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Original Article

An alternative approach for the decontamination of hospital settings

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ABSTRACT

Background: The increasing emergence and spread of multiresistant microorganisms in hospital wards is a serious concern. Traditional protocols are often not sufficient to protect patients susceptible to serious and life-threatening infections, therefore new strategies for decontaminating hospital environments are crucial to reducing microbial transmission and the spread the nosocomial infections. The adoption of modern technologies is indicated to supplement traditional methods and to improve desired levels of surface disinfection.

Aim: This work aims to report the development, implementation, and validation of cleansing and sanitizing procedure for critical clinical settings through the innovative use of disposable cloths pre-impregnated with solutions containing different active formulations and biocidal agents, relating to the areas to be treated (low, moderate, high-risk).

Methods: The implementation and validation of the sanitizing system were conducted in different wards of two healthcare structures. The protocol for the study involved a structured selection of representative surfaces, such as the floor, bathroom, desk, and beds. Microbiological analyses were performed according to ISO 4833-1:2013.

Findings: The efficiency of the proposed system was measured through the estimation of total microbial count values on the different surfaces before and after the sanitization operations by traditional methods and by the system described here. The results demonstrated a significant reduction in the microbial count that always fell below the threshold value. For the analyzed surfaces such as shower tray, bathroom floor, toilet edge, the traditional system had an effectiveness of less than 10%, whereas pre-impregnated cloths succeed to eliminate about 90% of the bacteria present. As an example, on the floor we observed a microbial count reduction from >42 to 10 CFU/11 cm² with the new method (76% of colonies were destroyed), while with the traditional one we have a reduction from >42 to 28 CFU/11 cm² (33% of microbial colonies).

Moreover, the advantages of using this sanitization system are not limited to disinfecting surfaces and limiting cross-contamination but involve all activities related to the cleaning and disinfection operations, including the training and education of the operators and traceability of the operations.

Conclusions: The innovative disinfection and cleaning protocol used in the present study proved to be a highly valuable alternative to the traditional cleaning procedures in healthcare settings for the sanitizing process of all kinds of surfaces. All tools were specifically designed to improve disinfection efficiency and to reduce the problems associated with traditional methods, such as preventing cross-contamination events, limiting the physical efforts of operators, and avoiding incorrect practices. Our findings add support to the knowledge that an effective sanitization procedure is critical in minimizing microorganisms' transmission and cross-contamination.

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Introduction

The recent public health emergency of coronavirus disease (COVID-19) declared by the World Health Organization (WHO) introduced the need for new strategies to face the pandemic. In particular, hospitals have to use appropriate protocols to manage their space, staff, suppliers, patients to reduce infection, and

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in-hospital transmission. The virus aerosol deposition on protective apparel or floor surface and their subsequent resuspension is a potential transmission pathway and effective sanitization is critical in minimizing aerosol transmission of pathogens. Cleaning practices are of utmost importance to improve the healthiness of indoor environments and hospitals to prevent further spread and nosocomial infections diffusion [1–4]. Hospitals and some critical clinical departments, such as intensive care units, oncological units, departments with dialyzed patients, are considered potential points for opportunistic pathogenic microbes [5,6]. Pathogens can spread from patient to patient through contact with inanimate surfaces, including medical equipment and the environment close to the patient [7–9]. There is clinical evidence of a close relationship between environmental hygiene and transmission of microorganisms which produces nosocomial infections such as environmental contamination from methicillin-resistant *Staphylococcus aureus*, the transmission of *Norovirus*, *Clostridium difficile*, *Pseudomonas aeruginosa*, and *Acinetobacter* spp. [10–15,47]. Various approaches have been used to disinfect critical environments but there are still many difficulties related to traditional equipment used and to implementation of procedures. Moreover, in many cases, due to lack of formal surveillance, the rate of healthcare-associated infections is high and compliance with hygiene is low.

