this standard (see Table 5). These findings are concerning as they indicate that the residents in the settlement may have had limited access to hand sanitizers with the effectiveness required to combat germs and viruses. This issue was particularly critical during the ongoing COVID-19 pandemic. It was found that the average ethanol content of all non-compliant samples was 47% by volume. Furthermore, the study revealed that the lowest observed ethanol content of any sample was 9%, as indicated in Table 5. Additionally, it was noted that no samples with isopropanol as the sole active ingredient were found on site.

Table 5. The alcohol concentration in Kosovo found in hand sanitizer samples.

Hand Sanitiser Sample	Formulation	Ethanol Concentration (% *v*/*v*)	Isopropanol Concentration (% *v*/*v*)	Total Alcohol Concentration (% *v*/*v*)	Compliance to CDC Recommendations
HS_1	Liquid	48	0	48	No
HS_2	Liquid	69	0	69	Yes
HS_3	Liquid	9	0	9	No
HS_4	Liquid	9	0	9	No
HS_5	Liquid	69	0	69	Yes
HS_6	Liquid	69	0	69	Yes
HS_7	Liquid	18	0	18	No
HS_8	Liquid	67	0	67	Yes
HS_9	Liquid	70	0	70	Yes
HS_10	Liquid	32	0	32	No
HS_11	Liquid	61	0	61	Yes
HS_12	Liquid	70	0	70	Yes
HS_13	Liquid	23	0	23	No
HS_14	Liquid	70	0	70	Yes
HS_15	Liquid	23	0	23	No

3.11. Total Alcohol Concentration at the Kosovo Informal Settlement

The findings of this study reveal significant concerns regarding the quality and compliance of alcohol-based hand sanitizers (ABHS) used in Cape Town's informal settlements, particularly Kosovo, Masiphumelele, and Marikana. The non-compliance of 26% of the tested samples poses a direct threat to public health in these densely populated areas, where access to basic healthcare and hygiene products is limited. As displayed in Figure 11, the total alcohol concentration measured at the Kosovo informal settlement indicates the levels of ethanol and isopropyl alcohol present.

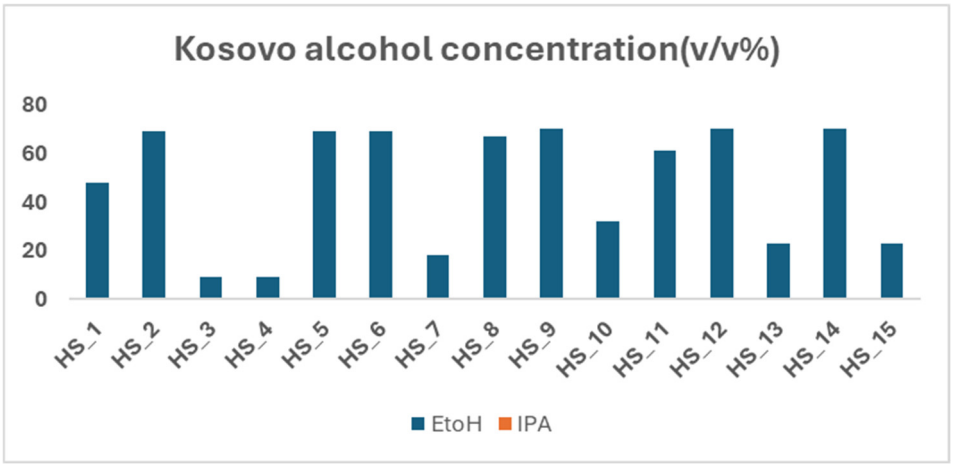

Figure 11. Graph with a total alcohol concentration at the Kosovo informal settlement.

The fact that 47% of ethanol-based sanitizers in Kosovo fell below the WHO-recommended threshold of 60% ethanol content is alarming. The low ethanol concentrations, with some samples as low as 9%, underscore the insufficient regulatory oversight in these areas. This highlights a broader issue of informal settlements being marginalized in terms of access to quality products and services, exacerbating their vulnerability during public health emergencies. Inadequate sanitizers fail to provide the necessary protection against communicable diseases like COVID-19, contributing to higher transmission rates in these communities. This has critical implications, as informal settlements are already grappling with overcrowded conditions, poor sanitation infrastructure, and limited access to healthcare, creating a perfect storm for rapid disease spread. Notably, no samples with isopropanol as the sole active ingredient were found on site. Figure 12 displays the ethanol concentration in ABHS samples sourced from the Kosovo informal settlement. These findings emphasize the importance of regular monitoring and regulation of hand sanitizer

formulations to ensure their effectiveness in preventing disease transmission. Efforts should be made to address the non-compliance observed in Kosovo, potentially through improved manufacturing processes, increased regulatory oversight, and public education campaigns on the importance of using compliant hand sanitizers for effective hand hygiene.

