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RESEARCH ARTICLE

REVISED IMPROVING HAND HYGIENE IN CRUISE SHIP: AN INTERVENTION STUDY

[version 3; peer review: 3 approved, 1 approved with reservations]

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Abstract

Background

Cruise ships are relatively small, crowded spaces where many people travel in a new environment, making infection control especially important. Proper hand hygiene is the first line of defense against the spread of infection. This study aimed to measure the effectiveness of different hand hygiene improvement measures onboard.

Methods

The study took place on the *Celestyal Olympia*, a medium-sized cruise ship. Our intervention study had four arms: first, baseline parameters were measured. Then, three different interventions were implemented—surface disinfection with antimicrobial spray, behavioral change through hand hygiene monitoring, and training.

Results

Each person onboard used on average 7.6 soap doses and 1.6 hand-rub doses per day, indicating suboptimal hand hygiene frequency. Surface disinfection sprays were not proven to effectively reduce microbial loads on surfaces. Staff members missed an average of 9.6% of hand surface during hand rubbing when hand hygiene was first monitored. Hand hygiene monitoring devices can only be effective if crew members can use them during their shifts. Designing hand hygiene training for crew members is challenging, as they have very limited preexisting knowledge of health sciences.

Open Peer Review

Approval Status ✓ ✓ ? ✓

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Any reports and responses or comments on the article can be found at the end of the article.

Conclusions

Surface disinfection, technique monitoring, and passenger training did not improve hand hygiene in the forms applied in this study. Crew training improved theoretical knowledge, but we were not able to demonstrate any measurable behavioural change. There were some additional lessons from the study. Hand hygiene compliance is primarily determined by the setting—the placement of dispensers and whether passengers are reminded to use them. Language barriers are a limiting factor that should be considered when planning communication strategies for both crew and passengers. On cruise ships, hand hygiene is often associated with food hygiene. While there are clear recommendations in that area, there is a lack of guidelines on how to improve passengers' hand hygiene. Some passengers have strong opinions about hand hygiene—either positive or negative—but they are a minority. The majority of passengers are not interested on hand hygiene; they perform it when the setting is optimal but otherwise skip it. Clear recommendations are needed to establish an environment that effectively promotes hand hygiene.

Keywords
hand hygiene, hand hygiene intervention, infection prevention, infection control measures, cruise



This article is included in the Horizon Europe gateway.



This article is included in the Health Sciences gateway.

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REVISED **Amendments from Version 2**

Major differences from the previously published version

This revised version of the article incorporates substantial clarifications, restructuring, and expansions in response to peer-review feedback. The core study design and results remain unchanged; however, the presentation and interpretation have been strengthened to improve transparency, clarity, and usefulness for readers.

Key changes include clearer definitions and terminology, particularly a more explicit explanation of *hand hygiene* as encompassing both handwashing and alcohol-based hand disinfection, and improved consistency in language throughout the manuscript. The rationale for each intervention—especially surface disinfection and its relevance to hand hygiene—has been clarified. Several sections were reorganized to improve logical flow, including relocation of the cruise ship description and correction of figure order and captions.

The Methods and Results sections were expanded with additional contextual detail, including clearer explanations of questionnaire timing (before vs. after training), voluntary participation, and practical constraints affecting intervention uptake. The revised Discussion now explicitly frames the study as a pilot or exploratory intervention study, highlighting limitations related to study design, sample size, and real-world constraints on cruise ships. Importantly, a new, dedicated section on limitations and a set of concrete recommendations for future studies were added, addressing reviewer concerns about generalizability and methodological development.

Finally, several numerical clarifications and minor errors were corrected, and the Discussion was enriched with more explicit reflections on human factors, staff well-being, and implementation challenges. Overall, this version provides a more transparent, balanced, and practically oriented account of the study, while preserving the original findings and conclusions.

Any further responses from the reviewers can be found at the end of the article

Introduction

Cruise tourism has become increasingly popular. Outbreaks of infectious diseases are frequently reported aboard cruise ships[1]. Traveling on cruise ships exposes individuals to new environments and large numbers of people, increasing the risk of infection transmission[2]. Frequent personal interactions, complex population flows, limited space, and defective infrastructure aboard many cruise ships make them potential incubators for infectious diseases. Infection control on cruise ships is particularly challenging due to shared living and dining spaces, rapid turnover of passengers, and numerous opportunities for germs to be introduced on board[3].

Proper hand hygiene is the first line of defense against the spread of many illnesses on board[4]. Hand hygiene is a general term referring to all actions of hand cleansing, including handwashing with soap and water and hand rubbing with alcohol-based hand rubs. Hand hygiene recommendations provide detailed guidance on when hand rubbing or handwashing should be applied[5]. In an outbreak investigation, more than 90% of passengers reported increasing their hand hygiene practices after becoming aware of the outbreak[3]. However, evidence-based strategies to proactively improve hand hygiene among cruise ship passengers (outside of outbreak scenarios) are not well established. Few studies have systematically tested interventions in this unique setting, leaving a gap in guidance for cruise operators.

This study was designed to assess the effectiveness of various interventions aimed at increasing hand hygiene practices using multiple objective, evidence-based evaluation methods. In healthcare settings, hand hygiene interventions have been more extensively researched and documented. Most of these studies use multimodal approaches, combining a variety of strategies aimed at addressing barriers to improving compliance. Multimodal strategies almost always include some form of education or training, as well as compliance monitoring[6]. However, another review concluded that both multimodal and single-intervention studies can achieve modest to moderate improvements in hand hygiene compliance[7].

Our study implemented a multimodal strategy to improve hand hygiene, incorporating antimicrobial surface treatments, a technology-based hand hygiene performance monitoring, and targeted training. These elements were introduced stepwise, each added on top of the previous one.

Methods

The intervention study aimed to investigate the impact of various infection-control measures on several outcomes (Table 1). The recruitment and data collection for this study were conducted from 02/06/2023 to 10/11/2023, following these timeframes; Arm#1 from 02/06/2023 to 09/06/2023 and from 14/08/2023 to 20/08/2023, Arm#2 from 21/08/2023 to 28/08/2023, Arm#3 from 29/09/2023 to 09/10/2023 and Arm #4 from 27/10/2023 to 10/11/2023. All participants were recruited exclusively onboard the Celestyal Olympia, with no other sites involved. No exclusion criteria were applied.

Interventions

The study had four arms. In the first arm, baseline data were collected. Each subsequent arm introduced a new element of infection control measures.

Surface disinfection

Frequently touched surfaces are significant in infection transmission, as microorganisms may persist on surfaces and recontaminate hands during contact, increasing the risk of cross-transmission. Decontamination of these surfaces minimizes environmental sources of hand contamination[5]. Antimicrobial sprays are marketed as treatments that can make surfaces continuously self-disinfecting. That would be huge step forward in infection control, as these self-cleaning surfaces would break the infection transmission chain.

Two commercially available antimicrobial surface treatment sprays were selected. To protect the manufacturers' commercial interests, the product names will not be disclosed. The active ingredients of these sprays were two different quaternary ammonium compounds; dimethyl-octadecyl-(3-trimethoxysilylpropyl)-azanium-chloride (DMOAP) in Spray#A, and a combination of didecyldimethylammonium chloride (DDAC)

Table 1. Structure of the intervention study.

Arm	Interventions	Outputs
#1 – Baseline	No intervention	• Hand hygiene product consumption • Environmental microbiological samples • Hand hygiene compliance rate • Questionnaire
#2 – Surface disinfection	Antimicrobial surfaces	
#3 – Technology induced behavioral change	Semmelweis hand hygiene monitoring system	
#4 – Hand hygiene training	On-board training of crew members	

and benzalkonium chloride (BAC) in Spray#B. Spray #A claims that it reduces colony-forming units (CFU) by 90% compared to conventional cleaning, even after 60 days. Spray #B claims to kill 99.9999% of germs, and to keep surfaces bacteria-free for up to 30 days.

The two sprays were applied on several frequently touched surfaces of the ship: at the two main staircases, all inner rail, restroom knobs in Deck 4, 5 and 7. All outside and inside elevator panels were treated in case of the 6 main elevators. The manufacturer's instructions were followed precisely during application. For Arm2, sampling was conducted 1–2 days after the spray treatment.

Technology-induced behavioral change

The Semmelweis Hand Hygiene System (HandInScan Zrt.) was installed on the ship as an innovative solution designed to visualize hand coverage after a hand hygiene. The system operates using the fluorescence-based method, one of the most widely applied techniques for assessing hand hygiene effectiveness. The handrub contains a fluorescent marker. After hand disinfection, under UV-A light, properly treated areas glow, while untreated areas remain dark. The Semmelweis System detects these covered (and theoretically disinfected) areas and provides immediate, objective feedback on hand hygiene performance (Figure 1).

Crew members were given QR codes to allow the system to identify them. The QR codes were assigned randomly. Participation was voluntary for all crew members; only a portion of the crew took part in the study. Passengers were also offered the opportunity to use the device but without identification.

Hand hygiene training

Hand hygiene training sessions were conducted by USN researchers on October 30th, 31st, and November 2nd. The training sessions lasted between 20 and 25 minutes. The crew's hand hygiene training was conducted in small groups (approximately 15 people each) and structured as an interactive discussion rather than a traditional lecture. The content was continuously refined based on feedback collected by the researcher. Over the course of the three days, a total of 367 crew members participated. Crew were asked to complete a questionnaire assessing knowledge and attitudes, some before and some after the training, to gauge knowledge improvement (see Outcomes).

After the training, the latest version of the training material was recorded as a video for future use. The video was edited using Microsoft PowerPoint. It is available in other languages besides English. Translations were provided by ChatGPT, and the text was read aloud using NaturalReaders (https://www.naturalreaders.com/online/).

During the training, some crew members had the opportunity to participate in an experiment (Figure 2). Volunteers were asked to touch the left side of a contact plate with a finger. They then performed hand hygiene using the handrub gel commonly used onboard and touched the right side of the plate with their disinfected finger. After culturing, the plates were photographed, printed, and displayed in the corridor next to the crew mess, where crew members eat three times a day. Plates from the previous day's experiments were also presented during the training session.

Meanwhile, passengers received a flyer emphasizing the importance of hand hygiene onboard (Figure 3). The flyer was distributed as a pillow letter, placed in passenger rooms upon arrival. It highlighted cruise-specific moments when hand hygiene is required and invited passengers to use the Semmelweis System to check their hand hygiene performance at any time.

Outcomes

Hand hygiene product consumption

Hand hygiene product consumption was calculated using the following data: usage records from the Provision Master's database were compared to the number of guest nights provided by the F&B Manager's database. The number of crew members remained relatively stable throughout the season, with data sourced from the Hotel Manager. The volume of product dispensed by onboard dispensers was also measured using the same method previously described[8].

Environmental microbiological samples

Eight frequently touched surfaces were sampled onboard, once during each Arm (Figure 4, Supplementary Table 1). Depending on the size and shape of the surfaces, samples were collected



Figure 1. The Semmelweis System device installed at the entrance of the restaurant, displaying feedback on properly disinfected hand surface areas.

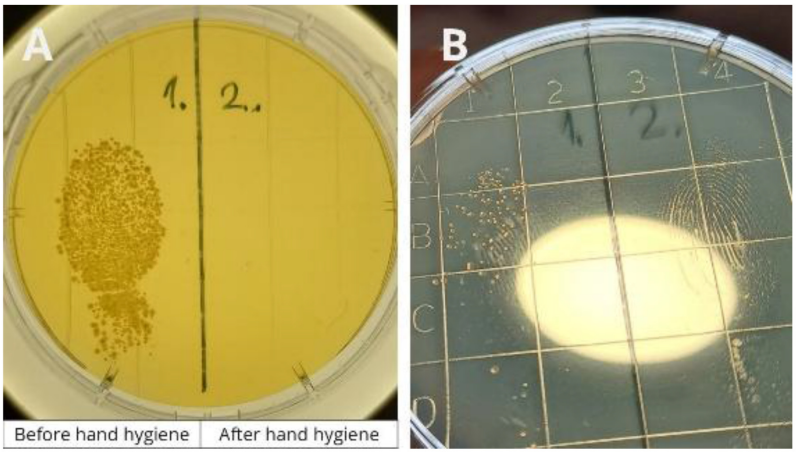


Figure 2. The hand hygiene experiment demonstrates the effectiveness of hand hygiene. During crew training, volunteers pressed one finger onto the left side of a contact plate before hand hygiene and onto the right side after disinfection.

using tryptic soy agar (TSA) contact plates (VWR C31114TI), contact slides containing nutrient agar (NA) (VWR 535092Q), or FLOQ swabs (Copan) moistened with 200 µl sterile 0.9% NaCl solution (R-Biopharm Z0301), and cultured on TSA plates (VWR 17114ZA). Samples were incubated at 35–36°C for 48 hours. After incubation, colony-forming units (CFUs) were counted. In each case, a maximum of 200 colonies were counted; any sample exceeding this number was labeled as "200+". Traffic at the selected surfaces was also recorded, by direct observations.

