Toxicology International, *31(2) : 257-264; 2024. DOI: 10.18311/ti/2024/v31i2/36349*

Online ISSN : 0976-5131; Print ISSN : 0971-6580

Toxicology International

Contents available at: www.informaticsjournals.com/index.php/toxi



Detection of Ethanol and Methanol in Hand Sanitizers used in Public Places in Delhi during the COVID-19 Pandemic

Neha Afaria[1#], Rohit Kanojia[2#], A. K. Jaiswal[1*], Sudhir K. Gupta[1] and T. Millo[1]

[1]Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, New Delhi - 110029, India; ashokjaiswal72@gmail.com

[2]Department of Chemistry, University of Delhi, Delhi - 110007, India

Abstract

Since the COVID-19 (coronavirus disease of 2019) pandemic, alcohol-based hand sanitizers are being used widely to prevent the transmission of corona virus. But a major concern is the adulteration of methanol in hand sanitizer. Cases of methanol poisoning increased drastically during the pandemic. This study was carried out to detect ethanol and methanol in hand sanitizers that are being sold and used in public places. The hand sanitizer samples for this study were collected from different public places in Delhi from June- August 2022. A total of 53 samples were collected and the samples were run on Gas Chromatography (GC-HS) for analysis of ethanol and methanol. Methanol was detected in 25 samples. During the COVID-19 pandemic, various cases of methanol poisoning due to consumption or chronic absorption of hand sanitizer have been reported all over the world. Methanol is a toxic alcohol and long-term dermal exposure to this toxic substance can cause severe health effects. During the pandemic, the increased demand of hand sanitizer resulted in uncontrolled manufacturing and sale of hand sanitizers. Data obtained from this study highlight the need to monitor the manufacturing and sale of alcohol-based hand sanitizer by the regulatory bodies and to raise awareness among the public about the toxic effects of methanol.

Keywords: Adulteration, COVID-19, GC-HS, Hand Sanitizer, Methanol

1. Introduction

The global health emergency caused by COVID-19 has raised demand for hand sanitizers[1]. The Centre for Disease Control and Prevention (CDC) and World Health Organization (WHO) has recommended to disinfect hands with soap and water or 60% alcohol disinfectant as a preventive measure to control and reduce the transmission of coronavirus (SARS-CoV-2) and hand sanitizer should contain only ethanol or 2-propanol for antisepsis[1-3]. Hand sanitizers are generally available in the form of gel, foam or liquid[4]. As the demand for the hand sanitizer surged during the pandemic, many small businesses produced and distributed sanitizer locally at small scale[1]. Since there was minimal regulation over the sale, distribution and usage of hand sanitizer during the pandemic, and thus the major concern was adulteration of methanol which was not listed as an ingredient[1,5]. According to the U.S Food and Drug Administration (US-FDA), methanol should not be used in hand sanitizer and by 20

**Author for correspondence*
 # Authors contributed equally

Article Received on: 24.01.2024 Revised on: 03.03.2024 Accepted on: 20.03.2024

November, 2020, FDA placed a warning for 212 products that contained methanol in drastically exceeding amount and raised a warning for public awareness[1,6]. Since 19 January 2021, FDA issued a guideline for pharmaceutical manufacturers to test ethanol and isopropyl alcohol for methanol contamination or adulteration before using them to manufacture drugs and hand sanitizer products[7].

Death due to methanol contaminated sanitizer have been reported worldwide since the pandemic. More than 700 fatalities have been reported since February 2020 due to methanol contaminated sanitizer in U.S[1]. In Iran, about 800 deaths have been reported due to methanol poisoning outbreak from February 2020 to May 2020[8,9]. In India, 54 cases of accidental deaths have been reported in media due to consumption of toxic chemicals due to non-availability of alcohol during the lockdown period and the most consumed toxic substance was hand sanitizer[10]. As methanol is cheap in comparison to ethanol, so local manufacturers used methanol in production of hand sanitizer[11]. Methanol is a toxic substance, and it can be absorbed through the skin and can cause irritation, redness, dermatitis and eczema[12]. Chronic absorption of methanol through skin can cause severe health effects, including blindness, nervous system damage and even death when absorbed in large quantities[13,14].

