Cape Peninsula University of Technology

QUALITY OF ALCOHOL-BASED HAND SANITISERS USED FOR COVID-19 PREVENTION IN MASIPHUMELELE, CAPE TOWN

by

SISANDA VINOLIA DALASILE

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Master of Environmental Health

Faculty of Applied Science, Department of Environmental and Occupational studies

Cape Peninsula University of Technology

Supervisor: DR ELIE ITOBA TOMBO

Co-supervisor:

MR BENETT SIYABONGA MADONSELA & DR PHILANI PERFECT MPUNGOSE

District six, Cape Town

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DECLARATION

I, Sisanda Vinolia Dalasile, declare that the contents of this dissertation/thesis represent my own unaided work, and that the dissertation/thesis has not previously been submitted for academic examination towards any qualification. Furthermore, it represents my own opinions and not necessarily those of the Cape Peninsula University of Technology.

Signed **Date**

ABSTRACT

The COVID-19 pandemic and other infectious diseases are still prevalent and continue to infect people across the country. It is essential to note that hand sanitisation has been proven to be the most effective way to prevent and kill infectious bacteria, especially in the wake of the devastating impact of COVID-19 in South Africa since March 2020. Maintaining good hand hygiene remains vital for preventing diseases and it is important to treat it with seriousness. Nevertheless, the increased need for hand sanitisers caused a depletion in retail markets, resulting in authorities allowing the temporary utilisation of inferior raw materials during the COVID-19 pandemic. As a result, some businesses were manufacturing their own formulations for alcohol-based hand Sanitisers (ABHS). This study aimed to identify the quality of alcohol-based hand sanitisers used in informal settlements around Cape Town. The primary objective of this study was to determine whether the communities emanating from poor backgrounds living within densely populated areas were using safe alcohol-based hand sanitisers. Various spaza shops around three informal settlements were visited, and hand sanitiser samples were randomly collected. The samples were examined with an Agilent Auto sampler connected to a gas chromatograph using flame ionisation detection. Approximately 76% of the ethanol samples adhered to the compliance standards, whereas 24% did not meet these standards. Isopropanol levels were compliant (≥ 70%) in only 36% of the tested samples. Alarmingly, the majority 64% of the isopropanol samples failed to comply with CDC guidelines, as they contained less than the recommended 70% isopropanol (see Figure 21). The study conclusively demonstrates that 74% of the tested hand sanitisers conform to the CDC and FDA guidelines for the recommended alcohol percentage. However, 26% of the tested samples do not meet these recommended standards, posing a health risk mitigation factor. This is due to the high demand for alcohol-based hand sanitisers that has negatively impacted their quality. It is crucial to note that these substandard hand sanitisers can lead to a falsification sense of security thus advance the risk of infections.

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"For in God we live, move, and have our being".

Book of Acts 17:28

DEDICATION

This thesis is dedicated to the memory of my beloved father, continue resting in peace, Skhosana, Mntungwa, Novaphi, Msi-kaMhlanga

Thabo General Gwayana (1967-2007)

To my Beautiful mother **(Nontumelo Cynthia Dalasile)** and son **(Aqhame Oluhle Dalasile)**

“There is freedom waiting for you, On the breezes of the sky, and you ask, **"What if I fall?" Oh but my darling, What if you fly?”**

(Erin Hanson*)*

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GLOSSARY

Terms/Acronyms/Abbreviations	Definition/Explanation
ABHS	Alcohol Based Hand Sanitisers
SARS	Severe Acute Respiratory Syndrome
MERS	Middle East Respiratory Syndrome
RNA	Ribonucleic Acid
SA	South Africa
SABS	South African Bureau Standards
SANS	South African National Standards
WHO	World Health Organisation
CDC	Centres for Disease Control and Prevention
US FDA	United States Food and Drug Administration
MS	Mass Spectrometry
GC	Gas Chromatography
LC-MS	Liquid Chromatography- Mass Spectrometry
GC/MS	Gas Chromatography Mass Spectrometry
COVID-19	Coronavirus Disease 2019
EPA	United States Environmental Protection Agency
ES	External Standard

CHAPTER ONE

1.1 Introduction and Background of the Study

Before the 1970s, most known viruses were recognised as human pathogens, with others such as *Escherichia coli (E. coli)* O157 only being discovered in the following decades (Bloomfield et al., 2016). 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-Cov2*) (Berardi et al., 2020) known for causing the coronavirus disease of 2019 (COVID-19) (Gorbalenya et al., 2020). 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 behaviours such as coughing and sneezing (Burrell et al., 2016) On the other hand, the three remaining viruses (SARS, MERS, and SARS-Cov2) can cause serious respiratory infections with symptoms such as fever, cough, and difficulty breathing. According to Yin and Wunderink (2018) this could result in more severe illnesses and, in certain instances, even life-threatening conditions. SARS-Cov2 is the third coronavirus documented to have jumped from animals to humans (Sahin et al., 2020). Research on genetics has found similarities in sequences between SARS and SARS-CoV2, indicating that they both likely originated from bats (Zhu et al., 2020). SARS-CoV-2 leads to symptoms similar to the flu, such as fever and pneumonia (Sahin et al., 2020).

As per the findings of Yang et al (2020) the lethal virus originated as a small-scale outbreak that involved several cases of pneumonia identified in Wuhan, China in December 2019. Afterwards, 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 had 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 Organisation (WHO) on 11 March 2020 (Onyeaka et al., 2021). 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 (Kelly, 2011 and Samal, 2014). In order for a disease to be classified as a pandemic, it needs to be contagious (Samal, 2014). 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 (Potter and Jennings, 2011). 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 (Jeffries and Visser, 2021). 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. (2020), 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 distance, wearing masks, practicing proper hand hygiene, and avoiding close contact with sick individuals. Through 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. (2020) certain nations implemented preemptive 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 defence before introducing larger interventions like vaccines (Warnes et al., 2015). The WHO and national disease control agencies have consistently stressed the significance of hand hygiene in efforts to minimize the 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 (Kumar et al., 2020). Studies by both Warnes et al. (2015) and Bloomfield et al. (2016) 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. (2000) indicated that incorporating alcohol-based gel hand sanitiser 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 sanitisers into individuals' hygiene routines, even after the COVID-19 pandemic. As a result, the need for hand sanitisers stayed elevated for a prolonged period of time according to Berardi et al. (2020). Nevertheless, the rise in need for alcohol-based sanitisers caused shortages in the nation, with different companies such as chemical industries, breweries, and perfumeries manufacturing sanitisers - some of which were not authorised for use. As a result, the quality of alcohol-based hand sanitisers 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.

1.2 Statement of the Research Problem

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 sanitisers 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 sanitisers. Recent reports have shown that almost 50% of hand sanitisers 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.

1.3 Research Questions

This study is aimed to answer the following research questions:

- What are the levels of ethanol and isopropanol present in hand sanitisers available in the three informal settlements in Cape Town?
- Do the hand sanitisers available in the selected informal settlements meet national and international standards for alcohol content?
- What percentage of the tested hand sanitisers comply with these regulatory standards?
- Which hand sanitiser (60% ethanol or 70% isopropanol) is more effective?

1.4 Aim and Objectives of the Research

This study aims to evaluate the alcohol content and quality of locally available hand sanitisers. The objectives of the study are:

1. To measure the levels of ethanol and isopropanol in hand sanitisers available in three informal settlements in Cape Town.
2. To determine the compliance of these hand sanitisers with national and international standards for alcohol content.
3. To determine the comparative effectiveness of hand sanitisers with 70% ethanol versus those with 70% isopropanol in terms of their efficacy

1.5 Delineation of the Study

This study aimed to thoroughly evaluate the effectiveness and quality of hand sanitisers within three informal settlements around Cape Town. The selection of these specific locations was specifically chosen for their dense population and lack of basic infrastructure which addresses the urgent public health issues prevalent in these areas. Sanitisers from outside these specified townships will not be included in the study, ensuring a focused evaluation relevant to the target demographic. Only sanitisers collected from local spaza shops within the settlements will be considered. Sanitisers acquired from shopping centers or other external sources are excluded to maintain consistency and relevance to the local context. The study will concentrate solely on measuring the levels of ethanol and isopropanol in the sanitisers. Other compounds, that might be present in the sanitisers, will not be analysed. Due to equipment limitations, the study will not assess the scent or appearance of the sanitisers. The study will evaluate only liquid sanitisers. Gel and foam sanitisers will not be tested, as the available equipment is not suited for their analysis. By defining these parameters, the study aimed to provide a clear and focused assessment of the quality and effectiveness of hand sanitisers available in these informal settlements.

1.6 Significance of the Study

Proper hand hygiene is essential for stopping the transmission of COVID-19. Frequent handwashing with soap and water or using hand sanitizers when soap and water are not accessible is one of the best methods to decrease the spread of the SARS-CoV-2 virus. Nevertheless, as a result of the worldwide pandemic, there was a lack of hand sanitiser products, causing numerous companies to manufacture products that were either ineffective or unsafe. In order to tackle this issue, a study was carried out to offer detailed information on the appropriate quality of sanitiser utilised, its concentration, and proper use. The research seeks to help the inhabitants of Cape Town area, particularly those in Masiphumelele, Kosovo, and Marikana informal settlements, by offering them essential information to manage COVID-19 and other contagious illnesses. The study provides detailed information on the concentration of alcohol required in hand sanitisers to be effective against viruses. It also highlights the importance of using sanitisers in conjunction with other preventive measures, such as social distancing and wearing masks, to effectively combat the spread of the virus. The findings from this research will assist the National Institute for Communicable Diseases and policymakers in creating guidelines to avoid the transmission of additional communicable diseases that may re-emerge, particularly in informal settlements. Furthermore, it will make the community aware of how they can protect themselves against the re-emerging coronaviruses and other diseases. Overall, the study provides valuable information to the community, which will help them fight the re-emerging pandemics and other infectious diseases.

1.7 Expected Outcomes of the Study

- Identify the levels of ethanol and isopropanol in hand sanitisers available in Masiphumelele, Kosovo, and Marikana informal settlements.
- Determination of the percentage of hand sanitisers that meet the national and international standards for alcohol content (60-95%).
- Comprehensive assessment of the quality of hand sanitisers in the selected informal settlements, highlighting any discrepancies in alcohol concentration.
- Identification of substandard or unsafe hand sanitiser products available in the local markets.
- Analysis of the potential health risks associated with the use of substandard hand sanitisers.
- Assessment of the impact of non-compliant hand sanitisers on the effectiveness of hand hygiene practices in the settlements.
- Formulation of recommendations for improving the quality control and regulation of hand sanitizers in informal settlements.
- Contribution to policy development by the National Institute for Communicable Diseases and legislators to ensure the availability of safe and effective hand sanitisers.
- Increased awareness and knowledge among the residents of the selected informal settlements about the importance of proper hand hygiene and the correct use of hand sanitisers.
- Development of educational materials and campaigns to inform residents about protecting themselves against COVID-19 and other infectious diseases.

- Empowerment of the community with knowledge to combat the spread of re-emerging pandemics and other infectious diseases.
- Furthermore, the study findings will be published in the DHET accredited (local and international) journals and conference proceedings. After completion of the study, the researcher will obtain a master's degree in environmental health.

1.8 Research Limitations and Future Research Needs

The study anticipated several limitations that could affect its outcomes:

- The pandemic posed significant challenges in accessing facilities and engaging with participants. This restriction likely led to hesitancy among some Spaza shop owners to participate, reducing the sample size at site 1 (Masiphumelele).
- The high sensitivity of the GC/MS analysis was a double-edged sword; while it provided detailed data, it also made it difficult to detect certain impurities like methanol and butanol. This limitation could affect the thoroughness of the sanitiser composition analysis.
- The absence of necessary equipment to determine the relationship between the odour and colour of alcohol-based hand sanitisers and their ethanol concentration limited the study's ability to fully explore this aspect of sanitiser efficacy.
- These limitations collectively may have impacted the study's ability to provide a comprehensive understanding of the efficacy of the sanitisers against infectious diseases. The lack of complete and standardised data could lead to less definitive conclusions.
- Given that the study was conducted during the pandemic, its findings might not fully apply to a post-COVID-19 context, where the usage patterns and types of available sanitisers might differ.

1.9. Recommendations for Future Research

- Explore the relationship between the sensory characteristics of sanitisers (such as odour and colour) and their chemical composition to better understand their effectiveness.
- Conduct longitudinal studies to assess the ongoing efficacy of sanitisers in a post-pandemic environment.

CHAPTER TWO:

LITERATURE REVIEW

2.1. Introduction

The goal of this chapter is to offer a thorough comprehension of how coronaviruses have affected humanity over the course of history. The scientist will explore the origins of coronaviruses, their evolution throughout history, and their impact on human populations worldwide. Examining the different tactics used to manage these contagious illnesses, ranging from age-old cures to contemporary vaccines. Next, we will turn our attention to the ongoing COVID-19 pandemic, specifically looking at how South Africa's laws play a role and exploring the various steps taken to control the virus, such as lockdowns, social distancing, and the use of PPE. Furthermore, we will emphasise the critical importance of alcohol-based hand sanitizers as the primary defense against infectious diseases.

2.2. History of Coronaviruses

The Coronaviruses (CoVs) family is extensive and consists of numerous viruses within the Nidovirales order, which is named after the spike-shaped protein (Williams et al., 2021). The reason these viruses are called Coronaviruses is because of their distinct look, with crown-shaped spikes on their external layer. The spikes consist of proteins that facilitate the virus's ability to adhere to host cells. Coronaviruses have been important viral agents for humans and animals for an extended period (Zhou et al., 2020). The initial identification of a human Coronavirus was in the 1960s, with the misconception that it was not harmful (Kahn and McIntosh, 2005). Coronaviruses are very tiny, measuring between 65-125 nanometers in diameter according to (Shereen et al., 2020). Their genetic material is enclosed by a lipid envelope, which consists of single-stranded RNA as depicted in (Figure 1). Coronaviruses have been identified to be one of the largest RNA viruses known, with their genome typically ranging from 26 to 32 kilobases in length (Shereen et al., 2020). These viruses are responsible for causing respiratory, gastrointestinal, and neurological illnesses in both animals and humans. Some of the most famous coronaviruses are SARS-CoV, MERS-CoV, and SARS-CoV-2 (the virus that causes COVID-19). As COVID-19 appeared, there has been a resurgence in studying the biology and development of coronaviruses.

Structure of respiratory syndrome causing human coronavirus.