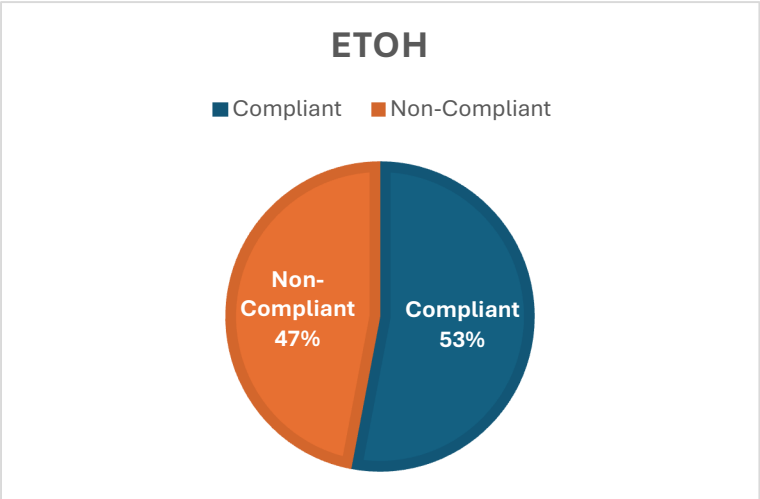

Figure 12. Ethanol concentration in ABHS samples sourced from the Kosovo informal settlement.

3.12. Overall Alcohol Content for All Three Sites

The study evaluated the alcohol content (both ethanol and isopropanol, two active ingredients allowed by FDA's interim ABHS production guidelines) for 72 total ABHS samples from the three informal dwellings in Cape Town. ABHS is an important tool in the fight against the spread of illnesses such as SARS-CoV-2. However, many of the collected ABHS products do not meet the required industry standards set forth by the WHO. Specifically, this study discovered that only 36% of isopropanol samples had an alcohol percentage between 70 and 80%, which is the required standard to effectively combat SARS-CoV-2. The study's findings raise significant public health concerns, particularly in the context of informal settlements where access to quality-controlled sanitation products is already limited. The inadequate alcohol content in many alcohol-based hand sanitizers (ABHS) collected from these areas highlights a critical gap in the fight against communicable diseases such as SARS-CoV-2. Given that only 36% of the isopropanol samples met the recommended 70–80% alcohol concentration standard, the efficacy of these products in preventing viral transmission is severely compromised. This is especially alarming in informal settlements, where high population density and limited healthcare infrastructure heighten the risk of rapid disease spread. Hand sanitizers, particularly those containing isopropanol or ethanol, are a first line of defense against viruses with lipid envelopes, including SARS-CoV-2, ZIKA, and EBOLA, as previously demonstrated by Siddharta et al. [36]. However, the fact that 64% of the ABHS tested in this study contained substandard levels of isopropanol suggests that residents in these areas may unknowingly use products that do not provide the necessary protection. This has broad implications for public health, as the inability to access or trust effective sanitation tools could result in more frequent outbreaks of not only COVID-19 but also other communicable diseases. This is particularly concerning in densely populated and resource-poor settings where infection control is already challenging.

The absence of appropriate labeling and the use of homemade or unregulated formulations further exacerbate these risks. Without clear declarations of ingredients and alcohol content, consumers in informal settlements are left in the dark regarding the efficacy and safety of the products they rely on for protection. The use of refilled or unlabeled sanitizers, as observed in both Cape Town and Johannesburg, underscores the urgent need for regulation and education around the production and use of ABHS in these vulnerable communities. The lack of regulation and quality control not only puts individuals at