Hand hygiene compliance rate

Hand hygiene compliance is a rate that tells us from all the opportunities when hand hygiene would be required how many times people actually performed it. Three key moments were selected where hand hygiene would be necessary and observation was feasible: entering the ship, leaving the ship, and entering the restaurants (Figure 5). There are additional critical moments for hand hygiene, (after using the restroom or upon entering a cabin), but these could not be observed due to privacy concerns.

Direct observation is considered the gold standard for measuring compliance. We recorded the number of people who performed hand hygiene and those who did not. All measurements were conducted by a single observer, so inter-observer variability was not a factor. The study focused exclusively on passengers, as crew members quickly recognized the observer,



Figure 3. **Flyer about hand hygiene for passengers, distributed as a pillow letter.**

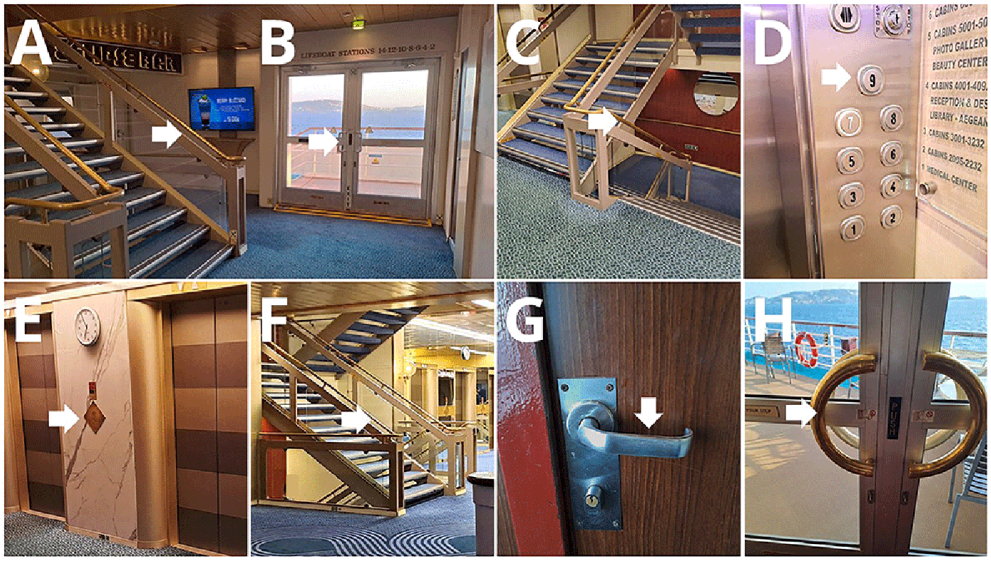


Figure 4. **Selected surfaces for environmental sample collection.**



Figure 5. **Hand hygiene moments that were monitored during the study.**

which could have introduced significant bias. Some of the crew may have been counted during embarkation or disembarkation if they were leaving the ship during their free time and wearing civilian clothes.

Questionnaire

An online questionnaire was created to assess the basic knowledge of crew members regarding infection control topics and to gather information about their educational background. The questionnaire included topics addressed during the training as well as general hygiene-related topics that were not directly covered. Some crew members completed the questionnaire before the training, while others did so afterward.

Responses to the general questions were used to measure the crew's initial knowledge. This was particularly important since we were informed that the hand hygiene training could not exceed 30 minutes due to logistical constraints. Understanding their baseline knowledge helped us determine how to structure the training. Comparing the hand hygiene-related responses collected before and after the training made it possible to validate the effectiveness of our training.

Crew members were asked to fill out the questionnaire through their supervisors. Participation was entirely voluntary. A paper with a QR code linked to the questionnaire was provided to the supervisors. During their regular daily meetings, the supervisor showed the paper to the group of crew members, who scanned the QR code with their phones and completed the online questionnaire. The questionnaire is available in Supplementary Table 2.

The cruise ship

Sample collection was carried out aboard the *Celestyal Olympia*, a middle-size cruise ship sailing across the Aegean Sea. The vessel accommodates up to 1'664 passengers and 540 crew members. The ship has 12 decks, 2 large restaurants as well as 5 smaller bars. It is equipped with seven elevators and two main staircases.

Ethical approval

As the project coordinator (University of Thessaly) is based in Greece and the work package leader (University of South-Eastern Norway) is Norwegian, the research proposal was submitted to both the Greek and Norwegian ethical boards. The Research Ethics Committee of the University of Thessaly approved the project (decision number: 59/19.09.2022, date Sep 19, 2022). The proposal was submitted to the Norwegian Medical Research Ethics Committee (REK), which determined that the project falls outside the scope of the Health Research Act (i.e., it is not considered a clinical study) and therefore does not require ethical approval (reference number: 562942, date: Jan 30, 2023). The Norwegian Agency for Shared Services in Education and Research (Sikt) was notified of the project and granted approval (reference number: 164497, date: Oct 15, 2023).

Although our study did not involve any human-derived clinical samples, it was conducted in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

All crew participants provided written informed consent before taking part in the study. The consent process ensured that participants were fully informed about the study's purpose, procedures, potential risks, and their right to withdraw at any time without consequences.

Data analysis

All data were stored and subjected to further analysis using Microsoft Excel (Version 2308, Build 16.0.16731.20310). A two-tailed paired t-test was used to compare microbial loads in Arm 2–4 to baseline. Fisher's exact test was applied to calculate the one-tailed p-value to compare results collected before and after the training.

Results

Hand hygiene product consumption

Unfortunately, we were unable to generate monthly statistics. The Provision Master's log only recorded the hand hygiene products released from the main storage. However, after distribution to various units (e.g., housekeeping, restaurants), the products were stored in smaller supply rooms, and their usage was not documented. Additionally, the month-end closing dates differed between the two databases, making direct comparisons difficult. However, summarized data from a 15-month period can be analyzed together, and at this resolution, the data appears reliable.

Three types of hand hygiene product were used onboard: alcohol-based gel hand rub, regular soap, and antibacterial soap (Table 2). Antibacterial soap was primarily used in the kitchen, as it was odorless and tasteless. The next section details the number of night passengers and crew members spent onboard. Note that "months" do not necessarily align with calendar months; for example, August 2022 was recorded from July 22 to August 28. Product consumption per capita was calculated. For handrub gel and regular soap, total consumption was divided by the total number of people onboard (passengers and crew), as they all used the same products. Antibacterial soap, however, was used exclusively in kitchens and sanitization areas, where 79 crew members had access to it. Therefore, its consumption was calculated based only on this group.

Soap consumption remained relatively stable between the two years studied, whereas hand rub gel consumption significantly declined—from 2.3 ml/person/night in 2022 to 0.7 ml/person/night in 2023. This decrease can be attributed to the lingering impact of COVID-19 in 2022, when extra hygiene measures were still in place and heightened awareness of hand hygiene persisted. By 2023, conditions had returned closer to normal, making the lower consumption figure more representative of current trends. In contrast, antibacterial soap usage increased, suggesting that kitchen and sanitization staff were required to take hand hygiene more seriously.

On average, a person uses fewer than eight doses of soap per day and disinfects their hands less than twice daily (Table 3). Considering all situations where hand hygiene is necessary (e.g., after restroom use, before eating), this frequency appears insufficient. The issue is even more concerning when considering that 1 ml of gel handrub is often inadequate to cover the entire hand surface, double or even triple doses may be required for effective disinfection[9]. In contrast, antibacterial soap consumption is surprisingly high, indicating that kitchen staff take hand hygiene seriously; they perform hand hygiene frequently and use an adequate amount of product.

Environmental microbiological samples

For environmental sampling, we aimed to select frequently touched surfaces. Samples were collected on three different occasions. One of these occasions was the lifeboat drill, mandatory for all passengers on the first day of the cruise. All master stations were located on Deck 7. People arrived gradually, but at the end of the drill, they all attempted to leave the open deck at the same time, creating a sharp increase in traffic (Figure 6). Samples #A and #B were collected immediately after this spike.

This cruise ship visited two destination each day, giving passengers the opportunity to disembark twice daily for excursions. The morning disembarkation was more gradual, as the ship typically arrived at the port between 6:00 and 7:00 AM, but many passengers woke up later. In contrast, when the ship arrived to the afternoon destination, which occurred between 4:30 and 6:00 PM, nearly all passengers tended to leave at the

Table 2. Hand Hygiene Product Consumption Onboard. *Note that months do not necessarily start on the first day or end on the last day of the calendar month.

	Data provided by the cruise company							Data calculated		
	Product consumption (liter)			People onboard				Product consumption (ml/people/night)		
	ABHR Gel	Soap	Antibac. soap	Nights*	Passenger night	Crew night	People nights	ABHR Gel	Soap	Antibac. soap*
2022 May	88	209	226	32	19782	17280	37062	2.4	5.6	89.4
2022 Jun	75	232	55	32	31341	17280	48621	1.5	4.8	21.8
2022 Jul	79	280	35	21	22307	11340	33647	2.3	8.3	21.1
2022 Aug	233	214	90	38	38486	20520	59006	3.9	3.6	30.0
2022 Sep	75	226	75	32	25258	17280	42538	1.8	5.3	29.7
2022 Oct-Nov	95	80	65	42	35310	22680	57990	1.6	1.4	19.6
Dry dock				121	0					
2023 Mar	0	79	85	19	9415	9540	18955	0.0	4.2	56.6
2023 Apr	30	98	230	28	25650	15203	40853	0.7	2.4	104.0
2023 May	40	162	170	31	31255	17120	48375	0.8	3.3	69.4
2023 Jun	35	292	105	32	32560	17823	50383	0.7	5.8	41.5
2023 July	35	246	85	31	34295	17686	51981	0.7	4.7	34.7
2022				197				2.3	4.5	35.1
2023				141				0.7	4.2	60.6
Total								**1.6**	**4.3**	**45.7**

Table 3. Hand hygiene product consumption onboard together with dispenser output per dose.

	ABHR Gel	Soap	Antibac. soap
Product consumption (ml/people/day)	1.6	4.3	45.7
Average dose the dispenser provides (ml)	1.0	0.6	0.7
Product consumption (dose/people/day)	**1.6**	**7.6**	**65.3**

same time. The crew made huge effort to organize this process, ensuring passengers could disembark as quickly as possible. Afternoon destinations included Mykonos, Patmos, and Santorini, where the ship was unable to dock directly at the port, requiring tender boats to transport passengers ashore. Despite the well-organized procedure, it often took up to an hour for all passengers to leave the ship. Figure 7 presents traffic data recorded during afternoon disembarkation. Three separate disembarkation events were analyzed: 1'053 passengers disembarked within an hour (Figure 7A). On average, 26.4% of them touched the stair rails (Figure 7B). Only 6% of passengers used the elevator during disembarkation (data not shown).

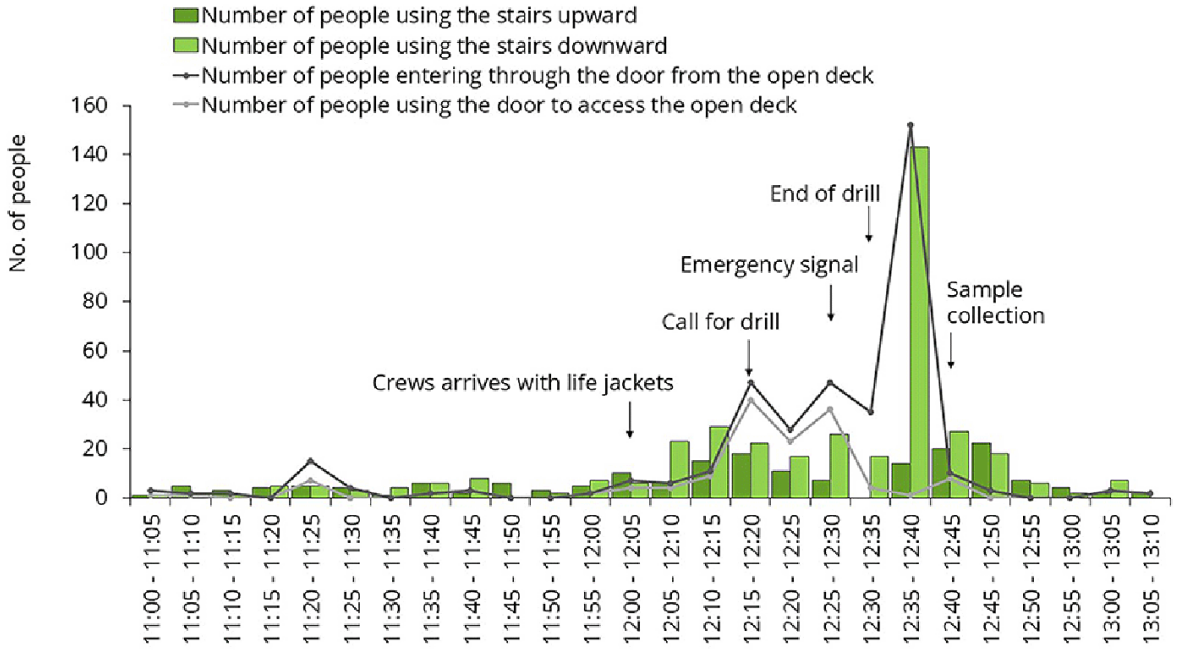


Figure 6. Traffic data during the mandatory lifeboat drill. Samples were collected from the door handle leading to the open deck and from the staircase rail.

