





# Surface Disinfection Practice in Public Hospitals in the Era of COVID-19: Assessment of Disinfectant Solution Preparation and Use in Addis Ababa, Ethiopia

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**Background:** Surface disinfection of healthcare facilities with appropriate disinfectants is among the infection control strategies against the spread of coronavirus disease 2019 (COVID-19). As sodium hypochlorite solution (SHS) is a commonly used surface disinfectant, its preparation and proper use should be given a due attention. The current study aimed at assessing the practice of Addis Ababa public hospitals in the preparation and use of SHS.

**Methods:** A cross-sectional observational study was employed to assess the adequacy of disinfectant solution preparation and use. Checklists were used for data collection. Descriptive statistics were used for data analyses, and categorical variables were described by frequencies and percentages.

**Results:** Out of the twelve public hospitals included in the study; only three hospitals checked the potency of the working SHS. Majority of the hospitals (8 hospitals) stored the concentrated SHS products in cool, dry, and direct sunlight protected places. It was only in one hospital where appropriate personal protective equipment was used during the preparation and quality control activities. Surfaces were not cleaned in all hospitals before disinfection; and the rooms were ventilated only in 2 hospitals during the application of the disinfectant solution.

**Conclusion:** The study revealed that the preparations of SHS in the public hospitals did not comply with most of the requirements of good compounding practice. Moreover, standard practices were not maintained in majority hospitals during the use of SHS for surface disinfection. As a control strategy in the spread of COVID-19 and other infections, appropriate corrective actions shall be implemented in the studied hospitals to mitigate the limitations observed in the preparation and use of SHS.

**Keywords:** compounding, COVID-19, disinfectants, proper use, public hospitals, sodium hypochlorite solution

## Introduction

The emergence of the COVID-19 (Coronavirus Disease-2019) pandemic has become a significant global public health concern. The prevention and control measures for the spread of coronavirus include hand hygiene, disinfection of surfaces, avoidance of touching one's face, and use of face masks and they are effective when combined.<sup>1,2</sup>

Contaminated surfaces are an important potential source for transmission of coronavirus and many other healthcare-associated pathogens.<sup>3,4</sup> Severe acute respiratory syndrome, coronavirus 2 (SARS-CoV-2), the virus for COVID-19, can remain on surfaces viable for between eight hours and several days, depending on the type of surface.<sup>5-7</sup> Surfaces become contaminated when virus-containing droplets land on them, or when someone with contaminated hands touches

the surfaces. Decontamination of the healthcare environment is therefore vital because it can efficiently disrupt the lipid envelope of coronavirus.<sup>7,8</sup> The term disinfection describes a process that eliminates many or all pathogenic microorganisms, except bacterial spores, on inanimate objects.<sup>9</sup>

Effective infection prevention and control programs help in the reduction of healthcare-associated infections (HCAIs) and prevent morbidity and mortality and also reduce healthcare costs.<sup>10</sup> The World Health Organization (WHO) recommends implementation of appropriate environmental cleaning and disinfection procedures in hospitals using disinfectants such as sodium hypochlorite solution.<sup>11</sup>

In hospitals, compounding practice is practiced when the market failed to provide medicines and disinfectants in the required dosage form and strength.<sup>12</sup> Supply and stability issues of disinfectants in the market call attention for its preparation at the point of care. During the preparation, principle of good compounding practice (GCP) shall be implemented to assure the products' quality and protect compounders and the environment from chemical exposure. The requirements of GCP include use of appropriate ingredients, equipment, and premises for compounding and storage; maintaining sanitation and hygiene during preparation; applying quality control activities; involvement of qualified personnel; and documentation.<sup>13</sup>