greater risk but also undermines broader public health efforts aimed at curbing the spread of viruses in these high-risk areas. In informal settlements, where access to clean water and sanitation facilities is already compromised, ABHS serves as a crucial alternative for hand hygiene. However, if these products are ineffective or unsafe, they leave residents exposed to greater health risks. The study's findings point to the need for more robust public health interventions, including tighter monitoring of ABHS manufacturing and distribution, particularly in informal economies like spaza shops. Ensuring compliance with WHO guidelines is not just a matter of public safety but also a means of protecting already vulnerable populations from the heightened risks of infectious diseases. Furthermore, the lack of methanol detection in this study stands in contrast to other findings from Matatiele et al. [37], which reported the presence of this toxic substance in similar settings. This discrepancy calls attention to the uneven quality and safety of ABHS products being used across South Africa. While no recalls have been issued in South Africa, unlike in the USA, where methanol contamination has led to significant public health actions, the findings of this study highlight the need for proactive regulatory oversight to prevent a potential public health crisis in the future.

Ultimately, the study underscores the need for systemic changes to ensure the safety and efficacy of ABHS products, particularly in marginalized communities. This involves not only tighter regulation but also efforts to educate both manufacturers and consumers about the importance of adhering to WHO-recommended formulations. Public health strategies must take into account the unique challenges faced by informal settlements, where access to proper sanitation and healthcare is limited, and create targeted interventions to prevent the spread of diseases like COVID-19, protecting the most vulnerable populations.

3.13. Compliance and Effectiveness of ABHS

About 76% of the ethanol samples were compliant, while 24% of the samples were non-compliant. Isopropanol was found to be $\geq$70% in only 36% of the tested samples that were compliant. Shockingly, a majority, 64% of the IPA samples, were non-compliant with the CDC recommendations as they contained less than 70% isopropanol (See Figures 13 and 14). The study provides conclusive evidence that 74% of the tested hand sanitizers meet the recommended alcohol percentage by both the CDC and FDA guidelines. However, the remaining 26% of the tested samples fail to meet the recommended standards. The results show that users of alcohol-based hand sanitizers are being exposed to substandard and falsified products that are unsafe and ineffective against COVID-19, including other infectious viruses and diseases. Similarly, a thesis published in 2022 about the efficacy and toxicity of hand sanitizers by Zgheib [38] showed that only 26% were compliant, while 74% were non-compliant. A majority of hand sanitizers in community settings do not comply with standards, further highlighting the prevalence of ineffective products. This situation not only puts individuals at risk but also threatens public health on a larger scale, as the virus can spread more easily in environments where basic hygiene measures are not adequately met. These findings also point to a larger issue of health inequity in informal settlements, where residents are more likely to be exposed to substandard products, whether due to cost, availability, or lack of awareness about product quality. This situation deepens the vulnerability of these communities to outbreaks of infectious diseases, as access to effective disease prevention tools is often compromised by economic and structural barriers. The lack of routine widespread testing and enforcement to ensure product safety further compounds this issue, leaving consumers without recourse and increasing their susceptibility to health risks. Furthermore, the presence of unregulated or falsified hand sanitizers, as observed by Matatiele et al. [37] in Johannesburg, where nearly 20% of products contained methanol or had ineffective alcohol concentrations, highlights the broader issue of inadequate regulatory oversight in South Africa. Methanol, a toxic alcohol, poses serious health risks, including blindness, organ failure, or death if ingested or absorbed through the skin. The absence of regulatory intervention in South Africa, despite similar reports of methanol contamination, underscores the need for stronger public health policies, routine post-market surveillance,

and strict enforcement of product quality standards, particularly in vulnerable communities. As previously indicated by Abuga and Nyamweya [39], regular routine post-market surveillance is needed to prevent such products from reaching the market.

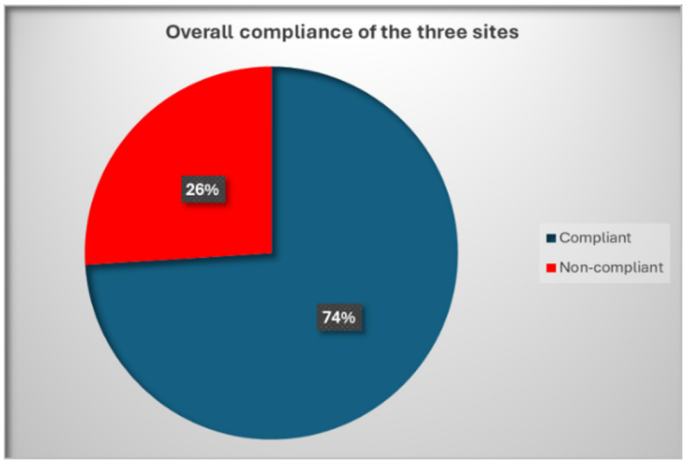

Figure 13. Overall compliance of the three sites.