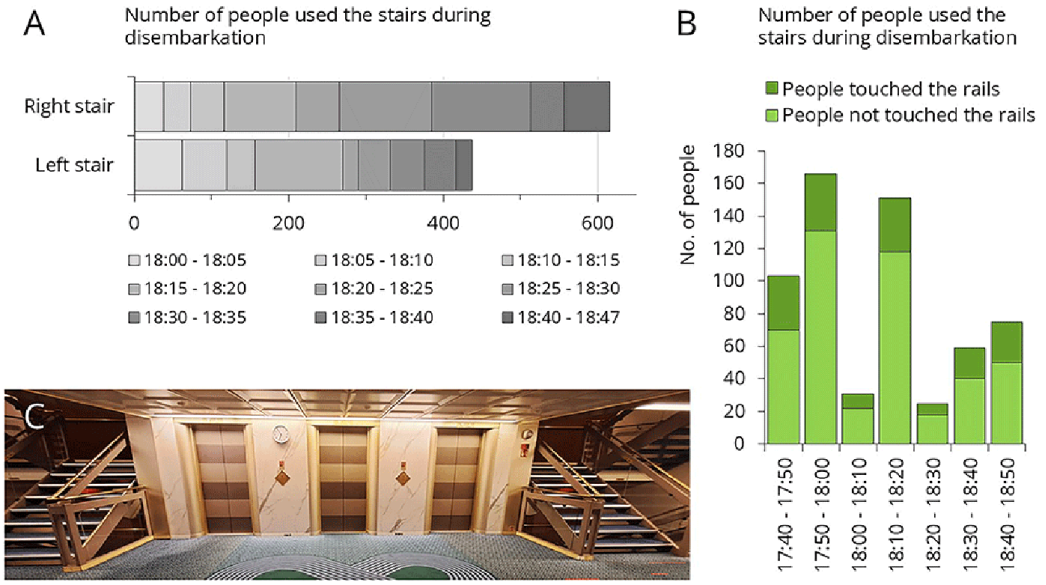


Figure 7. Traffic data during afternoon disembarkation. A: Number of people who used the left or right staircase. **B**: Number of people who used the left staircase, categorized by whether they touched the staircase rail. **C**: Empty staircase. From this setting, samples were collected from the staircase rail, the interior and exterior elevator panels.

The third sampling occasion took place after the late-night show. During the night, Deck 5 hosted various entertainment programs. Passengers had the opportunity to watch the daily show at the Muses Lounge, enjoy drinks at the bar, or dance at the Selene Lounge (Figure 8A). As shown in the traffic data, there was a continuous, elevated flow of people for several hours during these events (Figure 8B). Samples were collected from restroom door knobs and staircase rails, both located between the Muses Lounge and the bar. Additionally, sample were taken from the door handle leading from the Selene Lounge to the open deck, the nearest designated smoking area.

Compared to the baseline arm, none of the intervention arms show significant differences in microbial load (Figure 9). There was no statistically significant reduction in bacterial counts on treated surfaces in Arm 2 compared to baseline ($p = 0.368$). Similarly, neither Arm 3 nor Arm 4 showed significant differences in surface CFUs from baseline ($p = 0.673$ and 0.251, respectively).

Hand hygiene compliance rate

22'012 hand hygiene opportunities were observed; however, we do not have data on the exact number of unique individuals these observations represent (Table 4, Figure 10). Due to the lack of passenger identification, some individuals may have been counted multiple times (e.g., once during embarkation and again when entering a restaurant).

The most interesting observation during the study was that hand hygiene compliance was remarkably high before passengers entered the restaurant (70.2%) but remained low before they entered the buffet (7.5%). Passengers were free to choose whether to eat in the buffet or the restaurant, so the difference can only be partially explained by different passenger characteristics. The main difference between these two locations was that, at the restaurant entrance, a hostess not only asked how many people arrived together and helped them find a suitable table but also offered hand hygiene products. In addition to the dispenser, the hostess had a spray bottle to provide hand rub for everyone—a surprisingly cost-effective yet highly effective solution. At the buffet entrance, the same dispensers and spray bottle were left unattended, and no one reminded passengers to use them.

Note that even in the case of the restaurant, compliance never reached 100%. Most instances of noncompliance occurred when the hostesses were busy with a complex case and didn't have the chance to engage with newly arrived guests. However, some passengers actively refused to perform hand hygiene. When the hostess was asked about the most common excuses, she reported that many passengers said rubbing their hands reminded them of COVID. It seems that some people became familiar with alcohol-based handrub during the pandemic and, as a result, perceive it as merely an emergency solution. Many people used the excuse, "I just had a shower." Even the researcher overheard this excuse during compliance observations. Based on the intonation used by passengers, the message sounded more like, "I'm not that dirty that you need to disinfect me before letting me into the restaurant." This suggests that these individuals do not fully understand the role of hands in infection transmission—or perhaps even the

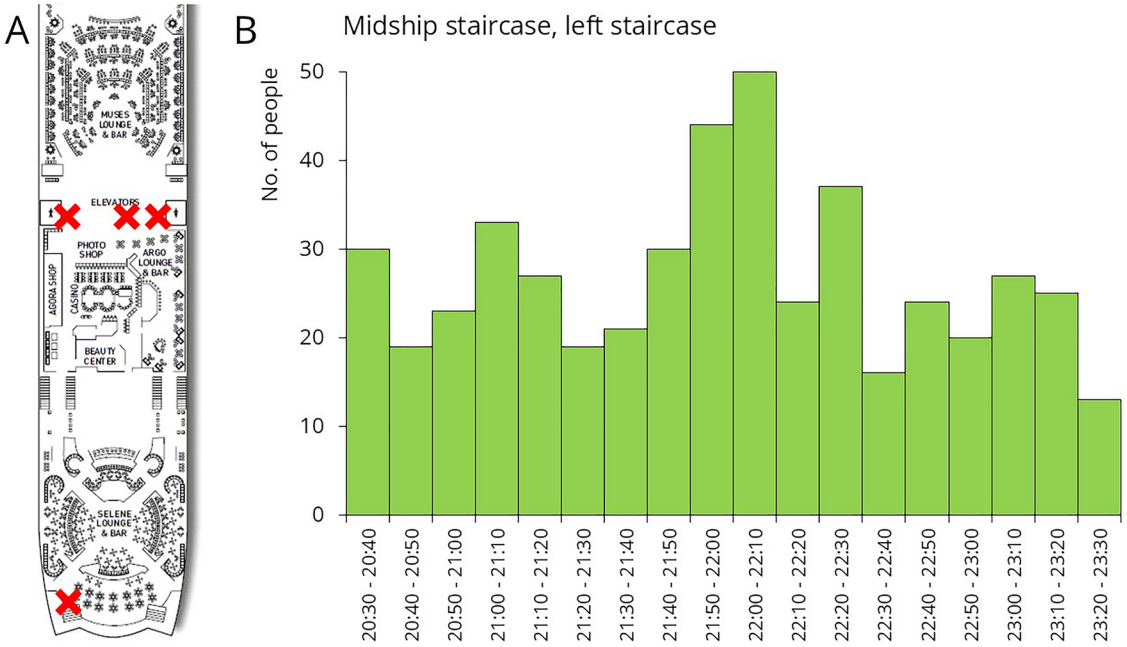


Figure 8. Traffic data and sampling sites during late-night shows. The figure shows the number of people who exited Deck 5 using the left midship staircase (downward). Sample collection sites are marked with a red X on the floor plan.

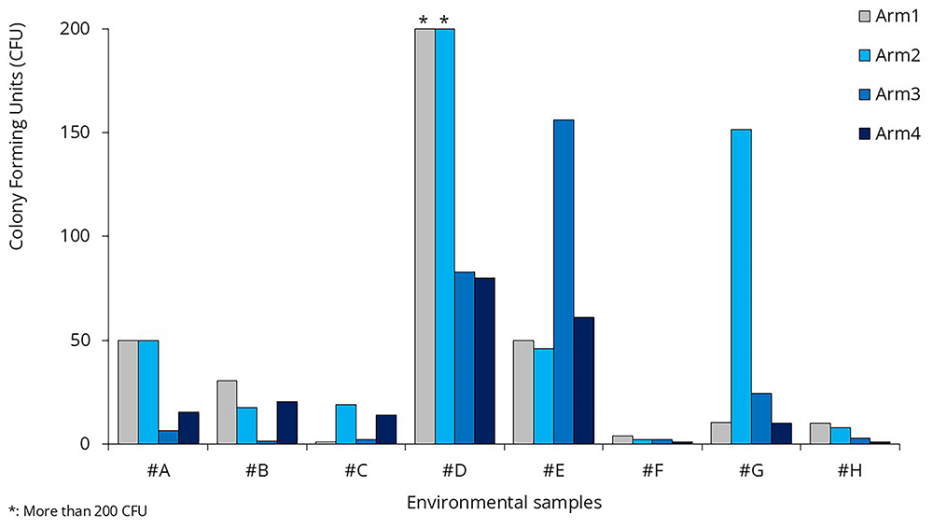


Figure 9. **Colony Forming Units in the environmental samples.**

Table 4. **Compliance values and the number of observed hand hygiene moments during the four arms of the study.**

	Hand hygiene comliance in %, (n)				n
	Embarkation (Entering the ship)	Disembarkation (Leaving the ship)	Before entering the Restaurant	Before entering the Buffet	Total
Arm1	3.7% (2'408)	1.8% (2'188)	61.4% (1'120)	4.7% (919)	6'635
Arm2	10.4% (1'555)	7.0% (1'881)	76.5% (885)	9.1% (592)	4'913
Arm3	12.0% (1'505)	23.5% (1'518)	84.5% (889)	10.7% (844)	4'756
Arm4	9.6% (2'058)	6.3% (1'886)	60.4% (866)	6.5% (898)	5'708
Total	8.9% (7'526)	8.6% (7'473)	70.2% (3'760)	7,5% (3'253)	22'012

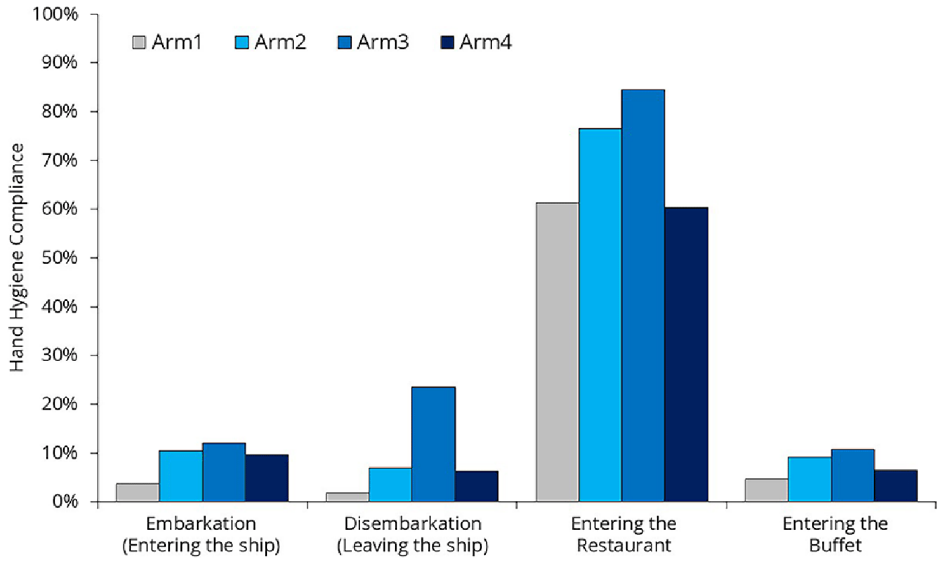


Figure 10. **Hand hygiene compliance across different moments.**

entire concept of hand hygiene. Addressing this issue is a far more complex challenge than what a hostess can resolve in just a few seconds.

Passengers also complained about the hand rub—both in general and regarding the specific product used onboard. Some refused to use hand rub, claiming it caused them skin problems. This concern can be valid for two reasons: if handrub is used incorrectly, it can lead to skin issues (this topic will be discussed later). Additionally, during the pandemic, due to handrub shortages, anyone was allowed to produce handrub, some of which were of low quality because they lacked emollients. These low-quality products appear to caused long-term damage, leading some individuals to avoid handrub entirely. Other passengers stated that they generally accept handrubs but disliked the specific product available onboard. The handrub provided was a gel, which left a sticky feeling after use. Additionally, in some cases, residue remained on the hands as a whitish debris (Figure 11), which alarmed users who feared their skin was peeling due to the hand rub. Product acceptance is a crucial factor in improving compliance[5].

The placement of the dispenser also had a major effect on compliance. We discussed this issue in a different communication[10]. Here, we highlight some settings where compliance dropped to nearly zero (Figure 12A and B), and present an ideal setting



Figure 11. Residue of the gel handrub on the hand after hand hygiene.