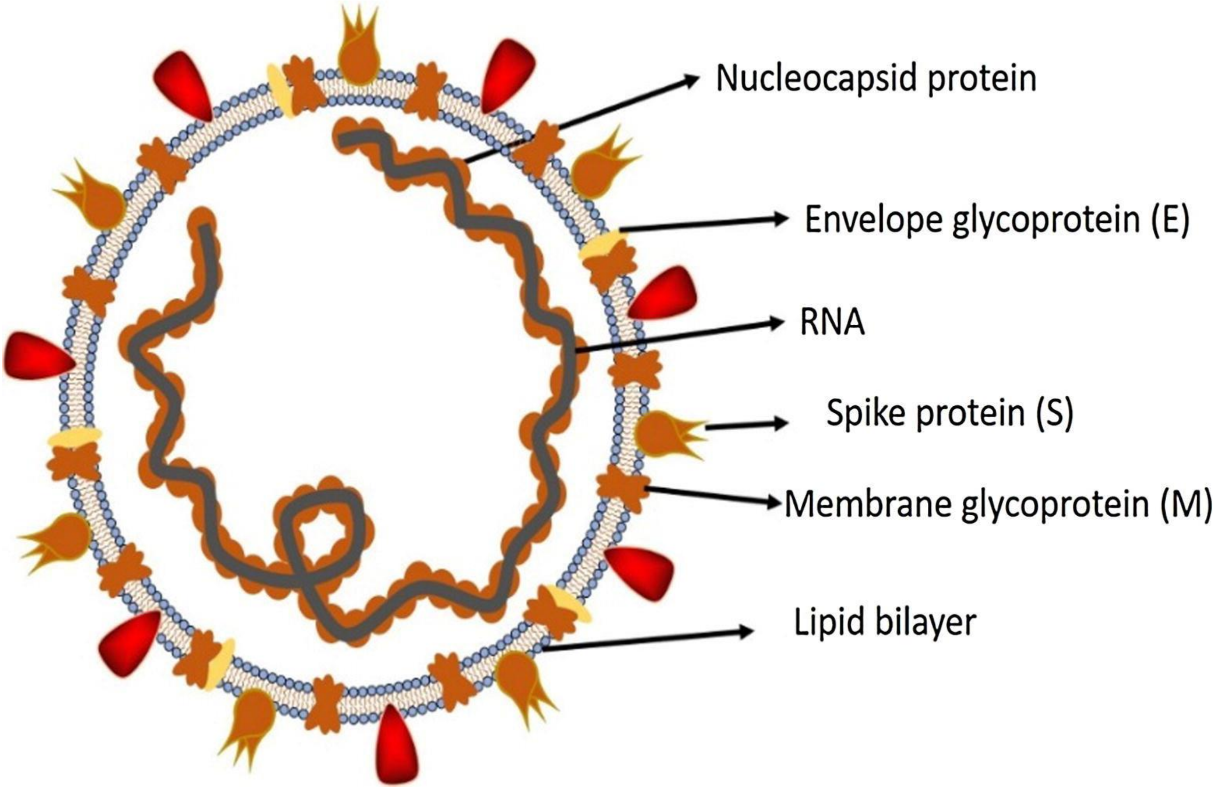

Figure 1. Illustration of the SARS-CoV-2 showing structural proteins and genetic material (Chatterjee et al., 2022).

Seven human pathogens in the Coronavirus family are HCoV-OC43, HCoV-HKU1, HCoV-229E, HCoV-NL63, MERS-CoV, SARS-CoV, and SARS-CoV-2, leading to respiratory infections (Su et al., 2016) Four of the CoVs that are unique to a specific region, including CoV-OC43, HCoV-HKU1, HCoV-229E, and HCoV-NL63, are present on a global scale and typically result in mild upper respiratory infections. Beta-coronaviruses are a group of viruses that are recognized for causing respiratory diseases in people. This trio of viruses consists of three extremely pathogenic viruses, specifically SARS-CoV, MERS-CoV, and SARS-CoV-2 (Abdu and Mariamenatu, 2021). These viruses have caused significant alarm worldwide because they can easily transmit between individuals and have the potential to result in serious respiratory diseases. It is essential to research the transmission patterns of MERS-CoV and SARS-CoV, as well as create effective treatments and vaccines to prevent their spread, due to their potential to cause deadly respiratory diseases in humans. Both are connected, on a phylogenetic level, to bat Coronaviruses, though the exact timing of transmission to humans is still uncertain. Different sources and origins exist for CoVs, but rodents are the source and origin of HCoV-OC43 and HCoV-HKU1 (Corman et al., 2018). Millions of years ago, all known Coronaviruses had a shared ancestor (Malik et al., 2017). The SARS-CoV-2 virus was genomically studied by (Shereen et al., 2020). The analysis results show that the virus is closely related genetically to viruses found in bats. These bat viruses share genetic similarities with the virus responsible for causing severe acute respiratory syndrome (SARS). The examination indicates that bats may be the main source of the virus. Nevertheless, the method of transmission of the virus from bats to humans remains uncertain (Shereen et al., 2020). The origin of the virus and how it spread to humans is currently unclear, and researchers are working to determine the potential intermediate host. It is a well-established fact that the virus is easily transmitted between individuals through respiratory droplets and close contact, as displayed in (Figure 2). It is crucial to follow social distancing, mask-wearing, and good hygiene practices to stop the virus from spreading.

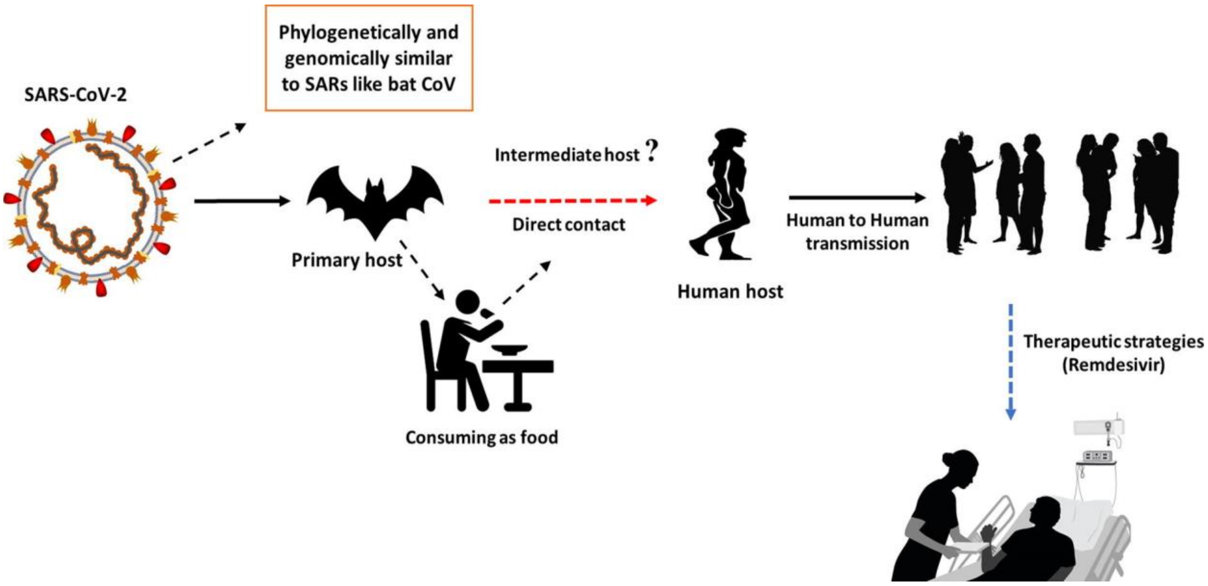

Figure 2.Emergence and spreading of Coronaviruses (Shereen *et al.*, 2020).

2.2.1. SARS-CoV

The identification of Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV) took place in 2003 in Guangdong province, China (Berger et al., 2004). It falls under the category of a zoonotic virus, indicating transmission from animals to humans. It is thought that SARS-CoV came from bats and is primarily spread through respiratory droplets. When someone who is infected coughs or sneezes, they release the virus into the air in droplet form, which can be breathed in by others. Nevertheless, it is crucial to be aware that the virus can be spread through proximity to an infected individual, like hand contact or handshakes (Ayenigbara, 2020). Fecal-oral transmission of SARS-CoV has been identified as a potential mode of transmission, along with respiratory droplets. This indicates that the virus can be transmitted via tainted food or water, or by coming into contact with a surface that has the virus and then touching one's mouth, nose, or eyes (Van Der Hoek et al., 2004). Because of its quick transmission and significant death toll, SARS-CoV became a worldwide public health issue. Patients who are infected might encounter unusual symptoms like nausea, vomiting, diarrhea, breathing difficulties, and weakness. Respiratory failure was the leading reason for death, according to (Van Der Hoek et al., 2004). Luckily, the spread of SARS-CoV was not very effective, as it only occurred through direct contact with infected individuals once they started showing symptoms (Sabir et al., 2016). In order to stop the spread, steps like testing, isolating patients, and screening the public in airports and other locations were put in place, based on recommendations from (Weinstein, 2004). Through the implementation of surveillance studies and public health measures, the spread of the virus was confined to households and healthcare settings, managing it effectively with quarantine protocols (Leung et al., 2004, Cheng et al., 2013)

2.2.2. MERS-CoV

MERS-CoV was first reported in Saudi Arabia a decade ago and its origin is still unknown (Al-Omari et al., 2019). However, research has shown that the virus may have been transmitted to humans from dromedary camels through direct or indirect contact, as well as through bats. The virus has been identified as the cause of various clinical symptoms such as respiratory tract issues, pneumonia, organ failure, and kidney problems (Qian et al., 2013). The exact pathways for human transmission are still being investigated (Wang et al., 2017), but it is believed that airborne transmission may be the most likely route. The virus has been detected in urine and stool samples, as well as in blood, indicating that transmission through these routes is possible. The disease can be highly lethal and is mainly transmitted in hospital settings, which is why the WHO recommends rapid identification of infected individuals and appropriate quarantine measures to limit its spread.

2.2.3. SARS COV-2

Late in 2019, China experienced the emergence of a new coronavirus named SARS-CoV-2, leading to the COVID-19 outbreak. As per Dong et al. (2020) it is part of the subgenus Sarbecovirus and is the seventh Coronavirus identified to infect humans. Though the virus is thought to have originated from the Wuhan seafood market, it is still unknown which animal passed it to humans. Various animals such as bats, snakes, and pangolins have been recognized as possible carriers (Adams and Abhayawansa, 2022). The likelihood of outbreaks is heightened by the close contact of exotic animals in markets, leading to an increased risk of cross-species transmission (Sabir et al., 2016). The rapid global spread of the outbreak led to the WHO declaring it a pandemic on 11 March 2020, according to (Zhou et al., 2020). By April 2020, over 3 million cases had been reported globally, with healthcare workers being particularly impacted, according to (Zhou et al., 2020). During the beginning of August 2020, the World Health Organization announced around 17,918,582 total COVID-19 cases globally, resulting in 686,703 fatalities. The main modes of transmission of the SARS-CoV-2 virus are through breathing in infected droplets or touching contaminated surfaces, sneezing, and hands (Kratzel et al., 2020).

South Africa reported its initial COVID-19 case on 5 March 2020, traced back to a man who had recently returned from Italy with his wife. The number of positive cases in South Africa significantly rose after that (Zhou et al., 2020). In order to tackle the virus, multiple nations, such as South Africa, enforced a global lockdown on 26 March 2020. More stringent actions, like staying indoors, telecommuting, isolation, shutting down schools, and steering clear of large gatherings, were implemented (Koh et al., 2020). Alcohol-based hand sanitizers, masks, temperature monitoring, and social distancing were all identified as crucial strategies for lowering the transmission of the virus (Dalasile et al., 2024). Controlling the SARS-CoV-2 outbreak was difficult because symptoms were mild, and some people were asymptomatic but still able to spread the virus (Johansson et al., 2021). While not as lethal as SARS or MERS, the potential of SARS-CoV-2 to spread unnoticed makes it more perilous than any previous Coronavirus (Petersen et al., 2020).

2.2.4. New Variants of Concern

South Africa has a high predominance of communicable and non-communicable diseases, many of which necessitate specialised and targeted prevention and treatment programs. SARS-CoV-2, a novel Coronavirus disease, has caused many pandemic waves in multiple countries in less than two years (Tegally et al., 2022). By February 2022, South Africa had already experienced pandemic waves caused by three variants of concern (VOC) - Beta, Delta, and Omicron BA.1. These new variants of concern (VOCs) or variants of interest (VOIs) have led to successive waves of the pandemic by reducing protection from previous infections or vaccines, enhancing transmissibility, or a combination of both (Gong et al., 2023). In the last two years, various variants of Omicron have been spreading in South Africa without a rise in hospital admissions (Tegally et al., 2022). Throughout the COVID-19 outbreak, numerous versions of SARS-CoV-2 have been discovered, with only a small number classified as variants of concern (VOCs). The most recent WHO report has identified 5 SARS-CoV-2 VOCs since the start of the pandemic: Alpha in the UK, Beta in South Africa, Gamma in Brazil, Delta in India, and Omicron in South Africa. In August 2023, the National Health Department confirmed the first case of the new COVID-19 sub-variant EG.5 or Eris, which was still circulating with milder flu-like symptoms compared to earlier. The sample was found in a patient from Gauteng (Katella, 2023). The WHO has classified this new variant as a "variant of interest" because it has genetic changes that provide an advantage, and it is becoming more prevalent. According to the most recent information released in November 2023, the global number of confirmed COVID-19 cases was 4,076,463 (WHO, 2023). A total of 102,595 fatalities were documented from these instances, proving to have had a substantial effect on both the healthcare system and global population (WHO, 2023). Yet, there is a bright side as the number of people recovering reached 3,912,506, showing a favourable improvement in the fight against the pandemic (WHO, 2023). The rate of recovery is an important measure of how well the treatment and healthcare services are working for patients. Table 1 offers a comprehensive schedule of the Covid-19 outbreak in South Africa. The initial case of the virus was detected on March 5th, 2020, and by March 15th, there was an increase in confirmed cases of Covid-19 along with more than 83,000 deaths.

Table 1. Timeline of the COVID-19 outbreak in South Africa

Date	**Covid-19 Pandemic Developments**
06 March 2020	South Africa declares its first case of Covid-19.
12 March 2020	Covid-19 is declared a global pandemic by the WHO.
15 March 2020	President Ramaphosa announces a state of emergency and outlines various measures to control the spread of the virus.
18 March 2020	The Covid-19 Regulations are mandated by the Minister of Cooperative Governance and Traditional Affairs (COGTA) in accordance with Section 27(2) of the Disaster Management Act of 2002.
23 March 2020	The President declares a 21-day National Lockdown, restricting non-essential movement and closing all businesses except for essential ones. Several regulations and directives are announced, targeting some sectors and institutions, namely business; transport; immigration; and provincial and local governments.
25 March 2020	The Minister of COGTA issues the Covid-19 Disaster Response Directives; they are amended on 30 March 2020 targeting provinces. The finance minister has granted municipalities and municipal entities an exemption from certain requirements in the Municipal Finance Management Act, (Act 56 of 2003), and its regulations/directives, which have been revised. Deviations are critical in responding to realities on the ground, and the monitoring system, both in terms of predictability and stability, is a challenge.
09 April 2020	The lockdown is extended for an additional two weeks to 30 April.
21 April 2020	The President announces a R500 billion Covid-19 aid package for the country.
01 May 2020	The country moves to Alert Level 4 of the lockdown.

Date	Covid-19 Pandemic Developments
01 June 2020	The lockdown restrictions are relaxed even more, leading South Africa to transition to Alert Level 3 of the lockdown.
21September 2020	South Africa transitions to Alert Level 1 in response to the lockdown.
14 October 2020	The Minister of COGTA extends the national state of emergency from 15 October to 15 November 2020.
11 November 2020	President Ramaphosa extends the state of emergency to 15 December 2020.
December 2020-April 2021	President spoke to the nation during the second wave. Dr Zweli Mkhize pointed out a return of COVID-19 in certain areas and labelled them as coronavirus hotspots, where new Variants of concern were identified.
May 2021-October 2021	President Ramaphosa addressed the nation on 30 May about the third wave of COVID-19 infections, announcing the upgrade in restrictions from adjusted level lockdown 1 to 2, effective from 31 May 2021.
December 2021-April 2022	The fourth wave of the National State of Disaster was lifted, but certain transitional measures will still be in effect for 30 days.
May 2022-July 2022	Fifth wave- In a notification published in the Government Gazette, Health Minister Joe Phaahla revoked the country's Covid-19 laws, eliminating restrictions like the requirement to wear face masks.
16 August 2023,	The presence of the new COVID-19 variant EG.5, also called Eris, has been verified by the National Department of Health in South Africa. This iteration, a subtype of the Omicron lineage, has been labeled by the World Health Organization as a variant of concern, potentially impacting infection rates.