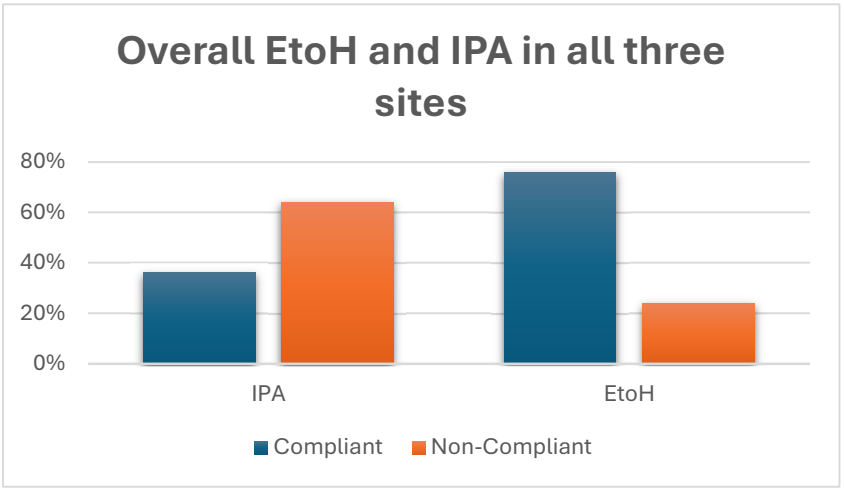

Figure 14. Overall EtOH and IPA in all three sites.

Figure 13 illustrates the overall compliance rates across the three sites.

Figure 14 below focuses on the concentrations of ethanol (EtOH) and isopropyl alcohol (IPA) detected at these sites, highlighting differences in the levels of these sanitizing agents.

3.14. Effectiveness of Hand Sanitizers: 60% Ethanol vs. 70% Isopropanol

When comparing the effectiveness of hand sanitizers, both 60% ethanol and 70% isopropanol are considered effective antimicrobial agents. However, there are differences in their antimicrobial activity, largely due to their chemical properties and mechanisms of action. Ethanol, at a concentration of 60%, is effective against a broad spectrum of microorganisms, including bacteria, viruses, and fungi [34]. It is particularly potent against enveloped viruses, such as coronaviruses, due to its ability to disrupt the lipid membrane of these viruses, rendering them inactive. On the other hand, isopropanol at a concentration of 70% exhibits strong antimicrobial activity against bacteria and viruses, including non-enveloped viruses. Non-enveloped viruses are typically more resistant to disinfection, but isopropanol effectively disrupts their protein structures, leading to their inactivation. The choice between 60% ethanol and 70% isopropanol may depend on various factors, including regional availability, personal preferences, and institutional guidelines. Both

formulations meet the recommendations of organizations such as the CDC and WHO for effective hand sanitizers.

3.15. Health Risks of Hand Sanitizers with Insufficient Alcohol Content

Hand sanitizers with low alcohol content pose significant health risks and can compromise their effectiveness in eliminating viruses, bacteria, and other pathogens. Insufficient sanitization increases the risk of infections, especially in settings where proper hand hygiene is crucial. Low alcohol levels may fail to eradicate all microorganisms, allowing some to survive and potentially develop resistance to antimicrobial agents over time. To compensate for low alcohol content, manufacturers may incorporate other harsh chemicals, which can lead to skin irritation, dryness, or allergic reactions upon prolonged use. Moreover, substandard hand sanitizers may contain toxic substances such as methanol or other impurities. Research, like the study conducted by Matatiele et al. [37], has detected high levels of methanol in certain sanitizers. Methanol exposure can result in various symptoms, ranging from headaches and dizziness to severe health complications like blindness or death [40]. Continuous use of substandard hand sanitizers can exacerbate chronic skin conditions, particularly among individuals with sensitive skin. Ineffective hand sanitizers contribute to the wider dissemination of diseases within communities, especially in regions with limited access to healthcare facilities. Ensuring that hand sanitizers meet the required alcohol content standards is essential for their efficacy in curbing the spread of infectious diseases and safeguarding public health. The findings from the studies conducted by Hashemi et al. [40] highlight the essential role of regulatory oversight and comprehensive public health strategies in ensuring the safety and efficacy of hand sanitizers. This study advocates for stricter enforcement measures to prevent the distribution of non-compliant ABHS. These combined insights point to a critical need for coordinated efforts to enhance product safety and protect public health during and beyond the COVID-19 pandemic.