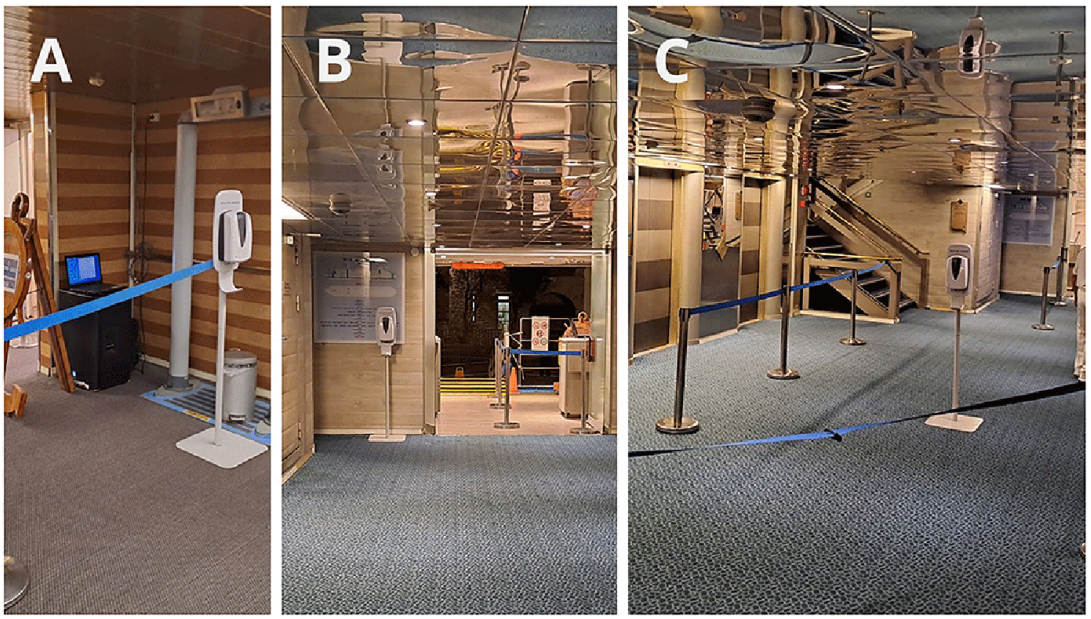


Figure 12. Examples of proper and improper dispenser placement, that affect the compliance. A: The dispenser was placed in a corner because it was used to hold the rope. **B**: The dispenser was hidden behind the door, out of sight of passengers returning to the ship. **C**: Ideal placement.

(Figure 12C). It is important to emphasize that the optimal location of the dispensers differs during embarkation and disembarkation, requiring repositioning of the dispensers (in our case, twice daily).

During the observation, the researcher had an impression that young adults were less likely to perform hand hygiene, while elderly individuals and young children were more likely to do so. Elderly individuals are likely more concerned about health risks. Children have spent a significant portion of their lives during the epidemic, where hand hygiene was strictly enforced in nurseries and schools, making it a routine part of their daily habits. It was also observed that passengers from Asia and the United States performed hand hygiene more frequently, suggesting possible cultural differences in the acceptance of handrubs. Additionally, women tended to use handrub more often than men. In many instances, wife applied handrub first and then explicitly asked her husband to do the same. Future studies should explore these behavioral aspects further.

The placement of dispensers has a significant impact on compliance rates. The increase in compliance can be attributed to the fact that the researcher positioned the dispensers during Arm #2 and Arm #3, gradually identifying better locations. In contrast, the decline in compliance during Arm #4 can be explained by the fact that the researcher was occupied with crew training and was unable to closely monitor dispenser placement.

Questionnaire

A total of 179 crew members completed the online questionnaire: 69 before the training and 89 after (each participant completed the questionnaire only once, either before or after the meeting, depending on their schedule). The remaining respondents did not answer this question. After receiving the initial responses, we made slight modifications to the questionnaire. Regarding their educational background, the data suggests that crew were not undereducated, with most having attended school for 10 to 16 years (Figure 13). However, more than a quarter of them (n=50) reported never having studied biology.

To better assess their preexisting knowledge, we presented several health-science-related statements and asked crew members to determine whether each statement was true or false (Figure 14). Only 69% of respondents knew that water is H_2O, suggesting that the training should avoid explaining the differences in chemical composition of disinfectants. Only one-third of them knew how many kidneys and livers humans have, suggesting that a training attempting to explain the exact workings of the immune system would likely not be effective. One-third of respondents were unaware that antibiotics kill bacteria or that not all bacteria are harmful. While 63% correctly recognized that bacteria existed on Earth before humans, 17% believed that dinosaurs were even more ancient. This suggests that complex topics such as the endosymbiotic theory, the bacterial origins of mitochondria, and their implications for antibiotic use should be excluded from the training. Twenty-three percent of the participants believed that bacteria do not have DNA, suggesting that it would be challenging to impress them with the latest sequencing results — that was performed as part of the same intervention study[11]. As we shifted from bacteria to viruses and yeast, the results worsened, with the responses becoming nearly evenly split, around 50–50%. The data strongly suggested that we needed to design the training in a way that did not rely on any preexisting knowledge.

Interventions

Surface disinfection

As evident from the environmental sample data, there were no significant changes in bacterial load during the surface treatment arm (Arm 2) compared to the baseline arm (Figure 9). When analyzing the effects of the sprays separately, neither

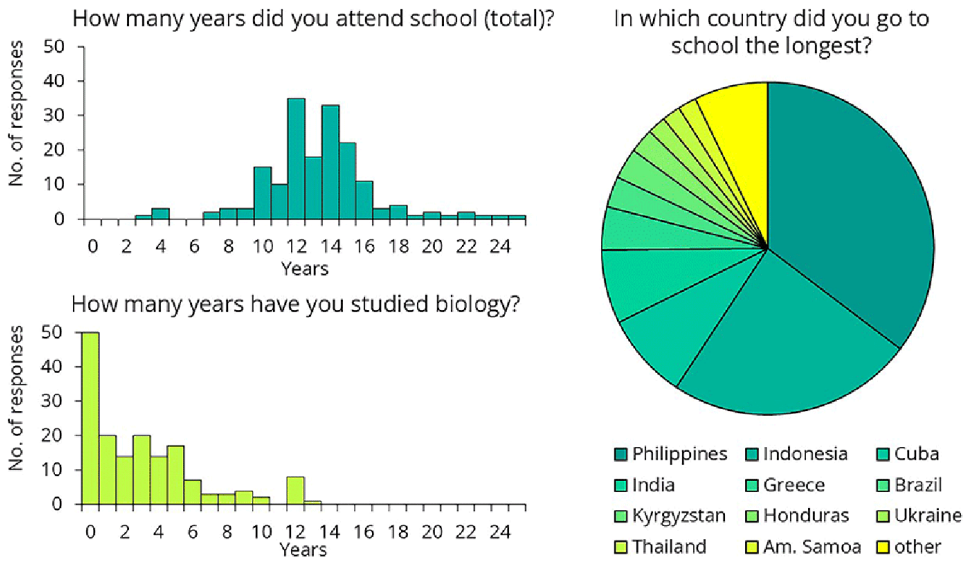


Figure 13. Crew members' responses to the questionnaire on their educational background.

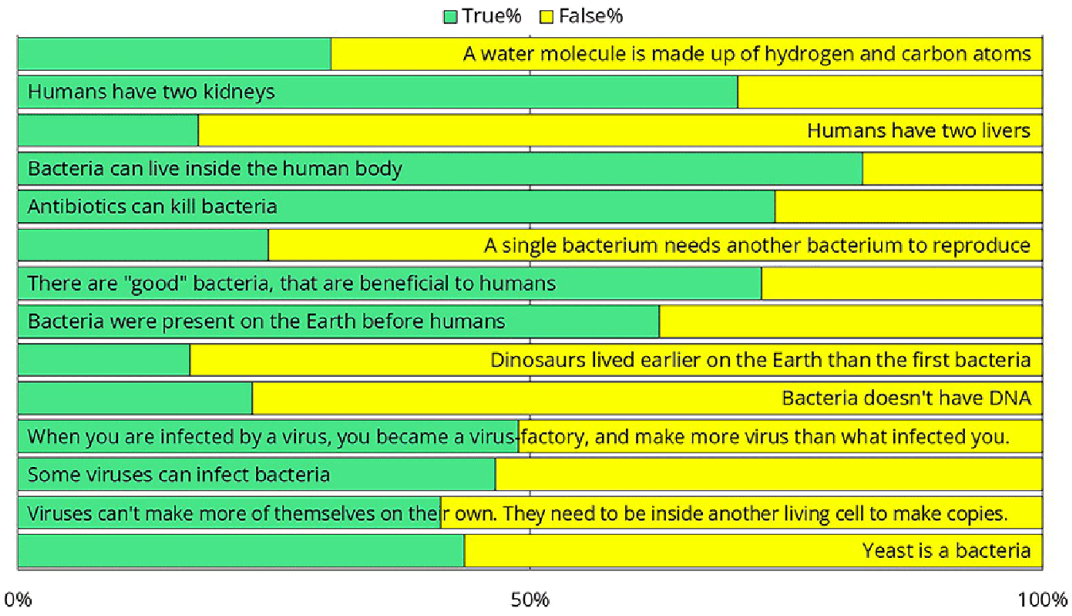


Figure 14. Responses to survey questions aimed at measuring preexisting health-science knowledge. Note that since these were yes-or-no questions, answers with a distribution near 50–50% indicate that the respondents had no clear idea.

showed a significant difference compared to the baseline. The p-value was 0.082 for Spray #A and 0.336 for Spray #B.

Technology induced behavioral change

The Semmelweis System was installed onboard on September 1, 2023, and remained operational until November 9. During this period, a total of 1'636 measurements were conducted, with 204 QR codes in use. Analyzing only the first measurements of the participants, an average of 9.6% of the hand surface was not covered by hand rub. The system's primary advantage is that it provides immediate feedback about missed surfaces, initiating a learning process. The system should be used multiple times, as development occurs continuously during the first 5 to 20 uses[12,13]. Although more than 200 crew members tried the system, only 76 used it at least twice (Figure 15). Only 10 participants used it 10 times, which was the desired number for analyzing improvement. The results from these 10 participants are shown on the left. In their case, the system effectively taught the correct hand hygiene technique; the percentage of missed hand surfaces was initially 9.6%, which reduced to 1.6% by the 10th use.

Unfortunately, teaching 10 crew members how to properly rub their hands will not bring significant change on a ship with 540 crew members. The researchers asked some of the crew why they were not using the system more frequently. They mentioned that they were extremely busy throughout the day and hand hygiene was simply not a priority for them — at least not enough to spend their free time practicing it. The system was used most frequently by restaurant staff, where managers were highly committed to hand hygiene and encouraged the crew to perform the test during their shifts. A possible solution might be to make the use of such monitoring devices mandatory for the crew while on duty. These measures will not be effective if crew members are required to do it during their free time, just for fun.

Hand hygiene training

The passengers' pillow letter was ineffective (Figure 10). Despite the fact that the surveyed moments were clearly highlighted in the flyer, compliance decreased in Arm4 compared to the previous arm. While we don't have a clear explanation for this, some phenomena were observed. Language barrier was evident. Although the official ship language was English, many passengers arrived in groups with a group leader who translated for them, meaning they did not necessarily understand English. A one-language flyer may not be effective.

The crew's hand hygiene training was conducted in small groups and structured as an interactive discussion rather than a traditional lecture. As mentioned, the content was continuously refined based on participants' feedback. The latest version of the training material can be found at the following link: https://sites.google.com/view/usn-hs-2023/traning-material. We would be happy to offer this version as a starting point for further development of training materials.

Based on 19 experiments, the average colony-forming unit (CFU) count before hand hygiene was 150.1, which decreased to 1.5 after hand hygiene—representing a $\log_{10}1.99$ reduction. However, this reduction is likely underestimated, as colonies in the "before" samples were often so dense that they merged, making precise counting difficult.

Some of the crew members attended the hand hygiene training before (n=79) and some after (n=69) filling out the

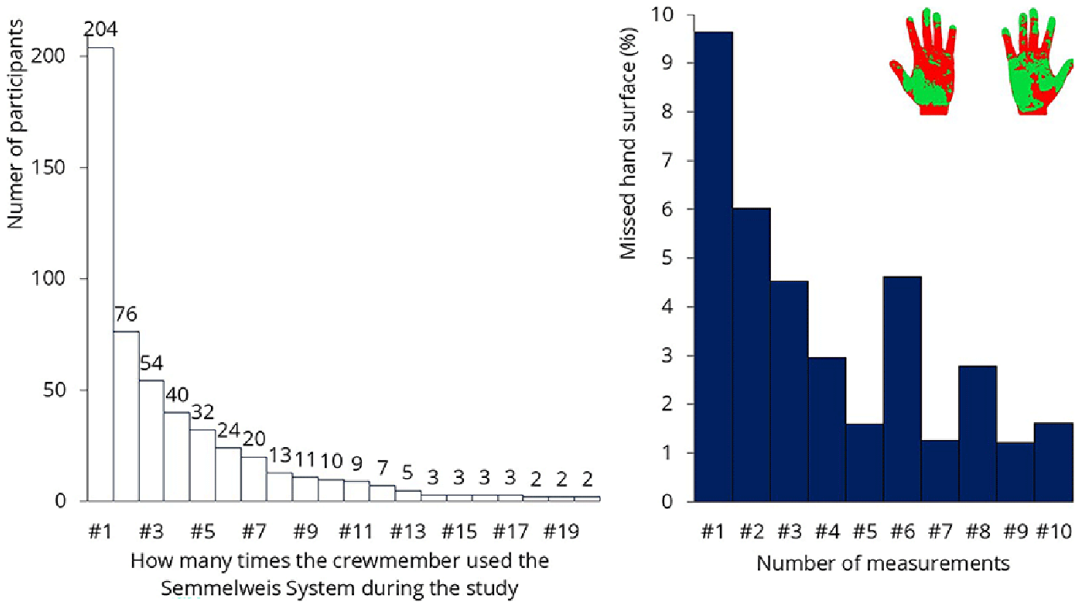


Figure 15. Results of the hand hygiene monitoring. Left: the number of times participants tested themselves is shown. Only 10 participants used the system 10 times. Right: results of that 10 people: missed hand hygiene surfaces decreased from 9.6% to 1.6%.

questionnaire. The questionnaire included questions comparing soap-and-water handwashing with hand rubbing using alcohol-based handrub. Since this topic was directly addressed during the training, comparing the knowledge of the "before" and "after" groups provides a valuable opportunity to assess the effectiveness of the training.

