

Article

Factors Influencing Compliance with COVID-19 Disinfection Safety Guidelines among Disinfection Workers in South Korea

Seulki Son ¹, Yoon Hyeon Lee ² and Sarang Jang ^{3,*}

¹ Graduate School of Public Health, Seoul National University, Seoul 08826, Republic of Korea; estherish@snu.ac.kr

² Department of Health Administration, Namseoul University, Cheonan 31020, Republic of Korea; skylee@nsu.ac.kr

³ Department of Public Health, Sahmyook University, Seoul 01795, Republic of Korea

* Correspondence: jangsarang@gmail.com

Abstract: The Coronavirus Disease 2019 (COVID-19) pandemic has increased the global demand for disinfection services. Disinfection work involves specialized expertise in the use of chemicals and equipment. However, many studies have not illuminated the essential knowledge and practices of disinfection workers. This study aims to investigate factors influencing disinfection practices to enhance the quality and safety of infection-control measures. A cross-sectional descriptive study among 215 disinfection workers in South Korea was undertaken. The survey questionnaire was designed to collect information on demographic characteristics, disinfection methods, knowledge of COVID-19 disinfectants and their application, and the use of personal protective equipment. Data were analyzed using SPSS 26. Participants who received COVID-19 disinfection training had more knowledge regarding disinfectant products, demonstrated greater adherence to disinfection guidelines, and used more disposable PPE items. The multiple linear regression analysis revealed that being female, completing prior training on COVID-19 disinfection, obtaining disinfectant information through official education, and possessing a subjective awareness of COVID-19 disinfectants and disinfectant knowledge were associated with increased compliance with guidelines for disinfection. This study revealed a gap between perceived compliance and actual knowledge between groups. These findings highlight the importance of retraining disinfection workers, enhancing their qualifications, and promoting responsible disinfection practices.

Keywords: COVID-19; disinfection workers; disinfection practice and knowledge; personal protective equipment



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1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has heightened the global awareness of the crucial role of hygiene and sanitation practices, leading to the widespread adoption of disinfection, resulting in an increased demand for professional disinfection services, particularly in health facilities and public spaces [1]. This has led to a significant increase in the number of pest control and disinfection businesses in South Korea, from approximately 5300 in 2016 to 10,876 as of July 2023 [2]. The shift in the main scope of workers' jobs from pest control to disinfection has increased their exposure to disinfectants, potentially affecting their health [3]. A knowledge of the disinfectant ingredients, proper equipment handling techniques, and potential hazards, informed by official governmental safety guidelines, are essential.

The World Health Organization (WHO) provides technical guidance on disinfection in situations involving COVID-19, such as the concentration and contact time of the solution, equipment including personal protective equipment (PPE), the importance of training, and identification of areas requiring disinfection [4]. The guidelines also state that spraying or fumigating outdoor spaces such as streets or marketplaces is not recommended for

eliminating viruses or pathogens and spraying porous surfaces such as sidewalks is even less effective. The WHO strongly advises against spraying individuals with disinfectants in tunnels, cabins, or chambers, because it is ineffective in reducing virus transmission and can cause physical and psychological harm. Likewise, the United States Centers for Disease Control and Prevention (CDC) suggests a low risk of infection through surface contact with the coronavirus [5]. Daily cleaning is sufficient in confirmed or suspected COVID-19 cases, and the Environment Protection Agency's List N disinfectants are recommended to eliminate the remaining virus on surfaces. Areas with a high population density, poor ventilation, limited access to handwashing facilities or hand sanitizers, or where vulnerable individuals reside may require more frequent cleaning and disinfection. However, the guidelines do not specify the exact frequency of these practices. Similarly, the Korean CDC (KCDC) also recommends regular cleaning and disinfection to prevent the spread of COVID-19 [6]. Disinfectants containing specific concentrations of sodium hypochlorite and wiping surfaces after their application is recommended. Furthermore, avoiding spraying or misting disinfectants is recommended.

During the initial phase of the COVID-19 pandemic, it was evident that a lack of awareness regarding the proper use of disinfectants led to confusion. This resulted in high-risk behaviors such as excessive disinfectant use beyond the recommendations of the CDC and an increased frequency of inappropriate human exposure to disinfectants [7]. Particularly concerning was the widespread dissemination of misinformation regarding disinfectant use, underscoring the need for the government to prioritize effective health communication [8]. In healthcare settings, a diverse range of methods for infection control was proposed, including the use of chemical-based disinfectants as well as non-contact methods like ultraviolet (UV) disinfection and materials to prevent transmission [9]. In Korea, although healthcare facilities generally managed cleaning and disinfection well during the early stages of the pandemic, there was a recognized need for developing specific guidelines [10]. Furthermore, even when disinfection guidelines were unclear, extensive disinfection practices were prevalent in everyday settings [11]. Although basic surface cleaning proved effective when areas were left unoccupied for approximately a week, the prevalent approach in South Korea involved the application of disinfectants through spraying [11].