In this study, Gas Chromatography-Headspace (GC-HS) was used for the detection and analysis of ethanol and methanol in hand sanitizer samples due to its high selectivity, sensitivity, precision, ease of sample preparation, less interferences and contamination. The major advantage of headspace over other techniques is that only vapourised components of the sample solution are introduced into the column and thus it protects the column from contamination. Also, GC-HS is efficient and less costly as compared to other techniques for quantitative estimation of volatile substances[13,15].

By 2026, the hand sanitizer market is expected to be 4.5 billion USD in the Asia Pacific region and 2.2 billion USD in the U.S[1]. There is a need for surveillance in the production and trading of hand sanitizers, so that low standard products containing methanol and other toxic substances could be identified and eradicated from the market. This will protect the public from adverse effects of methanol in future[16,17]. This study was carried out to assess and detect the content of methanol in hand sanitizers that are being used in public places in Delhi, India and to raise awareness about the toxic effects of methanol.

2. Material and Methods

2.1 Collection of Samples

Hand sanitizer samples for the study were collected randomly from public places such as malls, markets, gyms, restaurants etc. in Delhi from June- August 2022. A total of 53 samples of hand sanitizer were collected. 15 samples were collected from South Delhi, 10 samples were collected from South-West Delhi, 11 samples were collected from Central Delhi, 8 samples were collected from East Delhi and 9 samples were collected from North Delhi (Figure 1). The hand sanitizers samples were labelled as S1 to S53. All the samples were analysed for ethanol and methanol on Gas Chromatography-Headspace (GC-HS).

2.2 Experimental

2.2.1 Instrumentation

Gas Chromatography system, Model No. 7890A, and headspace Sampler, Model No. 7697A with a Flame Ionisation Detector (FID) from Agilent, U.S.A. were used for the detection of ethanol and methanol in samples.

2.2.2 Chemicals

GC grade (99.9%) ethanol, methanol and n-propanol were used from Merck, Germany. Double distilled water was used from Rions, India.

2.2.3 Laboratory Ware

Volumetric flasks were used from Merck, India. 20 ml Headspace (HS) vials, aluminium crimp, septa, crimper were used from Agilent, USA.

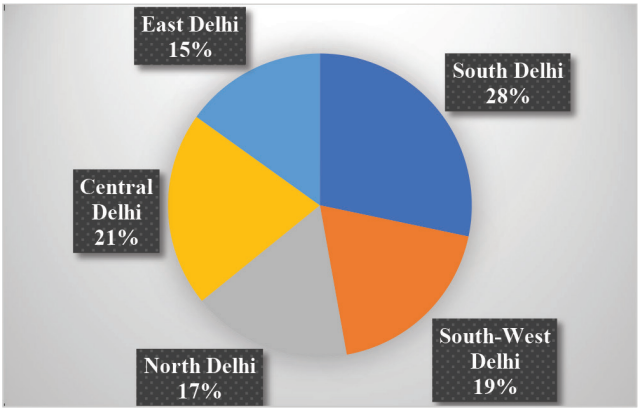


Figure 1. Pie Chart showing district-wise sample collection of hand sanitizer samples.

2.2.4 Preparation of Stock Solutions

Stock solution of ethanol was prepared by dissolving 1 ml of GC grade ethanol in a 100 ml volumetric flask with double distilled water.

Stock solution of methanol was prepared by dissolving 1 ml of GC grade methanol in a 100 ml volumetric flask with double distilled water.

2.2.5 Preparation of Internal Standard

Internal standard (n-propanol) was prepared by dissolving 300 µl of GC grade n-propanol in 100 ml volumetric flask with double distilled water.

2.2.6 Preparation of Calibration Standard

Six standard solutions of ethanol and methanol mixture were prepared from the stock solution of ethanol and methanol.

2.2.7 Sample Preparation

1ml of the hand sanitizer (diluted with double distilled water) was taken in HS vial and 90 µl of internal standard was added to the vial. The vials were then sealed using septa and crimp.