In all four questions presented in Figure 16, a higher proportion of participants answered correctly after the training than before (correct answers are marked with a star in Figure 16); however, the changes were statistically significant in only two cases (Table 5). We were not fully satisfied with the extent of this improvement, indicating that there is still room for improvement in how the message was targeted.

Less than half of the crew members were aware that hand rubbing takes less time than hand washing, despite this being one of the primary reasons alcohol-based hand rubs were introduced—first in healthcare and later in other sectors. Proper hand washing takes approximately 1.5 minutes, whereas handrubbing can be completed in just 30 seconds[14].

Alcohol-based handrubs are more effective at removing microorganisms than soap-and-water hand washing[5,15]. Alcohols exhibit excellent in vitro germicidal activity against vegetative bacteria and fungi. However, they have virtually no activity against bacterial spores or protozoan oocysts and are less effective against some non-enveloped viruses. At first glance, this may seem contradictory, making it difficult for participants to understand how handrubs can be more effective overall if they are ineffective against certain germs. We believe this is a critical concept, and future training sessions should dedicate more time to explaining it clearly.

Alcohol-based solutions or gels containing humectants cause significantly less skin irritation and dryness than soap[5]. This was surprisingly new information for many crew members. During the training, several participants expressed skepticism. They mentioned that their skin problems started when hand rubs were introduced onboard. Upon further discussion about how exactly they are using handrub, it became evident that many crew members were applying to gel immediately after handwashing, while their hands were still wet. The World Health Organization's Hand Hygiene Guidelines explicitly state that washing hands with soap and water immediately before or after using an alcohol-based product is not only unnecessary but may also lead to dermatitis[5]. The European ShipSan Manual for Hygiene Standards on Passenger Ships suggests that sanitizer may be used after washing, but it also defines proper handwashing as rubbing the hands with soap in hot water, followed by drying[16]. The CDC Vessel Sanitation Program Manual states that hand antiseptics should be applied to clean hands but does not explicitly mention the need to dry hands first[2]. However, it does specify that soap, paper towels or air dryers, and a waste towel receptacle must be available at handwashing stations, implying that drying is necessary. Future training sessions should emphasize that handrub should never be applied to wet hands.

Alcohol-based solutions containing 60%–95% alcohol are the most effective[15]. Applying hand rub to wet hands dilutes the alcohol content, which not only increases the risk of skin

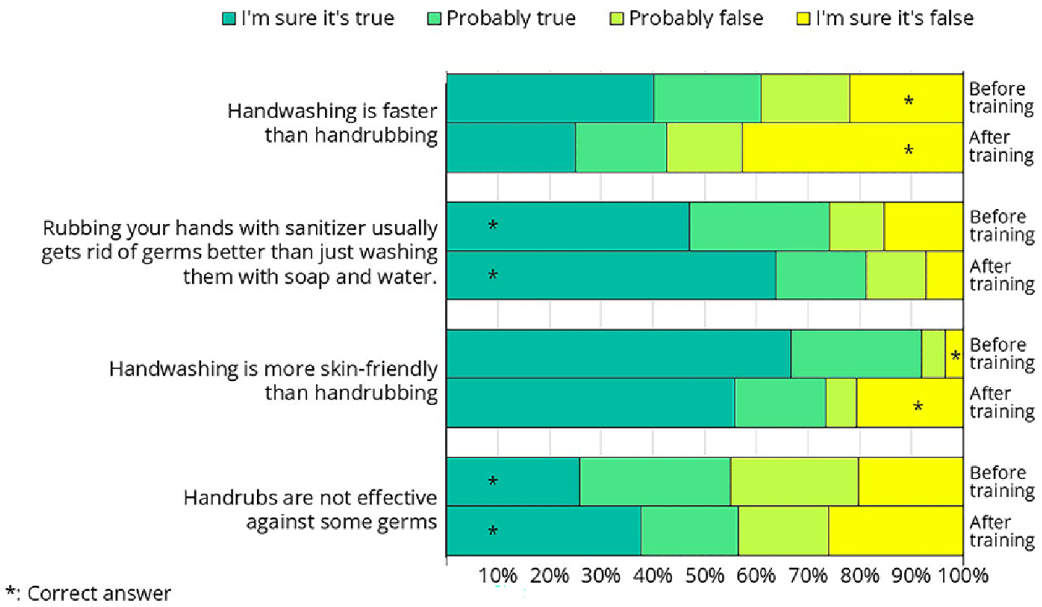


Figure 16. Responses from the questionnaire on hand hygiene-related questions that were directly addressed during the training. Some crew members completed the questionnaire before the hand hygiene training, while others did so afterward.

Table 5. Statistical analysis of knowledge as an effect of the training. A significant shift was observed in only two cases.

Question	Answer		Before training	After training	One-tailed p-value
Handwashing is faster than handrubbing	Correct	I'm sure it's false, Probably false	34	54	0.001*
	Not correct	I'm sure it's true, Probably true	53	30	
Handwashing is more skin-friendly than handrubbing	Correct	I'm sure it's false, Probably false	7	32	0.000*
	Not correct	I'm sure it's true, Probably true	80	52	
Rubbing your hands with sanitizer usually gets rid of germs better than just washing them with soap and water.	Correct	I'm sure it's true, Probably true	63	72	0.064
	Not correct	I'm sure it's false, Probably false	22	13	
Handrubs are not effective against some germs	Correct	I'm sure it's true, Probably true	49	39	0.913
	Not correct	I'm sure it's false, Probably false	40	46	

irritation but may also reduce its effectiveness. In addition, damaged skin may harbor more pathogens than healthy skin[17]. Future training sessions should emphasize that hand rub should never be applied to wet hands.

Discussion

Microbial loads of frequently touched surfaces have not changed significantly; none of the employed interventions were able to reduce bacterial load. Environmental microbiological

samples only measured the CFU count. The microbial composition of these samples was analyzed in a separate publication[11], where the sample codes were slightly different: #A = #A1, #B = #A2, #C = A5, #D = A6, #E = #A4, #F = #A3, #G = #A10, and #H = #A8.

The location of the dispensers largely influenced hand hygiene compliance[18]. In a previous communication[10], we outlined key recommendations for optimal dispenser placement to maximize effectiveness: dispensers should be clearly visible from a distance, allowing people time to process and react. They should be placed in areas where people walk slowly and are not in a hurry. Dispensers should be positioned along natural walking paths, as people are unlikely to take extra steps to reach them. People should have free hands when approaching a dispenser. When required to show cards, tickets, their hands are not free, so they cannot perform hand hygiene. When they hold items, many attempted hand hygiene by dispensing sanitizer onto only one hand or the back of their hands, creating an illusion of proper hand hygiene without achieving effective bacterial reduction. Some people holding items (ship cards, phones, wallets) in their mouths to free their hands, which, from an infection control perspective, is an even worse alternative than skipping hand hygiene altogether. The high compliance observed at restaurant entrances clearly indicates that reminders play a crucial role in encouraging dispenser use.

Compliance at the "before entering the restaurant" moment dropped from 84.5% in Arm 3 to 60.4% in Arm 4. According to the hostess, an incident occurred during the gap between the study arms: she offered handrub to a passenger who reacted aggressively, yelling at her and throwing the sanitizer onto her clothes and into her eyes. The situation was so extreme that she broke down in tears in front of everyone. Since then, she reported that she felt uncomfortable offering handrub to passengers. This incident serves as a critical reminder that cruise companies must prioritize the motivation and mental well-being of their staff. A single traumatic event led to an approximately 25% drop in compliance (from 84.5% to 60.4%, Table 4) in the following weeks, potentially increasing the infection risk for thousands of passengers. In a previous study, four antimicrobial surface treatment sprays were tested, two of which were the same as those used in this study. That study was able to validate their effectiveness *in vitro* when bacteria were applied in suspension. However, in real-life settings, the sprays did not demonstrate the same level of efficacy[19].

Regarding hand hygiene training, based on the feedback collected, several general conclusions can be drawn. The training cannot assume any prior infection control-related knowledge. Questionnaire results indicate that while crew members are not undereducated, their education often lacks a background in biology. Additionally, a language barrier exists in this area. Although crew members speak English well enough for their daily tasks, biological terminology is not necessarily part of their vocabulary. To address this, we recommend that the training rely heavily on images and videos rather than text. If feasible, translating the training materials could further enhance comprehension and engagement.

It should be mentioned that we encountered various conspiracy theories among crew members, mostly regarding COVID-19, but also vaccination, mask-wearing, disinfection, and other various health-related topics. The hand hygiene experiment (Figure 2, performed during crew training) was especially effective, as it allowed participants to witness the results firsthand rather than simply being told what to believe. Observing the outcomes of their own experiments from the previous day made the lesson more tangible and credible.

Additionally, crew members were surprised by the effectiveness of their hand rub. Many expressed dissatisfaction with the handrub used onboard, describing it as "sticky" and uncomfortable, as it was previously mentioned. This led them to associate the product with low quality and to doubt its germicidal efficacy.

Our paper should be understood primarily as a report rather than a standardized, large-scale study. Hand hygiene research and education on cruise ships remain underinvestigated areas. Many of the methods applied in this work were originally developed for hospital settings. For example, systematic monitoring of hand hygiene technique has not previously been implemented on cruise ships. As our findings demonstrate, interventions that are effective in hospitals cannot always be directly transferred to such a distinct operational environment. We therefore believe that this work offers several novel insights that may support other professionals in further developing and adapting hand hygiene methods for application in the cruise ship industry.

Limitations

This study provides valuable insights into hand hygiene interventions on cruise ships; however, several limitations should be considered when interpreting the findings.

Study design limitations

The study employed a sequential intervention design on a single cruise ship without a parallel control group. While each intervention arm was compared to the baseline, the lack of a concurrent control means that external factors, such as increased general awareness over time or study fatigue, may have influenced compliance rates. For example, by the time the hand hygiene training was introduced, passengers and crew may have already become more familiar with the study, potentially affecting their behavior independently of the intervention itself. Similarly, situational factors, such as the observed negative passenger-staff interaction affecting compliance enforcement, could not be isolated from intervention effects. Despite these challenges, the use of a defined baseline arm provides a

reasonable control for assessing changes across study arms, and the ship's operational environment remained relatively stable during the study period, allowing for meaningful comparisons. Future studies employing a randomized or multi-ship design could further strengthen causal inferences.

Sample size and data limitations

Certain aspects of the study had limited sample sizes, which may impact the generalizability of the findings. The environmental microbiological sampling included only eight surfaces, which, while representative of high-touch areas, may not capture broader microbial trends across the ship. Additionally, engagement with the hand hygiene monitoring device was lower than expected; although 204 QR codes were issued, only 10 crew members completed the recommended 10 scans necessary for meaningful assessment of hand hygiene improvement. This limited data prevents definitive conclusions on the long-term effectiveness of the device-based intervention.

Hand hygiene compliance observations, while extensive in total (over 22,000 opportunities recorded), did not track individuals over time. Thus, the dataset reflects overall compliance rates at different locations rather than behavioral changes in specific passengers. As a result, it is unknown whether the same individuals improved their compliance or whether compliance levels fluctuated among different groups of passengers. Individual passengers could not be identified; therefore, some may have been observed more than once. The crew questionnaire was also subject to selection bias, as responses were voluntary and self-reported, meaning those with a stronger interest in hygiene may have been overrepresented. While these factors do not invalidate the findings, they should be considered when applying the results to broader cruise ship populations.

Potential biases

The presence of observers recording compliance may have introduced the Hawthorne effect, wherein passengers modified their behavior due to awareness of being watched. While observers were instructed to remain discreet and dressed in plain clothing to minimize this effect, some passengers may have still noticed them. This could lead to an overestimation of compliance rates compared to unobserved, real-world conditions. Additionally, the crew's participation in the questionnaire and training may have been influenced by social desirability bias, where respondents provided answers they perceived as favorable rather than reflecting their actual knowledge or behavior.

Despite these limitations, the study offers valuable practical insights into the challenges and opportunities for improving hand hygiene on cruise ships. Future research with larger, randomized samples and more controlled conditions could further refine these findings and contribute to the development of stronger, evidence-based guidelines for infection control in maritime settings.