Pest control and disinfection services, recognized as specialized professions registered in many countries [12,13], involve the control and eradication of pests and disinfection in residential and commercial buildings. The qualifications and renewal requirements of pest control operators are governed by the California Department of Pesticide Regulation [14], and the Structural Pest Control Board (SPCB) classifies pest control into fumigation, general pest control, and termite control, each requiring a minimum number of training hours [15]. The SPCB categorizes expertise into the operator, field representative, and applicator licenses, each with specific roles and responsibilities to ensure industry competence and safety. In South Korea, initiating a disinfection business requires compliance with the specific facilities, equipment, and personnel prerequisites outlined in the Infectious Diseases Control and Prevention Act [16]. This includes operators and workers receiving sixteen-hour compulsory education under the law and enforcement ordinance, and eight-hour in-service education every three years.

Several studies have investigated the current practices and working environments in terms of the disinfection and usage patterns of disinfectants in South Korea, with a specific focus on their application in primary healthcare facilities, residential facilities, and schools for disinfection. The predominant use of spraying and fumigation as primary disinfection methods and the widespread use of pyrethroid-based insecticides and fourth-grade ammonium-based substances by local governments have raised concerns about potential risks to workers and users [17]. The shortage of professionals in the pest control and disinfection industry in South Korea may result in a heavy workload and increased insecticide exposure to existing workers, potentially causing adverse effects on their health [18]. Similarly, the high turnover rate of disinfection workers was related to

the lower quality of practice. Workers expressed the need for more specialized instructors, additional practical training, expanded education hours, and enhanced educational content, particularly focusing on chemical usage in practical settings [19]. To the best of our knowledge, more research is needed to examine disinfection workers' practices during the COVID-19 pandemic, particularly factors influencing their knowledge and guideline compliance concerning disinfection measures and disinfectants. We aim to determine the extent to which workers have the required knowledge of COVID-19 disinfection and their adherence to current disinfection methods and related guidelines. By evaluating their knowledge levels and work practices, we identified areas that require further education and improvement. This will enhance the quality and safety of disinfection operations, maintain a safer work environment, and prevent health risks to workers. These findings are crucial for implementing more effective infection control measures.

2. Materials and Methods

2.1. Participants and Procedures

This study was conducted as a cross-sectional survey to assess the knowledge level and current disinfection practices among workers involved in pest control and disinfection work as of 2021. This study was conducted using a self-administered online survey. The participants were recruited from the Korea Pest Control Association and Korea Hygienist Association members as a total population. These two organizations are representative private entities responsible for issuing disinfectant licenses. Using random sampling, voluntary participants were recruited for the survey by sending text messages to potential candidates. A total of 215 participants were included in this study.

The questionnaire collected information on disinfection methods such as regular spraying, spraying using ultra-low-volume (ULV) sprayers, and surface disinfection in the context of the COVID-19 pandemic. Additionally, the disinfection workers' knowledge of COVID-19 disinfectants and their adherence to appropriate disinfectant use and PPE were investigated.

Prior to administering the prepared questionnaire, the study protocol was approved by the Institutional Review Board of Namseoul University (NSU-202108-004), and informed consent was obtained from all participants. The survey was conducted online from September to October 2021.

2.2. Measures

2.2.1. Outcome Variables: Compliance with COVID-19 Disinfection Guidelines

Disposable PPE use. Disposable PPE is important to ensure the safety and effectiveness of disinfection. Protective equipment plays an important role in safeguarding the personal safety of disinfection workers, preventing cross-contamination, and halting the spread of viruses and bacteria [20–22]. This study assessed the number of disposable PPE items used, including hats, coveralls, masks, and gloves, and whether these items were used in a disposable manner on a scale of 0–4, with higher values indicating more frequent usage of disposable PPE.