2.2.8 Analysis of Samples

Gas Chromatography-Headspace (GC-HS) with Flame Ionisation Detector (FID) was used for the analysis of ethanol and methanol in hand sanitizer samples. First, the standard solutions of ethanol and methanol were prepared and run on GC-HS to calibrate the method (Figure 2). The method for analysis of ethanol and methanol in hand sanitizer samples using n-propanol as internal standard was validated and Limit of Detection (LOD) for ethanol and methanol was 0.003 g/l and 0.005g/l respectively; and Limit of Quantitation (LOQ) for ethanol and methanol was 0.01 g/l and 0.015 g/l respectively. The proposed method showed excellent linearity with a correlation coefficient (r^2) of 0.99975 for ethanol and 0.99960 for methanol (Figure 3).

After calibrating the method, samples were prepared and then placed on to the Headspace (HS) for analysis. The headspace oven, loop and transfer line temperature were fixed at 70°C, 80°C and 90°C respectively. Nitrogen was used as the carrier gas with a flow rate of 8 ml/min. Hydrogen and zero air were used with a flow rate of 40 ml/min and 400 ml/min respectively. The Gas Chromatography (GC) oven was heated at 50°C for 5 min, then 35^{0}C/min to 200^{0}C for 1 min. The FID temperature was fixed at 250°C. A DB-624 column (30m × 530 µm × 3 µm) from Agilent was used for separation and quantitation of the signals was performed using Chem Station software. Dilution factor was applied to the results obtained from GC-HS.

3. Results

The study aimed to assess the presence of ethanol and methanol in hand sanitizers available in public places during

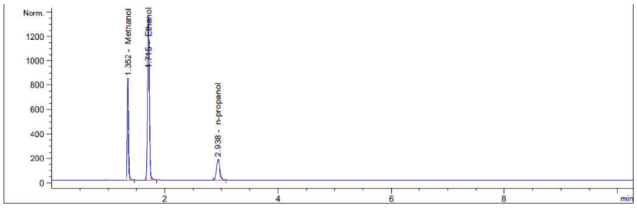
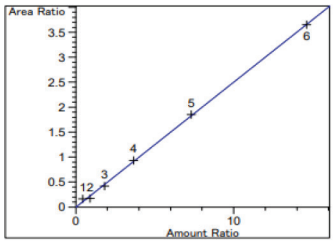
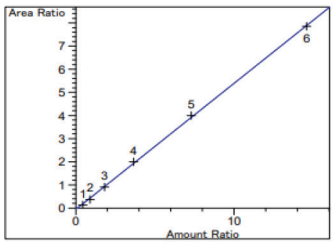


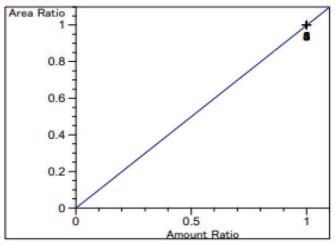
Figure 2. GC-HS chromatogram of standard (Ethanol, methanol and n-propanol).




```
Methanol at exp. RT: 1.352
FID1 A, Front Signal
Correlation:            0.99960
Residual Std. Dev.:     0.04098
Formula: y = mx + b
      m:       2.50941e-1
      b:      -3.91032e-3
      x: Amount
      y: Area
```




```
Ethanol at exp. RT: 1.715
FID1 A, Front Signal
Correlation:            0.99975
Residual Std. Dev.:     0.06998
Formula: y = mx + b
      m:       5.46340e-1
      b:      -6.25637e-2
      x: Amount
      y: Area
```




```
n-propanol at exp. RT: 2.937
FID1 A, Front Signal
Correlation:            1.00000
Residual Std. Dev.:     0.00000
Formula: y = mx + b
      m:       1.00000
      b:       0.00000
      x: Amount
      y: Area
```

Figure 3. Calibration curves of methanol, ethanol, and n-propanol.