4. Conclusions

The findings of this study highlighted the critical importance of ensuring the quality and efficacy of alcohol-based hand sanitizers, especially in vulnerable communities living in informal settlements. The COVID-19 pandemic has heightened the demand for hand sanitizers, leading to challenges in maintaining product standards and safety. Despite efforts to provide accessible hand hygiene solutions, such as allowing the temporary utilization of inferior raw materials, this study reveals concerning deficiencies in the quality of hand sanitizers used in informal settlements around Cape Town. With 26% of samples testing below the recommended alcohol concentration levels set by regulatory authorities, there is a significant risk of inadequate protection against infectious diseases, including COVID-19. Particularly alarming is the observation that a majority of non-compliant samples were collected from Masiphumelele, indicating potential disparities in access to safe hand sanitizers among different informal settlements. This highlights the urgent need for targeted interventions to ensure equitable access to quality hand hygiene products across all communities, regardless of socioeconomic status. The compliance rate of 74% with CDC guidelines indicates that a considerable proportion of hand sanitizer samples met recommended standards, providing some level of assurance in hand hygiene practices. However, the presence of substandard products underscores the importance of continuous monitoring, enforcement of regulations, and public education on the selection and use of effective hand sanitizers. Moving forward, policymakers, regulatory authorities, and public health agencies must collaborate to reformulate regulations and enforce stringent quality control measures to safeguard public health. Additionally, community awareness campaigns should be intensified to educate residents on the importance of using recommended hand sanitizers to prevent the spread of infectious diseases. By addressing these challenges and implementing targeted interventions, we can mitigate the risk of infections and contribute to flattening the infection curve, not only for COVID-19 but also for other communicable diseases that may resurface in the future, particularly in vulnerable com-

munities like informal settlements. Empowering communities with access to quality hand hygiene products and knowledge on proper usage remains paramount in our collective efforts to combat infectious diseases and protect public health.

Author Contributions: Conceptualization, B.S.M. and E.I.T.; Methodology, N.M. and M.M.; Writing—original draft, S.D.; Writing—review and editing, P.P.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Research Foundation grant number: TTK23041994766.