Environmental surfaces in healthcare settings include furniture and other fixed items inside and outside of patient rooms and bathrooms, such as tables, chairs, walls, light switches, etc. These surfaces are likely to be contaminated with the COVID-19 virus and must be properly cleaned and disinfected to prevent further transmission.<sup>7,14,15</sup> Several studies indicated the effectiveness of surface disinfection to prevent the secondary transmission of SARS-CoV-2.<sup>5,16–18</sup> Various disinfectants have been recognized and used against SARS-CoV-2 in different environments. These include chlorine-containing disinfectants, alcohol, hydrogen peroxide, and others.<sup>19,20</sup> Hypochlorites are widely used in healthcare facilities in a variety of settings. For disinfection of noncritical surfaces and equipment, a 1:10 to 1:100 dilution of 5.25% to 6.15% sodium hypochlorite (ie, household bleach) has been recommended for decontamination.<sup>21</sup>

Organic matter can impede direct contact of a disinfectant to a surface and inactivate several disinfectants' germicidal properties or modes of action. The disinfectant concentration which is directly affected by dilution accuracy<sup>22</sup> and contact time are also critical for effective surface disinfection. Target microorganisms; application surfaces; compatibility, toxicity, stability and ease of use are among the criteria for selection of disinfectants. For the prevention of COVID-19 transmission, standard disinfectant preparation and surface disinfection procedures should be followed.<sup>7,23</sup>

During the COVID-19 pandemic, the cleaning and disinfection of environmental surfaces shall take place on a regular basis. It should follow detailed standard operating procedures (SOPs) with a clear delineation of responsibilities (eg, housekeeping or clinical staff) regarding the type of surfaces and frequency of disinfection of surfaces.<sup>7,23</sup> Since effective cleaning and disinfection remain the cornerstone of environmental control programs, strategies should be devised to monitor cleaning and ensuring the adequacy of the disinfection practices.<sup>9</sup> In general, the use of the chosen disinfectant, at the appropriate concentration and for the appropriate time, should kill pathogenic microorganisms including SARS-CoV-2, rendering an object and environment safe for use.

Some studies have demonstrated contamination of surfaces after completion of a cleaning and disinfection process. Such contamination has been attributed primarily to poor quality products and suboptimal application of disinfectants, a common problem in healthcare facilities.<sup>4,24,25</sup> Moreover, the pandemic has created a shortage of supplies such as disinfectants, compounding and quality control equipment, and personal protective equipment (PPE) that make the preparation of the disinfectants at the hospital level and their proper use challenging. Lack of necessary information, including correct methods of preparation and application of disinfectants, use of PPE during the application of disinfectants, and safe storage of disinfectants were also reported somewhere else<sup>20,26</sup> as gaps in preparation and use of disinfectants in healthcare settings.

Most African countries had been struggling to contain the rapidly spreading pandemic due to weak healthcare system and limited resources, and Ethiopia is not an exception. As of 13 October 2022, Ethiopia has reported 493,723 confirmed cases of COVID-19 with 7572 deaths.<sup>27</sup> Following the COVID-19 outbreak, various healthcare facilities in Ethiopia have started compounding of different disinfectant solutions, mainly sodium hypochlorite solutions (SHS), at the facility level. The effectiveness of disinfectant products is dependent on their quality and rational use. These compounded products are required to meet minimum regulatory requirements and quality standards. Moreover, standard practices need to be

followed during the application of the disinfectant on surfaces in the healthcare settings; which if violated may result in health risks for patients, healthcare providers, compounders, cleaning staff, and the environment. Hence, the present study focused on the evaluation of the adequacy of SHS preparation and utilization practice for surface disinfection in the era of COVID-19 in public hospitals found in Addis Ababa, Ethiopia.

## Methods

### Study Design and Settings

An observation-based cross-sectional study design was employed to assess the disinfectant solution preparation and the disinfection practice in the study hospitals. The current assessment was conducted in all of the 12 public hospitals found in Addis Ababa, Ethiopia. The hospitals are referral and provide all types of clinical services. They serve large number of people coming from different parts of the country (during a period of July 2021–June 2022, a total of 1,930,675 outpatient visits were recorded in the hospitals). The list of hospitals included in this study is indicated in Table 1. The study was conducted between May and June 2022.