Source: adapted from (Kariuki et al., 2023)*Corona Virus Regulations.*

2.2.5 SARS-CoV-2 testing.

The SARS-CoV-2 Rapid Test is a highly efficient medical diagnostic tool utilised to detect the presence of the SARS-CoV-2 virus within a patient's system. This virus is infamous for causing COVID-19, a serious respiratory disease that has resulted in a worldwide pandemic. The test is designed to quickly detect the virus in a patient's sample, which is usually collected from a nasal or throat swab and provides results in just a few minutes (WHO, 2021). The rapid test is particularly useful in identifying infected individuals quickly, which allows for prompt isolation and treatment to prevent further spread of the virus (Drain, 2022). This is particularly important when new variants of the virus emerge because these variants often spread much faster than the original strain. The higher transmission rate means the virus can infect more people in a shorter time. Rapid testing helps quickly identify those who are infected, so they can be isolated before they unknowingly pass the virus to others. This prevents larger outbreaks and helps control the spread more efficiently during times when the virus is more contagious. The test works by identifying viral proteins found in the sample of the patient in case the virus is present. The test will give a positive result, indicating that the patient is infected with the virus. The test has proven to be highly sensitive and specific, indicating its high accuracy in detecting even small virus levels in a patient's sample (Drain, 2022). In case of a positive test result, patients are advised to quarantine and seek medical attention immediately. This aids in stopping the virus from spreading more, ensuring the patient gets prompt treatment to handle their symptoms and avoid complications (WHO, 2021). Overall, the SARS-CoV-2 Rapid Test, illustrated in

Figure *3* is an important tool in the fight against COVID-19 and helps to ensure the safety and well-being of individuals and communities around the world (Baldanti et al., 2022).

Rapid testing for SARS-CoV-2 virus

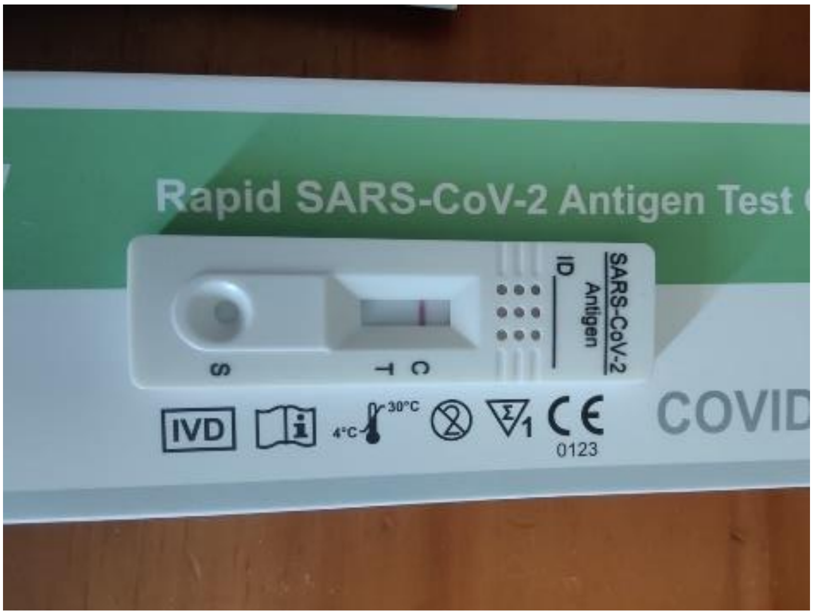

Figure 3. SARS-CoV2 Rapid test

2.2.6. Vaccines in history

Vaccines play a vital role in contemporary healthcare and have effectively fought against bacterial and viral infections. Diseases like polio and smallpox, once dreaded and causing widespread destruction in the past, are now rare. This is largely due to the advancements in vaccines and antimicrobial therapy during the 20th century (Lombard et al., 2007). However, this progress has led to a need for more emphasis on proper hygiene practices (Bloomfield et al., 2007). According to Riedel (2005) the practice of immunisation dates back to the 12th and 15th centuries in China and the Middle East, respectively. During that time, a technique called variolation was used, involving the use of smallpox patients' skin or pustule liquid for inoculation to create immunity and provide protection against the virus. However, this method posed a high risk of causing disease and even death. It was not until May 1796 that Dr Edward Jenner developed the initial vaccine created globally. He applied the identical concept as variolation, but utilised a safer virus, cowpox, instead (Riedel, 2005). Additionally, Dr Edward Jenner vaccinated 8-year-old James Phipps using material from the cowpox lesion on Sarah Nelmes' hand, who was a milkmaid in the area (Tahamtan et al., 2017). Because of insufficient information and fundamental understanding of microbes and microbiology, no additional vaccines were brought out until the following century. Immunisation science emerged in the late 19th century with scientists like Pasteur, Koch, and Ehrlich, leading to extensive research, production of vaccines against various pathogens, and mass production of vaccines from 1931 (Plotkin and Plotkin, 2011)Targeted vaccination programs have greatly improved public health, reducing mortality and eradicating smallpox and polio. The golden age of vaccine science brought about new generations of vaccines, including recombinant and DNA vaccines. Progress has also been made in developing vaccines for previously untreatable diseases like HIV and malaria (Kesik-Brodacka, 2018), researchers are working to create vaccines for many cancer kinds. Vaccines not only prevent and treat infectious diseases but also non-infectious diseases like cancer (Poland, 2003). Since their creation, vaccinations have been seen as a practical way to save medical expenses. Extending the list of diseases that immunization can prevent is a current research focus (Tahamtan et al., 2017). AstraZeneca, Pfizer, Johnson & Johnson, and CoronaVac are the four COVID-19 vaccines for which the South African Health Products Regulatory Authority (SAHPRA) approved emergency use under section 21 during the disastrous pandemic. The Pfizer (BNT162b2) and Johnson & Johnson (J&J) (Ad.26.COV2.S) vaccines are the two currently in use in South Africa that have been approved by SAHPRA to prevent COVID-19 (Mavundza et al., 2022). Pfizer is given in two doses, but the J&J vaccination is given in a single dosage. Over 32 million vaccination doses had been given out in South Africa as of March 15, 2022 (Mavundza et al., 2022).

It's crucial to wash your hands before and after using the restroom, as well as after you cough, sneeze, or blow your nose. The FDA also advised using an alcohol-based hand sanitizer to clean hands that aren't obviously unclean when soap and water aren't available (Rai et al., 2020). Hand sanitisers are liquid, gel, or foam formulations that are frequently used in healthcare settings to eradicate infectious agents, according to Golin et al. (2020). These sanitizers have the ability to eliminate bacteria and lower the risk of infection by dissolving their protective protein coats.

2.3. Evolution of sanitisers and their formulation

Infectious agents are microscopic organisms that can cause diseases and infections in humans. These agents are often transmitted through contaminated surfaces, such as doorknobs, countertops, and handrails. One of the most common ways that infectious agents are spread is through contact with contaminated human hands (Knudson, 2022). This is why hand hygiene is so important in preventing the spread of diseases. In response to concerns about the ability of medical professionals to use soap and water before interacting with patients, a nursing student invented an alcohol gel hand sanitiser in 1966 (Bedi, 2020). Hand sanitisers gained significant popularity during the 1990s, particularly within healthcare settings (Kash et al.,2021). Their convenience and effectiveness made them a practical alternative to traditional hand washing with soap and water (Ho et al., 2012). The compact and easy-to-use nature of hand sanitisers allowed healthcare professionals to maintain hand hygiene more efficiently in various clinical situations where quick and frequent hand cleaning is essential. In 1985, a notable development in the field of hygiene products occurred when Sterillium, a German company, introduced the world's first alcohol-based disinfectant. This innovation marked a significant milestone, as it paved the way for the widespread use of alcohol-based hand sanitisers (Shenoy and Brundha, 2016). Hand sanitisers are typically formulated to contain a minimum of 60% alcohol, which is necessary to ensure their lasting antiseptic properties. Research by Shenoy and Brundha in 2016 has demonstrated that alcohol-based hand sanitisers are highly effective in eradicating a wide range of bacteria, including those resistant to antibiotics and those responsible for tuberculosis (Shenoy & Brundha, 2016). Purell, introduced in 1988, was the first-hand sanitiser to use 70% ethyl alcohol, significantly boosting its popularity among the public and healthcare professionals. Studies confirm that alcohol-based hand sanitisers effectively reduce microbes on hands, making them essential for preventing the spread of infectious diseases (Kash et al.,2021). Isopropyl alcohol (IPA) was first incorporated into hand sanitisers in 2004, with recent products containing up to 99.8% IPA for enhanced efficacy. Key ingredients include hydrogen peroxide (3%) for infection prevention and virus elimination, glycerol (98%) for moisture retention, aloe vera gel for hydration, and vitamin E oil for skin healing. Hydrogen peroxide also extends the shelf life of sanitisers. The evolution of hand sanitizers from the 1980s to today underscores their essential role in public health, particularly in healthcare settings, by effectively reducing the spread of infections.

During the pandemic the WHO-recommended hand sanitizer formulations, consisting of either ethanol or isopropyl alcohol mixed with hydrogen peroxide, glycerol, and distilled water, were devised to provide cost-effective and easy-to-produce solutions to address shortages of commercial hand sanitisers during the pandemic (Abuga and Nyamweya, 2021). By utilising readily available ingredients and simplifying the manufacturing process, these formulations empowered governments, health organisations, and individuals to produce effective hand sanitisers locally, contributing significantly to public health measures aimed at controlling the spread of COVID-19. The formulations have been proven effective against a wide range of viruses and bacteria, including SARS-CoV-2, and their significance lies in their role in mitigating the spread of the virus, especially in resource-limited settings (Abuga and Nyamweya, 2021).

2.3.1. Formulations of Hand Sanitiser

Alcohol-based hand sanitisers come in various forms, including liquids, gels, foams, creams, sprays, and wipes, catering to different user preferences and tolerances (Tarka et al., 2019). However, health organisations generally favour gel-based sanitizers over liquid ones (Gold & Avva, 2020). However, some studies indicate that gel sanitizers may not completely replace liquid alcohol-based hand sanitizers because they have a shorter application time, which may affect their effectiveness. Still, gels can aid in decreasing skin irritations and dryness resulting from liquid formulations (Abuga and Nyamweya, 2021). This preference is due to the ease of use and portability of gel formulations, making them more convenient for use while on the move. Furthermore, gels reduce the risk of spillage compared to liquid-based products (Berardi et al., 2020). Hand sanitisers, whether in liquid, gel, or foam forms, work by breaking apart the protective protein layers of pathogens, effectively destroying them and reducing the risk of infection (Seal, 2020). This mechanism makes them a critical tool in maintaining public health and safety, particularly in healthcare settings where infection control is paramount.

2.4. Types of sanitisers: Alcohol-based and non-alcohol-based.

Hand sanitisers play a key role in combatting germs and viruses such as COVID-19. There are two primary kinds: alcohol-based and alcohol-free. Alcohol-based sanitisers are frequently utilized and are very successful in eliminating various germs, such as viruses (Jing et al., 2020). These hand sanitizers have ethanol, isopropanol, or n-propanol, which are all known for killing germs (Gold et al., 2021). Additionally, they may contain other substances called excipients, which serve to enhance their effectiveness or provide extra benefits such as moisturizing the skin (Jing et al., 2020). In contrast, alcohol-free hand sanitisers do not contain any alcohol. Instead, they use other active ingredients like benzalkonium chloride, triclosan, or povidone-iodine to kill germs. While these ingredients can be effective against germs, they may not be as effective as alcohol-based sanitisers against some types of viruses (Gold et al., 2021). Hence, the CDC advises against using alcohol-free sanitisers for protection against coronavirus. It is important to note that alcohol-based sanitisers are highly effective in killing the coronavirus, especially when used correctly (CDC, 2022). It is recommended to use an alcohol-based sanitiser with a concentration of at least 60% alcohol and to apply it thoroughly to all surfaces of your hands (Dhama et al., 2021). Rub your hands together until they are dry, which usually takes around 20 seconds. Consistently using hand sanitiser and washing hands with soap and water for a minimum of 20 seconds are crucial measures in stopping the transmission of germs and viruses such as coronavirus (CDC, 2022). To this end, Jing et al. (2020) have created an extensive inventory of alcohol-based and alcohol-free hand sanitisers, as well as the frequently utilised excipients, in (Table *2*). The table provides a detailed comparison of the different types of hand sanitisers, their active ingredients, and the excipients used in their formulation (Jing et al., 2020). This information can be particularly useful for individuals and organisations looking to select the most appropriate hand sanitiser based on their specific needs and preferences.

Table 2. Alcohol- and alcohol-free hand sanitisers, and commonly used excipients (Jing *et al.*, 2020)

Type of Hand Sanitiser	Common chemicals present.	Ingredients
Alcohol based	Alcohol (60-95% v/v/)	Ethanol
		Isopropanol
		n-propanol
	Hydrogen peroxide	
Alcohol free	Antiseptics	Chlorhexidine,
		Chloroxylenol
		Iodine/iodophors,
		Quaternary ammonium compounds,
		Triclosan

Commonly used excipients		Glycerin, fragrance, colorant

2.5. Composition and Dosage Forms of Alcohol-Based Hand Sanitisers (ABHS) Recommended By WHO.

ABHS generally consist of ethanol or isopropanol, which are the two alcohols most frequently utilized. ABHS consists of water and various other ingredients such as emollients, moisturisers, and fragrances (Jing et al., 2020). These additional substances can enhance the effectiveness of these sanitisers, but they can also impact its safety and long-term usability. The efficacy, safety, and long-term usability of ABHS depend on various constituents, including the type and amount of alcohol, the type and amount of additional substances, the pH of the solution, and the presence of impurities (Jing et al., 2020). The WHO has established two formulations for ABHS based on either ethanol or isopropanol. The ethanol-based formulation consists of 80% v/v ethanol, while the isopropanol-based formulation consists of 75% v/v isopropanol. Both solutions contain glycerol (1.45% v/v) and hydrogen peroxide (0.125% v/v) and are successful in neutralising various microorganisms, including SARS-CoV-2 (Kratzel et al., 2020; Singh et al., 2020). However, commercial ABHS manufacturers often use proprietary formulas that may differ from the WHO recommendations. The effectiveness of different ABHS formulations can vary depending on the type of microorganism being targeted and the physical properties of the object. For example, isopropanol has been found to display increased antibacterial effectiveness in comparison to ethanol, whereas ethanol is more efficient in fighting viruses (Gold et al., 2021). On the other hand, the effectiveness of ABHS can be affected by the percentage levels of alcohol and the characteristics of the specific microorganism it is intended to combat. For instance, isopropanol is not as efficient in killing hydrophilic viruses such as polioviruses because it has a higher affinity for lipids compared to ethanol. In contrast, SARS-CoV-2 shows greater sensitivity to isopropanol due to its nature as a lipophilic-enveloped virus (Singh et al., 2020). It is recommended that the best ABHS options have a 60 to 80% alcohol content, as having a higher concentration does not always result in better effectiveness. So, proteins cannot be easily denatured unless there is a specific level of water present (Zgheib, 2022). The US FDA, CDC, and WHO all advise using concentrations ranging from 60-95% (v/v) to effectively eradicate microorganisms, including SARS-CoV-2 (Villa and Russo, 2021). Table *3* offers a complete inventory of the main active components commonly present in alcohol-based hand sanitizers. These components are essential for the hand sanitiser to effectively eliminate germs and bacteria. Understanding these active ingredients will allow you to make educated choices when selecting the appropriate hand sanitiser for your requirements.

Table 3. The main active ingredients required in alcohol-based hand sanitisers (Matatiele et al., 2022)

Reagents for Formulation 1	Reagents for Formulation 2
Ethanol 96%	Isopropanol 99.8%
Hydrogen peroxide 3%	Hydrogen peroxide 3%
Glycerol 98%	Glycerol 98%
Sterile distilled water or boiled water	Sterile distilled water or boiled water

2.6. Toxicology of Hand Sanitisers

As the COVID-19 pandemic persisted, hand sanitisers became a common item in households, with a notable rise in their usage. Although they are commonly used to stop the virus from spreading, it is crucial to be aware of the potential dangers associated with their use. Recently, the US FDA has issued a recall of hand sanitisers that were found to be contaminated with methanol, a toxic substance that can cause serious health issues when absorbed through the skin or ingested (Jairoun et al., 2021). The contamination is believed to have occurred during the manufacturing process, and several major US department stores and supermarkets have been found to have sold these contaminated products (Zgheib, 2022). It is important to check the ingredients of any hand sanitiser you purchase to ensure that it does not contain methanol and also search for items that have no less than 60% ethanol or 70% isopropanol, as they have been shown to be successful in fighting the coronavirus (Zgheib, 2022). Additionally, ensure that the hand sanitiser is being used correctly by following guidelines on the label and avoiding contact with the eyes and mouth. By taking these precautions, we can continue to use hand sanitisers safely and effectively in the fight against COVID-19 as well as other communicable diseases (Nelson et al., 2021). Moreover, there have been several complaints of skin irritation that have been reported to the FDA. The FDA has established guidelines categorizing impurities in hand sanitisers as Level 1 or Level 2 based on their toxicity (FDA, 2020) as indicated in Table 4. Due to the pandemic, regulatory bodies such as the FDA and Health Canada have temporarily relaxed standards to address the shortage of hand sanitisers. However, consumers must remain vigilant and source products solely from reputable sources to mitigate the associated risks.