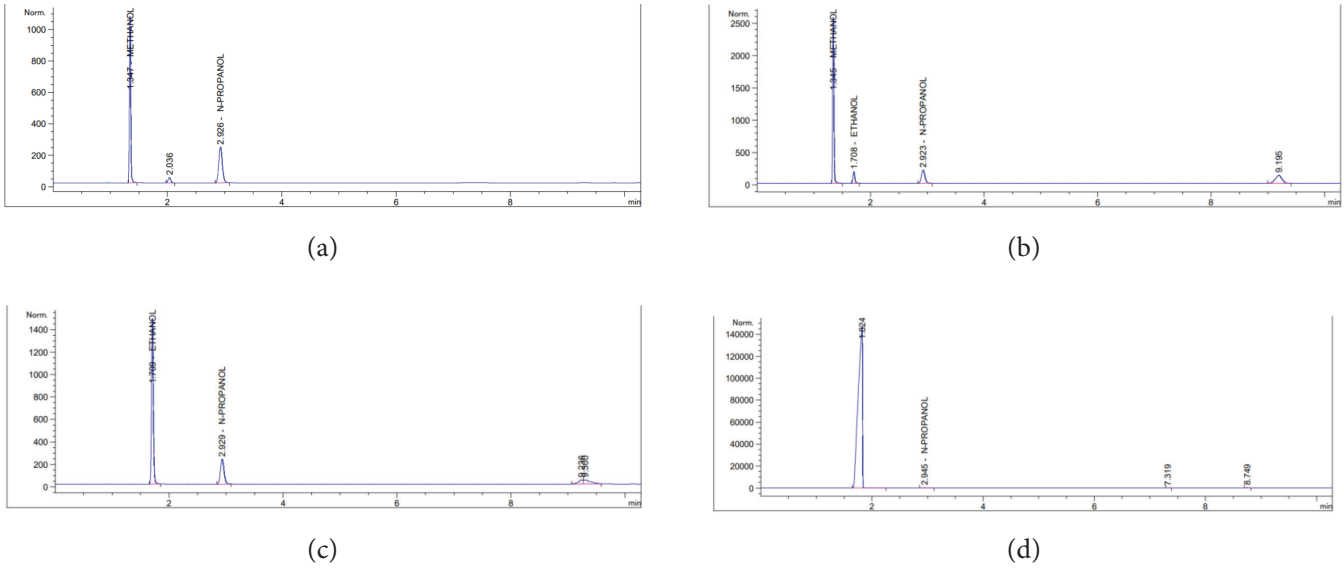


Figure 4. GC-HS Chromatograms of Samples – **(a)** S45; **(b)** S5; **(c)** S46; **(d)** S12.

the COVID-19 pandemic. 53 samples of hand sanitizer were collected from public places in Delhi during the period from June- August 2022. The sanitizer samples were labelled as S1 to S53 and were run on GC-HS for the quantitative determination of ethanol and methanol (Figure 4).

8 samples have gel formulation, and 45 samples have liquid formulation. Out of the 53 hand sanitizer samples analysed, ethanol was detected in 15 samples; and methanol was detected in 25 samples (Figure 5). And out of these 25 hand sanitizer samples, methanol was found to be used as a major ingredient in 15 samples.

This study included both branded and local samples. Branded samples refer to those which are from a brand and are labelled with ingredients list. Local samples are those which are from local manufacturers and were without any label or ingredients list. 14 samples were branded, and 39 samples were from local manufacturers.

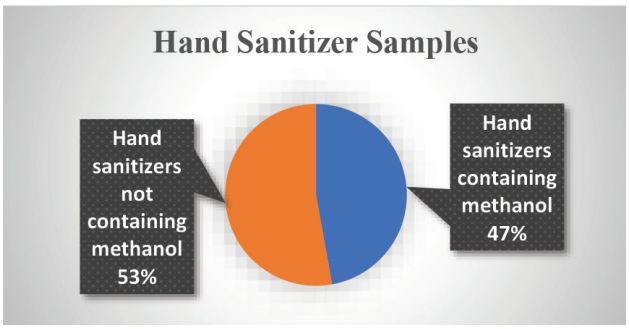


Figure 5. Pie chart showing hand sanitizer samples containing methanol.

The detection of methanol in nearly half of the samples, raises significant concern about the safety and quality of hand sanitizers available to the public. Methanol is a toxic substance, poses serious health risks, particularly upon dermal exposure. The presence of such toxic ingredients renders the hand sanitizer harmful and unfit for humans and such low-quality products may increase the risk of infection to people[14,16,18].