### Sample Size and Sampling Technique

A purposive sampling technique was used for the current study. All public hospitals having disinfectant solution preparation units and those using their disinfectant solutions for surface disinfection purposes were included in the study. Therefore, a total of 12 hospitals from Addis Ababa were purposively selected and included in the study.

### Eligibility Criteria

Public hospitals with functional disinfectant solution preparation unit and implementing surface disinfection in their compound during the study period were included in the study.

### Data Collection Procedure

The data for the study were collected at disinfectant solution preparation units and at places where surface disinfections were taking place in the study hospitals. Data collection was done using checklists that were prepared by adopting standard documents of WHO, Federal Ministry of Health-Ethiopia, and USP.<sup>23,28–30</sup> The preparation units and surface

**Table 1** List of Public Hospitals Included in the Study in Addis Ababa, Ethiopia, 2022

S.N	Public Hospitals
1	Tikur Anbessa Specialized Hospital
2	St Paul Hospital Millennium Medical College
3	All African Leprosy, Tuberculosis Rehabilitation and Training Centre Hospital (ALERT) Hospital
4	Eka Kotebe General Hospital
5	St Peter Specialized Hospital
6	Menelik II Referral Hospital
7	Yekatit 12 Hospital Medical College
8	Tirunesh Beijing Hospital
9	Gandhi Memorial Hospital
10	Zewditu Memorial Hospital
11	Amanuel Mental Specialized Hospital
12	Ras Desta Damtew Memorial Hospital

disinfection places were observed in addition to the compounders and cleaning staff to assess the compliance with the practice to requirements for disinfectant solution preparation and use. The observation checklists were comprised of closed-ended items on the preparation of disinfectant solutions and quality control activities; adequacy of premises; the adequacy of storage practices; hygiene, sanitation, and personnel protection; recording and documentation; and availability of trained personnel. Additionally, the surface disinfection processes in the hospitals were investigated for their rationality. Data collectors were trained for two days on the study's purpose, details of the data collection checklist, ensuring the participants' confidentiality, and COVID-19 prevention methods. Follow-up and supervisions were done by the principal investigators throughout the data collection period. The supervision focus includes on complying of data collectors to the COVID-19 prevention measures, their visit to the compounding and disinfection areas, their involvement in checking the presence of working documents, etc.

## Data Quality Assurance

The data collection tools were reviewed by the experts from Addis Ababa University and Ethiopian Food and Drug Authority. Revision of the data collection tools according to the existent situation was done before the real data collection. Data consistency and correctness were ensured throughout the data collection, data entry, and analysis by cross-checking the hard copy of the checklists containing the data with the database.

## Data Analysis

The data were entered and analyzed using Statistical Package for IBM Social Sciences (SPSS) version 25. Descriptive statistics were used for analyses of data. Categorical variables were described by frequencies and percentages.

## Ethical Approval and Consent to Participate

Ethical approval was obtained from the Ethical Review Board of School of Pharmacy, Addis Ababa University (ERB/SOP/422/14/2022). An informed consent to participate in the study was obtained from each participant of the study hospitals. Participation was voluntary, and participants (pharmacy professionals and cleaners) were aware of their rights to withdraw from the study at any time. The data obtained from the observation were kept confidential.

## Results

All the 12 public hospitals were observed for the assessment of their compliance with the practice at the time of compounding of SHS and surface disinfection.

### Compounding of SHS

#### The Premise for the Compounding and Quality Control Activities

Of the 12 hospitals included in the study, only 5 (41.7%) and 1 (8.3%) hospitals had a dedicated room for compounding and quality control (QC) activities, respectively. It was only in 3 (25%) hospitals where the preparation of SHS was carried out in well-ventilated areas (Table 2).