Table 4. FDA Listed Impurities and Additives in Hand Sanitisers (FDA, 2020)

	Compound name/impurities	**Interim Limit Listed in FDA Guidelines (ppm)**
Level 1 Impurities	Methanol	630 ppm
	Benzene	2 ppm
	Acetaldehyde	50 ppm*
	1,1-diethoxyethane(acetal)	50 ppm
Level 2 Impurities	Acetone	4400 ppm
	1-Propanol	1000 ppm
	Ethyl Acetate	2200 ppm*
	2-Butanol	6200 ppm
	1-Butanol	1000 ppm
	Isobutanol	21700 ppm
	3-Methyl-1-Butanol	4100 ppm
	Amyl Alcohol	4100 ppm

2.7. Soap and water vs sanitisers

Practicing proper hand hygiene is among the most powerful techniques for stopping the transmission of infections and diseases. The CDC suggests washing hands frequently with soap and water to lower the amount of bacteria and toxins present on hands. In situations where soap and water are not accessible, an alcohol-based hand sanitiser with a minimum of 60% alcohol content can serve as a practical and efficient substitute. Based on research conducted by (Eggerstedt, 2013) it was found that using ABHS is gentler on the skin compared to handwashing with soap and water. It is also a fast and easy method to eliminate germs from your hands. Nonetheless, it is crucial to apply a sufficient amount of hand sanitiser and allow it to dry before rinsing it off in order to guarantee its efficacy (Jing et al., 2020). Even though ABHS can greatly decrease the amount of bacteria on hands, it is crucial to understand that it does not entirely eradicate or deactivate all germs (Hoffmann et al., 2021). Certain types of pathogens, such as Cryptosporidium, norovirus, and Clostridium difficile, are only eliminated using soap and water and not by using hand sanitisers (Hoffmann et al., 2021). In cases where hands are oily or dirty, hand sanitisers may not be as effective, and hand cleaning with soap and water is advised. However, hand sanitisers remain useful in hospital settings despite hands encountering pathogens often, even if they are not usually very dirty (Jing et al., 2020). In conclusion, while hand sanitisers are a convenient and effective way to prevent infections, they should not be used as a substitute for washing hands with soap and water (Figure 4). When using ABHS, it is important to ensure that you are using enough sanitiser and allowing it to dry before washing it off. Additionally, in cases where hands are oily or dirty, hand cleaning with soap and water is advised.

Figure 4 Prevention of Coronavirus: Hand Washing vs Alcohol-Based Hand Sanitisers (Knight, 2021)

2.8. Efficacy of Alcohol-Based Hand Sanitisers

Choosing a hand sanitiser requires careful consideration of multiple factors to guarantee effective sanitisation. The alcohol concentration is one of the key factors to consider. Research shows that hand sanitizers with a minimum of 70% alcohol are the most successful in eliminating germs, such as viruses and bacteria (Jing et al., 2020). On the other hand, sanitisers with less than 40% alcohol content were found to be less effective in combating germs. Therefore, it is recommended that hand sanitisers have an alcohol concentration ranging from 60 to 70% to be effective (Muleba et al., 2022). Another factor to consider when selecting a hand sanitiser is the application technique. Moreover, Jing et al. (2020) suggests applying sanitizer to one palm and rubbing it over both hands until dry. This technique ensures that all areas of the hands are covered, and the sanitizer can effectively kill germs. Moreover, the amount used is an essential factor in ensuring proper sanitisation. A sufficient amount of sanitizer must be used to cover all surfaces of the hands (Jing et al., 2020). This ensures that all germs present on the hands are killed. In 2016, research carried out by Song et al revealed that non-alcoholic hand sanitisers might not be as efficient in stopping the spread of infectious diseases. Ultimately, it is alarming that certain companies released harmful or faulty items amid the COVID-19 outbreak, leading to recalls of specific hand sanitizer products, as indicated by research like (Blount et al., 2020). It is essential to choose a reliable brand of hand sanitizer and check the product label to ensure that it meets the recommended standards for alcohol concentration and is safe for use.

2.9. Public Health System Quality in South Africa Before COVID-19

South Africa is a country that has been facing significant healthcare challenges for a long time. These challenges include a lack of adequate capacity, limited health awareness, and enduring funding disparities (Azevedo, 2017). Even before the COVID-19 pandemic, South Africa had been dealing with additional obstacles such as limited access to healthcare, inadequate staffing, operational inefficiencies, lack of responsiveness, overcrowding, and economic inequality, as pointed out by Mukumbang et al. (2020). The pandemic further exposed the country's unpreparedness and substandard care. It brought to light the access inequalities and the dire state of public health services in the country, which are burdened by the majority's inability to afford private care (Rosenthal and Waitzberg, 2023). Staff shortages and inadequate funding for primary healthcare provision are some of the challenges faced by public health services, which lead to longer wait times and lower patient satisfaction (Rosenthal and Waitzberg, 2023). The shortage of personnel is the most crucial healthcare asset in the nation, and it has been a major factor in the difficulties experienced in the healthcare industry. Despite significant strides made in addressing these challenges, socially disadvantaged communities still face inequalities in accessing and receiving quality public healthcare. Since 1994, efforts to restructure South Africa's healthcare system have shown substantial improvements. However, as revealed in a study by Oleribe et al. (2019), underdeveloped countries like South Africa must address persistent issues of service quality, infrastructure, funding, budget constraints, and a shortage of well-trained healthcare workers in comparison to middle-income countries. In 2023 shared similar views (Rosenthal and Waitzberg, 2023). It is evident that South Africa's healthcare sector is facing numerous challenges that require urgent attention. Addressing these challenges will require the government and other stakeholders to come together and work towards providing better health services to all citizens, regardless of their socio-economic background.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This research sought to evaluate the effectiveness of ABHS in informal settlement spaza shops in Cape Town before and after COVID-19. A total of 78 ABHS samples were collected from these shops between 12 December 2020, and 13 April 2022. To ensure a representative sample, 19 of these samples were randomly acquired from various community settings across Masiphumelele Township. These settings included Somalia spaza shops, street vendors, barbershops, and salons etc. Additionally, 44 samples were obtained from the Marikana informal settlement in the Philippi area. Finally, 15 samples were collected from the Kosovo informal settlement. It is crucial to mention that the sample collectors specifically collected samples from refillable dispensers that were currently being used and available to the public. This was to ensure that the samples accurately reflected the items being used by community members. Additionally, the samples contained two hand sanitizers, one with ethanol and the other with isopropanol as the main component.

3.2. 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 (Fru, 2020). 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 coloured 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 5). The City of Cape Town organizes these groups of clusters, known as "pockets," to create informal settlements. It's 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 5 City of Cape Map, displaying Marikana, Masiphumelele, and Kosovo informal settlement locations (Google Earth Pro, 2023, Dalasile.SV).

3.3. Sample Sites

The research setting pertains to the location where data is gathered. In this study, data was collected from three sample sites that focused on informal settlements in Cape Town, 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., 2020). People in these informal settlements are at the highest risk of getting infected with COVID-19 because they do not have basic needs like proper housing, water, electricity, 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 conducted by Gibson and Rush (2020) 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.

3.3.1. Kosovo Informal Settlement (34°0’59.77” S 18°35’16.12” E)

Kosovo is a makeshift community situated in the Philippi neighbourhood 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 6. This led to the first illegal land occupation and the formation of what is now known as the Kosovo settlement (Mseleku, 2021). 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 (Mseleku, 2021). The settlement is home to approximately 5500 people during the pandemic and has been promised relocation (Fort, 2020). Like many other informal settlements, Kosovo lacks the necessary infrastructure and services, which leads to substandard living conditions and limited access to resources (Armitage et al., 2010). The absence of essential amenities like sanitation, clean water, electricity, and waste disposal creates considerable health hazards for the inhabitants (Mseleku, 2021). 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 (Mseleku, 2021). 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 (Armitage et al., 2010). 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.

Figure 6: An aerial view of Kosovo informal Settlement showing the sampling area (Dalasile, 2024)

3.3.2. Marikana informal settlement (34°0'16.39" S 18°36'36.03" E)

Marikana informal settlement is situated in Philippi East Ward 35 as illustrated in Figure 7. According to (Danti and Sanya Tom, 2017) 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 (Teo, 2016). The settlement is named after the Marikana miners who died protesting for better wages in 2012 in Marikana, Rustenburg (Teo, 2016). It is one of the biggest townships, about 7km away from Cape Town International Airport and 20km from the Cape Town city center. The informal dwelling is encountering a range of issues such as poverty and the absence of essential amenities (Danti and Sanya Tom, 2017). 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 (Batyi, 2022). 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 (Batyi, 2022). 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.

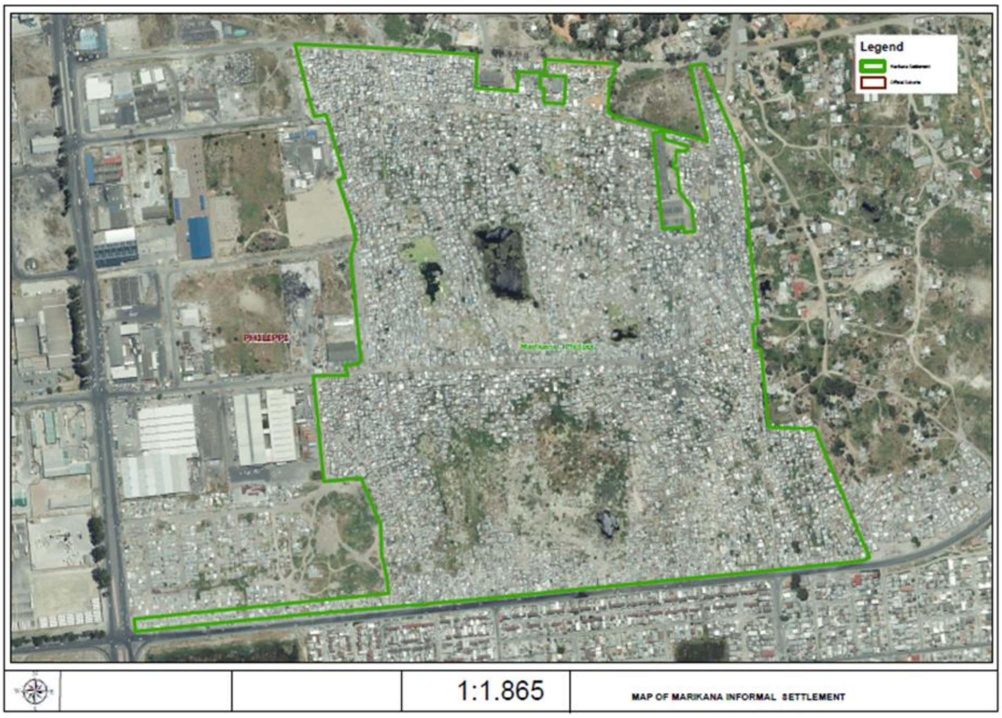

Figure 7: An aerial view of Marikana informal Settlement showing the sampling area (Dalasile, 2024)

3.3.3. Masiphumelele Informal Settlement (34°7'41.46" S 18°22'25.76" E)

Masiphumelele is a small town situated in the Western Cape region of South Africa. Located between Kommetjie, Capricorn Village, and Noordhoek (Madonsela, 2019), as shown in Figure 8. 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 (Mascorp, 2020). 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 (Monqo, 2023). 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 (Mascorp, 2020). 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 (Monqo, 2023). The poor access to housing in Masiphumelele leads to health risks, especially for children, pregnant women, and the elderly (Monqo, 2023). The City of Cape Town neglected to deal with the unsanitary conditions, leading to prevalent illnesses such as diarrhoea 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 (Monqo, 2023). Additionally, the absence of established sanitation facilities hinders efforts to manage the transmission of contagious illnesses, like COVID-19, among the population.

Figure 8: An aerial view of Masiphumelele informal Settlement showing the sampling area (Dalasile, 2024)

3.4. 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., 2012). Obtaining accurate, statistically significant data and successfully conducting your study heavily relies on having the appropriate sample size (Baloyi et al., 2024). 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 utilised 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 (Jakeni et al., 2024; Madonsela et al., 2024).

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

$n=180/(1+(180)(0,05)^2)$

$n=124$

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 sanitisers 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 sanitiser samples were gathered randomly from various Spaza shops which are common grocery shopping area 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.

3.5. Collection of Alcohol-based hand sanitisers

A total of 78 hand sanitisers (73 liquid and 5 gel) were randomly collected at entrance points of various spaza shops, (informal convenience shop business) 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 no labelling on the dispensers or that 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 sanitisers, prepared based on WHO's recommendations for daily use by staff or individuals was also gathered. These sanitisers were collected directly from the container using 1.5-mL sterile Eppendorf tubes then transferred into 10 mL glass vials. The first batch of sanitiser samples was collected in Masiphumelele and Kosovo informal settlement between April to November 2021 while the second batch was collected in Marikana informal settlement between January and June 2022. For the purpose of determining the alcohol content and compliance with labeling requirements, all hand sanitisers of different types and brands were chosen and tested. Each hand sanitiser was assigned a unique sample identifier code, ranging from HS1_site 1, HS1_site 2, and HS1_site 3, which were collected from local shops and supermarkets in Masiphumelele, Marikana, and Kosovo informal settlements.

3.6. Qualitative Analysis

Observations are critical in creating trustworthy data to verify the information provided in the sample results (Magolda, 2007).This approach provides significant information especially for a study that considers qualitative data as highlighted by Maphanga and Madonsela (2023). During the visits to informal settlements in the Western Cape, observations were made regarding service delivery challenges. The researcher paid close attention to the type of sanitisers being used and checked whether they were displayed at the entrance doors in accordance with the regulations set by the World Health Organization. Their brands were not recorded because this information was not visible. The research project had a primary objective of gathering detailed and accurate information regarding the actions and behaviours of both spaza store owners and community members in response to the ongoing pandemic. To achieve this, the study involved checking the availability of soap and water in case sanitisers were unavailable. This specific aspect was considered essential because it is widely known that frequent hand washing is one of the best ways to stop the virus from spreading. The study's objective was to examine the availability of soap and water for spaza shop owners and community members in areas facing a shortage of sanitisers. By collecting this data, the research aimed to offer valuable understandings about how the local community is reacting to the pandemic and pinpoint any areas that may require additional assistance.

3.6.1. Sanitiser formulation

The samples consisted of seventy-three (73) liquids and five (5) gels, as presented Figure 9. Gel hand sanitisers were only found at Masiphumelele informal settlement (site 1); the other two sites used liquid hand sanitisers. Out of the 78 samples, only 72 were analysed.

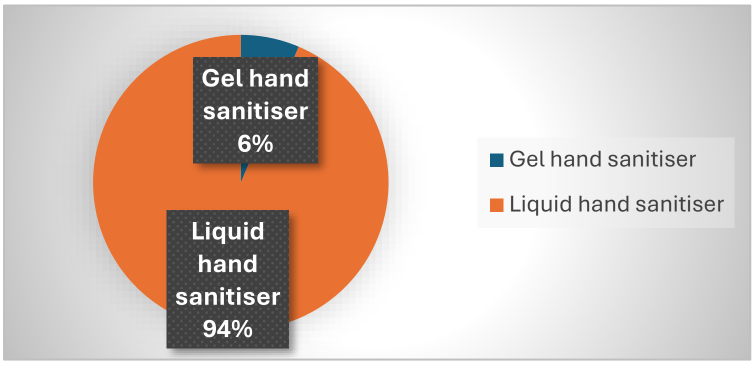

Figure 9. A pie chart of hand sanitizers collected around Cape Town's informal settlements, comprising of gels and liquids.