Disinfectant guideline compliance. Adhering to proper guidelines for disinfectant use is key in effective virus removal, safe use, health protection, resource management, cost-effectiveness, and prevention of microbial resistance [3,23]. The disinfection guidelines for the COVID-19 response created by the KCDC [6] describe the disinfectant use, methods, and precautions presented by organizations such as the European CDC (ECDC) [24] and the WHO [4]. In the disinfection guidelines for COVID-19 response created by the KCDC [6], considerations were given to “compliance with disinfectants” based on effective concentrations and contact times for each major disinfectant component, specific to everyday surfaces and patient areas. In this study, we investigated whether each of the five disinfectant components, namely sodium hypochlorite, benzalkonium chloride, ethanol, hydrogen peroxide, chloroxylenol, and isopropanol, met the requirements for both effec-

tive concentration and surface contact time on a scale of 0–7 points, with higher values indicating greater compliance.

Disinfection guideline compliance. Compliance with disinfection guidelines by disinfection operators is crucial for virus removal, safety, health protection, operational consistency, and standardization, as well as for incorporating preventive measures and updated information [25,26]. Adhering to these guidelines is very helpful in effectively responding to COVID-19 and maintaining a safe environment. In this study, “disinfection guideline compliance” was constructed using a checklist of nine items specified in the disinfection guidelines for COVID-19 response created by the KCDC [6]. Specifically, the disinfection scope was defined to ensure sufficient ventilation prior to disinfection. The approved disinfection products recommended by the Ministry of Environment were utilized following the instructions on the disinfectant labels. Adequate PPE and cleaning supplies were prepared and visibly contaminated surfaces were cleaned with water and detergent before disinfection. Surface disinfection was performed by wiping the surface with a cloth soaked in an ample amount of disinfectant, followed by wiping with a clean cloth soaked in clean water. Adequate ventilation was maintained throughout the procedures. The compliance level for each item was assessed using a 5-point Likert scale. Responses were categorized as “compliant” for those who indicated “tend to comply” or “always comply” under the variable “compliance with disinfection guidelines”, while the remaining responses were classified as “non-compliant”. This variable was measured by summing the compliance of the nine items on a scale of 0–9, with higher values indicating greater compliance with requirements.

2.2.2. Independent Variables

Subjective awareness of disinfectant. This study assessed the level of awareness regarding disinfectant management for COVID-19 from various perspectives. Participants were asked to rate their awareness on a 5-point Likert scale for factors including usage amount, usage method, expected effects, precautions, and expiration dates. Subsequently, responses indicating “generally aware” or “completely aware” under the variable “subjective awareness of disinfectants” were categorized as “aware”, while the remaining responses were categorized as “unaware”. The dichotomized variable was measured by summing the awareness of the five items on a scale of 0–5, with higher values indicating a higher level of awareness.

Disinfectant Knowledge. Disinfectant knowledge was assessed using a checklist consisting of seven items specified in the disinfection guide for COVID-19 response created by the KCDC [6]. The checklist included knowledge on the effective concentration and contact time for each major component of the disinfectant for each surface and space used by the patient. Specifically, we asked whether the effective concentration or surface contact time was accurately known for each of the five disinfection ingredients (sodium hypochlorite, benzalkonium chloride, ethanol, hydrogen peroxide, chloroxylenol, and isopropanol). Each item was formulated as a true or false question, and the accuracy of the answers was measured (as shown in Table S1). This variable was calculated by summing the number of correct responses for the seven items on a scale of 0–7, with higher values indicating a higher level of awareness.

2.2.3. Sociodemographic Variables

This study collected detailed information on the sociodemographic variables, which were primarily analyzed as dichotomous or categorical variables. The sociodemographic variables included gender (male, female), age group (divided into 20–49 years and over 50 years old), education (college or university graduation or not), work experience (less than 1 year, over 1 year), certification status (yes or no), frequency of spraying during COVID-19 disinfection (less than once a week, once a week, or more), use of ULV sprayers (yes or no), disinfectant information source (not through official education, through official education), and prior training on COVID-19 disinfection (yes, no).

2.3. Statistical Analysis

The collected data were analyzed using SPSS statistics software package version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to obtain the participants' general characteristics, including frequencies and proportions. A cross-tabulation analysis using the χ^2 test was conducted to examine the relationship between general characteristics and prior training in COVID-19 disinfection. Additionally, an independent t-test was conducted to compare the level of awareness about disinfectants and compliance with disinfection guidelines based on their general characteristics. Finally, a multiple linear regression analysis was conducted to identify the factors influencing the use of disposable PPE, compliance with standard disinfectants, and adherence to standard disinfection guidelines.