**Table 2** Adequacy of Premises for the Preparation and QC of SHS in Public Hospitals, Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
Dedicated room for compounding is available	5 (41.7%)	7 (58.3%)
The compounding room/area is located away from high traffic area	3 (25.0%)	9 (75.0%)
The compounding room/area is well-ventilated	3 (25.0%)	9 (75.0%)
The compounding room/area is protected from direct sunlight	8 (66.7)	4 (33.3%)
A dedicated room is available for QC tests	1 (8.3%)	11 (91.7%)

### Compounding and QC Activities

Among the study hospitals, it was only in one hospital where the preparation of SHS was made in a dedicated compounding room. All of the hospitals failed to follow SOP during the preparation of the disinfectant. Only one hospital verified the strength of the undiluted SHS before operation (Table 3).

### Storage Premise and Condition

All 12 hospitals consumed the final diluted SHS within 24 hours. More than half of the hospitals (80%) stored the concentrated SHS in sunlight-protected places (Table 4).

### Hygiene, Sanitation and Personnel Protection

In all of the hospitals, the operator/s did not wash their hands before starting the compounding process. Appropriate PPE was not used by most of the hospitals (91.7%) during the preparation of the SHS (Table 5). The preparation areas were not cleaned both before and after the activity in all hospitals.

### Documentation and Recording

The SOP for the production and QC operation of the SHS were found to be available only in 2 and 1 hospitals, respectively. Only a quarter of the hospitals had distribution records for the prepared SHS. Majority of the hospitals (66.7%) had reference documents for the preparation of SHS (Table 6).

**Table 3** Compounding and QC Activities for Sodium Hypochlorite Working Solution in Public Hospitals, Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
All the necessary raw materials and equipment are ready in the working area before starting the compounding	6 (50.0%)	6 (50.0%)
Preparation is made in a dedicated compounding room	1 (8.3%)	11 (91.7%)
The expiry date of the undiluted SHS/starting material is checked	1 (8.3%)	11 (91.7%)
The quantity of each ingredient (water, undiluted SHS and salt) is measured	8 (66.7%)	4 (33.3%)
The compounder follows SOP during the preparation of SHS	–	12 (100%)
The strength of the undiluted SHS is determined*	1 (10%)	9 (90%)
The strength of the final working SHS is determined	3 (25%)	9 (75%)
The product/dispensing container is checked for the presence of label and its comprehensiveness	–	12 (100.0%)
SOP is followed during QC testing	1 (8.3%)	11 (91.7%)

**Note:** \*Only 10 hospitals which used the concentrated SHS as starting material were considered.

**Table 4** Storage Premise and Condition for the SHS at the Public Hospitals in Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
A separate storage room for raw materials was available	3 (25.0%)	9 (75.0%)
The concentrated SHS was stored in a cool and dry place in a way protected from direct sunlight*	8 (80%)	2 (20%)
The final diluted product was stored in a cool and dry place in a way protected from direct sunlight	7 (58.3%)	5 (41.7%)
The final diluted product was used within 24 hours	12 (100%)	–

**Note:** \*Only hospitals which use household bleach as starting material are considered.

**Table 5** Hygiene, Sanitation, and Personal Protection During the Preparation and QC of SHS in Public Hospitals, Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
The operator/s washed hands before starting the compounding process	–	12 (100%)
The operator/s worn appropriate PPE (glove, medical mask, eye google, apron/gown, and closed shoes) during compounding	1 (8.3%)	11 (91.7%)
The operator/s worn appropriate PPE (glove, medical mask, eye google, and apron/gown) during QC activities	1 (8.3%)	11 (91.7%)
The compounding area/space was cleaned before and after the operation	–	12 (100%)
All working equipment was cleaned before and after the compounding activity	–	12 (100%)