3.6.2. Sanitiser Active Ingredients

The research observed that ethanol was the most common alcohol present, constituting 74% of the total alcohol content. Following ethanol, isopropanol was found to make up the remaining 26% of the alcohol content, as indicated in Figure 10.

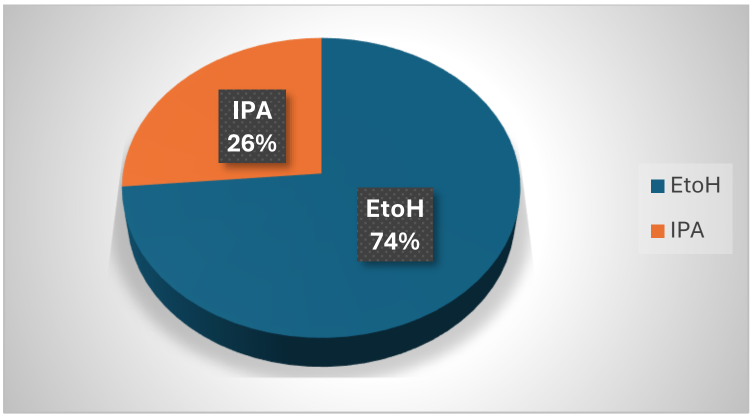

Figure 10 A pie chart of hand sanitizers collected around Cape Town's informal settlements, comprising of gels and liquids.

3.7. Equipment/Instrument

All sampling tools (such as 1.5-mL sterile Eppendorf, 10 mL glass vials, scoops, 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 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 ultimate diluted mixtures of hand sanitizers. A 100 mL beaker was used for measuring solvents and solutions. The sanitisers in these samples were collected from various spaza shops, as shown in Figure 9. The purpose of collecting the samples was to assess their efficiency, standard, 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 utilisation of these sanitisers and will offer valuable insights to enhance the quality and safety of the products.

Hand sanitiser samples collected for analysis

Figure 11. Sanitiser samples collected for analysis

3.8. Analytical system and conditions

The conditions for the Agilent 7890A Gas Chromatograph with Flame Ionisation Detector (7890 GC-FID) used in this study are shown in Table *5*. The carrier gas utilised in the research was nitrogen, and the column employed was HP88 type (100 m x 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 5.GC-FID analytical conditions for analysis of alcohol content in hand sanitisers

Analytical system and conditions	
Column type	HP88, (100 m x 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	40minutes.

3.9. Preparation of calibration standards

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 2mL 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. 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, 100%) versus GC peak areas (refer to Figure 12)

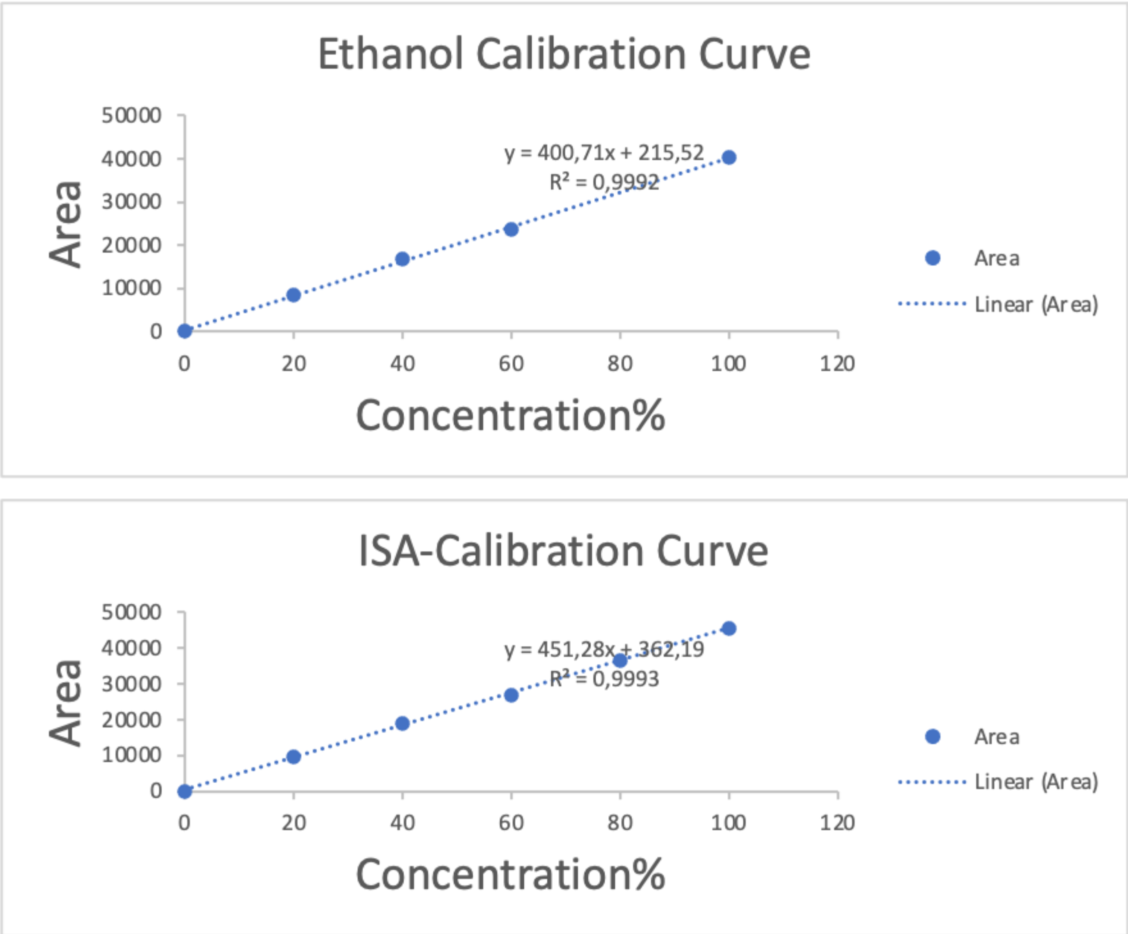

Figure 12 Calibration curves for isopropanol (a) and ethanol (b) indicating the accuracy of detection (R2) and the regression parameters of the line y=mx+c.

3.10. Preparation of hand sanitiser samples.

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

CHAPTER FOUR

RESULTS AND DISSCUSSION

4.1 Introduction

Ensuring effective hand hygiene and disinfection is of utmost importance in mitigating the spread of COVID-19. Conversely, the usage of substandard sanitiser products can unknowingly expose individuals to the virus by amplifying the likelihood of transmission. The quantification of alcohols in alcohol-based hand Sanitisers (ABHSs) is a crucial aspect of their development and quality control. Among the analytical methods employed for this purpose, GC-MS are the standard methods of choice, that have been previously utilised by authors such as Berardi et al. (2020). It is noteworthy that the accurate quantification of alcohols in ABHS is essential for ensuring their effectiveness in reducing microbial counts and minimizing the risk of infection transmission from COVID-19. During the pandemic, there has been a surge in panic buying of alcohol-based hand sanitisers. Unfortunately, this has led to the formulation and sale of substandard sanitisers by some local retailers. In response to this issue, governments have implemented regulations that require store owners to place sanitisers at entrances for both customers and employees. The objective of this research was to evaluate the alcohol concentration (ethanol and isopropanol) in hand sanitisers. This was done to ensure that the manufactured sanitisers comply with the regulated standard of at least 60% alcohol concentration. The finding of this study will also reveal most effective sanitiser against infectious diseases since this is largely based on the alcohol content of the sanitiser. This study aims to address the issue of substandard and hazardous alcohol-based hand sanitisers that have been affecting the public during and after the pandemic. Additionally, it seeks to establish whether people from disadvantaged communities and informal settlements were adequately protected against the coronavirus and other infectious diseases.

4.2. Determination of alcohol concentration in hand sanitizer samples

The study analysed 78 samples of hand sanitiser from various brands to determine the concentration of ethanol and isopropyl alcohol. The results of these parameters are presented in the Table 6 below. Each sample was given a unique code based on the sample site and shop number. Different batches of sanitisers were labelled 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 6 showing the 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	14140,2
Concentration %	[x]	30

Alcohol-based hand sanitisers 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 sanitiser 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 utilised 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% hand sanitiser products containing isopropanol do not meet the 70% of the required alcohol content. While only 77% of Ethanol samples meet the required standards. Moreover, all five gel sanitisers were not quantified, and one liquid hand sanitisers did not demonstrate any peaks for either ethanol or isopropanol. However, Ethanol was the more dominant in all three sites whereas isopropanol was only detected in site 1 (Masiphumelele) and site 2 (Marikana).

4.3. Determining and Measuring Alcohol Levels.

Several studies in South Africa have focused on quantifying the amount of alcohol present in hand sanitisers. In this particular study, it was found that gas chromatography is a suitable technique for measuring the alcohol content of the sanitisers. Isopropanol and ethanol are the two types of alcohols that were measured in hand sanitiser samples. The research revealed that 77% of alcohol-based hand sanitisers (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 sanitiser collected at entrance shops in Masiphumelele and Marikana informal settlement might have been ineffective in preventing the transmission of SARS CoV2 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 as effective and safe for disinfection by regulatory organisations such as the US FDA, CDC and WHO (FDA, 2020) In hand sanitisers, ethanol and isopropanol were the two most commonly used alcohols, with ethanol consisting of 53 samples, and isopropanol in 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., 2020). However, IPA was only detected in Masiphumelele and Marikana making ethanol the dominant alcohol in all three sites.

4.4. Masiphumelele Alcohol Concentration.

As shown in the table below it presents the alcohol concentration analysis results for hand sanitizer samples collected from Masiphumelele (site 1). Out of the 13 samples analysed, 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 7.Displays the alcohol concentration in ABHS at Masiphumelele, found in hand sanitiser 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

Total alcohol concentration in ABHS at Masiphumelele informal settlement

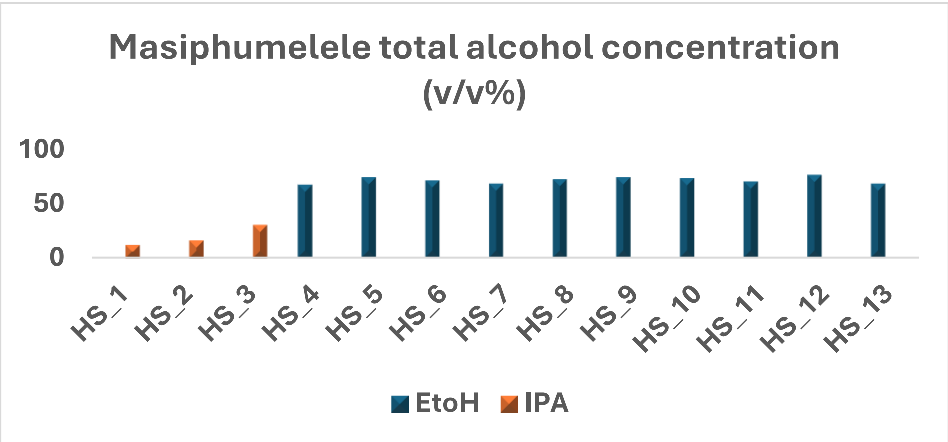

Figure 13. Graph with total alcohol concentration at Masiphumelele informal settlement.

4.4.1. Alcohol concentration and effectiveness.

Out of the 13 sanitiser samples collected in Masiphumelele, 77% contained ethanol within the recommended range of 60-95%, indicating adequate protection against COVID-19. These findings suggest a proactive approach by the community in ensuring public health during the pandemic. However, it was observed that the majority of compliant sanitisers contained ethanol, while most isopropanol samples were non-compliant. Studies by Otokunefor and Princewill (2018) have demonstrated that hand sanitisers with higher alcohol concentrations are more effective in combating viruses. Therefore, the presence of compliant ethanol-based sanitisers in Masiphumelele is encouraging. However, the lower concentrations of isopropanol in some samples may lead to reduced effectiveness and potential skin irritation, as reported by Babeluk et al. (2014). Governor et al. (2022) also found ethanol to be the most prevalent alcohol in their study, further supporting its effectiveness against viruses. Thus, the dominance of ethanol-based sanitisers in Masiphumelele aligns with existing research on effective hand hygiene practices. The findings from Masiphumelele highlight the importance of adequate alcohol concentration in hand sanitisers for effective virus prevention. The prevalence of compliant ethanol-based sanitisers indicates a proactive approach by the community in safeguarding public health. However, efforts to address the lower concentrations of isopropanol in some samples are warranted to ensure optimal effectiveness and minimise skin irritation risks.

Compliance with the regulated 60% alcohol-based hand sanitisers concentration

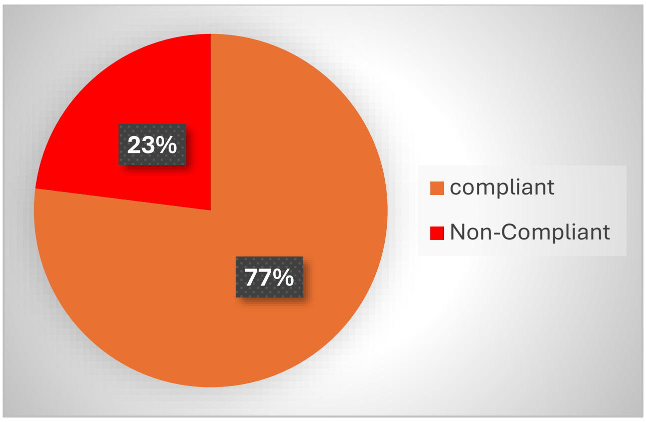

Figure 14. Overall compliance for Masiphumelele

The importance and effectiveness of alcohol-based hand sanitisers 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 sanitisers during the pandemic. The majority of the hand sanitiser products analysed in Masiphumelele were found to meet the alcohol content requirements. However, significant gaps were observed in sanitiser 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 14 illustrates that the majority of sanitisers met the regulatory requirements set by the WHO and 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.

4.5. Marikana Alcohol Concentration.

As illustrated in Figure 15 and detailed in Table 8 below, 64% of the hand sanitiser samples collected in Marikana contained ethanol, while the remaining 36% contained isopropanol. Ethanol emerged as the predominant sanitiser formulation used in the Marikana informal settlement, with a majority of the samples meeting the international and national standards set.

Table 8. Displays 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

Total alcohol concentration at Marikana informal settlement

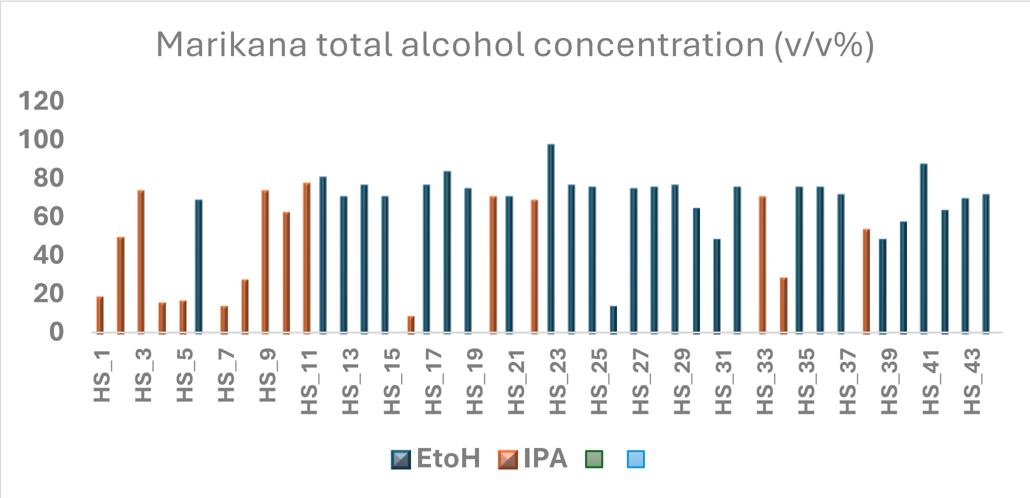

Figure 15 Graph with a total alcohol concentration at Marikana informal settlement.