Recommendations for future studies

During compliance measurements, we observed that factors such as age, sex, and nationality may influence hand hygiene compliance; future studies should specifically address these parameters. We also found that strong management commitment is necessary to successfully implement new interventions. Crew members are often busy and fatigued, and infection control is not a priority for them; as a result, non-mandatory tasks are frequently overlooked. Hand hygiene training should be tailored to the target audience, taking into account that many crew members have limited formal education in biology and that language barriers may exist. Training should begin with basic concepts and rely heavily on visual materials, such as pictures, videos, and diagrams, rather than text.

Conclusions

Hand hygiene product consumption data suggests that hand hygiene practices onboard need improvement, with the exception of the kitchen area, where standards appear to be well maintained. Notably, during our study, when we mentioned that we were there to improve hygiene, most people immediately associated it with food hygiene. This indicates that food hygiene is a well-recognized area with clear guidelines and regular monitoring, leading to high standards. In contrast, other areas, such as passenger hand hygiene, receive less attention and have fewer established recommendations. This also suggests that cruise companies tend to comply with hygiene guidelines and regulations when they exist, highlighting the need for clearer recommendations in understudied areas like passenger hand hygiene.

From the compliance data (Figure 10), we can see that some people are aware of the importance of hand hygiene and perform it under any circumstances (they carry their own handrub or actively seek out dispensers), but this represents less than 5% of the passengers. There is also a small group, less than 10%, who are strongly committed to NOT performing hand hygiene, for whatever reason. For the majority of passengers, hand hygiene is simply not a priority. If they find a dispenser in the right place at the right time, or if they are directly asked to use it, they will comply. However, they will not make any extra effort to do so. This highlights the importance of establishing clear recommendations for cruise ship companies on how to create an effective hand hygiene setup.

Our study also underscores that, unfortunately, there is no simple solution to improving hand hygiene. Measures such as spraying surfaces once a month, placing informational leaflets in cabins, or installing an unattended control machine in the hall are unlikely to significantly change hand hygiene behavior on their own. Hand hygiene interventions need to be more complex, and it appears that human resources will be essential—crew members should be specifically assigned to promote and facilitate hand hygiene.

These findings can inform cruise operators and public health guidelines – emphasizing convenient access to hand hygiene, active promotion by crew, and selecting acceptable products could collectively raise hygiene standards and reduce outbreak risks on ships.

Ethics and consent

The Research Ethics Committee of the University of Thessaly approved the project (decision number: 59/19.09.2022, date Sep 19, 2022). The proposal was submitted to the Norwegian Medical Research Ethics Committee (REK), which determined that the project falls outside the scope of the Health Research Act (i.e., it is not considered a clinical study) and therefore does not require ethical approval (reference number: 562942, date: Jan 30, 2023). The Norwegian Agency for Shared Services in Education and Research (Sikt) was notified of the project and granted approval (reference number: 164497, date: Oct 15, 2023). All crew participants provided written informed consent before taking part in the study. The consent process ensured that participants were fully informed about the study's purpose, procedures, potential risks, and their right to withdraw at any time without consequences.

Declarations

Data availability

Hand images collected by the Semmelweis System were personal data and have already been deleted for data protection purposes; only the evaluated results (coverage %) are available.

The extended data underlying this article (training material and supplementary tables) are available on Figshare: https://doi.org/10.23642/usn.29064080.v2

Data are available under the terms of the Creative Commons Attribution International License (CC BY 4.0)

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Open Peer Review

Current Peer Review Status: ✔ ✔ ? ✔

Version 3

Reviewer Report 21 January 2026

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✔ **Colum Dunne**
University of Limerick, Limerick, County Limerick, Ireland

The authors have dealt with all reviewer comments well.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Medical microbiology; infection prevention and control; innovation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 21 January 2026

https://doi.org/10.21956/openreseurope.24565.r68139

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✔ **Ida Hellum Sandbekken**
Oslo Metropolitan University, Oslo, Norway

Thank you for submitting the revised manuscript. All comments raised in the previous review have been adequately addressed, and I am satisfied with the changes made.
I therefore recommend the manuscript for indexing.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Hand hygiene, interventions for improving hand hygiene.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 19 January 2026

https://doi.org/10.21956/openreseurope.24565.r68140

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Samantha Lange
University of Johannesburg, Auckland Park, Gauteng, South Africa

I am happy with version 3 of the article

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 26 December 2025

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Ida Hellum Sandbekken
Oslo Metropolitan University, Oslo, Norway

Thank you for the opportunity to review this interesting paper.
The relevance is clear, as cruise ships accommodate many people in confined spaces, allowing infections to spread rapidly.
Overall, this is a well-written paper, but I have some minor suggestions for revision:

1. **Introduction:** I suggest adding a sentence defining hand hygiene, clarifying that it includes both handwashing and the use of disinfectants. Also, ensure there is a clear rationale for when handwashing versus hand disinfection should be used.
2. **Intervention: Surface disinfection:** Regarding surface disinfection, could you add a sentence explaining its relevance to hand hygiene? For example: *Frequently touched surfaces play a significant role in infection transmission because...*

3. **Intervention: Hand Hygiene Training:** The first two sentences are unclear. You refer to "small groups" twice: first, *Crew attended in small groups*, then *Crew's hand hygiene training was conducted in small groups.* Is this repetition, meaning the second phrase can be deleted? Or are these two different groupings?
4. **Outcomes: Hand Hygiene Compliance Rate:** You use the term *handwashing* (Please check your manuscript for consistency in using "handwashing" (one word) rather than "hand washing"). However, I think you may be referring to hand disinfection instead—please clarify.
5. **Outcomes: Questionnaire:** Why did some participants complete the questionnaire before and others after the training? Were they the same individuals? Additionally, I suggest noting that participation was voluntary.
6. The heading **"The Cruise Ship"** currently appears under the bold heading **"Outcomes."** Could it be moved to a more appropriate section?
7. **Results: Environmental Microbiological Samples (page 9):** Can the figures be placed in the correct order? Currently, Figure 8B appears before 8A. You may need to rename the figures if you want to maintain the sentence order.
8. **Interventions: Technology-Induced Behavioral Change (page 15):** Please correct the grammar in this sentence: *The researchers asked **the** some of the crew why they were not using the system more frequently.*
9. **Interventions: Hand Hygiene Training:** The sentence *"In all four questions, there was some shift, with more participants answering correctly after the training than before"* is unclear. Which four questions? Also, the word *shift* is vague, consider using a more descriptive term.
10. **Discussion:** The phrase *"A single traumatic event led to a 15%…",* are you referring to 84.5 – 60.4 = 24.1? Where does 15% come from?
11. In the second-to-last paragraph, *"The hand hygiene experiment…",* are you referring to the Semmelweis hand hygiene system? If so, use the same term; if not, clarify what you mean.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Hand hygiene, interventions for improving hand hygiene.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Jan 2026

Jörn Klein

We are grateful to the reviewers for their careful assessment of our manuscript and for the insightful and constructive comments. We appreciate the time and effort invested in the review process. The suggestions provided were highly valuable and helped us improve the clarity of the manuscript, refine the presentation of the methods and results, and enhance the overall quality of the work. Below, we address each comment in detail and describe how the manuscript was revised in response.
Please note that some references were renumbered following the relocation of the WHO reference from [9] to [5].”
Reviewer#4 - Ida Hellum Sandbekken
Thank you for the opportunity to review this interesting paper. The relevance is clear, as cruise ships accommodate many people in confined spaces, allowing infections to spread rapidly. Overall, this is a well-written paper, but I have some minor suggestions for revision:

1. Introduction: I suggest adding a sentence defining hand hygiene, clarifying that it includes both handwashing and the use of disinfectants. Also, ensure there is a clear rationale for when handwashing versus hand disinfection should be used.
Response: The following sentences was added to the Introduction section: P4 L54: “Proper hand hygiene is the first line of defense against the spread of many illnesses on board [4]. Hand hygiene is a general term referring all actions of hand cleansing, including handwashing with soap and water and hand rubbing with alcohol-based hand rubs. Hand hygiene recommendations provide detailed guidance on when hand rubbing or handwashing should be applied [5].”

2. Intervention: Surface disinfection: Regarding surface disinfection, could you add a sentence explaining its relevance to hand hygiene? For example: Frequently touched surfaces play a significant role in infection transmission because…
Response: Thanks for pointing out: P7 L100: “Frequently touched surfaces are significant in infection transmission, as microorganisms may persist on surfaces and recontaminate hands during contact, increasing the risk of cross-transmission. Decontamination of these surfaces minimizes environmental sources of hand contamination [5].”

3. Intervention: Hand Hygiene Training: The first two sentences are unclear. You refer to “small groups” twice: first, Crew attended in small groups, then Crew’s hand hygiene training was conducted in small groups. Is this repetition, meaning the second phrase can be deleted? Or are these two different groupings?
Response: These were the same, the section was rephrased: P9 L141: “Hand hygiene training sessions were conducted by USN researchers on October 30th, 31st, and November 2nd. Crew members attended in small groups of approximately 15 people each. The

training sessions lasted between 20 and 25 minutes. The crew's hand hygiene training was conducted in small groups (approximately 15 people each) and structured as an interactive discussion rather than a traditional lecture."

4. Outcomes: Hand Hygiene Compliance Rate: You use the term handwashing (Please check your manuscript for consistency in using "handwashing" (one word) rather than "hand washing"). However, I think you may be referring to hand disinfection instead—please clarify. **Response:** P12 L198: "Three key moments where selected where hand hygiene would be necessary and observation was feasible" Handwashing (one word) was corrected in L569, L571 and L574.

5. Outcomes: Questionnaire: Why did some participants complete the questionnaire before and others after the training? Were they the same individuals? Additionally, I suggest noting that participation was voluntary.
Response: The original plan was for all participants to complete the questionnaire before the training, but for logistical reasons, half of the participants received the invitation only after the training. This provided an opportunity to compare results before and after the training. Each participant completed the questionnaire only once, either before or after the training. Explanation was added: P28 L453: "A total of 179 crew members completed the online questionnaire: 69 before the training and 89 after (each participant completed the questionnaire only once, either before or after the meeting, depending on their schedule)." The following sentence was added: P14, L227: "Crew members were asked to fill out the questionnaire through their supervisors. Participation was entirely voluntary."

6. The heading "The Cruise Ship" currently appears under the bold heading "Outcomes." Could it be moved to a more appropriate section?
Response: Right, it was moved. Now it started in P6, L89

7. Results: Environmental Microbiological Samples (page 9): Can the figures be placed in the correct order? Currently, Figure 8B appears before 8A. You may need to rename the figures if you want to maintain the sentence order.
Response: Figure 8 was changed: refer following link - https://openreseurope-files.f1000.com/linked/266544.Ms_id_20172-_Fig.8.jpg
P22 L344: "Passengers had the opportunity to watch the daily show at the Muses Lounge, enjoy drinks at the bar, or dance at the Selene Lounge (Figure 8A). As shown in the traffic data, there was a continuous, elevated flow of people for several hours during these events (Figure 8B)." P22 L353: "Figure 8: Traffic data and sampling sites during late-night shows. Sample collection sites are marked with a red X on the floor plan. The figure shows the number of people who exited Deck 5 using the left midship staircase (downward)."

8. Interventions: Technology-Induced Behavioral Change (page 15): Please correct the grammar in this sentence: The researchers asked the some of the crew why they were not using the system more frequently.
Response: Corrected: P32 L518: "The researchers asked some of the crew why they were not using the system more frequently."

9. Interventions: Hand Hygiene Training: The sentence "In all four questions, there was

some shift, with more participants answering correctly after the training than before" is unclear. Which four questions? Also, the word shift is vague, consider using a more descriptive term. **Response:** Rephrased: P34 L559: "In all four questions presented in Figure 16, a higher proportion of participants answered correctly after the training than before (correct answers are marked with a star in Figure 16); however, the changes were statistically significant in only two cases (Table 5). We were not fully satisfied with the extent of this improvement, indicating that there is still room for improvement how the message was targeted."

10. Discussion: The phrase "A single traumatic event led to a 15%…", are you referring to 84.5 – 60.4 = 24.1? Where does 15% come from?
Response: Thanks for noticing it! Yest, it should be 25% P38 L634: "A single traumatic event led to an approximately 25% drop in compliance (from 84.5% to 60.4%, Table 4) in the following weeks, potentially increasing the infection risk for thousands of passengers."

11. In the second-to-last paragraph, "The hand hygiene experiment…", are you referring to the Semmelweis hand hygiene system? If so, use the same term; if not, clarify what you mean. **Response:** No, we tried to refer to the fingerprint-culture experiment. P39, L653: "The hand hygiene experiment (Figure 2, performed during crew training) was especially effective, as it allowed participants to witness the results firsthand rather than simply being told what to believe."

Competing Interests: No competing interests were disclosed.