**Table 6** Availability of Documents and Records for the Preparation and QC Activities of SHS in Public Hospitals, Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
An SOP for the compounding of SHS is available	2 (16.7%)	10 (83.3%)
An SOP for the QC operation of SHS is available	1 (8.3%)	11 (91.7%)
An SOP for cleaning of premises and equipment available	–	12 (100.0%)
A record for the distribution of the final product is available	3 (25.0%)	9 (75.0%)
Document on safety and precaution measures available	–	12 (100.0%)
Reference documents/books/guidelines available	8 (66.7%)	4 (33.3%)

### Compounding Personnel

All the studied hospitals had dedicated teams for the preparation of SHS. It was only in a single hospital that the compounding was performed by pharmacy professionals. Compounders in more than half of the hospitals (58.3%) did not take training on disinfectant preparation.

## Use of Disinfectants for Surface Disinfection

### Disinfection Process

Out of the 12 hospitals, only 3 hospitals applied the SHS only on non-metallic surfaces. Half of the hospitals included in this study gave sufficient contact time for the SHS with the surfaces in which the solution was applied. None of the hospitals cleaned the surfaces before disinfection and the majority (83.3%) did not wear the appropriate PPE during disinfection (Table 7).

### Documentation and Cleaning Personnel

Relevant documents for the effective use of SHS such as SOP for proper use, safety and precaution guideline, and records of the disinfection process were not available in all hospitals. It was also reported that only persons in 4 of the hospitals (33.3%) took formal training on the surface disinfection process using SHS.

## Discussion

COVID-19 has confirmed the central role that infection prevention and control play in the prevention and containment of outbreaks in healthcare facilities and in the community.<sup>31</sup> There is increasing evidence that rigorous disinfection is needed to prevent surface transmission of coronavirus 2<sup>32</sup> as the virus can remain viable on surfaces for days. Potentially

**Table 7** Disinfection of Surfaces Using SHS in Public Hospitals, Addis Ababa, Ethiopia

Parameters	Observations	
	Yes	No
A mechanical applicator/spraying equipment is used for the surface disinfection process	10 (83.3%)	2 (16.7%)
Disinfection was done only on non-metallic surfaces	3 (25.0%)	9 (75.0%)
The rooms were ventilated during the application of a disinfectant solution	2 (16.7%)	10 (83.3%)
There was sufficient contact time (10 min) after the application of the disinfectant solution	6 (50.0%)	6 (50.0%)
The rooms/surfaces were cleaned before disinfection	-	12 (100.0%)
The cleaners used appropriate PPE (glove, eye google, medical mask, gown, and closed shoes) during surface disinfection	2 (16.7%)	10 (83.3%)

contaminated surfaces must be frequently cleaned and disinfected to prevent further spread of the virus. The selected disinfectant products should be recognized as being effective in killing the COVID-19 virus.

Most healthcare facilities in Ethiopia and other developing countries are commonly using SHS as a surface disinfectant mainly due to its low cost and relatively simple preparation technique (ie, dilution) in comparison with other disinfectants. The use of this product for surface disinfection in healthcare facilities and other environmental places is increasing amid COVID-19.

Although new cases, hospitalizations, and deaths due to COVID-19 are down in Ethiopia, the implementation of various infection control strategies need to continue until the pandemic is under control worldwide. Surface disinfection in healthcare facilities is among the measures exercised in hospitals to control the spread of SARS-CoV-2 and other pathogens responsible for HCAs. Sodium hypochlorite solution, at a concentration of 0.1 to 0.5% is a commonly used hospital-level disinfectant that is applied on environmental surfaces in Ethiopian healthcare facilities.<sup>33</sup>

The current study evaluated the practice of sodium hypochlorite working solution preparation and its use for surface disinfection in public hospitals during the time of COVID-19 crisis. At the time of observation, most of the hospitals (75%) prepared less than 50 liters of SHS at once. Ten of the studied hospitals used commercial household bleaches as starting materials which are to be diluted and the rest two hospitals prepared the working SHS using on-site chlorine generator machines. In all the hospitals, where concentrated household bleach was available, a manual dilution method was followed for the preparation of the working SHS of the required strength (ie, 0.5%).