4.5.1. Alcohol concentration and effectiveness.

Table 8 reveals that 64% of the samples contained ethanol, while 36% contained isopropanol, indicating a preference for ethanol-based sanitisers 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 analysed 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. Villa and Russo (2021) emphasize the importance of a balanced mixture of water and alcohol in hand sanitisers 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 sanitisers 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 sanitisers and were adequately protected against the virus. These findings highlighted the importance of monitoring and regulating alcohol concentrations in hand sanitisers to ensure their effectiveness in preventing disease transmission. Future efforts should focus on promoting the use of sanitisers with balanced alcohol concentrations and educating communities on proper hand hygiene practices.

4.5.2. Compliance with the regulated 60% alcohol-based hand sanitisers concentration.

Figures 16 and 17 depict the compliance of hand sanitiser samples collected from Marikana with the regulated 60% alcohol-based concentration.

Overall compliance for Marikana

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

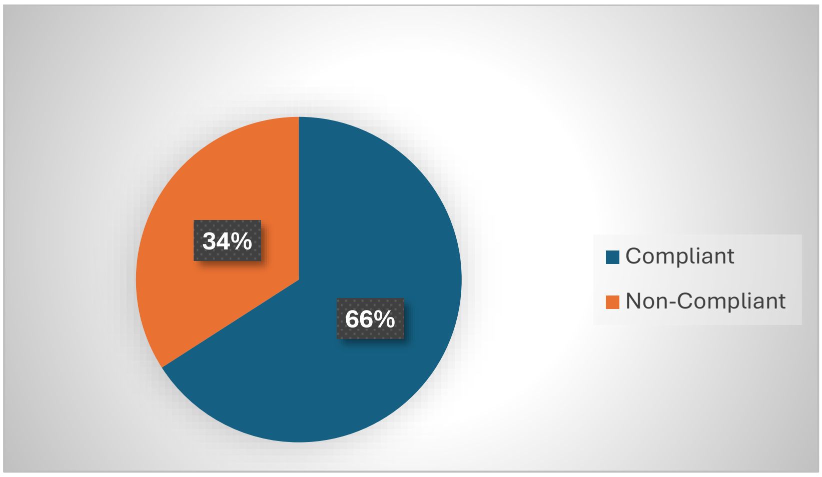

Figure 16. Overall compliance for Marikana

Ethanol and Isopropanol Compliance

This figure shows the compliance rates specifically for ethanol and isopropanol-based hand sanitisers. It indicates that the majority of ethanol-based sanitisers were compliant with regulated concentrations, while a smaller proportion of isopropanol-based sanitisers met the requirements. This suggests that ethanol-based sanitisers 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 sanitisers, which are more prevalent in the area, were compliant with regulatory standards. However, attention should be given to the compliance of isopropanol-based sanitisers, 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 sanitiser dispensers, particularly at entrance points (Cure et al., 2014). Therefore, efforts to improve the availability and visibility of hand sanitiser dispensers may further enhance hand hygiene practices in public spaces like spaza shops.

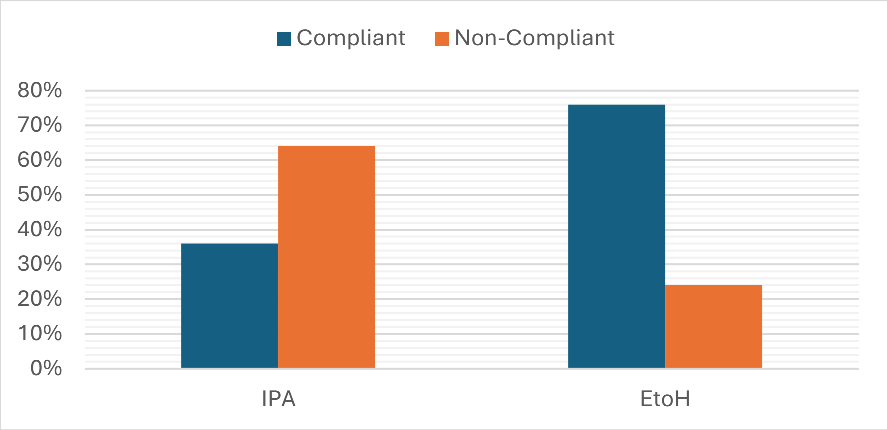

Figure 17.Ethanol and Isopropanol compliance

4.6. Kosovo Alcohol Concentration.

The analysis of hand sanitiser 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 sanitisers 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 9). These findings are concerning as they indicate that the residents in the settlement may have had limited access to hand sanitisers with the effectiveness required to combat germs and viruses. This issue is 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 9. Additionally, it was noted that no samples with isopropanol as the sole active ingredient were found on site.

Table 9.Displays the alcohol concentration in Kosovo, found in hand sanitiser 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

Total alcohol concentration at Kosovo informal settlement

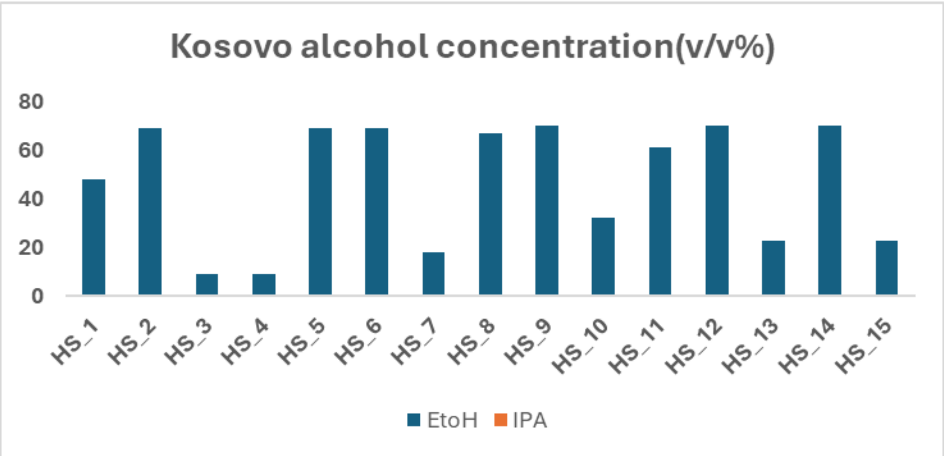

Figure 18 Graph with total alcohol concentration at Kosovo informal settlement.

4.6.1. Ethanol effectiveness and compliance with the regulated 60%

The study found that ethanol was the predominant alcohol present in the hand sanitisers tested in Kosovo. However, concerning results emerged, with 53% of the samples exceeding the recommended standard set by the WHO of 60%-95% ethanol concentration, while the remaining 47% fell below this standard. The average ethanol content of all non-compliant samples was 47% by volume, with the lowest observed ethanol content being 9%. Notably, no samples with isopropanol as the sole active ingredient were found on site. Figure 19 displays the ethanol concentration in ABHS samples sourced from the Kosovo informal settlement. The data indicates that nearly half of the samples analysed did not meet the standards set by the CDC and US FDA, raising concerns about the effectiveness and safety of the sanitisers. This non-compliance may have significant implications for public health during the ongoing COVID-19 pandemic. 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 sanitisers for effective hand hygiene.

Figure 19.Ethanol concentration in ABHS samples sourced from the Kosovo informal settlement

4.7. Determination of 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 ABS samples from the three informal dwellings in Cape Town. ABHS are 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 WHO. Specifically, this study discovered that only 36% of Isopropanol samples had an alcohol percentage between 70-80%, which is the required standard to effectively combat SARS-CoV-2. While Isopropanol has been proven to be effective against viruses with lipid envelopes, 64% of products demonstrated a percentage range between 0-69%, indicating lower concentrations of Isopropanol. This could result in a product that is not as effective in protecting against viruses. In addition, it was also found that most of the products did not contain the appropriate or correct declaration as recommended by the South African Bureau of Standards (SANS). This means that consumers may not be fully aware of the product's efficacy or safety. These findings suggest that manufacturers should closely monitor the production of ABHS products to ensure that they comply with industry standards and offer consumers the protection they need against SARS-CoV-2 and other communicable diseases. Siddharta et al (2017) reported that two alcohol-based formulations, one containing ethanol 80% and the other isopropyl alcohol 75%, recommended by WHO, efficiently killed pathogens that cause diseases such as ZIKA, EBOLA, SARS, MERS, and other enveloped viruses. This is evidence that alcohol-based hand sanitisers can successfully be used as an effective infection-preventative measure against viral outbreaks when used correctly and with the required alcohol content meeting the standards. These results make it evident that the use of sanitisers can help stop the spread of infectious diseases during and after COVID-19 and protect the public. In contrast, it was found that 76% of the samples tested had ethanol levels exceeding 60% by volume. Notably, the FDA mandates a minimum alcohol concentration of 60% for ethanol and 70% for isopropanol by volume in ABHS products. Consequently, any ABHS marketed with an ethanol content below this threshold is considered non-compliant as per drug manufacturing regulations. shockingly, 24% of the samples had the lowest ethanol content. These findings are consistent with other research conducted during the COVID-19 pandemic, which also identified sub-potent ranges of alcohol content. Despite the alarming concentrations of methanol reported by (Matatiele et al., 2022). South Africa has not issued any recalls, unlike the USA, where recalls have been made due to possible methanol contamination.

4.8. Observations

During the Covid-19 pandemic, it has been observed that some spaza shops in community settings are using their own formulations of sanitisers. This is not new, as a similar study conducted in Johannesburg by Matatiele et al. (2022). made the same observations. It is imperative to understand that while manufacturers were permitted to produce their own sanitisers, they must follow the WHO formulations to ensure their effectiveness against the virus. However, in informal settlements, spaza shop owners frequently resort to using their own formulations when sanitisers are not readily available due to the lockdown and limited access to proper sanitisation products and supplies in these areas. Additionally, most of the sanitisers used lack labels because some are homemade, while others are being refilled, and the original bottles were not assessed for this study. This situation poses significant risks to the health and safety of people living in these areas. The use of improper sanitation products can lead to the spread of the virus, which can have devastating consequences, particularly in densely populated areas. Therefore, it is crucial to ensure that proper sanitation measures are put in place to prevent the spread of COVID-19 or any other communicable diseases and protect the health of everyone in the community.

4.9. 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 ≥ 70% in only 36% of the tested samples 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

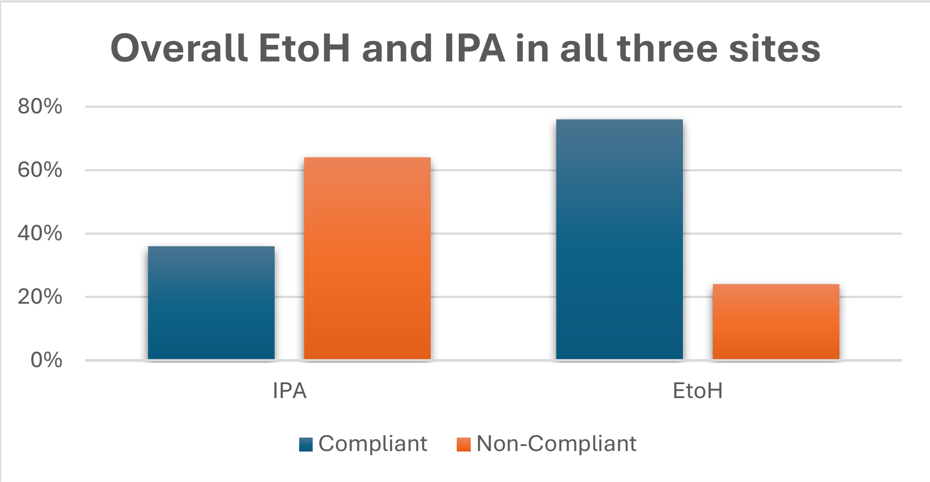

Figure 21). The study provides conclusive evidence that 74% of the tested hand sanitisers meet the recommended alcohol percentage by both the CDC and FDA guidelines. However, the remaining 26% of the tested samples fail to meet the recommended standards, as shown in

Figure 20. The results show that users of alcohol-based hand sanitisers are being exposed to substandard and falsified products which 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 (2022) showed that only 26% were compliant, while 74% were non-compliant. It has been observed that many hand sanitisers being used in community settings do not comply with regulatory standards. This means they may be less effective in preventing the transmission of SARS-CoV-2 from hand surfaces due to lower ethanol and isopropanol content. In addition, other studies have like Matatiele et al (2022) found impurities in these sanitisers tested in Johannesburg. In one study, nearly 1 in 5 samples

contained methanol and some had ineffective alcohol concentrations. Therefore, there is a need for greater oversight, widespread testing, and enforcement to ensure the safety and effectiveness of these products. As previously indicated by Abuga and Nyamweya (2021) regular, routine post-market surveillance is needed to prevent such products from reaching the market.

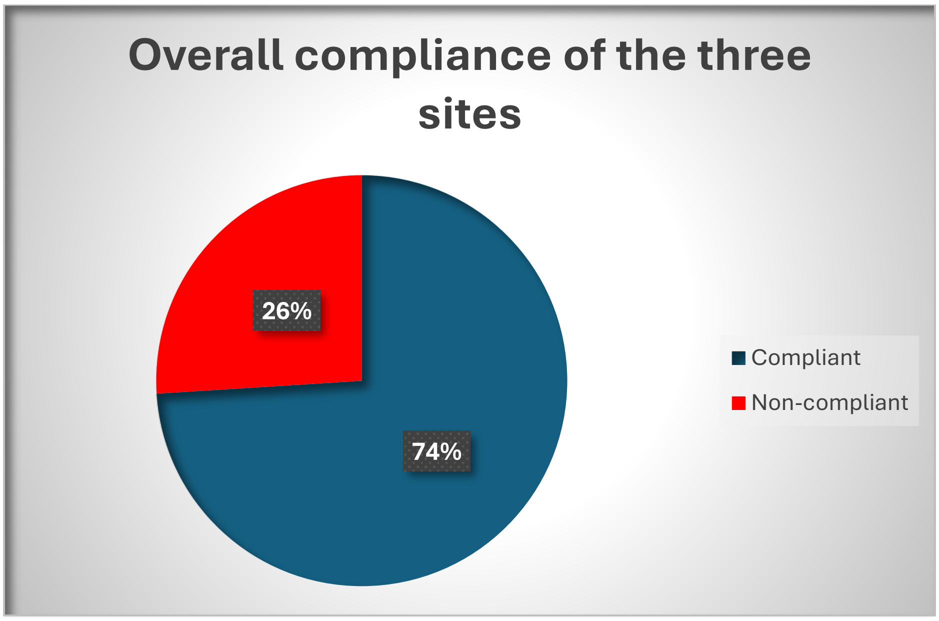

Figure 20. Overall compliance of alcohol sanitisers for the three sites

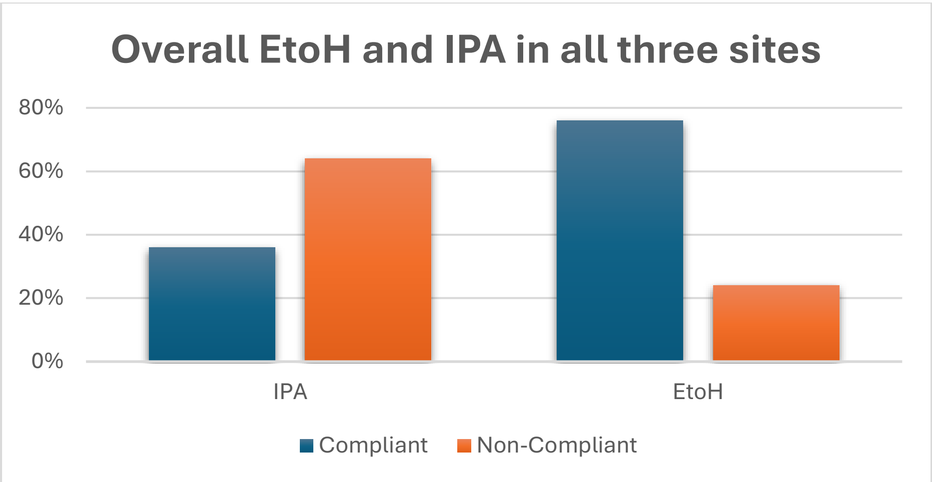

Figure 21. Overall EtOH and IPA in all three sites

4.10. Effectiveness of Hand Sanitisers: 60% Ethanol vs. 70% Isopropanol

When comparing the effectiveness of hand sanitisers, 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 (Jing et al., 2020). 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 (O'Donnell et al., 2020). 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 organisations such as the CDC and WHO for effective hand sanitisers.