3. Results

3.1. General Characteristics of Study Participants

Table 1 presents the general characteristics of the disinfection workers. The participants in this study consisted of more males (165 participants, 76.7%) than females (50 participants, 23.3%). Sixty-six participants (30.7%) were in their forties, sixty-four (29.8%) in their fifties, forty-six (21.4%) in their sixties and above, thirty-two (14.9%) in their thirties, and seven (3.3%) in their twenties. Most participants had completed at least one vocational college degree (154 participants, 71.6%). Regarding disinfection work experience, most had worked for one year or more (179 participants, 83.3%), while many still had less than one year of experience (36 participants, 16.7%). The number of participants without a disinfection-related certificate (114 participants, 53%) was slightly higher than those with a certificate (101 participants, 47%). Regarding the frequency of spraying or misting during disinfection, 113 participants (52.6%) reported it as less than once a week and 102 participants (47.4%) reported it as once a week or more. The use of ULV foggers during disinfection was reported as always used by one hundred and fifty-nine participants (74%), sometimes used by fifty-one participants (23.7%), and not used by five participants (2.3%). Most respondents (169 participants, 78.6%) reported that the major source of disinfectant information was independently reading instruction manuals, obtaining explanations from sellers or colleagues, or Internet searches, rather than taking an official education program. A total of 163 participants (75.8%) received prior training on COVID-19 disinfection, which was approximately three times higher than the 52 participants (24.2%) who did not receive such training. Cross-tabulation with chi-square analysis showed statistically significant differences between the frequency of spraying or misting for COVID-19 disinfection and prior training on COVID-19 disinfection ($\chi^2 = 3.27$, $p < 0.05$).

Table 1. General Characteristics of Participants.

Characteristics	n (%)	Prior Training on COVID-19 Disinfection		χ^2
		No	Yes	
		n (%)	n (%)	
Gender				
Male	165 (76.7)	40 (76.9)	125 (76.7)	0.00
Female	50 (23.3)	12 (23.1)	38 (23.3)	
Age group				
20–29	7 (3.3)	2 (3.8)	5 (3.1)	3.83
30–39	32 (14.9)	4 (7.7)	28 (17.2)	
40–49	66 (30.7)	20 (38.5)	46 (28.2)	
50–59	64 (29.8)	15 (28.8)	49 (30.1)	
≥60	46 (21.4)	11 (21.2)	35 (21.5)	
Education				
≤High school	61 (28.4)	16 (30.8)	45 (27.6)	0.19
>College	154 (71.6)	36 (69.2)	118 (72.4)	

Table 1. *Cont.*

Characteristics	n (%)	Prior Training on COVID-19 Disinfection		χ^2
		No	Yes	
		n (%)	n (%)	
Work experience (years)				
≤1	36 (16.7)	10 (19.2)	26 (16.0)	0.30
>1	179 (83.3)	42 (80.8)	137 (84.0)	
Certification status				
No	114 (53.0)	28 (53.8)	86 (52.8)	0.02
Yes	101 (47.0)	24 (46.2)	77 (47.2)	
Frequency of spraying during COVID-19 disinfection				
≤Once a week	113 (52.6)	33 (63.5)	80 (49.1)	3.27 *
>Once a week	102 (47.4)	19 (36.5)	83 (50.9)	
Use of ULV sprayers				
Never	5 (2.3)	0 (0.0)	5 (3.1)	1.90
Sometimes	51 (23.7)	14 (26.9)	37 (22.7)	
Always	159 (74.0)	38 (73.1)	121 (74.2)	
Disinfectant information source				
Non-official education	169 (78.6)	44 (84.6)	125 (76.7)	1.47
Official education	46 (21.4)	8 (15.4)	38 (23.3)	
Prior training on COVID-19 disinfection				
No	52 (24.2)			
Yes	163 (75.8)			

n: Number of respondents, COVID-19: Coronavirus Disease 2019, * $p < 0.05$.

3.2. Differences in the Level of Awareness and the Disinfection Guideline Compliance According to the Prior Training on COVID-19 Disinfection

Table 2 shows the differences in the awareness of disinfectant products, the usage of disposable PPE, and compliance with disinfection guidelines based on whether workers received prior training in COVID-19 disinfection. The results demonstrated that disinfection workers who received COVID-19 training exhibited significantly higher levels of knowledge regarding disinfectant products and higher adherence to disinfection guidelines.

Table 2. Differences in the level of awareness and disinfection guideline compliance according to prior training on COVID-19 disinfection.