The present study showed the availability of compounding rooms in 5 of the 12 hospitals. However, except in one hospital where SHS was prepared in the dedicated compounding room, the preparations of the disinfectant solution in the rest of the hospitals were carried out in other rooms, corridors, and, in some cases, in toilets which were not convenient and difficult to adhere with the standard compounding practice. It was only in 3 hospitals where the preparation areas were properly ventilated which is necessary during handling of such chemicals.

During the preparation of the SHS in the studied hospitals, gaps were identified in that none of them did the dilution process by following the working document (ie, SOP), 91.7% did not check the starting household bleach for its usable shelf life, the strength of the undiluted and the working solutions, and none of them checked the dispensing container for the labeling information. This indicates the insufficiency of the disinfectant preparation to the standard practice. Generally, disinfectants must be used in the dilution specified by the manufacturer or reference documents for optimal decontamination and hence attention must be given to quality control activities as the germicidal activity of SHS depends on its concentration. Commercially available household bleaches with claimed potency of 3–5% are the main sources of concentrated SHS for the healthcare facilities in the country in which the strength of the disinfectant shall be verified with appropriate tests before dilution. Failing to verify the potency of the starting SHS may lead to an incorrect dilution that will affect the strength of the final working solution and its effectiveness. In addition, the working SHS of higher strength resulting from incorrect dilution may expose compounders and cleaners to this hazardous chemical during preparation and disinfection, respectively, if handled inappropriately. Three hospitals used to check the potency of the working SHS



with chemical titration technique (1 hospital) and test strips (2 hospitals), but the majority did not conduct the test which could be due to the absence of a test strip in the domestic market which is a relatively simple testing method for checking the potency.

Moreover, the disinfectant containers should be labeled with the relevant information such as product name, strength, warnings, and expiry date to ensure that the right product is selected for the intended use. Labels should also show directions for users, which can be read clearly, to reduce improper use and prevent unnecessary chemical exposures.<sup>34</sup> None of the hospitals read the labels for the information from the containers collected from the compounding unit. Lack of some of the malpractices observed in the preparation and QC activities by the public hospitals may be due to the use of the working solution at or around the preparation area immediately or within a short period after the preparation is over.

The SHS is generally unstable and the available chlorine concentration deteriorates with time if exposed to light and heat.<sup>35,36</sup> Therefore, the SHS should be stored properly and used in the recommended usable time. The current study revealed that most of the hospitals (80%) complied with the storage requirements for the concentrated SHS products in that they were stored in cool, dry places, and protected from sunlight. Ideal SHS should be prepared fresh every day which otherwise needs to be tested for potency if used for days.<sup>37</sup> With this aspect, all the public hospitals prepared and used the fresh SHS within a day for surface disinfection.

Another huge gap was also observed from the hospitals with regard to PPE use both in the preparation and disinfection time. When disinfecting a healthcare setting, WHO recommended to use, at minimum, rubber gloves, waterproof aprons, eye protection, medical masks, and closed shoes to protect against chemicals.<sup>38</sup> Only one and two hospitals were found to wear the minimum PPE during the disinfectant preparation and use, respectively. Such inadequate implementation of good practice leads to the exposure of workers to chemicals and occupational risks. The domestic household bleach at its concentration (ie, 3–5%) may produce ocular irritation or oropharyngeal, esophageal, and gastric burns if handled inappropriately.<sup>33,39</sup> A study done in the United States to characterize knowledge and practices of disinfection during the COVID-19 pandemic identified knowledge gaps in the safe preparation of disinfectant solutions, use of recommended PPE, and safe storage of disinfectants.<sup>26</sup> When using chlorine-based disinfectants, the proper barrier protection should be used.<sup>40</sup> The poor practice of wearing appropriate PPE in the investigated hospitals may be due to the shortage of PPE materials, lack of awareness of their potential benefits, or the health workers' negligence. Insufficient PPE supplies for the workers in developing countries' healthcare facilities were also reported elsewhere during the COVID-19 pandemic.<sup>40</sup> WHO also reported that in response to COVID-19, countries allocated more budgets for the procurement of PPE, hand hygiene, and cleaning supplies.<sup>31</sup>