The findings underscore the potential for adverse health effects among individuals using methanol-contaminated hand sanitizers. These results align with global trends observed during the pandemic, where cases of methanol poisoning associated with hand sanitizer use have been reported worldwide. The increased demand for hand sanitizers during the COVID-19 pandemic likely contributed to uncontrolled manufacturing and distribution practices, leading to the presence of methanol in commercial products[14,22]. Overall, the results highlight the need for stringent regulatory oversight of hand sanitizer production and sales to ensure consumer safety. Additionally, public awareness campaigns are imperative to educate individuals about the risks associated with methanol exposure and the importance of using safe and reliable hand hygiene products[14,23].

Concentration of ethanol and methanol in hand sanitizer samples is mentioned in Table 1.

Table 1. Concentration of ethanol and methanol in hand sanitizer samples

S.NO.	Sanitizer Sample	Branded/Local	Formulation	Ethanol (g/l)	Methanol (g/l)
1.	S1	Local	liquid	0.0	0.0
2.	S2	Local	liquid	0.0	0.0
3.	S3	Local	liquid	0.0	0.0
4.	S4	Local	liquid	0.0	0.17
5.	S5	Branded	liquid	0.19	394.63
6.	S6	Branded	gel	26.84	542.47
7.	S7	Local	liquid	0.12	1.27
8.	S8	Branded	gel	0.0	0.0
9.	S9	Local	liquid	0.0	0.0
10	S10	Local	liquid	0.04	0.73
11.	S11	Local	liquid	0.0	0.0
12	S12	Local	gel	0.0	0.0
13.	S13	Local	liquid	0.77	575.23
14.	S14	Local	liquid	0.0	0.19
15.	S15	Local	liquid	0.0	0.30
16.	S16	Local	liquid	0.0	2.10
17.	S17	Local	liquid	1.62	0.0
18.	S18	Branded	liquid	0.64	454.74
19.	S19	Local	liquid	0.0	0.0
20.	S20	Local	liquid	0.0	0.0
21.	S21	Branded	gel	0.0	0.0
22.	S22	Local	liquid	0.48	0.0
23.	S23	Local	liquid	0.23	379.33
24.	S24	Local	liquid	0.0	0.18
25.	S25	Local	liquid	0.0	0.55
26.	S26	Local	liquid	0.0	2.51
27.	S27	Local	liquid	0.0	0.0
28.	S28	Local	liquid	0.43	337.5
29.	S29	Local	liquid	59.57	0.0
30.	S30	Branded	gel	0.0	0.17
31.	S31	Local	liquid	0.0	5.57
32.	S32	Branded	gel	0.0	409.02
33.	S33	Branded	liquid	0.0	0.19
34.	S34	Branded	liquid	0.0	0.0
35.	S35	Local	liquid	0.0	0.0
36.	S36	Local	Liquid	0.0	0.0
37.	S37	Local	liquid	0.0	0.0
38.	S38	Local	liquid	0.0	331.45
39.	S39	Branded	gel	0.0	0
40.	S40	Local	liquid	0.0	0.0

Table 1. continued...

S.NO.	Sanitizer Sample	Branded/Local	Formulation	Ethanol (g/l)	Methanol (g/l)
41.	S41	Local	liquid	0.0	0.0
42.	S42	Branded	liquid	0.0	0.0
43.	S43	Branded	liquid	0.06	376.11
44.	S44	Local	liquid	0.12	10.03
45.	S45	Local	liquid	0.0	151.46
46.	S46	Local	liquid	132.25	0.0
47.	S47	Local	liquid	0.0	155.98
48.	S48	Local	liquid	0.0	0.0
49.	S49	Local	liquid	0.01	0.0
50.	S50	Local	liquid	0.0	5.99
51.	S51	Local	liquid	0.0	0.0
52.	S52	Branded	Gel	0.0	0.0
53.	S53	Branded	liquid	0.0	0.0