Institutional Review Board Statement: The study, which involved human participants, was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Cape Peninsula University of Technology (211148199/10/2022; 28 October 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is available upon reasonable request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Bloomfield, S.F.; Rook, G.A.W.; Scott, E.A.; Shanahan, F.; Stanwell-Smith, R.; Turner, P. Time to abandon the hygiene hypothesis: New perspectives on allergic disease, the human microbiome, infectious disease prevention and the role of targeted hygiene. *Perspect. Public Health* **2016**, *136*, 213–224. [CrossRef] [PubMed]
2. Berardi, A.; Perinelli, D.R.; Merchant, H.A.; Bisharat, L.; Basheti, I.A.; Bonacucina, G.; Cespi, M.; Palmieri, G.F. 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. [CrossRef] [PubMed]
3. Gorbalenya, A.E.; Baker, S.C.; Baric, R.S.; de Groot, R.J.; Drosten, C.; Gulyaeva, A.A.; Haagmans, B.L.; Lauber, C.; Leontovich, A.M.; Neuman, B.W.; et al. The species Severe acute respiratory syndrome-related coronavirus: Classifying 2019-nCoV and naming it SARS-CoV-2. *Nat. Microbiol.* **2020**, *5*, 536–544.
4. Burrell, C.J.; Howard, C.R.; Murphy, F.A. *Fenner and White's Medical Virology*, 5th ed.; Elsevier: Amsterdam, The Netherlands, 2016; 583p.
5. Yin, Y.; Wunderink, R.G. MERS, SARS and other coronaviruses as causes of pneumonia. *Respirology* **2018**, *23*, 130–137. [CrossRef]
6. Zhu, Z.; Meng, K.; Meng, G. Genomic recombination events may reveal the evolution of coronavirus and the origin of SARS-CoV-2. *Sci. Rep.* **2020**, *10*, 21617. [CrossRef]
7. Sahin, A.R.; Erdogan, A.; Mutlu Agaoglu, P.; Dineri, Y.; Cakirci, A.Y.; Senel, M.E.; Okyay, R.A.; Tasdogan, A.M. 2019 Novel Coronavirus (COVID-19) Outbreak: A Review of the Current Literature. *Eurasian J. Med. Oncol.* **2020**, *4*, 1–7. [CrossRef]
8. Yang, Y.; Peng, F.; Wang, R.; Guan, K.; Jiang, T.; Xu, G.; Sun, J.; Chang, C. The deadly coronaviruses: The 2003 SARS pandemic and the 2020 novel coronavirus epidemic in China. *J. Autoimmun.* **2020**, *109*, 102434. [CrossRef] [PubMed]
9. Onyeaka, H.; Anumudu, C.K.; Al-Sharify, Z.T.; Egele-Godswill, E.; Mbaegbu, P. COVID-19 pandemic: A review of the global lockdown and its far-reaching effects. *Sci. Prog.* **2021**, *104*, 00368504211019854. [CrossRef]
10. Kelly, H. The classical definition of a pandemic is not elusive. *Bull. World Health Organ.* **2011**, *89*, 540–541. [CrossRef] [PubMed]
11. Samal, J. A historical exploration of pandemics of some selected diseases in the world. *Int. J. Health Sci. Res.* **2014**, *4*, 165.
12. Potter, C.W.; Jennings, R. A definition for influenza pandemics based on historial records. *J. Infect.* **2011**, *63*, 252–259. [CrossRef] [PubMed]
13. Jeffries, D.; Visser, L.S. Infectious and Communicable Diseases. In *Rapid Access Guide for Pediatric Emergencies: Providing Expert Nursing Care*; Springer Publishing Company: New York City, NY, USA, 2021; pp. 228–259.
14. Dong, L.; Hu, S.; Gao, J. Discovering drugs to treat coronavirus disease 2019 (COVID-19). *Drug Discov. Ther.* **2020**, *14*, 58–60. [CrossRef]
15. Alshammari, T.M.; Altebainawi, A.F.; Alenzi, K.A. Importance of early precautionary actions in avoiding the spread of COVID-19: Saudi Arabia as an Example. *Saudi Pharm. J.* **2020**, *28*, 898–902. [CrossRef] [PubMed]
16. Kumar, D.; Malviya, R.; Kumar Sharma, P. Corona Virus: A Review of COVID-19. *EJMO* **2020**, *4*, 8–25.
17. Warnes, S.L.; Little, Z.R.; Keevil, C.W. Human coronavirus 229E remains infectious on common touch surface materials. *mBio* **2015**, *6*, 10–1128. [CrossRef]
18. Hammond, B.; Ali, Y.; Fendler, E.; Dolan, M.; Donovan, S. Effect of hand sanitizer use on elementary school absenteeism. *Am. J. Infect. Control* **2000**, *28*, 340–346. [CrossRef]
19. Fru, W. Copper and Zinc in Water, Sediment and Gastropods in the Harbours of the Cape Town Metropole, South Africa. Doctoral Dissertation, Cape Peninsula University of Technology, Cape Town, South Africa, 2020.
20. Austrian, K.; Pinchoff, J.; Tidwell, J.B.; White, C.; Abuya, T.; Kangwana, B.; Ochako, R.; Wanyungu, J.; Muluve, E.; Mbushi, F.; et al. COVID-19 Related Knowledge, Attitudes, Practices and Needs of Households in Informal Settlements in Nairobi, Kenya. *SSRN Electron. J.* **2020**. [CrossRef]