4.11. Hand sanitisers with insufficient alcohol content can pose significant health risks.

Hand sanitisers with low alcohol content pose significant health risks and can compromise their effectiveness in eliminating viruses, bacteria, and other pathogens. Insufficient sanitisation 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 sanitisers may contain toxic substances such as methanol or other impurities. Research, like the study conducted by Matatiele et al. (2022) 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 (Mousavi-Roknabadi et al., 2022). Continuous use of substandard hand sanitisers can exacerbate chronic skin conditions, particularly among individuals with sensitive skin. Ineffective hand sanitisers contribute to the wider dissemination of diseases within communities, especially in regions with limited access to healthcare facilities. Ensuring that hand sanitisers meet the required alcohol content standards is essential for their efficacy in curbing the spread of infectious diseases and safeguarding public health.

5. Recommendations

- **Stringent Monitoring and Compliance:** Manufacturers should implement rigorous monitoring systems to ensure compliance with industry standards for alcohol-based hand sanitisers (ABHS). This includes regularly testing product formulations to verify alcohol content and adherence to regulatory guidelines set by organisations like the WHO and FDA.
- **Improved Transparency and Labeling:** To enhance consumer awareness and safety, ABHS products should accurately declare their alcohol content on labels, as recommended by the South African Bureau of Standards (SANS). Clear and comprehensive labeling will empower consumers to make informed choices about the efficacy and safety of hand sanitisers.
- **Education and Awareness Campaigns:** Public health authorities should conduct educational campaigns to inform consumers about the importance of using ABHS with adequate alcohol concentrations (60% or higher) to effectively combat the transmission of diseases like SARS-CoV-2. These campaigns can also raise awareness about the potential risks associated with substandard hand sanitisers.
- **Industry Collaboration and Standards Enforcement:** Collaboration between regulatory bodies, industry stakeholders, and consumer advocacy groups is essential to uphold standards and ensure the quality and safety of ABHS products. Authorities should enforce regulations and take swift action against non-compliant manufacturers to protect public health.
- **Recalls and Quality Assurance Measures:** In cases where ABHS products are found to be non-compliant with alcohol content standards or pose safety risks, regulatory authorities should initiate recalls and implement quality assurance measures. This includes conducting thorough investigations, issuing warnings to consumers, and imposing penalties on errant manufacturers.
- **Research and Development:** Continued research and development efforts are needed to explore innovative formulations and manufacturing processes that can improve the effectiveness and safety of ABHS products. This includes investigating alternative ingredients and delivery mechanisms to enhance antimicrobial efficacy and user experience.
- **International Collaboration and Information Sharing:** Collaboration with international health organisations and sharing of research findings and best practices can facilitate global efforts to address challenges related to ABHS quality and safety. Cross-border cooperation can lead to the development of harmonised standards and guidelines for ABHS production and distribution.

By implementing these recommendations, stakeholders can work together to enhance the quality, safety, and efficacy of alcohol-based hand sanitisers, ultimately contributing to the prevention and control of infectious diseases, including COVID-19, within communities.

6. Conclusion

The findings of this study highlighted the critical importance of ensuring the quality and efficacy of alcohol-based hand sanitisers, especially in vulnerable communities living in informal settlements. The COVID-19 pandemic has heightened the demand for hand sanitisers, leading to challenges in maintaining product standards and safety. Despite efforts to provide accessible hand hygiene solutions, such as allowing temporary utilisation of inferior raw materials, this study reveals concerning deficiencies in the quality of hand sanitisers 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 sanitisers 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 sanitiser 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 sanitisers. 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 sanitisers 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 communities 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.

7. References

Abdu, E.M. & Mariamenatu, A.H., 2021. Biological Property of Novel Coronavirus SARS-CoV-2 (2019-nCoV). *Int. J. Appl. Sci. Biotechnol.* **9**, 16–22.

Abuga, K. & Nyamweya, N., 2021. Alcohol-Based Hand Sanitizers in COVID-19 Prevention: A Multidimensional Perspective. *Pharmacy* **9**, 64.

Adams, C.A. & Abhayawansa, S., 2022. Connecting the COVID-19 pandemic, environmental, social and governance (ESG) investing and calls for 'harmonisation' of sustainability reporting. *Crit. Perspect. Account.* **82**, 102309.

Al-Omari, A., Rabaan, A.A., Salih, S., Al-Tawfiq, J.A. & Memish, Z.A., 2019. MERS coronavirus outbreak: Implications for emerging viral infections. *Diagn. Microbiol. Infect. Dis.* **93**, 265–285.

Alshammari, T.M., Altebainawi, A.F. & Alenzi, K.A., 2020. Importance of early precautionary actions in avoiding the spread of COVID-19: Saudi Arabia as an Example. *Saudi Pharm. J.* **28**, 898–902.

Armitage, N., Beauclair, R., Ashipala, N. & Spiegel, A., 2010. Draining the shantytowns; lessons from Kosovo informal settlement, Cape Town, South Africa. *NOVATECH Int. Conf.* 28-30 June 2010.

Austrian, K., Pinchoff, J., Tidwell, J.B., White, C., Abuya, T., Kangwana, B., Ochako, R., Wanyungu, J., Muluve, E., Mbushi, F., Mwanga, D., Nzioki, M. & Ngo, T.D., 2020. COVID-19 Related Knowledge, Attitudes, Practices and Needs of Households in Informal Settlements in Nairobi, Kenya. *SSRN Electron. J.*

Ayenigbara, I.O., 2020. COVID-19: An International Public Health Concern. *Cent. Asian J. Glob. Heal.* **9**.

Azevedo, M.J., 2017. The State of Health System(s) in Africa: Challenges and Opportunities. In *African Histories and Modernities*: 1–73.

Babeluk, R., Jutz, S., Mertlitz, S., Matiasek, J. & Klaus, C., 2014. Hand hygiene - Evaluation of three disinfectant hand sanitizers in a community setting. *PLoS One* **9**, e111969.

Baldanti, F., Ganguly, N.., Wang, G., Möckel, M., O'Neill, L.., Renz, H., dos Santos Ferreira, C.., Tateda, K. & Van Der Pol, B., 2022. Choice of SARS-CoV-2 diagnostic test: challenges and key considerations for the future. Critical Reviews in Clinical Laboratory Sciences **59**, 445-459.

Baloyi, T. M., Maphanga, T., Madonsela, B. S., Mongwe, Q. G., Malakane, K. C., Grangxabe, X. S., & Gqomfa, B. 2024. Indigenous Strategies for Managing Bush Encroachment in Rural Areas of South Africa. *Challenges*, *15*(3), 33.

Batyi, M., 2022. *Adulthood, home-leaving and informal settlement: A study of the Marikana informal settlement in Philippi East, Cape Town.*

Bedi, J., 2020. Lupe Hernandez and the Invention of Hand Sanitizer | Lemelson Center for the Study of Invention and Innovation. *Lemelson Cent. Study Invent. Innov.*

Berardi, A., Perinelli, D.R., Merchant, H.A., Bisharat, L., Basheti, I.A., Bonacucina, G., Cespi, M. & Palmieri, G.F., 2020. 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.* **584**.

Berger, A., Drosten, C., Doerr, H.W., Stürmer, M. & Preiser, W., 2004. Severe acute respiratory syndrome (SARS) - Paradigm of an emerging viral infection. *J. Clin. Virol.* **29**, 13–22.

Bloomfield, S.F., Aiello, A.E., Cookson, B., O'Boyle, C. & Larson, E.L., 2007. The effectiveness of hand hygiene procedures in reducing the risks of infections in home and community settings including handwashing and alcohol-based hand sanitizers. *Am. J. Infect. Control* **35**, S27-S64.

Bloomfield, S.F., Rook, G.A.W., Scott, E.A., Shanahan, F., Stanwell-Smith, R. & Turner, P. ,2016. 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* **136**, 213–224.

Blount, G., Webb, K. & Morgan, G., 2020. Sanitizing hand sanitizer — managing FDArecalled hand sanitizer. [WWW Document]. *Singer Isl. Newstex.* URL https://www.proquest.com/docview/ 2434881487?accountid=26389

Burrell, C.J., Howard, C.R. & Murphy, F.A., 2016. Fenner and White's Medical Virology: Fifth Edition. *Fenner White's Med. Virol. Fifth Ed.* 1–583.

CDC. 2022. Frequent Questions About Hand Hygiene [WWW Document]. *Centers Dis. Control Prev.* URL https://www.cdc.gov/handwashing/faqs.html

Chatterjee, S., Kim, C.M., Lee, Y.M., Seo, J.W., Kim, D.Y., Yun, N.R. & Kim, D.M., 2022. Whole-genome analysis and mutation pattern of SARS-CoV-2 during first and second wave outbreak in Gwangju, Republic of Korea. *Sci. Rep.* **12**, 11354.

Cheng, V.C.C., Chan, J.F.W., To, K.K.W. & Yuen, K.Y., 2013. Clinical management and infection control of SARS: Lessons learned. *Antiviral Res.* **100**, 407–419.

Corman, V.M., Muth, D., Niemeyer, D. & Drosten, C., 2018. Hosts and Sources of Endemic Human Coronaviruses. In *Advances in Virus Research*: 163–188.

Cure, L., Van Enk, R. & Tiong, E., 2014. A systematic approach for the location of hand sanitizer dispensers in hospitals. *Health Care Manag. Sci.* **17**, 245–258.

Dalasile, S., Itoba Tombo, E., Madonsela, B. S., Mpungose, P. P., Mshicileli, N., & Menziwa, M. 2024. Alcohol-Based Hand Sanitizers Used for COVID-19 Prevention in the Informal Settlements of Cape Town, South Africa. *COVID*, *4*(10), 1655-1675.

Danti, N. & Sanya Tom. 2017. Critical assessment of right to safe water and sanitation in a South African informal settlement: A Case Study of Marikana, Cape Town 227.

Dhama, K., Patel, S.K., Kumar, R., Masand, R., Rana, J., Yatoo, M.I., Tiwari, R., Sharun, K., Mohapatra, R.K., Natesan, S., Dhawan, M., Ahmad, T., Emran, T. Bin, Malik, Y.S. & Harapan, H., 2021. The role of disinfectants and sanitizers during COVID-19 pandemic: advantages and deleterious effects on humans and the environment. *Environ. Sci. Pollut. Res.* **28**, 34211–34228.

Dong, L., Hu, S. & Gao, J., 2020. Discovering drugs to treat coronavirus disease 2019 (COVID-19). *Drug Discov. Ther.* **14**, 58–60.

Drain, P.K., 2022. Rapid Diagnostic Testing for SARS-CoV-2. *N. Engl. J. Med.* **386**, 264–272.

Eggerstedt, S., 2013. Comparative efficacy of commercially available alcohol-based hand rubs and World Health Organization-recommended hand rubs. *Am. J. Infect. Control* **41**, 472–474.

Fort, F. Van Der., 2020. Kosovo residents in the dark about Covid-19 move [WWW Document]. *Plainsm.* URL https://www.plainsman.co.za/news/kosovo-residents-in-the-dark-about-covid-19-move

Fru, W., 2020. *Copper and Zinc in Water, Sediment and Gastropods in the Harbours of the Cape Town Metropole, South Africa*. *Cape Penins. Univ. Technol.*

Gibson, L. & Rush, D., 2020. 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 Heal. Surveill.* **6**, e18844.

Gold, N.., Mirza, T.. & Avva, U.,2021. Alcohol Sanitizer. *StatPearls. StatPearls Publ.*

Golin, A.P., Choi, D. & Ghahary, A., 2020. Hand sanitizers: A review of ingredients, mechanisms of action, modes of delivery, and efficacy against coronaviruses. *Am. J. Infect. Control* **48**, 1062–1067.

Gong, W., Parkkila, S., Wu, X. & Aspatwar, A., 2023. SARS-CoV-2 variants and COVID-19 vaccines: Current challenges and future strategies. *Int. Rev. Immunol.* **42**, 393-414.

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., Penzar, D., Perlman, S., Poon, L.L.M., Samborskiy, D. V., Sidorov, I.A., Sola, I. & Ziebuhr, J., 2020. The species Severe acute respiratory syndrome-related coronavirus: classifying 2019-nCoV and naming it SARS-CoV-2. *Nat. Microbiol.* **5**, 536–544.

Govender, K., Mdanda, S., Baijnath, S., Kruger, H.G., Govender, T. & Naicker, T., 2022. The analysis of alcohol content in hand sanitisers (in the Durban region) using gas chromatography-mass spectrometry during the COVID-19 pandemic. *South African J.*

Chem. **76**, 20–24.

Hammond, B., Ali, Y., Fendler, E., Dolan, M. & Donovan, S., 2000. Effect of hand sanitizer use on elementary school absenteeism. *Am. J. Infect. Control* **28**, 340–346.

Ho, M., Seto, W., Wong, L. & Wong, T., 2012. Effectiveness of Multifaceted Hand Hygiene Interventions in Long-Term Care Facilities in Hong Kong: A Cluster-Randomized Controlled Trial. *Infect. Control Hosp. Epidemiol.* **33**, 761–767.

Van Der Hoek, L., Pyrc, K., Jebbink, M.F., Vermeulen-Oost, W., Berkhout, R.J.M., Wolthers, K.C., Wertheim-Van Dillen, P.M.E., Kaandorp, J., Spaargaren, J. & Berkhout, B., 2004. Identification of a new human coronavirus. *Nat. Med.* **10**, 368–373.

Hoffmann, T., Bakhit, M., Krzyzaniak, N., Del Mar, C., Scott, A.M. & Glasziou, P., 2021. Soap versus sanitiser for preventing the transmission of acute respiratory infections in the community: a systematic review with meta-analysis and dose–response analysis. *BMJ Open* **11**, e046175.

Jairoun, A.A., Al-Hemyari, S.S. & Shahwan, M., 2021. The pandemic of COVID-19 and its implications for the purity and authenticity of alcohol-based hand sanitizers: The health risks associated with falsified sanitizers and recommendations for regulatory and public health bodies. *Res. Soc. Adm. Pharm.* **17**, 2050–2051.

Jakeni, Y., Maphanga, T., Madonsela, B. S., & Malakane, K. C. (2024). Identification of Illegal Dumping and Community Views in Informal Settlements, Cape Town: South Africa. *Sustainability*, *16*(4), 1429.

Jeffries, D. & Visser, L.S., 2021. Infectious and Communicable Diseases. *Rapid Access Guid. Pediatr. Emergencies Provid. Expert Nurs. Care* 228–259.

Jing, J.L.J., Yi, T.P., Bose, R.J.C., McCarthy, J.R., Tharmalingam, N. & Madheswaran, T., 2020. Hand sanitizers: A review on formulation aspects, adverse effects, and regulations. *Int. J. Environ. Res. Public Health* **17**, 3326.

Johansson, M.A., Quandelacy, T.M., Kada, S., Prasad, P.V., Steele, M., Brooks, J.T., Slayton, R.B., Biggerstaff, M. & Butler, J.C., 2021. SARS-CoV-2 Transmission from People without COVID-19 Symptoms. *JAMA Netw. Open* **4**, e2035057-e2035057.

Kahn, J.S. & McIntosh, K., 2005. Discussion. *Pediatr. Infect. Dis. J.* **24**, S223–S227.