4. Discussion

Methanol or methyl alcohol, also known as wood alcohol, is a toxic chemical. It acts as a cumulative poison as it is slowly excreted from the body[18]. During metabolism, methanol is converted into formaldehyde and formic acid which are responsible for its toxic action. Accumulation of formic acid in the body can cause severe metabolic acidosis and optical atrophy[19,20]. Methanol poisoning cases have been generally reported due to inhalation and ingestion, or accidental exposure to methanol or due to consumption of illicit country liquor[21]. But since the Covid-19 pandemic, cases of methanol poisoning increased drastically and have been reported in all parts of the world. Due to non-availability of alcohol during the lockdown period, people consumed ethanol containing hand sanitizer[22-24]. As many cases of methanol poisoning were reported due to consumption of hand sanitizer and investigation in these cases revealed that methanol was found to be present in many hand sanitizers as a non-listed ingredient. Methanol is toxic to humans and long-term exposure to methanol through hand sanitizer can pose serious health risks such as damage to the liver, nervous system, blindness and even death[14,16,25]. The study highlights that it is crucial to monitor the quality control in the manufacturing of hand sanitizers.

Various new manufacturers sold hand sanitizers to meet its increased demand during the pandemic. The major concern was the quality of these products[5,26]. During the pandemic, FDA introduced a temporary policy that the quantity of methanol in ethanol containing hand sanitizer should be less than 630 ppm (0.62 g/l)[21]. This study was carried after two and a half year since the pandemic started. Hand sanitizers were still being used widely in the public places to control the transmission of SARS CoV-2. In this study, hand sanitizer samples were collected from different public places such as markets, malls etc. in Delhi. Major districts of Delhi – South Delhi, North Delhi, Central Delhi, South-West Delhi and East Delhi were covered in this study. The samples were collected during June-August 2022. GC-HS is considered the gold standard for analysis of volatiles in complex mixtures and thus was used for determination of ethanol and methanol in the hand sanitizer samples. Out of 53 samples, 14 samples were branded, and 39 samples were from local manufacturers. Out of 14 branded samples, methanol was found positive in 7 samples. In these branded hand sanitizer samples, methanol was not listed as an ingredient in composition list. And in the 39 local samples, methanol was found positive in 18 samples. This was a result of increased demand of hand sanitizer during the pandemic and uncontrolled manufacturing and sale of hand sanitizers and lack of awareness. In many sanitizer samples, unidentified volatiles were found during the analysis. More sophisticated technique such as Gas Chromatography-Mass Spectrometry (GC-MS) may be used for future studies to identify the complete composition of sanitizers and to detect other impurities or toxic substances.

In such scenarios of global health emergency, as the demand of hand sanitizer is high, but use of such spurious or low-quality products may expose the people to more risk of infection and thus analysis of such products is essential to ensure the safety of the product[14,24,26]. The results of this study highlight the need to monitor the manufacturing of hand sanitizers, particularly from local manufacturers. Production of hand sanitizers should follow the WHO recommendations[5,27]. This study provides data on ethanol and methanol content in hand sanitizer that are being used and sold in public places in Delhi. The study also highlights the need to conduct systematic surveillance throughout the country to analyse and assess the quality of hand sanitizer products. The regulatory bodies should develop policy to control the manufacturing and sale of hand sanitizer products[26-28].

5. Conclusion

GC-HS is a simple and reliable technique for analysis of volatiles and the proposed method in this study can be used for analysis of ethanol and methanol in hand sanitizer samples. The findings of this study show that majority of the hand sanitizers have very high methanol content and highlight the pressing issue of adulteration and unregulated production within the hand sanitizer market during the COVID-19 pandemic. The data obtained from this study might inform policy formulation and regulation by the Ministry of Health in India on sanitizer use and production as the presence of methanol as an unlisted ingredient in sanitizer samples pose serious health risk to consumers. The results reported in the study could serve as a baseline data for future studies and also provides valuable information to the public and thus will help in raising awareness about the severe health effects due to adulteration of methanol.