It is clearly indicated that GCP encompasses good documentation as standard of practice<sup>29</sup> as it gives clear directions on the safe and precise practice of compounding and QC and other operations and minimizes the risk of errors. Appropriate documents should be maintained in a hospital compounding unit so that preparations can be replicated consistently and the safety of compounders is ensured.<sup>41</sup> Majority of the hospitals in the current study had poor documentation, and it is only in very few hospitals that SOP for SHS preparation and QC activities were obtained. Caution must be exercised to avoid hazards with handling or using disinfectants. With respect to the availability of precautionary documents, none of the hospitals had such document for the safe handling, processing and use of SHS. This type of document usually contains information about health hazards associated with specific disinfectants and suggestions on how individuals can protect themselves against those health hazards while handling the products.<sup>42</sup>

Although the presence of a dedicated team in all hospitals for the preparation of SHS is a good start, the assignment of personnel with appropriate knowledge, skill, and experience for the practice is lacking and this personnel issue should not be overlooked. Though the preparation of SHS for surface disinfection purpose is simple and involves the dilution of the concentrated solution, basic knowledge and skill in compounding are essential to prepare quality products and protect oneself and the environment from unwanted chemical exposure. In this regard, the engagement of pharmacy professionals in the compounding service is an essential step towards strengthening the practice at the hospital level. It is only in one hospital that the SHS preparation was run by pharmacy professionals which may be due to the absence of compounding practice in most of the hospitals, as evidenced by the lack of compounding premises, where pharmacy professionals are mostly involved. Compounders in more than half of the study hospitals (58.3%) engaged in the



preparation of SHS without taking training on GCP which might contribute to the substandard practices observed during the product preparations.

Even if the commonly used disinfectants meet the safety standards, if the instructions for their use are not followed correctly, they may be harmful to the health of workers. Therefore, before use, it is necessary to properly understand the method of use, precautions, and first-aid measures recommended for the disinfectant product.<sup>40</sup> The disinfectant concentration and contact time are the two key variables determining the efficiency of disinfection using SHS.<sup>35</sup> Items and surfaces must be exposed to the germicide for the appropriate minimum contact time using the correct potency of disinfectants. It is recommended to expose the items and surfaces to the SHS disinfectant for a minimum of 10 minutes to get the desired germicide effect<sup>28,40</sup> though the contact time varies depending on the concentration of disinfectant and the nature of surfaces or items to be decontaminated. In half of the facilities (6 hospitals), the applied surfaces were wiped and back into business before the indicated contact time has passed.

Hypochlorites are known to have some disadvantages including corrosiveness to metals, inactivation by organic matter, discoloring or “bleaching” of fabrics, and release of toxic chlorine gas when mixed with ammonia or acid.<sup>35,39</sup> Hence, to perform disinfecting operations effectively, it is necessary to understand both the chemical properties of sodium hypochlorite and the mechanisms by which microbes are killed.<sup>35</sup> The interference of germicidal activity of SHS in the presence of organic matter emphasizes the importance of meticulous cleaning (with detergent or soap and water) as a pretreatment step to perform disinfection efficiently. All hospitals in the current study did not clean the environmental surfaces before applying the SHS which could have helped in reducing the microbial load on the contaminated surfaces. Moreover, it was only in 3 hospitals where disinfections were carried on non-metallic surfaces/items, but the disinfectant solution was applied on both metallic surfaces (like door handles and beds) and non-metallic surfaces in the rest of the hospitals. When applied on metallic surfaces repeatedly, the SHS may have negative results on the life of buildings and equipment. It is reported that some damages were observed on the hospital furniture, surgery tools, and equipment due to disinfection treatment by various chemicals.<sup>43</sup> Hence, the selection of disinfectant type and its concentration should consider its damaging effects on the surfaces.