Strategies for the decontamination of hospital environments are described in guidelines proposed by various international committees [16], in particular, the advisory committee for the practice of controlling sanitary infection underlines the importance of correct cleaning operations to promote decontamination and the necessary use of disinfectants to reduce the microbial contamination in hospitals [17–19]. Although traditional cleaning protocols are applied and appropriate disinfectants are used in the right concentrations, statistical analyses revealed increasing infections and data suggest that traditional protocols are not sufficient to protect patients susceptible to serious and life-threatening infections [20]. We call for extra care and attention on the proper design, use, and disinfection of the surfaces in hospitals to minimize the potential spread of microorganisms and the risk of cross-contamination thus reducing the infections.

Traditional cleaning methods in medical and healthcare facilities include dry cleaning and dusting. These methods can disperse dust particles throughout the area surrounding the patient, negatively influencing the quality of the air and promoting contamination. Moreover, they cannot be able to contrast the dry deposition of the airborne dispersed microorganisms in a patient room, where it has been hypothesized that contamination may come from the resuspension of dust particles from the floors or other hard surfaces [21–23].

Multiple Drug Resistance (MDR) microorganisms and healthcare-associated infections (HAIs) remain significant challenges, both in hospitals and in long-term care facilities [3,5,24,25]. They may cause patients or residents to suffer from additional ailments, and sometimes result in death (in Italy it is estimated in 49,000 cases per year). The existing problem of MDR microorganisms and HAIs show us that, in order to properly follow the *primum non nocere* principle in healthcare, we should take into account all of the epidemiological, biological, organizational, and social aspects of healthcare. In this study, we propose a multidisciplinary approach based on the use of disposable microfibre or spunlace cloths impregnated with different disinfectant solutions to be used in the cleaning operations of healthcare settings. This approach also considers of primary importance the use of a specifically designed trolley and mandatory training and education of the operators. This procedure leads to an improvement in air quality, disinfection of surfaces close to the patient, and a significant reduction in cross-contamination. In addition to the antimicrobial efficacy, the disinfectant products proposed have low toxicity, low

flammability index, low skin irritation and no residue are even detectable.

The cleaning activity is part of a complex holistic approach that combines the need to ensure the disinfection of the area close to the patient with the safety of the cleaning operator, considering also the right training and education.

Principles of decontamination

Some studies have highlighted the importance of decontamination processes after the use of reusable detergents and/or cloths to avoid cross-contaminations [20]. In common cleaning protocols, the same mop is used to clean a large area, without any difference between contaminated and uncontaminated spaces. There is a mandatory practice required for the washing procedure with frequent replacement of disinfectant solutions (e.g. after every three or four chambers, with intervals of no more than 60 min) and high temperature treatment of the mop. However, cloths and mop, subjected to continuous high temperature decontamination treatments, progressively lose their cleaning capability crumbling their texture.

On the other hand, disinfection methods used in many intensive care units and other healthcare facilities include the innovative use of antimicrobial wipes. These products seem to be more efficient to remove the microbial load on surfaces [27]. The use of alcohol wipes has also been shown to reduce the microbial load usually present on toilets [28]. However, very elaborate procedures are required to ensure maximum effectiveness of the antibacterial wipes, otherwise even these, if not properly used, can favor the spread of microorganisms (e.g. tables, headboards) [29]. Operators should not use the same wipe repeatedly to clean and disinfect different surfaces and have to be correctly trained.

Disposable wipes pre-impregnated with a disinfectant can also be used for low-level disinfection when spot cleaning of non-critical surfaces is required [30].

An important question raised by the use of disinfectants for non-critical surfaces, such as wardrobe and bedside table, and in healthcare facilities is the contact time specified on the product label, which is often too long to be practiced. The labels of most products registered by EPA (Environmental Protection Agency) to be used against HBV (Hepatitis B virus), HIV (Human Immunodeficiency Virus), or *Mycobacterium tuberculosis* specify a contact time of at least 10 min. Such a long contact time is not practical for surface disinfection in a healthcare environment, since most healthcare facilities apply a disinfectant leading it to dry for about 1 min [16].