	Range	Overall Mean (SD)	Prior COVID-19 Disinfection Training No Mean (SD)	Yes Mean (SD)	<i>T</i>
Subjective awareness of disinfectants	0–5	4.50 (1.14)	4.00 (1.64)	4.66 (0.87)	−2.76 **
Disinfectant knowledge	0–7	3.87 (2.36)	3.44 (2.41)	4.01 (2.34)	−1.52
Disposable PPE use	0–4	3.10 (1.18)	2.60 (1.32)	3.26 (1.09)	−3.28 ***
Disinfectant guideline compliance	0–7	4.88 (2.75)	3.98 (2.91)	5.17 (2.63)	−2.61 *
Disinfection guidance compliance	0–9	7.55 (2.12)	6.40 (2.82)	7.92 (2.82)	−3.67 **

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Specifically, the subjective awareness of disinfectant (rated from 0 to 5) was considerably high, with an overall mean of 4.50 (SD = 1.14). Moreover, workers who received prior training in COVID-19 disinfection had a significantly higher average score of 4.66 (SD = 0.87) than those who did not ($M = 4.00$, $SD = 1.64$) ($t = -2.76$, $p < 0.01$). Regarding the disinfectant knowledge (rated from 0 to 7), the overall mean was 3.87 (SD = 2.36), indicating a relatively low average score with fewer than four correct answers. However, there was no statistically significant difference in knowledge levels based on COVID-19-related disinfection training

($p > 0.05$). Furthermore, we examined whether differences existed in the use of disposable PPE and the implementation of safe disinfection practices among different groups based on COVID-19 disinfection training. The average number of disposable items used (rated from 0 to 4) was 3.10 (SD = 1.18), and disinfection workers who received COVID-19 training were found to use a significantly higher number of disposable PPE ($t = -3.28, p < 0.001$).

The overall mean for compliance with disinfection guideline standards (rated from 0 to 7) was 4.88 (SD = 2.75). Statistically significant differences were observed in compliance with disinfection guidelines among workers who received COVID-19 training, with a higher level of adherence ($t = -2.61, p < 0.05$).

Finally, the overall mean for compliance with disinfection practices based on the guideline standards (rated from 0 to 9) was 7.55 (SD = 2.12), and disinfection workers who had received prior training on COVID-19 showed significantly higher compliance levels ($t = -3.67, p < 0.01$).

3.3. Factors Affecting Compliance with Standard Guidelines of Disinfection Work

Compliance with the standard guidelines for disinfection is necessary to ensure the safety of disinfection operations. Therefore, the impact of the general characteristics of disinfection workers in South Korea, prior training on COVID-19 disinfection, sources of information related to disinfectants, and knowledge levels regarding safe disinfection behaviors were examined, as shown in Table 3. The influence of various factors on safe disinfection practices was also investigated. These factors included the general characteristics of disinfection workers, prior training in COVID-19 disinfection, information sources related to disinfectants, and knowledge levels. The multiple linear regression analysis model was statistically significant (adjusted $R^2 = 0.09, p < 0.01$) for the factors influencing the use of disposable PPE. The analysis indicated that those under the age of 40 years ($\beta = -0.15, p < 0.05$), who possessed disinfection certification ($\beta = 0.14, p < 0.05$), and had completed prior training on COVID-19 ($\beta = 0.21, p < 0.01$) were associated with a greater utilization of disposable PPE.

Table 3. Multiple regression analyses predicting disposable PPE use and compliance with disinfection guidelines.