Reviewer Report 11 December 2025

https://doi.org/10.21956/openreseurope.23773.r64632

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Samantha Lange
University of Johannesburg, Auckland Park, Gauteng, South Africa

Thank you for addressing the comments from my previous review. As you stated in your rebuttal, this study should be viewed as a pilot study. I would recommend that you bring this in to the manuscript as this will provide a more transparent view of the study and explain some of the concerns that I had and that future readers may have. I would also suggest that you bring in recommendations for future studies such as using a validated tool, expanding the sample size to include more ships etc. The information will be very valuable in a space where little information is available.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: D Tech Environmental Health with published research in hand hygiene interventions as well as 30 years experience in the environmental health/ food hygiene/hygiene foeld

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 08 Jan 2026

Jörn Klein

Thank you for addressing the comments from my previous review. As you stated in your rebuttal, this study should be viewed as a pilot study. I would recommend that you bring this in to the manuscript as this will provide a more transparent view of the study and explain some of the concerns that I had and that future readers may have. P40 L661: “Our paper is rather a report, and not a standardized, large-scale study. Hand hygiene research and education on cruise ships is an underinvestigated area. Most of the methods we used were originally developed for hospital environments. For example, hand hygiene technique monitoring has never been implemented on any cruise ship before. As our paper highlights, not all of the solutions that work in hospitals can be directly applied to such different settings. We believe that our work provides several new insights that can help other professionals further develop and adapt these methods for use in the cruise ship industry”. I would also suggest that you bring in recommendations for future studies such as using a validated tool, expanding the sample size to include more ships etc. The information will be very valuable in a space where little information is available. The following paragraph was added: P43, L726: “Recommendations for future studies: During compliance measurements, we observed that factors such as age, sex, and nationality may influence hand hygiene compliance; future studies should specifically address these parameters. We also found that strong management commitment is necessary to successfully implement new interventions. Crew members are often busy and fatigued, and infection control is not a priority for them; as a result, non-mandatory tasks are frequently overlooked. Hand hygiene training should be tailored to the target audience, taking into account that many crew members have limited formal education in biology and that language barriers may exist. Training should begin with basic concepts and rely heavily on visual materials, such as pictures, videos, and diagrams, rather than text.”

Competing Interests: No competing interests were disclosed.

Reviewer Response 16 Jan 2026

Samantha Lange

Thank you, my previous concerns have been adequately addressed.

Competing Interests: No competing interests were disclosed.

Reviewer Report 11 December 2025

https://doi.org/10.21956/openreseurope.23773.r64852

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Sudip Bhattacharya
All India Institute of Medical Sciences, Deoghar, Jharkhand, India

Major Revision

Title & Abstract

- The title does not specify the study design clearly.
- Abstract is descriptive but lacks concise presentation of numerical outcomes; background and results sections read too narratively.

Introduction

- Some claims are overly general and not specific to cruise-ship epidemiology.
- Literature cited is insufficiently integrated to justify the multimodal intervention approach.

Methods

- Study design relies on sequential arms without a parallel control, which limits causal inference.
- Sampling strategy for environmental microbiology (only eight surfaces) is narrow and not fully justified.
- Questionnaire development process is not described in detail; validity and reliability remain unclear.
- The description of intervention components is lengthy and could be streamlined for clarity.

Results

- Several key results (e.g., CFU counts, compliance percentages) are repeated in multiple sections, reducing clarity.
- The hand hygiene compliance datasets may include repeated observations of the same individuals, but this limitation appears late rather than upfront.
- Interpretation of cultural and behavioral observations is anecdotal and lacks systematic measurement.
- Visual elements (Figures 6–12) require clearer captions to improve interpretability.

Discussion

- Discussion reiterates findings already stated in the Results section, creating redundancy.
- Some behavioural interpretations (e.g., passenger excuses, cultural differences) are speculative and not supported by structured qualitative data.
- The narrative is long and would benefit from sharper thematic organisation.
- Comparison with international literature is limited and should be expanded to contextualise why interventions failed.

Limitations

- Although several limitations are acknowledged, the section is verbose and includes methodological clarifications that should appear earlier.

- Observer bias (Hawthorne effect) and selection bias among crew respondents should be addressed more precisely.

Conclusion

- The conclusion is lengthy and introduces new information (e.g., passenger behaviour categories) instead of synthesising the study's findings.
- Recommendations remain broad and require clearer alignment with the study results.

Language & Formatting

- Multiple grammatical errors, repetitive phrasing, and inconsistent use of terminology appear throughout the manuscript.
- Figures and tables require more consistent formatting and clearer explanatory notes.

Additionally, the authors must add behavioural aspects, nudge theories and use of AI to improve the manuscript.

https://pubmed.ncbi.nlm.nih.gov/39917534/
https://icjournal.org/DOIx.php?id=10.3947/ic.2024.0147
https://journals.lww.com/chri/fulltext/2019/06010/namastey___greet_the_indian_way__reduce_the_chance.17.as

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Public Health

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 24 November 2025

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Colum Dunne
University of Limerick, Limerick, County Limerick, Ireland

Thank you for the opportunity to read this revised manuscript.

The authors have made a considerable number of revisions and, in particular, have detailed the limitations of the study more explicitly. This is an important amendment and clarifies the rationale, methods and outcomes of the study to a much great degree.

In turn, this allows any reader to judge the study and its relevant to them much easier and with a greater level of insight.

Overall then, this is a significant improvement on the first draft.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Medical microbiology; infection prevention and control; innovation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 06 November 2025

https://doi.org/10.21956/openreseurope.21824.r62861

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Colum Dunne
University of Limerick, Limerick, County Limerick, Ireland

Thank you for the invitation to review this manuscript. The study is interesting and reports hand hygiene practices in a cruise ship setting.

There are many limitations to the study, including but not limited to its single performance and the demographics of passengers who might be able to travel in such a way based on their education/professional or socio-economic attainment. The authors have dealt with this to some

degree but this could be expanded upon.

I was very interested in the study as it is a variation of studies performed in education of clinical settings. I think it would be of interest to the actors and readers to access these two papers that report the varying characteristics, successes and challenges of hand hygiene studies internationally and for the authors to then address similarities and difference as observed in their report.

The studies are: https://www.sciencedirect.com/science/article/abs/pii/S0195670115004892 (based on studies published between 2010 and 2015)

and

https://www.sciencedirect.com/science/article/pii/S019567012100102X (based on studies published between 2014 and 2020)

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
I cannot comment. A qualified statistician is required.

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Medical microbiology; infection prevention and control; innovation

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 18 Nov 2025

Jörn Klein

We would like to sincerely thank the reviewers for their thorough evaluation of our

manuscript and for the constructive comments provided. We greatly appreciate the time and effort dedicated to reviewing our work. The feedback has been extremely valuable in helping us clarify key points, improve the presentation of our methods and results, and strengthen the overall quality of the manuscript. Below, we provide a detailed point-by-point response to each comment, indicating how the manuscript has been revised in response to the suggestions. Please note that three additional references have been added, resulting in the renumbering of the reference list. Additionally, since Figure 15 was moved earlier in the manuscript, the numbering of nearly all figures has also changed.

Reviewer#2 - Colum Dunne Thank you for the invitation to review this manuscript. The study is interesting and reports hand hygiene practices in a cruise ship setting. There are many limitations to the study, including but not limited to its single performance and the demographics of passengers who might be able to travel in such a way based on their education/professional or socio-economic attainment. The authors have dealt with this to some degree but this could be expanded upon. I was very interested in the study as it is a variation of studies performed in education of clinical settings. I think it would be of interest to the actors and readers to access these two papers that report the varying characteristics, successes and challenges of hand hygiene studies internationally and for the authors to then address similarities and difference as observed in their report. The studies are: https://www.sciencedirect.com/science/article/abs/pii/S0195670115004892 (based on studies published between 2010 and 2015) and https://www.sciencedirect.com/science/article/pii/S019567012100102X (based on studies published between 2014 and 2020) Thank you for reviewing the manuscript.

You are clear, the purpose of the study was to explore how hand hygiene interventions that are effective in clinical settings can be applied in a different context. The two articles you suggested is very valuable, thank you for pointing them out. We have added both as references, and we incorporated the following text into the manuscript: L61 “In healthcare settings, hand hygiene interventions have been more extensively researched and documented. Most of these studies use multimodal approaches, combining a variety of strategies aimed at addressing barriers to improving compliance. Multimodal strategies almost always include some form of education or training, as well as compliance monitoring [5]. However, another review concluded that both multimodal and single-intervention studies can achieve modest to moderate improvements in hand hygiene compliance [6]. Our study implemented a multimodal strategy to improve hand hygiene, incorporating antimicrobial surface treatments, a technology-based hand hygiene performance monitoring, and targeted training. These elements were introduced stepwise, each added on top of the previous one.”

Competing Interests: No competing interests were disclosed.

Reviewer Report 06 October 2025

https://doi.org/10.21956/openreseurope.21824.r60603

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Samantha Lange
University of Johannesburg, Auckland Park, Gauteng, South Africa

This manuscript will benefit from major revisions. The methodology does not describe all aspects of the study that are discussed later in the paper. The results do not show any analytical results even though in some cases there was mention made of this. The discussion does not compare results to other studies. The researchers make use of many of their own observations and thoughts while not quantifying these in any way. Many of the limitations are discussed as outcomes. Outcomes should fall under the results section. The conclusions need to be directly linked to the results. In general this reads as a report and not as scientific, replicable, relevant research. My comments have been inserted onto the manuscript: *https://openreseurope-files.f1000.com/linked/259660.813bdc0e_fc49_4679_aaa1_a749c2f258d6_20172___jorn_klein_comments.pdf*

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
No

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: D Tech Environmental Health with published research in hand hygiene interventions as well as 30 years experience in the environmental health/ food hygiene/hygiene foeld

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 18 Nov 2025

Jörn Klein

We would like to sincerely thank the reviewers for their thorough evaluation of our manuscript and for the constructive comments provided. We greatly appreciate the time

and effort dedicated to reviewing our work. The feedback has been extremely valuable in helping us clarify key points, improve the presentation of our methods and results, and strengthen the overall quality of the manuscript. Below, we provide a detailed point-by-point response to each comment, indicating how the manuscript has been revised in response to the suggestions. Please note that three additional references have been added, resulting in the renumbering of the reference list. Additionally, since Figure 15 was moved earlier in the manuscript, the numbering of nearly all figures has also changed.

Comment:

This manuscript will benefit from major revisions. The methodology does not describe all aspects of the study that are discussed later in the paper. The results do not show any analytical results even though in some cases there was mention made of this. The discussion does not compare results to other studies. The researchers make use of many of their own observations and thoughts while not quantifying these in any way. Many of the limitations are discussed as outcomes. Outcomes should fall under the results section. The conclusions need to be directly linked to the results. In general, this reads as a report and not as scientific, replicable, relevant research. My comments have been inserted onto the manuscript: https://openreseurope-files.f1000.com/linked/259660.813bdc0e_fc49_4679_aaa1_a749c2f258d6_20172___jorn_klein_comments.pdf

Response: The authors acknowledge that our paper is not a standardized, replicable, large-scale study; rather a report. Hand hygiene research and education on cruise ships is an under investigated area. Most of the methods we used were originally developed for hospital environments. For example, hand hygiene technique monitoring has never been implemented on any cruise ship before. As our paper highlights, not all of the solutions that work in hospitals can be directly applied to such different settings. Although our work is more of a report, we believe it provides several new insights that can help other professionals further develop and adapt these methods for use in the cruise ship industry. Ultimately, this may contribute to standardized, large-scale data collection in the future. However, this development can only progress if our report is published, as publication is the primary way knowledge is shared within the scientific community. Quantify some of your significant results here The following additional result was included: L19: “Staff members missed an average of 9.6% of hand surface during hand rubbing when hand hygiene was first monitored.” Also to the Results / Technology induced behavioral change section: L495: “The Semmelweis System was installed onboard on September 1, 2023, and remained operational until November 9. During this period, a total of 1’636 measurements were conducted, with 204 QR codes in use. Analyzing only the first measurements of the participants, an average of 9.6% of the hand surface was not covered by hand rub.” Your conclusion doesn't speak to your objectives and study results The following sentences were added: L25: “Conclusions Surface disinfection, technique monitoring, and passenger training did not improve hand hygiene in the forms applied in this study. Crew training improved theoretical knowledge, but we were not able to demonstrate any measurable behavioural change. There were some additional lessons from the study.” Where these passengers or crew? Where there inclusions or exclusions? Both passengers and crew members were included, depending on the specific intervention. This is described in the sections detailing each intervention. There were no additional inclusion criteria beyond being on board: L82. “All participants were recruited exclusively onboard the Celestyal Olympia, with no other sites involved. No exclusion criteria were applied.” Why did you

choose these two sprays? As mentioned later in the manuscript (L631), we tested four sprays in a previous study that is unfortunately still under review. The antibacterial performance of the four sprays was similar. However, one spray consisted of two components, and another left a grey residue on surfaces. Therefore, we selected the remaining two sprays for the current study. Did you follow manufacturers instructions for application regarding frequency, re-application, preparation of surface prior to application? Yes, we followed the manufacturer's instructions during application. Re-application was not performed, as one spray claims a 30-day effect and the other a 60-day effect (L102). Sampling took place 1–2 days after the sprays were applied. L106: "The manufacturer's instructions were followed precisely during application. For Arm2, sampling was conducted 1–2 days after the spray treatment." How were hands disinfected and when? Hands were disinfected immediately before using the hand hygiene monitoring device. Participants were informed that the purpose of the measurement was to assess whether they were able to cover the entire surface of their hands with hand rub. No additional instructions were provided regarding the disinfection technique. How was the training material validated? As it was mentioned in the Result section, the content was continuously refined based on feedback collected by the researcher. This description was relocated form the Result section to the Methods. L130: "Hand hygiene training sessions were conducted by USN researchers on October 30th, 31st, and November 2nd. Crew members attended in small groups of approximately 15 people each. The training sessions lasted between 20 and 25 minutes. The crew's hand hygiene training was conducted in small groups and structured as an interactive discussion rather than a traditional lecture. The content was continuously refined based on feedback collected by the researcher. Over the course of the three days, a total of 367 crew members participated." The training was not formally validated. The latest version has been published to serve as the basis for a future, validated training program. Was this flyer piloted prior to use? How was information and wording validated? The flyer was not piloted prior to use. The study itself should be considered a pilot. How did you determine frequently touched surfaces and sample frequency? Frequently touched surfaces were selected by the researcher onboard. Many studies have focused on microbial loads on frequently touched surfaces in hospitals [https://pmc.ncbi.nlm.nih.gov/articles/PMC7087772/, https://www.cdc.gov/healthcare-associated-infections/hcp/cleaning-global/appendix-c.html]. However, many of these surfaces are not found on cruise ships. The researcher observed passenger behavior during her first days onboard, to identify the most frequently touched surfaces. To verify these observations, touch frequency was measured and is presented in Figures 6, 7, and 8. Why were these determined to be critical moments? Is there literature to support this? Are there HW facilites at these points to assist with HW? We used the "Advice to International Travellers for a Healthy Voyage," published by the EU Shipsan Act Joint Action, as a starting point. This document provides a list of situations in which hand hygiene is necessary.