The method proposed here uses disposable microfibre or spunlace cloths, pre-impregnated with a mixture specifically formulated to ensure a detergent and disinfectant synergic action. According to WHO guidelines the detergent and disinfectant solutions must meet the requirements for disinfectant/antimicrobial products for contaminated surfaces and may contain different active ingredients or mixtures of these, for example, alcohol, chlorine [31,32,33], phenols, polyphenols [34], quaternary ammonium salts [35], tertiary amines, chlorhexidine gluconate.

The formulations used for the pre-impregnation contain increasing concentrations of the selected disinfectant as required for the sanitification of environments in the different areas of a hospital (e.g. low, moderate, and high-risk areas).

Education and training

The staff dedicated to cleaning operations represents the most critical point in the cleaning and sanitizing processes of hospitals. The hospital staff or the company that carries out the cleaning oper-

CHECK LIST

U O _____ Date ____/____/____

EQUIPMENT	
N.1 Manual pol	<input type="checkbox"/>
N.1 Surface polblock	<input type="checkbox"/>
N.1 Floor pol	<input type="checkbox"/>
N.1 Headpol	<input type="checkbox"/>
N.1 Bench	<input type="checkbox"/>
N.1 E-FLY floor	<input type="checkbox"/>
N.1 Aluminium band	<input type="checkbox"/>
N.2 Wast basin	<input type="checkbox"/>
N.2 Rolled paper holder	<input type="checkbox"/>
WIPES	
N.2 Surface wipe	<input type="checkbox"/>
N.2 Bathroom wipe	<input type="checkbox"/>
N.2 Floor wipe	<input type="checkbox"/>
CHEMICAL PRODUCTS	
N.2 NaDCC	<input type="checkbox"/>
N.2 Disinfectant solution	<input type="checkbox"/>
N.2 WPC CLEANER	<input type="checkbox"/>
DPI	
N.2 Goggles	<input type="checkbox"/>
N.2 Glasses	<input type="checkbox"/>
N.1 Mask	<input type="checkbox"/>
Note	
NAME Operator _____	Signature Operator _____

Fig. 1. (a) Traceability cards for sanitization trolley. (b) Check list of trolley equipment for sanitization of a high-risk room.

ations must ensure that its manager and all the operators involved in the service, do their work or duties safely, guaranteeing a result capable of satisfying the requirements, the expected quality levels, and the objectives of the activity carried out.

The training plans should include, in addition to a general basic course for health service workers, targeted courses on the order to be performed.

It is necessary that the staff employed is well trained on the protocols drawn up according to the environment to be cleaned. In particular, it has to be employed personnel who have been properly trained to carry out cleaning activities e.g. in the infectious diseases and nuclear medicine departments, Operating Rooms, Intensive or Sub-Intensive Therapy services, which require greater attention to the cleaning process, avoiding turn-over. Employees must perform only the functions for which they were trained; they must receive specific training for the areas of intervention; they also need to be trained on the biological and chemical hazards to which they could be exposed on the intervention site. The environmental intervention program and its actuation mechanism may vary according to the size of the structure and to the services provided.

The staff training course programs include mainly the following themes:

Cleaning (products and procedures) and environmental disinfection; use of work equipment; correct use of the trolley, that is specifically designed to contain separately pre-impregnated cloths for the different surfaces and allows to avoid contact between dirty and clean cloths; definition of internal paths (clean/dirty); personal hygiene; hand washing; adoption of measures to prevent the transmission of infections; use of the supplied devices; staff clothing; disposal of medical waste; risk management; quality plan; significant impact.

Other training topics in compliance with the safety of the workers themselves may be the prevention of risks from the hospital environment; method of execution of the rooms service; correct use of protective devices; collection, transport, and disposal of dangerous substances and/or preparations, written protocols for daily disinfection activities, traceability cards, checklists.

Traceability cards/checklists

Documentation of work and registration of all phases can avoid legal problems and could increase professional credibility according to Presidential Decree 224/88 and EC Directive 2001/95 [36].