Dependent Variable		Disposable PPE Use				Disinfectant Guideline Compliance				Disinfection Guideline Compliance			
		B	SE.	β	t	B	SE.	β	t	B	SE.	β	t
(constant)		1.86	0.46		4.03 ***	1.08	1.03		1.05	3.26	0.75		4.37 ***
Sex ¶	Female	0.15	0.19	0.06	0.83	0.42	0.42	0.06	1.01	0.79	0.30	0.16	2.62 **
Age group ¶	≥40 years	−0.35	0.17	−0.15	−2.06 *	−0.33	0.38	−0.06	−0.86	−0.34	0.28	−0.08	−1.24
Education ¶	≤High school	0.13	0.18	0.05	0.70	0.30	0.41	0.05	0.73	−0.36	0.30	−0.08	−1.22
Workexperience ¶	≤1 year	−0.04	0.22	−0.01	−0.17	−0.75	0.49	−0.10	−1.55	−0.23	0.35	−0.04	−0.64
Certification status ¶	Yes	0.34	0.17	0.14	2.00 *	0.66	0.38	0.12	1.74	0.15	0.27	0.04	0.56
Frequency of spraying ¶	≥Once a week	0.00	0.16	0.00	0.00	0.36	0.35	0.07	1.03	0.27	0.26	0.06	1.07
Prior training on COVID-19 disinfection ¶	Yes	0.57	0.19	0.21	3.03 **	0.70	0.42	0.11	1.68	1.03	0.30	0.21	3.41 **
Disinfectant information source ¶	Official education	0.20	0.19	0.07	1.05	0.60	0.43	0.09	1.39	0.80	0.31	0.16	2.55 *
Subjective awareness of disinfectant		0.08	0.08	0.08	1.06	0.36	0.17	0.15	2.17 *	0.48	0.12	0.26	3.99 ***
Disinfectant knowledge		0.05	0.04	0.09	1.34	0.28	0.08	0.24	3.58 ***	0.16	0.06	0.17	2.76 **
F(p)		2.999 **				5.173 ***				8.487 ***			
Adj. R ²		0.085				0.163				0.259			

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, ¶ dummy variables.

Regarding compliance with the COVID-19 standard disinfectant guidelines, the multiple regression analysis model showed that the corrected explanatory power was 16.3% (adjusted $R^2 = 0.163$). The results indicated that a higher subjective awareness of COVID-19 disinfectants ($\beta = 0.15, p < 0.05$) and a higher correct answer rate ($\beta = 0.24, p < 0.001$) were associated with an increased level of compliance with the guidelines. These associations were statistically significant.

Furthermore, the multiple regression analysis model examining the factors influencing compliance with the standard guidelines for disinfection demonstrated a corrected explanatory power of 25.9% (adjusted $R^2 = 0.0259$). The results showed that several factors were associated with increased compliance. Specifically, more female than male workers ($\beta = 0.16, p < 0.01$), individuals who had completed prior training on COVID-19 disinfection ($\beta = 0.21, p < 0.01$), and those who reported obtaining disinfectant information through official education ($\beta = 0.16, p < 0.05$) were associated with an increased level of compliance with the guidelines. Additionally, a higher subjective awareness of COVID-19 disinfectant ($\beta = 0.26, p < 0.001$) and a higher correct answer rate regarding knowledge of COVID-19 disinfectant ($\beta = 0.17, p < 0.01$) were associated with increased compliance. Overall, our findings suggest that these factors contribute to increasing the level of compliance with work standard guidelines for disinfection.

4. Discussion

4.1. The Effectiveness of Prior Training on COVID-19 Disinfection

The chi-square test results indicated that prior training on COVID-19 disinfection was associated with better adherence to disposable PPE and disinfection guidelines. A detailed comparison with previous studies is difficult because of the lack of research specifically targeting disinfection workers. In Korea, prior training on COVID-19 disinfection is not a legal obligation. However, the KCDC recommends that disinfection operators conduct safety education on disinfectants, equipment, procedures, and PPE before initiating their work, as outlined in the guidelines. However, this finding is consistent with previous research on factors associated with adherence to infection-prevention guidelines among healthcare professionals [26–28].

It has been demonstrated that in pandemics, such as COVID-19, where the demand for disinfection is rapidly increasing, it is crucial to promptly provide education on disinfection guidelines tailored to the emerging infectious disease and to promote the use of proper PPE and adherence to disinfectant guidelines to protect the health of disinfection workers and the general population. The WHO recommends education and training as key elements of effective infection prevention and control programs for healthcare professionals [29]. Furthermore, to ensure thorough adherence to guidelines, improving knowledge and enhancing compliance levels through education is necessary [30]. Therefore, disinfection workers must be educated on suitable disinfectants for specific infectious diseases, equipment, PPE, and work procedures to ensure their safety while responding promptly to emerging infectious diseases.

4.2. Vulnerable Groups in COVID-19 Disinfection

Due to the increased demand for disinfection during the COVID-19 pandemic, the use of ULV sprayers has increased, enabling time efficiency [31]. Findings have indicated that the use of ULV foggers has approximately doubled compared with the pre-COVID-19 period [32]. This study found that approximately half of the disinfection workers perform spraying or fogging at least once a week. Previous research indicated that the disinfectant remains in the air for approximately one hour when using ULV foggers [33], posing a higher risk of inhalation exposure. Therefore, supervising the disinfection practice of those who mainly adopt spraying methods, using PPE, and ensuring adherence to safety guidelines when conducting disinfection with ULV sprayers is of great importance. Additionally, considering that spraying and fogging are not recommended as primary disinfection methods for COVID-19 prevention and control by organizations such as the WHO [29]

and KCDC [6], examining whether unnecessary disinfection methods may compromise the health of workers is important.