Moreover, while disinfection of the surfaces was undergone, rooms of 10 hospitals (83.3%) under the study were not well-ventilated. Disinfectant solutions should always be prepared and used in well-ventilated areas. When applying the SHS, the doors or windows should be left open, and fans can be used, if possible, to protect the operator from the chemical risk.<sup>28,38,44</sup> Exposures to chemicals associated with increased use of disinfectants have also been reported in a literature due to improper use, not wearing protective gear, and applying in poorly ventilated areas.<sup>34</sup>

It is dangerous to use SHS inappropriately because the effectiveness of its performance can be overestimated. The chemicals should only be used after providing training to the workers to familiarize them with the required information.<sup>40</sup> It is recommended that hospitals should provide training for cleaners and other staff in order to fully comply with the standard of practice required to disinfect SARS-CoV-2 on surfaces.<sup>35</sup> The training has to be audited, and feedback should be obtained.

Regular disinfection of surfaces in hospitals is among the simple strategies to control the spread of COVID-19 and other HCAs. In spite of the introduction of new disinfectants, due to the numerous advantages, the wide use of SHS is likely to continue in hospitals and other healthcare settings. Hence, considerable attention should be given to the preparation of this product and its appropriate use to maximize the benefits. Despite the challenges, the Ethiopian hospitals are facing during the COVID-19 pandemic, there is an urgent need to bridge the gaps identified in the preparation and use of disinfectants to ensure the quality of care and health workers' safety.

## Limitations of the Study

A single-time observation at the study settings may not reflect the real practice of the hospitals which makes the generalization of the findings difficult.

## Conclusion

The preparation of SHS in the public hospitals did not comply with most of the requirements of GCP. Only one hospital verified the potency of concentrated SHS and 33.3% of the studied hospitals did not store this starting material in

a proper place. It was only in one hospital that appropriate PPE was used properly, indicating that the operators in majority of the hospitals are at risk of exposure to hazardous chemicals. Moreover, majority of the hospitals lack the documents that are relevant for compounding operations, QC activities, and precautionary measures.

Similar negligence of standard practice was observed during the use of SHS for the surface disinfection in most of the studied hospitals. Only 3 hospitals applied the SHS only on non-metallic surfaces and none of the hospitals cleaned the surfaces before disinfection which could lower the germicidal effect of the product. In the majority hospitals (83.3%), the rooms were not well-ventilated during the application of SHS on surfaces. Cleaners in only 4 of the hospitals (33.3%) took formal training about the surface disinfection process.

In general, much has to be done in standardizing the compounding practice and use of SHS for surface disinfection in public hospitals to control the spread of COVID-19 and other HCAIs.

## Recommendations

The health workers handling disinfectants should be informed about the potential work hazards and trained on associated safety practices, procedures, and protective measures.

The Ministry of Health-Ethiopia shall continuously assess the health facilities for the proper use of SHS for surface disinfection and provide feedback for the improvement of the practice. The Ethiopian Food and Drug Authority shall regularly inspect the hospitals' compounding premises and their activities and provide guidance for compliance with regulatory standards.

Effective on-job training programs should be implemented for hospitals' workers involving in the disinfectant solution preparation and surface disinfection to ensure the adherence to rational practices, especially during the COVID-19 pandemic. Additionally, to promote best practices, hospitals that showed good compounding and disinfection practices shall share their experiences to the other hospitals.

## Data Sharing Statement

The datasets used for this publication can be obtained from the corresponding author on reasonable request.

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## Author Contributions

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current journal; gave final approval of the version to be published; and agreed to be accountable for all aspects of the work.

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## Disclosure

The authors declare no conflicts of interest in this work.

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