6. References

1. Güntner AT, Magro L, van den Broek J, Pratsinis SE. Detecting methanol in hand sanitizers. Iscience. 2021; 24(2):102050. https://doi.org/10.1016/j.isci.2021.102050
2. Arasteh P, Pakfetrat M, Roozbeh J. A surge in methanol poisoning amid COVID-19 pandemic: Why is this occurring? Am J Med Sci. 2020; 360(2):201. https://doi.org/10.1016/j.amjms.2020.05.019
3. Mousavi-Roknabadi RS, Arzhangzadeh M, Safaei-Firouzabadi H, Mousavi-Roknabadi RS, Sharifi M, Fathi N, Jelyani NZ, Mokdad M. Methanol poisoning during COVID-19 pandemic; A systematic scoping review. Am J Emerg Med. 2022; 52:69-84. https://doi.org/10.1016/j.ajem.2021.11.026
4. Dear K, Grayson L, Nixon R. Potential methanol toxicity and the importance of using a standardised alcohol-based hand rub formulation in the era of COVID-19. Antimicrob Resist Infect Control. 2020; 9(1):1-3. https://doi.org/10.1186/s13756-020-00788-5
5. Jairoun AA, Al-Hemyari SS, Shahwan M. The pandemic of COVID-19 and its implications for the purity and authenticity of alcohol-based hand sanitizers: The health risks associated with falsified sanitizers and recommendations for regulatory and public health bodies. Res Social Adm Pharm. 2021; 17(1):2050-1. https://doi.org/10.1016/j.sapharm.2020.04.014
6. Overbeek DL, Watson CJ, Castañeda NR, Ganetsky M. A geographically distinct case of fatal methanol toxicity from ingestion of a contaminated hand sanitizer product during the COVID-19 pandemic. J Med Toxicol. 2021; 17(2):218-21. https://doi.org/10.1007/s13181-021-00824-9
7. https://www.fda.gov/drugs/drug-safety-and-availability/fda-updates-hand-sanitizers consumers-should-not-use
8. Iranpour P, Firoozi H, Haseli S. Methanol poisoning emerging as the result of COVID-19 outbreak, radiologic perspective. Acad Radiol. 2020; 27(5):755-6. https://doi.org/10.1016/j.acra.2020.03.029
9. Mahdavi SA, Kolahi AA, Akhgari M, Gheshlaghi F, Gholami N, Moshiri M, Mohtasham N, Ebrahimi S, Ziaeefar P, McDonald R, Tas B. COVID-19 pandemic and methanol poisoning outbreak in Iranian children and adolescents: A data linkage study. Alcohol Clin Exp Res. 2021; 45(9):1853-63. https://doi.org/10.1111/acer.14680
10. Khadse PA, Murthy P. Accidental deaths from hand sanitizer consumption among persons with alcohol dependence during the COVID-19 lockdown in India: Analysis of media reports. Asian J Psychiatr. 2021; 63:102794. https://doi.org/10.1016/j.ajp.2021.102794
11. Nekoukar Z, Zakariaei Z, Taghizadeh F, Musavi F, Banimostafavi ES, Sharifpour A, Ghuchi NE, Fakhar M, Tabaripour R, Safanavaei S. Methanol poisoning as a new world challenge: A review. Ann Med Surg. 2021; 66:102445. https://doi.org/10.1016/j.amsu.2021.102445
12. Moon CS. Estimations of the lethal and exposure doses for representative methanol symptoms in humans. Ann Occup Environ Med. 2017; 29:1-6. https://doi.org/10.1186/s40557-017-0197-5
13. Berkkan A, Ulutaş OK. Analytical performance and validation of Head Space-Gas Chromatography-Flame İonization Detector (HS-GC-FID) method for alcohol content and evaluation of efficiency and possible toxicity of hand sanitizers at the time of pandemic. Rev Roum Chim. 2021; 66(6):547-56.
14. Timothy JT, Purdy SK, Shen J, Nelson FB, Mustafa R, Wiens DJ, Reaney MJ. Toxicology of alcohol-based hand rubs