Furthermore, older individuals, males, those without certification or prior training in COVID-19 disinfection, and individuals who acquired disinfectant-related information from non-official sources tended to exhibit lower compliance in terms of wearing PPE, adhering to disinfectant usage, and following general safety guidelines during disinfection procedures. In terms of adherence to general guidelines, women showed a higher compliance rate than men, which is consistent with several previous studies on gender differences concerning preventive measures and the risk perception of COVID-19 [34–36]. It was also found, within the Korean context, that women tended to adopt newly introduced personal preventive behaviors in the early phase of the COVID-19 pandemic [37]. The gender-specific difference emerged primarily in disinfection guideline compliance, suggesting that this difference is influenced by characteristics such as heightened health consciousness that led to applying guidelines in practical work settings. Previous studies targeting the general population and healthcare professionals have suggested that older generations are more likely to comply with measures than younger generations [34,38–40]. However, the findings of this study differ. Compliance with disinfection guidelines is closely related to education, such as training on disinfection procedures and knowledge of disinfectants. Older disinfection workers who received training long ago may have a lower understanding of the use of disinfectants for emerging infectious diseases. This speculation cautiously suggests that their lower knowledge levels may have contributed to lower compliance.

4.3. Considerations for Providing Education to Disinfection Workers

First, the importance of using disposable PPE and the need for education on disinfectants were identified as crucial factors for effective disinfection throughout this study. Education on the essential checklist for using disposable PPE and disinfectant products should focus primarily on relatively short-term foundational training. However, short-term training alone is insufficient for understanding the hazards of disinfectants and their potential health impact. Therefore, education regarding the quantity and duration of exposure, considering the specific chemical composition of disinfectants, must be provided [41]. Moreover, ensuring strictness in issuing certifications and enhancing the quantity and quality of mandatory official education for disinfection professionals is critical.

In this study, the subjective perception of COVID-19 disinfectants focused on the general understanding of disinfection principles, including the quantity of disinfectants used, usage instructions, precautions, and expiration dates. The subjective evaluations provided by the participants indicated a very high level of awareness, with an average rating of 4.5 out of 5. This high level of subjective perception suggests that the participants had strong self-efficacy toward disinfectants and proper usage. However, the results of measuring the participants' understanding of the effective concentrations and contact times of disinfectants, such as sodium hypochlorite, benzalkonium chloride, ethanol, hydrogen peroxide, chloroxylonol, and isopropanol, in different disinfection scenarios based on standard government guidelines, revealed an average score of 3.87 out of 7. This finding indicates a discrepancy between subjective perceptions and actual knowledge levels. In other words, although disinfection workers have sufficient knowledge, staying updated on the latest information, guidelines, and best practices related to the disinfection of specific pathogens is important.

As previously mentioned, the relatively short duration of training and insufficient on-the-job guidance have proven inadequate for practical fieldwork, particularly in mastering disinfectant usage. To address this, the establishment of a standardized training program is essential, accompanied by the promotion and intensive delivery of guidelines during pandemic periods. The inclusion of case management and rigorous practical training sessions within the standardized program is vital. A comparative analysis of training materials from other countries can serve as a benchmark. During the early stages of the

pandemic, online-based in-service education solely focused on COVID-19-related situations in Korea. However, it is imperative to provide recurrent and practical guideline education to nurture true professionals in the field of disinfection. Future training initiatives must ensure the swift dissemination of the WHO and governmental guidelines in the context of (re)emerging infectious diseases. Moreover, there should be a concentrated effort to strengthen disinfectant usage training, particularly focusing on volume, concentration, frequency, exposure time, and differentiation between ordinary and healthcare settings. It is recommended to proactively strengthen the curriculum during endemic periods, complemented by integrating skill-focused practical sessions.

Therefore, the government must enhance the effectiveness of disinfection against the spread of emerging infectious diseases, such as COVID-19, and ensure the safety of disinfection workers by providing timely pre-disinfection training. It is essential to develop official education channels, including official education, to disseminate specialized knowledge about disinfectants and create a safe disinfection working environment in which no marginalized groups are left behind. In addition, enhancing educational channels and improving the quality of education to prevent the outbreaks of emerging infectious diseases is necessary. This can be achieved by complementing the certification system and providing continuing education focusing on preventive measures against emerging infectious diseases.