Tracing processes helps the operator to identify errors and possibly to remedy. Therefore, the processing and use of traceability cards, (see Fig. 1), represent a medical-legal protection tool for operators and Healthcare companies. The traceability system must document the process steps: operator data and signature, date and time, process steps, hospital structure reference, any notes or observations, etc.

In order to monitor and make traceable all the phases of the cleaning process and simplify the organization of the operator's work, each activity must be recorded on special cards/checklists and signed by the operator who performed the interventions.

The introduction of traceability cards has proven to be a very useful tool integrated with the training and educational programs adopted by the hospitals for the implementation and validation of this new cleaning strategy for the selected hospital settings, leading to an overall improvement in the cleaning and sanitization activities of hospital wards.

Methods

In order to use measurable outcomes to investigate the hospital cleaning as a scientific process, we performed microbiological analyses in three different environments according to international standard UNI EN ISO 4833-1:2013, which specifies a horizontal method for enumeration of microorganisms able to grow and form colonies in a solid medium after aerobic incubation at 30 °C.

A specific quantity of the test samples, or a specified quantity of an initial suspension, was surface plated on a solid agar culture medium contained in Petri dishes. Other plates were prepared under the same conditions using decimal dilutions either of the test sample or of the initial suspension. The plates were incubated under aerobic conditions at 30 °C for 72 h. The number of microorganisms per gram of sample or the number of microorganisms per milliliter of samples was calculated from the number of colonies obtained on the plates containing less than 300 colonies/plate.

All samples were collected before and after disinfection processes, both by the traditional system and the one proposed by us, to evaluate the efficiency of the different cleaning protocols in the same hospital wards. The standard cleaning protocol of the hospitals included cleaning with a reusable mop dipped in a solution of water and a disinfectant, the same sanitization solution used with the innovative system. Once dipped the mop was used to clean approximately 40 square meters room, following which the mop was double dipped and reused in adjacent rooms. For the cleaning protocol purpose in this study, microfiber wipes were used that, thanks to their positive charge (containing polyester and nylon), attract negatively charged particles such as dust, liquid, and pathogens. Microfiber wipes used had the following characteristics: high density with 40× surface area than a conventional cotton-loop mop; were split to create gripping “hooks” that make them highly absorbent; weigh of 20 g and specifically 100 g/m²; various dimensions such as 20 × 27 cm² for surface cleaning and 22 × 60 cm² for floors and larger surface; more than 90% of disinfectant solution impregnated could be absorbed (0,04 mL/cm² of disinfectant solution). One single cloth was used for each medium surface/room to avoid contamination between different rooms: operator removed the wipe from the packet, seal the packet to avoid other wipes drying out, start wiping surfaces and at the end, it was thrown in the trash. The cleaned surface was allowed to air dry for 10 min and then we collected samples for bacterial culture. For each room 10–14 high-touch surfaces, such as sink, desk, shower, bed were chosen for the assessment of the cleanliness, and the cleaning staff was not informed about the sampling. About 10–14 samples were collected in triplicate for each room, in different locations, as reported in Tables 1a, 1b, 2. Statistical analysis was performed with

GraphPad Prism 7.0 (GraphPad Software, Inc., San Diego, CA). The results were considered significant at P-value <0,05.

Disposable pre-impregnated wipes with many different disinfectants were obtained from Cle.Pr.In. Srl and a specially designed cleaning trolley was delivered by Femir Srl. Wipes used in this work were impregnated with a sanitization solution of 70% alcohol, 5% chlorine, phenols, 10% quaternary ammonium salts, 5% chlorhexidine gluconate, all solutions were tested in the same conditions. All trolleys were designed to prevent cross-contamination events, limit the operators' physical efforts, avoid incorrect postures, and equipped with advanced accessories:

- N. 2 closed 150 L bag holders with divider and pedal set;
- Green base with wheels Ø 125 mm, for outdoors;
- N. 4 drawers of 22 L (green, white, gray, cream) for arranging the different types of cloths to be used for cleaning;
- Gray bar for handle hook;
- Hooks for storing cleaning tools;
- Plastic container to hold waste bags; the tray must be inserted interlocking on the handlebar handle of the trolley.
- Rolled paper holder, completely in plastic, which can be inserted into the edge of the container. It is complete with a transparent plastic cover, to avoid contact of the paper with the work environment.