- Before and after eating
- Before touching your eyes, nose or mouth
- After coughing, sneezing, or blowing your nose
- Before, during, and after preparing food (make sure you also wash in between handling meat or fish and moving on to other food items)
- After using the restroom
- After changing a diaper

- After touching plants or soil
- After visiting the ships' hospital
- After coming into contact with any body fluids or touching items that may have come in contact with body fluids (i.e. runny nose, watery eyes, saliva, blood, urine)
- After touching pets or other animals
- After touching surfaces such as door knobs or railings, which are subject to high hand contact.
- After returning to your cabin

Some items on the Shipsan list were not relevant for passengers on board. For example, there were no pets of plants on the ship, and all passengers were on a full-board plan with four meals provided daily, so no one prepared food. These irrelevant moments are labeled in blue. Some moments could not be observed for privacy reasons and are labeled in green. Other moments occurred too rarely to be reliably observed on a large scale by a single observer; these are labeled in orange.

- Before and after eating
- Before touching your eyes, nose or mouth
- After coughing, sneezing, or blowing your nose
- Before, during, and after preparing food (make sure you also wash in between handling meat or fish and moving on to other food items)
- After using the restroom
- After changing a diaper
- After touching plants or soil
- After visiting the ships' hospital
- After coming into contact with any body fluids or touching items that may have come in contact with body fluids (i.e. runny nose, watery eyes, saliva, blood, urine)
- After touching pets or other animals
- After touching surfaces such as door knobs or railings, which are subject to high hand contact.
- After returning to your cabin

This left us with the moments before and after eating, and after touching surfaces. We also considered the WHO hospital hand hygiene guideline, the "5 Moments for Hand Hygiene."
https://openreseurope-files.f1000.com/linked/262826.Image_1.png

Moments 1 and 4 (before and after touching a patient) are often operationalized in hospitals as before and after entering a patient's room, ensuring that nothing is brought into or taken out of the room via the hands. Based on these considerations, we selected the following three moments for observation, where hand hygiene compliance could be reliably measured.
https://openreseurope-files.f1000.com/linked/262827.image_2

How did you control for bias during observation? Were observers trained? All measurements were conducted by a single observer, so inter-observer variability was not a factor. Although the observer did not receive specific training for this study, she is a

researcher with over 10 years of experience in hand hygiene research. L196: “We recorded the number of people who performed hand hygiene and those who did not. All measurements were conducted by a single observer, so inter-observer variability was not a factor.” Were the passengers exposed to the other interventions or were the other interventions only directed to crew members? This is not clear in your methodolgy. The cruise company requested that passengers not be disturbed during their vacation, which typically lasted only 3–4 days. As a result, passengers were only involved in observation-type measurements (e.g., whether or not they performed hand hygiene) and were not asked to take any actions such as completing questionnaires or participating in training. Crew members were excluded from the compliance measurements because, after a few days, they became aware of the sole observer’s identity and subsequently adjusted their behavior; performing hand hygiene whenever they encountered the researcher. For this reason, the study used a mixed-methods approach. Open or closed ended questions? Binary or Likert-scale? Explain the questionnaire Supplementary Table 2 contains the full questionnaire. (L219, L745) How was this questionnaire validated? The questionnaire was not validated. The study itself should be considered a pilot. Why was this not done pre- and post-intervention for all? Each crew member completed the questionnaire once. The link was provided to all participants during their team meeting session. Responses were collected between October 30 and November 2. Meanwhile, training sessions were organized in small groups of approximately 15 people each, held also between October 30 and November 2. This means that some participants completed the questionnaire before the training, while others completed it afterward, depending on their shift. It was challenging to motivate the crew to take the time to complete the questionnaire. We are confident that if they had been asked to complete it twice, even fewer participants would have done so. How did you compare? Did the same crew members complete before and after? In your previous paprgraph you stated only some completed before and some after. This is confusing A total of 179 crew members completed the online questionnaire: 69 before the training and 89 after. The remaining respondents did not answer this question. Because assignment to pre- or post-training groups was random and determined solely by shift schedules, we assumed that hand hygiene–related knowledge was similar between groups before the training. Therefore, any differences observed between the pre- and post-training groups can reasonably be attributed to the hand hygiene training itself. L450: “A total of 179 crew members completed the online questionnaire: 69 before the training and 89 after. The remaining respondents did not answer this question.” How did you control for possible intimidation or power-plays if supervisors provided the information? We did not formally control for this. The questionnaire was anonymous and administered online, focusing solely on hand hygiene. Only the researcher had access to the individual responses; supervisors and management received only aggregated, analyzed data. Supervisors simply asked crew members to complete the questionnaire and provided as much time as was feasible under the circumstances. Participation was clearly voluntary, as evidenced by the fact that 179 out of approximately 600 crew members chose to complete the questionnaire. What about the passengers? As noted earlier, passengers participated only in observations in which we recorded whether hand hygiene was performed in specific situations. No personal data were collected, and no information that could identify individual passengers was recorded. Consequently, the ethics committee determined that individual informed consent was not necessary. Indicate p values in the table (Figure 8) Modified

https://openreseurope-files.f1000.com/linked/262828.image_3.jfif
This should be presented as a limitation We have added this to the Limitations section, although we believe it should also be mentioned here. L689: “Individual passengers could not be identified; therefore, some may have been observed more than once.” There is no mention of s seperate measurement for buffet in the methodology. Also two different approaches were applied here. The intervention should be consistent at each HH point. We did not initially plan to measure the Buffet and the Restaurant separately. During the observations we noticed a substantial difference between the two settings, which is why the data are presented separately. The difference appears to be related to the two different approaches applied in these areas. It is important to emphasize that we were not aware of this difference prior to the study. These practices were not part of our intervention and remained consistent across all four arms. Our intended intervention to improve passenger compliance was the distribution of flyers. How many? Was this significant? We did not record how many passengers actively refused hand rub or how many missed hand hygiene for logistical reasons. It was not feasible to document the reason of non-compliance- The observer watched from a distance of 3–5 meters, conversations were only noticeable during quieter periods. Nevertheless, since these active refusals happened repeatedly, we believe it is important to mention. You cannot make inferences based on your personal opinion. Please remove this We believe it is important to understand why people do not comply with hand hygiene recommendations. Identifying barriers is essential in order to address them. During our observations, we noted several such barriers. The reason “I just had a shower” may initially seem illogical, hence we attempted to describe the broader context in which it occurred. These observations are not presented as facts but rather as insights that may help guide future researchers to explore these aspects further. How was this information captured and analysed? This was not in the methodology The researcher observed complaints about the gel’s stickiness repeatedly during compliance observations and in everyday situations on board, such as while waiting in line to enter the restaurant. Crew members also reported during training sessions that passengers frequently complained about the handrub and noted that they themselves did not like it. Some noted that other gels are less sticky and that they would use handrub more frequently if a different product were provided. Even the Provision Master mentioned that they had considered switching to another gel due to passenger complaints. Unfortunately, the issue is more complex. All hygiene products on board (soap, shampoo, lotion, etc.) are supplied by the same provider. For a cruise ship, procurement is a significant logistical challenge, and the company concluded that it is safer to rely on a single trusted supplier capable of delivering all hygiene products in coordinated shipments, rather than switching to a different gel and potentially jeopardizing the supply chain. Why was this handrub chosen if this was the result? We did not select the handrub. The same product that had been used previously remained in use throughout the study. You can't have an impression- provide results to back up this statement We did not make recordings during the study, so retrospective analysis is not feasible. The single researcher observed more than 22000 hand hygiene opportunity, and we believe this provided a sufficient basis for forming an impression. Our study was not designed to address age-related differences, as we had no prior indication that age might be an important factor. For this reason, we consider it valuable to mention this topic, as it may help future researchers explore the issue more systematically and generate data that could either support or refute our impression. Quantify these results and state whether this is significant We cannot quantify this observation; it is an impression that we report

solely to inform other researchers and to support the design of future studies that may focus on cultural differences in hand hygiene related to nationality. Many passengers traveled in groups with designated group leaders, which made their nationality recognizable. This is a limitation Our study demonstrated that the location of the dispensers had a substantial impact on hand hygiene compliance. The purpose of the study was to identify ways to improve hand hygiene on a cruise ship, and although many of our interventions did not show significant effects, optimizing dispenser placement clearly emerged as a strategy that can meaningfully improve compliance. Additional details are provided in our abstract:
https://drive.google.com/file/d/1FKYe0nOd8wO5aZTt1Pdi3YF9gAwgXiHq/view?usp=sharing
Figure 8 does not talk to a pillow letter's effectiveness- explain in more detail here Thank you for the correction, it is Figure 10 (former Figure 9). L525: “The passengers' pillow letter was ineffective (Figure 9).” Another limitation We believe it is more an explanation of the experimental data. This should form part of your methodology Relocated, as well as Figure 15. Was this the same crew members or different ones? If so, why? As I was mentioned above, 69 crew members completed the online questionnaire before the training and 89 after. L450: “A total of 179 crew members completed the online questionnaire: 69 before the training and 89 after. The remaining respondents did not answer this question.” Provide p values for this statement. p values were added to the relevant figure (Figure 8). P values were also added to the Results part: L352: “There was no statistically significant reduction in bacterial counts on treated surfaces in Arm 2 compared to baseline ($p = 0.368$). Similarly, neither Arm 3 nor Arm 4 showed significant differences in surface CFUs from baseline ($p = 0.673$ and 0.251, respectively).” Link to other studies reference added L606: “The location of the dispensers largely influenced hand hygiene compliance [18].” How can you be sure this is the reason. Has something similar been proven to be the reason in previous studies? At the restaurant entrance, hand hygiene compliance was consistently high, mainly because the hostess actively offered handrub to everyone. It was observed that whenever the hostess temporarily left her position (for example, when a large group arrived and she stepped inside to check whether seating was available), compliance dropped immediately. During Arm4, the data showed a decrease in compliance, and the researcher noticed that this was because the hostess was less proactive in providing handrub. Previously, she asked every passenger to perform hand hygiene. During Arm4, she merely held up the spray bottle and dispensed it only if passengers extended their hands. This was a substantial difference, clearly observed by the researcher. During quieter periods, the researcher often had conversations with the hostess, as both were worked in the same place for weeks. In one of these conversations, the hostess shared the incident that we report. Because the researcher considered it important, she asked the hostess for permission to include this information in the study. How did you encounter these? Interviews with crew was not part of your methodology. If this is a result it should be in the results section There were no formal interviews with the crew. The researcher spent seven weeks on board and had both formal, planned interactions with the staff (training) as well as informal, unplanned ones. Crew members quickly noticed that the researcher presence had no negative consequences; for example, when she observed something, no manager arrived to demand corrections. Crew members also learned many personal details about the researcher, such as when she woke up, the color of her sundress, and whether she preferred wine or beer with dinner. This contributed to a friendly atmosphere and made conversations easier. Crew members frequently asked the researcher what exactly she was doing. Once they

understood that her focus was hand hygiene, they began to share many facts, feelings, and beliefs about it. They also felt they had found a competent person to answer their questions about germs, hygiene, pandemics, and related topics. The researcher experiences similar interactions during everyday life elsewhere, although in hospitals and universities (where she often organize hand hygiene trainings) staff members have different levels of knowledge about infection transmission. Where are these results? Compliance data are presented on Figure 10. L721: “From the compliance data (Figure 10), we can see that...”
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