4.4. Limitations

This study had several limitations. First, establishing clear temporal and causal relationships between the variables was difficult because this was a cross-sectional study. Future longitudinal studies of disinfection workers are required to examine these changes over time.

Second, the sample used in this study may have been limited in terms of generalizability to the target population. This study encouraged online survey participation among all the members of two private organizations representing the majority of disinfection workers. However, this approach may result in the exclusion of certain groups, such as individuals with limited Internet access or age groups who are less familiar with online platforms. Fortunately, approximately half of the survey participants in this study were over 50 years of age, and considering the excellent Internet accessibility in Korea, it is hard to say that there was an accessibility issue on the online survey. However, acknowledging that online surveys may be subject to self-selection bias is important because individuals more interested in the research may be more likely to participate. Considering these factors, we attempted to promote the participation of various groups during the survey. Multiple promotional messages were sent over a period of approximately one month to encourage participation.

The assessment of knowledge levels and compliance with disinfectant guidelines relied on self-report surveys. Social desirability bias could have impacted the collected data. To mitigate this bias, we measured objective knowledge through a set of quizzes in the true or false format based on the guidelines, rather than relying solely on subjective awareness levels of disinfectants. Additionally, we asked about compliance with the guidelines to gather information on adherence.

Despite these limitations, this study provides valuable insights into the relationships among knowledge, education, and guideline compliance. Further research is warranted to address these limitations and enhance our understanding of guideline compliance. Future studies should consider utilizing longitudinal designs, including more extensive and diverse samples, and incorporating objective measurements to provide a more comprehensive analysis of the factors determining guideline compliance.

5. Conclusions

This study examined the compliance of disinfection workers with COVID-19 prevention and disinfection guidelines as advised by the government and experts. This study

aimed to assess their level of knowledge, which is crucial for protecting public health and the safety of disinfection workers. This study revealed that disinfection workers had a high self-assessment of compliance with disinfection guidelines; however, their actual knowledge was insufficient. Notably, those who received appropriate education on COVID-19-related disinfection were more likely to wear PPE and comply with the disinfection guidelines. These results highlight the importance of retraining disinfection workers during infectious disease outbreaks.

Disinfection involves the use of toxic chemical agents and requires expertise in handling equipment. However, compared with other countries, disinfection work in South Korea is generally classified as low-skilled labor and is undertaken by small, self-employed businesses, with the exception of some large corporations. The fact that the requirements for starting and maintaining a disinfection business are not stringent reflects the status of the Korean disinfection industry. However, during the COVID-19 pandemic, there has been a shortage of disinfection workers, resulting in heavy workloads and an increasing demand for expertise to ensure safety and health. Therefore, referring to other countries' disinfection worker licensing systems and making efforts to enhance the training, qualifications, and expertise of disinfection workers is necessary.

The pandemic is anticipated to continue, necessitating more advanced disinfection measures in response to pathogens. This approach should be taken while considering the environmental impact of disinfection. However, as evident from our research findings, disinfection workers need help to consistently adhere to wearing PPEs, following guidelines, or accessing accurate information. In this context, the government should establish straightforward guidelines and instructions for disinfection practitioners to protect their health and ensure public safety. The government should implement comprehensive education programs for disinfection practitioners, with local authorities responsible for monitoring the effective execution of these training initiatives. Additionally, there is a critical need to elevate public awareness concerning the safe utilization of disinfectants and the anticipated advantages of disinfection. Such efforts are crucial to foster a heightened consciousness among citizens, ensuring the sustainability of disinfection practices during the pandemic era.

Further research is needed to thoroughly analyze the current status of disinfection work and assess whether appropriate practices are being implemented in the work environment. This study examined how the increased workload in disinfection work following the COVID-19 pandemic aligns with procedures and guidelines. The health of disinfection workers, who often engage in labor-intensive tasks in the background, must be prioritized to ensure that their well-being is not compromised. In addition, excessive and indiscriminate disinfection should be avoided. Therefore, a detailed examination of public awareness and perceptions of disinfection is necessary. Appropriate disinfection practices can be fostered by reducing the excessive use of disinfectants and minimizing unnecessary exposure to chemicals.

Supplementary Materials: The following supporting information can be downloaded from: <https://www.mdpi.com/article/10.3390/su151612645/s1>, Table S1 Questions on disinfectant knowledge and accuracy rate.

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