The trolley was designed to separate the storage of cloths from the waste section, to avoid contamination of the material and clean instruments. The surfaces were also made without corners and edges, and caps and covers were affixed to close any holes that are difficult to reach during cleaning operations. Furthermore, the basic idea of the project was that for each ward a specific trolley was used that had not to be moved in different wards to avoid cross-contamination events.

Results

The advantages of using this innovative cleaning system compared to traditional methods are shown by the results of Tables 1a, 1b, 2, which summarize the results of the swabs carried out in different areas of two healthcare facilities, one private and one public. The results showed in these tables were obtained with microfiber wipes pre-impregnated with ethanol 70%, however all disinfectant solutions were tested and gave the same performance. The significant reduction in the microbial count, that always falls below the threshold value, reported thereafter, demonstrates the effectiveness of the system proposed here.

Reference parameters to standard disinfection test:

Microbial load at 37 °C UNI EN ISO 4833

Hygienic performance CFU/11 cm ²	Very good Up to 1	Good 2–4	Satisfying 5–13	Controversial 14–42	Unsatisfying Over 42
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The following tables show that for the analyzed surfaces such as shower tray, bathroom floor, toilet edge, etc. the traditional system has little efficacy, with the effectiveness of less than 10%, whereas pre-impregnated cloths succeed to eliminate about 90% of the bacteria present.

Discussion

Cross-contaminations, disinfection, and cleaning strategies play an important role in the everyday organization of hospitals and many scientific studies are reporting precise protocols for sanitizing healthcare environments [37–39]. In the framework of the present international outbreak related to coronavirus disease COVID-19, rigorous measures are necessary to optimize the qual-

Table 1a

Total microbial load estimated on sampling performed on different surfaces (30 samples) in a patient room of a public healthcare structure (CFU/11 cm²), values are expressed as mean ± SD.

Samples	Before sanitization				After traditional sanitization				Before sanitization				After sanitization with the experimented method			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
WC	> 42	> 42	> 42	–	35	44	38	±5	> 42	> 42	> 42	–	0	5	3	±2
Sink	27	39	34	±6	9	18	13	±5	26	33	29	±4	1	3	2	±1
Water tap	24	29	26	±1	10	14	12	±2	> 42	> 42	> 42	–	0	3	2	±1
Shower	> 42	> 42	> 42	–	> 42	> 42	> 42	–	24	32	27	±4	1	6	4	±3
Bathroom floor	> 42	> 42	> 42	–	> 42	> 42	> 42	–	> 42	> 42	> 42	–	3	12	8	±5
Removable desk	15	20	17	±1	0	9	4	±5	29	37	33	±4	0	2	1	±1
Table	28	35	31	±2	8	13	10	±3	19	27	23	±4	0	4	2	±2
Bed	17	26	21	±2	9	13	11	±2	9	24	16	±7	3	8	6	±3
Door	8	13	10	±1	2	11	6	±5	8	15	12	±4	0	0	0	0
Bedroom floor	> 42	> 42	> 42	–	26	31	28	±3	> 42	> 42	> 42	–	2	15	10	±7

Table 1b

Total microbial load estimated on sampling performed on different surfaces (33 samples) in a staff room of public healthcare structure (CFU/11 cm²), values are expressed as mean ± SD.