21. Gibson, L.; Rush, D. Novel coronavirus in Cape Town informal settlements: Feasibility of using informal dwelling outlines to identify high risk areas for COVID-19 transmission from a social distancing perspective. *JMIR Public Health Surveill.* **2020**, *6*, e18844. [CrossRef]
22. Mseleku, E.S. *Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality A Case Study of Kosovo*; KTH Royal Institute of Technology: Stockholm, Sweden, 2021; 87p.
23. Van Der Fort, F. Kosovo Residents in the Dark about COVID-19 Move. 2020. Available online: https://www.plainsman.co.za/news/kosovo-residents-in-the-dark-about-covid-19-move (accessed on 31 May 2024).
24. Armitage, N.; Beauclair, R.; Ashipala, N.; Spiegel, A. Draining the shantytowns; lessons from Kosovo informal settlement, Cape Town, South Africa. In Proceedings of the NOVATECH International Conference, Lyon, France, 28–30 June 2010.
25. Teo, R. The Organisation of a Land Occupation: A Case Study of Marikana, Cape Town. Master's Thesis, University of Cape Town, Cape Town, South Africa, 2016; 156p.
26. Danti, N.; Sanya, T. Critical Assessment of Right to Safe Water and Sanitation in a South African Informal Settlement: A Case Study of Marikana, Cape Town. Master's Thesis, University of Cape Town, Cape Town, South Africa, 2017; 227p.
27. Batyi, M. *Adulthood, Home-Leaving and Informal Settlement: A Study of the Marikana Informal Settlement in Philippi East, Cape Town*; University of the Western Cape: Cape Town, South Africa, 2022.
28. Madonsela, B.S. Assessment of Environmental Exposure to Air Pollution within Four Neighbourhoods of the Western Cape, South Africa. Doctoral Dissertation, Cape Peninsula University of Technology, Cape Town, South Africa, 2019.
29. Mascorp. Masiphumelele Corporation and Trust NGO Operating in Masiphumelele. 2020. Available online: www.masicorp.org (accessed on 30 March 2023).
30. Monqo, B.P. Housing Delivery at the Masiphumelele Community. *Adm. Publica* **2023**, *31*, 85–106.
31. Tejada, J.J.; Raymond, J.; Punzalan, B. On the Misuse of Slovin's Formula. *Philipp. Stat.* **2012**, *61*, 8.
32. Madonsela, B.S.; Machete, M.; Shale, K. Indigenous Knowledge Systems of Solid Waste Management in Bushbuckridge Rural Communities, South Africa. *Waste* **2024**, *2*, 293–311. [CrossRef]
33. United States Food and Drug Administration. *FDA Advises Consumers Not to Use Hand Sanitizer Manufactured by Eskbiochem*; United States Food and Drug Administration: Silver Spring, MD, USA, 2020.
34. Jing, J.L.J.; Yi, T.P.; Bose, R.J.C.; McCarthy, J.R.; Tharmalingam, N.; Madheswaran, T. Hand sanitizers: A review on formulation aspects, adverse effects, and regulations. *Int. J. Environ. Res. Public Health* **2020**, *17*, 3326. [CrossRef] [PubMed]
35. Cure, L.; Van Enk, R.; Tiong, E. A systematic approach for the location of hand sanitizer dispensers in hospitals. *Health Care Manag. Sci.* **2014**, *17*, 245–258. [CrossRef]
36. Siddharta, A.; Pfaender, S.; Vielle, N.J.; Dijkman, R.; Friesland, M.; Becker, B.; Yang, J.; Engelmann, M.; Todt, D.; Windisch, M.P.; et al. Virucidal activity of world health organization-recommended formulations against enveloped viruses, including zika, ebola, and emerging coronaviruses. *J. Infect. Dis.* **2017**, *215*, 902–906. [CrossRef] [PubMed]
37. Matatiele, P.; Southon, B.; Dabula, B.; Marageni, T.; Poongavanum, P.; Kgarebe, B. Assessment of quality of alcohol-based hand sanitizers used in Johannesburg area during the CoViD-19 pandemic. *Sci. Rep.* **2022**, *12*, 4231. [CrossRef] [PubMed]
38. Zgheib, R. Efficacy and Toxicity of Hand Sanitizers. Doctoral Dissertation, Lebanese American University, Beirut, Lebanon, 2022.
39. Abuga, K.; Nyamweya, N. Alcohol-Based Hand Sanitizers in COVID-19 Prevention: A Multidimensional Perspective. *Pharmacy* **2021**, *9*, 64. [CrossRef] [PubMed]
40. Hashemi, H.; Ghareghani, S.; Nasimi, N. A review of poisonings originating from self-administration of common preventative substances during the COVID-19 pandemic. *Am. J. Emerg. Med.* **2023**, *63*, 147–148. [CrossRef]