Kariuki, P., Ofusori, L.O., Goyayi, M.L. & Subramaniam, P.R., 2023. Health-related misinformation and public governance of COVID-19 in South Africa. *Digit. Policy, Regul. Gov.* **25**, 58–74.

Katella, K., 2023. What to Know About EG.5 (Eris)—the Latest Coronavirus Strain > News > Yale Medicine [WWW Document]. URL https://www.yalemedicine.org/news/covid-eg5-eris-latest-coronavirus-strain

Kelly, H., 2011. The classical definition of a pandemic is not elusive. *Bull. World Health Organ.* **89**, 540–541.

Kesik-Brodacka, M., 2018. Progress in biopharmaceutical development. *Biotechnol. Appl. Biochem.* **65**, 306–322.

Knight, C., 2021. Hand Hygiene: Washing with Soap vs Using Hand Sanitizer [WWW Document].

Knudson, A., 2022. “Stop Using These Hand Sanitizers Immediately Due to Methanol Concerns.” Silive. Available from:

Koh, W.C., Naing, L., Chaw, L., Rosledzana, M.A., Alikhan, M.F., Jamaludin, S.A., Amin, F., Omar, A., Shazli, A., Griffith, M., Pastore, R. & Wong, J., 2020. What do we know about SARS-CoV-2 transmission? A systematic review and meta-analysis of the secondary attack rate and associated risk factors. *PLoS One* **15**, 0240205.

Kratzel, A., Kratzel, A., Todt, D., V’kovski, P., Steiner, S., Steiner, S., Gultom, M., Gultom, M., Thao, T.T.N., Thao, T.T.N., Ebert, N., Ebert, N., Holwerda, M., Holwerda, M., Steinmann, J., Steinmann, J., Niemeyer, D., Dijkman, R., Rajkmanilanei, K., Kampf, G., Drosten, C., Steinmann, E., Thiel, V., Thiel, V. & Pfaender, S.,2020. Inactivation of Severe Acute Respiratory Syndrome Coronavirus 2 by WHO-Recommended Hand Rub Formulations and Alcohols. *Emerg. Infect. Dis.* **26**, 1592–1595.

Kumar, D., Malviya, R. & Kumar Sharma, P., 2020. Corona Virus: A Review of COVID-19. *EJMO* **4**, 8–25.

Leung, G.M., Medley, A.J., Ho, L.M., Chau, P., Wong, I.O.L., Thach, T.Q., Ghani, A.C., Donnelly, C.A., Fraser, C., Riley, S., Ferguson, N.M., Anderson, R.M., Tsang, T., Leung, P.Y., Wong, V., Chan, J.C.K., Tsui, E., Lo, S.V. & Lam, T.H., 2004. The epidemiology of severe acute respiratory syndrome in the 2003 Hong Kong epidemic: An analysis of all 1755 patients. *Ann. Intern. Med.* **141**, 662–673.

Lombard, M., Pastoret, P.P. & Moulin, A.M., 2007. A brief history of vaccines and vaccination. *OIE Rev. Sci. Tech.* **26**, 29–48.

Madonsela, B. S. 2019. *Assessment of environmental exposure to air pollution within four neighbourhoods of the Western Cape, South Africa* (Doctoral dissertation, Cape Peninsula University of Technology).

Madonsela, B. S., Machete, M., & Shale, K. 2024. Indigenous Knowledge Systems of Solid Waste Management in Bushbuckridge Rural Communities, South Africa. *Waste, 2(3)*, 293-311.

Maphanga, T., & Madonsela, B. S. (2023). Evaluating waste management practices of street vendors in the informal settlement of Cape Town: a case study of Khayelitsha. *Anthropog. Pollut*, *7*, 1-11.

Magolda, P.M., 2007. Doing Case Study Research: A Practical Guide for Beginning Researchers (review). *J. Coll. Stud. Dev.* **48**, 123–125.

Malik, S.S., Azem-e-Zahra, S., Kim, K.M., Caetano-Anollés, G. & Nasir, A., 2017. Do viruses exchange genes across superkingdoms of life? *Front. Microbiol.* **8**, 297661.

Mascorp., 2020. Masiphumelele Corporation and Trust NGO operating in Masiphumelele [WWW Document]. *Popul. Stat. Estim.* URL www.mascorp.org

Matatiele, P., Southon, B., Dabula, B., Marageni, T., Poongavanum, P. & Kgarebe, B., 2022. Assessment of quality of alcohol-based hand sanitizers used in Johannesburg area during the CoViD-19 pandemic. *Sci. Rep.* **12**, 4231.

Mavundza, E.J., Ndwandwe, D. & Wiysonge, C.S., 2022. COVID-19 vaccine demand protest might have increased vaccine acceptance and uptake in South Africa. *Hum. Vaccines Immunother.* **18**.

Monqo, B.P., 2023. Housing Delivery at the Masiphumelele Community. *Adm. Publica* | **31**, 85-106.

Mousavi-Roknabadi, R.S., Arzhangzadeh, M., Safaei-Firouzabadi, H., Mousavi-Roknabadi, R.S., Sharifi, M., Fathi, N., Jelyani, N.Z. and Mokdad, M., 2022. Methanol poisoning during COVID-19 pandemic; A systematic scoping review. *The American journal of emergency medicine*, *52*, pp.69-84.

Mseleku, E.S., 2021. Guidelines for Integrated Flood Control Design in the Informal Settlements of Cape Town Municipality A case study of Kosovo , Philippi District 87.

Mukumbang, F.C., Ambe, A.N. & Adebiyi, B.O., 2020. Unspoken inequality: How COVID-19 has exacerbated existing vulnerabilities of asylum-seekers, refugees, and undocumented migrants in South Africa. *Int. J. Equity Health* **19**, 141.

Muleba, L., Van Wyk, R., Pienaar, J., Ratshikhopha, E. & Singh, T., 2022. Assessment of Anti-Bacterial Effectiveness of Hand Sanitizers Commonly Used in South Africa. *Int. J. Environ. Res. Public Health* **19**, 9245.

Nelson, T.L., Fosdick, B.K., Biela, L.M., Schoenberg, H., Mast, S., McGinnis, E., Young, M.C., Lynn, L., Fahrner, S., Nolt, L., Dihle, T., Quicke, K., Gallichotte, E.N., Fitzmeyer, E., Ebel, G.D., Pabilonia, K., Ehrhart, N. & Vandewoude, S., 2021. Association between COVID-19 Exposure and Self-reported Compliance with Public Health Guidelines among Essential Employees at an Institution of Higher Education in the US. *JAMA Netw. Open* **4**.

O'Donnell, V.B., Thomas, D., Stanton, R., Maillard, J.Y., Murphy, R.C., Jones, S.A., Humphreys, I., Wakelam, M.J., Fegan, C., Wise, M.P. and Bosch, A., 2020. Potential role of oral rinses targeting the viral lipid envelope in SARS-CoV-2 infection. *Function*, *1*(1), p.zqaa002.

Oleribe, O.E., Momoh, J., Uzochukwu, B.S., Mbofana, F., Adebiyi, A., Barbera, T., Williams, R. & Taylor Robinson, S.D., 2019. Identifying Key Challenges Facing Healthcare Systems In Africa And Potential Solutions. *Int. J. Gen. Med.* **Volume 12**, 395–403.

Onyeaka, H., Anumudu, C.K., Al-Sharify, Z.T., Egele-Godswill, E. & Mbaegbu, P., 2021. COVID-19 pandemic: A review of the global lockdown and its far-reaching effects. *Sci.*

Prog. **104**, 00368504211019854.

Otokunefor, K. & Princewill, I., 2018. Evaluation of antibacterial activity of hand sanitizers – an *in vitro* study. *J. Appl. Sci. Environ. Manag.* **21**, 1276.

Petersen, E., Koopmans, M., Go, U., Hamer, D.., Petrosillo, N., Castelli, F., Storgaard, M., Al Khalili, S. & Simonsen, L., 2020. Comparing SARS-CoV-2 with SARS-CoV and influenza pandemics. *Lancet Infect. Dis.* **20**, e238-e244.

Plotkin, S.A. & Plotkin, S.L., 2011. The development of vaccines: How the past led to the future. *Nat. Rev. Microbiol.* **9**, 889–893.

Poland, G.A., 2003. Vaccines in the 21st century. *Immunol. Allergy Clin. North Am.* **23**, 1301.

Potter, C.W. & Jennings, R., 2011. A definition for influenza pandemics based on historial records. *J. Infect.* **63**, 252–259.

Qian, Z., Dominguez, S.R. & Holmes, K. V., 2013. Role of the Spike Glycoprotein of Human Middle East Respiratory Syndrome Coronavirus (MERS-CoV) in Virus Entry and Syncytia Formation. *PLoS One* **8**.

Rai, N.K., Ashok, A. & Akondi, B.R., 2020. Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19. *Crit. Rev. Toxicol.* **50**, 513–520.

Riedel, S., 2005. Edward Jenner and the History of Smallpox and Vaccination. *Baylor Univ. Med. Cent. Proc.* **18**, 21–25.

Rosenthal, A. & Waitzberg, R., 2023. The challenges brought by the COVID-19 pandemic to health systems exposed pre-existing gaps. *Heal. Policy OPEN* **4**, 100088.

Sabir, J.S.M., Lam, T.T.Y., Ahmed, M.M.M., Li, L., Shen, Y., Abo-Aba, S.E.M., Qureshi, M.I., Abu-Zeid, M., Zhang, Y., Khiyami, M.A., Alharbi, N.S., Hajrah, N.H., Sabir, M.J., Mutwakil, M.H.Z., Kabli, S.A., Alsulaimany, F.A.S., Obaid, A.Y., Zhou, B., Smith, D.K., Holmes, E.C., Zhu, H. & Guan, Y., 2016. Co-circulation of three camel coronavirus species and recombination of MERS-CoVs in Saudi Arabia. *Science (80-.).* **351**, 81–84.

Sahin, A.R., Erdogan, A., Mutlu Agaoglu, P., Dineri, Y., Cakirci, A.Y., Senel, M.E., Okyay, R.A. & Tasdogan, A.M., 2020. 2019 Novel Coronavirus (COVID-19) Outbreak: A Review of the Current Literature. *Eurasian J. Med. Oncol.* **4**, 1–7.

Samal, J., 2014. A historical exploration of pandemics of some selected diseases in the world. *Int. J. Heal. Sci. Res. 2014•Citeseer* **4**, 165.

Shereen, M.A., Khan, S., Kazmi, A., Bashir, N. & Siddique, R., 2020. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. *J. Adv. Res.* **24**, 91–98.

Siddharta, A., Pfaender, S., Vielle, N.J., Dijkman, R., Friesland, M., Becker, B., Yang, J., Engelmann, M., Todt, D., Windisch, M.P., Brill, F.H., Steinmann, J., Steinmann, J., Becker, S., Alves, M.P., Pietschmann, T., Eickmann, M., Thiel, V. & Steinmann, E., 2017. Virucidal activity of world health organization-recommended formulations against enveloped viruses, including zika, ebola, and emerging coronaviruses. *J. Infect. Dis.* **215**, 902–906.

Singh, D., Joshi, K., Samuel, A., Patra, J. & Mahindroo, N., 2020. Alcohol-based hand sanitizers as first line of defense against SARS CoV-2: A review of biology, chemistry and formulations. *Epidemiol. Infect.* **148**, e229.

Su, S., Wong, G., Shi, W., Liu, J., Lai, A.., Zhou, J., Liu, W., Bi, Y. & Gao, G.F., 2016. Epidemiology, genetic recombination, and pathogenesis of coronaviruses. Trends in microbiology **24**, 490–502.

Shenoy, P.B. and Brundha, M.P., 2016. Awareness of polycystic ovarian disease among females of age group 18-30 years. *Journal of Pharmaceutical Sciences and Research*, *8*(8), p.813.

Tahamtan, A., Charostad, J., Hoseini Shokouh, S.J. & Barati, M., 2017. An Overview of History, Evolution, and Manufacturing of Various Generations of Vaccines. *J. Arch. Mil. Med.* **In Press**.

Tegally, H., Moir, M., Everatt, J., Giovanetti, M., Scheepers, C., Wilkinson, E., Subramoney, K., Makatini, Z., Moyo, S., Amoako, D.. & Baxter, C., 2022. Emergence of SARS-CoV-2 omicron lineages BA. 4 and BA. 5 in South Africa. *Nat. Med.* **28**, 1785-1790.

Tejada, J.J., Raymond, J. & Punzalan, B., 2012. On the Misuse of Slovin's Formula. *Philipp. Stat.* **61**, 8.

Teo, R., 2016. The Organisation of a Land Occupation: A Case Study of Marikana, Cape Town 1–156.

United States Food and Drug Administration., 2020. FDA Advises Consumers Not to Use Hand Sanitizer Manufactured by Eskbiochem. *United States Food Drug Adm.*

Villa, C. & Russo, E., 2021. Hydrogels in hand sanitizers. *Materials (Basel).* **14**, 1577.

Wang, X., Jiang, H., Wu, P., Uyeki, T.M., Feng, L., Lai, S., Wang, L., Huo, X., Xu, K., Chen, E., Wang, X., He, J., Kang, M., Zhang, R., Zhang, J., Wu, J., Hu, S., Zhang, H., Liu, X., Fu, W., Ou, J., Wu, S., Qin, Y., Zhang, Z., Shi, Y., Zhang, J., Artois, J., Fang, V.J., Zhu, H., Guan, Y., Gilbert, M., Horby, P.W., Leung, G.M., Gao, G.F., Cowling, B.J. & Yu, H., 2017. Epidemiology of avian influenza A H7N9 virus in human beings across five epidemics in mainland China, 2013–17: an epidemiological study of laboratory-confirmed case series. *Lancet Infect. Dis.* **17**, 822–832.

Warnes, S.L., Little, Z.R. & Keevil, C.W., 2015. Human coronavirus 229E remains infectious on common touch surface materials. *MBio* **6**.

Weinstein, R.A., 2004. Planning for Epidemics — The Lessons of SARS. *N. Engl. J. Med.* **350**, 2332–2334.

WHO., 2021. Antigen-detection in the diagnosis of SARS-CoV-2 infection using rapid immunoassays. *World Heal. Organ.* 1–9.

Williams, A., Branscome, H., Khatkar, P., Mensah, G.A., Al Sharif, S., Pinto, D.O., DeMarino, C. & Kashanchi, F., 2021. A comprehensive review of COVID-19 biology, diagnostics, therapeutics, and disease impacting the central nervous system. *J. Neurovirol.* **27**, 667–690.

Yang, Y., Peng, F., Wang, R., Guan, K., Jiang, T., Xu, G., Sun, J. & Chang, C., 2020. The deadly coronaviruses: The 2003 SARS pandemic and the 2020 novel coronavirus epidemic in China. *J. Autoimmun.* **109**, 102434.

Yin, Y. & Wunderink, R.G., 2018. MERS, SARS and other coronaviruses as causes of pneumonia. *Respirology* **23**, 130–137.

Zgheib, R., 2022. *Efficacy and Toxicity of Hand Sanitizers (Doctoral dissertation, Lebanese American University).*

Zhou, P., Yang, X. Lou, Wang, X.G., Hu, B., Zhang, L., Zhang, W., Si, H.R., Zhu, Y., Li, B., Huang, C.L., Chen, H.D., Chen, J., Luo, Y., Guo, H., Jiang, R. Di, Liu, M.Q., Chen, Y., Shen, X.R., Wang, X., Zheng, X.S., Zhao, K., Chen, Q.J., Deng, F., Liu, L.L., Yan, B., Zhan, F.X., Wang, Y.Y., Xiao, G.F. & Shi, Z.L., 2020. A pneumonia outbreak associated with a new coronavirus of probable bat origin. *Nature* **579**, 270–273.

Zhu, Z., Meng, K. & Meng, G., 2020. Genomic recombination events may reveal the evolution of coronavirus and the origin of SARS-CoV-2. *Sci. Rep.* **10**, 21617.