Samples	Before sanitization				After traditional sanitization				Before sanitization				After sanitization with the experimented method			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
WC	8	17	13	±5	4	8	6	±2	2	7	4	±3	0	0	0	0
Sink	7	11	9	±2	6	10	8	±2	1	3	2	±1	0	0	0	0
Water tap	9	14	12	±3	7	11	9	±2	7	9	8	±1	0	0	0	0
Shower	10	21	15	±6	2	7	4	±3	7	8	7	±1	0	0	0	0
Bathroom floor	12	18	15	±3	11	13	12	±1	8	11	10	±2	0	1	1	±1
Desk	33	43	37	±5	18	32	24	±7	27	40	35	±7	0	1	1	±1
Door	> 42	> 42	> 42	–	15	36	27	±11	30	47	38	±9	0	7	4	±4
Floor	> 42	> 42	> 42	–	9	15	13	±3	25	27	26	±1	0	5	3	±3
Wardrobe	> 42	> 42	> 42	–	7	21	14	±7	12	16	14	±2	0	0	0	0
Bedside table	20	26	23	±3	5	24	17	±10	15	20	17	±3	0	0	0	0
Mixer tap shower	8	11	9	±2	3	8	6	±3	5	7	6	±1	0	0	0	0

Table 2

Total microbial load estimated on sampling performed on different surfaces in a staff, attending, and patient room (39 samples) of the private healthcare structure (CFU/11 cm²), values are expressed as mean ± SD.

Samples	Before sanitization				After sanitization with the experimented method			
	Min	Max	Mean	SD	Min	Max	Mean	SD
WC	3	8	5	±3	0	0	0	0
Sink	33	43	38	±5	0	0	0	0
Water tap	5	9	7	±2	0	0	0	0
Toilet board	2	4	3	±1	0	0	0	0
Door handle bathroom	5	18	11	±9	1	1	1	0
Bathroom floor	2	7	4	±3	1	1	1	0
Desk	29	33	31	±2	0	2	1	±1
Door handle attending room	1	3	2	±1	0	0	0	0
Floor attending room	25	32	28	±4	5	15	10	±5
Floor_patient room	22	33	28	±5	0	0	0	0
Bed_patient room	1	6	4	±3	1	1	1	0
WC_patient room	18	24	21	±3	0	0	0	0
Sink_patient room	3	7	5	±2	0	0	0	0

ity of care provided to infected patients and to reduce the risk of pathogen transmission to other patients or healthcare operators. Regardless of the type of surface (hands, environmental surfaces, fabrics), the objective of a cleaning and sanitizing procedure is to reduce contamination to an acceptable level of safety by applying operating methods designed to remove pathogens from surfaces. The procedure described in this work is based on a holistic approach for the decontamination and sanitization of surfaces in healthcare facilities with different risk levels (low, moderate, high).

A careful analysis of the characteristics of the antimicrobial agent chosen to disinfect the critical surface was necessary and it was crucial to define the right composition of disinfectant solutions so that these were not corrosive to the treated surfaces and did not release strong odors. Regarding the use of disinfectants, guidelines

exist to define the minimum concentration of biocide in an optimal disinfectant solution to control the spread of harmful bacteria and other microorganisms. The disinfectant formulation must contain enough antimicrobial agents to be effective for a given application. The presence of a greater quantity of antimicrobial agent does not provide any advantage to the resulting composition, essentially it could only produce a disadvantage on the treated surface and, more generally, on environmental pollution. On the other hand, having a lower concentration of antimicrobial agent will make the composition less effective than necessary for the required use.

Results, reported in Table 1a, were obtained using microfiber wipes pre-impregnated with ethanol 70% to clean different surfaces in a patient room of public healthcare structure and showed a better performance than traditional cleaning protocols: for exam-

ple on the floor we observed a microbial count reduction from >42 to 10 CFU/11 cm² with the new method (76% of colonies were destroyed), while with traditional one we have a reduction from >42 to 28 CFU/11 cm² (33% of microbial colonies).

Moreover, in literature it was demonstrated that the microfiber system has superior microbial removal efficiency compared to cotton string mops [40,41], however, there is no experimental data on pre-impregnated wipes with various disinfectant solutions.

Previous experimental data record efficacy principally for cleaning and disinfection process with microfiber/steam technology or wipes dampened with water, where authors demonstrated that the introduction of microfiber into the hospital sanitization process, in particular into operating room environment, has been environmentally and fiscally beneficial [42–45].