formulated with technical-grade ethanol. Toxicol Rep. 2021; 8:785-92. https://doi.org/10.1016/j.toxrep.2021.03.034
15. Mihretu LD, Gebru AG, Mekonnen KN, Asgedom AG, Desta YH. Determination of ethanol in blood using Headspace Gas Chromatography with Flame Ionization Detector (HS-GC-FID): Validation of a method. Cogent Chem. 2020; 6(1):1760187. https://doi.org/10.1080/23312009.2020.1760187
16. Rafizadeh A, Kolahi AA, Shariati S, Zamani N, Roberts DM, Hassanian-Moghaddam H. The danger of the toxicity and inefficacy of alcohol-based hand rubs in Iran during COVID-19: A cross-sectional study. Antimicrob Resist Infect Control. 2023; 12(1):1-7. https://doi.org/10.1186/s13756-023-01244-w
17. Abuga K, Nyamwey N, King'ondu O. Quality of alcohol-based hand sanitizers marketed in the Nairobi metropolitan area. J Pharm Sci. 2021; 24(1):29-37. https://doi.org/10.20944/preprints202109.0427.v1
18. Seth S. Review of Forensic Medicine. Peepee Publishers and Distribution; 2018.
19. Pressman P, Clemens R, Sahu S, Hayes AW. A review of methanol poisoning: A crisis beyond ocular toxicology. Cutan Ocu Toxicol. 2020; 39(3):173-9. https://doi.org/10.1080/15569527.2020.1768402
20. Aggarwal S, Vijayakumar S, Singh R, Koner BC, Saijpaul R, Kumar N, Kumar A, Mittal T. Pitfalls of sanitizer use in the COVID-19 Era: A case report of hand sanitizer-induced blindness due to contamination by methanol. MAMC J Med Sci. 2022; 8(3):278.
21. Jang M, Yang H, Shin G, Koo JM, Hwang SY, Park J, X Oh D. Determination of methanol in commercialized alcohol-based hand sanitizing and other similar products using headspace GC-MS. Curr Anal Chem. 2022; 18(7):774-80. https://doi.org/10.2174/1573411018666220107145321
22. Holzman SD, Larsen J, Kaur R, Smelski G, Dudley S, Shirazi FM. Death by hand sanitizer: Syndemic methanol poisoning in the age of COVID-19. Clin Toxicol. 2021; 59(11):1009-14. https://doi.org/10.1080/15563650.2021.1895202
23. Yip L, Bixler D, Brooks DE, Clarke KR, Datta SD, Dudley Jr S, Komatsu KK, Lind JN, Mayette A, Melgar M, Pindyck T. Serious adverse health events, including death, associated with ingesting alcohol-based hand sanitizers containing methanol- Arizona and New Mexico, May-June 2020. Morb Mortal Wkly Rep. 2020; 69(32):1070. https://doi.org/10.15585/mmwr.mm6932e1
24. Chan AP, Chan TY. Methanol as an unlisted ingredient in supposedly alcohol-based hand rub can pose serious health risk. Int J Environ Health Res. 2018; 15(7):1440. https://doi.org/10.3390/ijerph15071440
25. Kweon H, Choi JW, Yoon SY. Analysis of consumer exposure cases for alcohol-based disinfectant and hand sanitizer use against coronavirus disease 2019 (covid-19). Int J Environ Health Res. 2021; 19(1):100. https://doi.org/10.3390/ijerph19010100
26. Matatiele P, Southon B, Dabula B, Marageni T, Poongavanum P, Kgarebe B. Monitoring quality of alcohol-based hand sanitizers used in Johannesburg area during the Covid-19 pandemic. 2021. https://doi.org/10.21203/rs.3.rs-612413/v1
27. Butt MH, Ahmad A, Misbah S, Mallhi TH, Khan YH, Muhammad K, Iqbal Z. Ensuring the quality and appropriate use of hand sanitizers during the COVID-19 pandemic: Suggestions and recommendations with the role of the pharmacist. Disaster Med Public Health Prep. 2022; 16(5):1708-9. https://doi.org/10.1017/dmp.2021.55
28. Jairoun AA, Al-Hemyari SS, Shahwan M. The pandemic of COVID-19 and its implications for the purity and authenticity of alcohol-based hand sanitizers: The health risks associated with falsified sanitizers and recommendations for regulatory and public health bodies. Res Social Adm Pharm. 2021; 17(1):2050-1. https://doi.org/10.1016/j.sapharm.2020.04.014