The antimicrobial efficacy of a pre-impregnated cloth is also related to the interaction of the disinfectant solution with the support. The interaction of the support with the disinfectant solution could lead to a decreasing amount of biocide in the solution. Therefore, in the realization of this work, we used pre-saturated cloths which means cloths that are saturated by the manufacturer with the desired disinfectant solution and delivered to the user in a wet format. Saturated pre-impregnated cloths solve, or at least reduce, the problem of decreasing the availability of the active ingredient because they offer the possibility of changing the concentration of disinfectant in the solution during the manufacturing process which is consistent with the desired percentage of biocide agent (solution concentration). The characteristics of the surface to be cleaned have also to be considered when choosing the cleaning support (spunlace or microfiber), in fact, in some cases, the presence of non-uniform surfaces seems to favor the use of microfiber wipes that are more adaptable, even in most hard-to-reach spaces. In Table 2 results showed that the total microbial load estimated on sampling performed on different surfaces in a staff room of public healthcare structure was reduced more than 90% CFU/11 cm², only for floor attending room we have a reduction of 64%. A possible weakness related to the use of pre-impregnated spunlace or microfiber could be the quick evaporation of the solvent if the package is not properly closed and there is no good adhesion between wipes and surfaces, with less efficiency of the system.

The use of a disinfectant solution pre-impregnated microfiber or spunlace cloth for different kinds of surfaces was supported by an appropriated trolley designed to help the operator during the cleaning procedure. All tools were specifically designed to improve disinfection efficiency and to eliminate the problems associated with traditional methods, such as preventing cross-contamination events, limiting the physical efforts of operators, avoiding incorrect postures and errors. Moreover, this innovative method for cleaning and disinfecting floors avoid the risks of falling or tripping because the presence of wet floors is significantly reduced thanks to the use of pre-impregnated microfiber cloths. In addition, this procedure involves the use of ergonomic cleaning tools capable of reaching even difficult-to-reach surfaces, significantly reducing the use of stairs and stools. However all tools must be cleaned and disinfected to improve cleaning procedures, otherwise they could be one of the possible sources for contamination.

This system shows several advantages for the operator, for occupation quality and work satisfaction, and helps in protecting the environment [48,49] according to the new parameters provided for by current regulations and international guidelines.

The use of pre-impregnated cloths reduces the amount of water to be used and spills into the pipes, also eliminating the disinfectant solutions that are thrown into the sewers daily. This item was also deeply investigated through an LCA (Life Cycle Assessment) study that allowed to confirm that the system can be suitably

included in an EPD (Environmental Product Declaration) system [46].

Conclusions

The procedure implemented in this work provides evidence on the sanitization of hospital settings and examination of different products in terms of commodity, variety, composition, and chemical nature, demonstrating that pre-impregnated microfiber cloths could be a useful alternative for hospital infection-control program. Quantitative assessment of the level of cleanliness by swab cultures revealed the better performance of the proposed method highlighting the vital role that infection prevention and control play in improving healthcare systems.

This approach also considers of primary importance the use of a specifically designed trolley and mandatory training and education of the operators. This procedure leads to an improvement in air quality, disinfection of surfaces close to the patient, and a significant reduction in cross-contamination. An additional advantage of this system is the simultaneous dusting, cleaning, and disinfection action which avoids passing three times on the same surface.

Overall this study showed that the use of disposable pre-impregnated cloths has many advantages:

- The cleaning operator will be able to achieve higher cleaning and decontamination standards than traditional methods, thanks to the synergistic action of microfiber cloths (which already show high microbicide capacity on their own) and of detergent and disinfectant mixtures.
- The use of pre-impregnated cloths for dusting and wet cleaning will prevent phenomena of air dispersion of contaminated particles
- The patient who occupies sanitized rooms with disposable cloths will be better protected from accidental cross-contamination diffusion.
- The cleaning operator is less exposed to chemical, biological, physical, and postural risks.
- The hospital will be less exposed to the risk of contamination and the spread of nosocomial infections and will be able to more easily manage the personnel involved in the cleaning procedures because these will be faster, less tiring, and require fewer extraordinary interventions (weekly, monthly).

Competing interests

None declared.

Ethical approval

Not required.

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