Igiene e Sanità Pubblica 2023; 81 (1):1-12

Role of environmental sanitization in health clinics: evaluation of potassium peroxymonosulfate (KMPS) efficacy at two different concentrations

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Keyword: *potassium peroxymonosulfate, air and surface disinfection, microbial reduction*

Abstract

Background: Healthcare-associated infections (HAI) are closely related to several factors, such as prolonged hospital stay in high-risk areas and intensive care units, potentially predisposing underlying conditions. It has also been demonstrated that HAI incidence may be related to non-respected standards of assistance, such as not adequately cleaned structures or medical devices contaminated by environmental bacteria and multidrug resistant enterobacteria. **Objective**: In this case it has been carried on an efficacy evaluation of a microionization system using potassium peroxymonosulfate (KMPS) for outpatient clinics indoor air disinfection. Material and methods: Two outpatient clinics (AMB-1 and AMB-2) were treated with KMPS (1% and 2% concentration), at the end of routinary clinic activities.

Microbial sampling of air (settle plates) and surfaces (contact plates) were submitted before and after sanitizing, checking total microbial load at 37°C, possible opportunistic pathogens and moulds. **Results**: Sanitizing system at 1% concentration was efficient in mesophilic bacteria reduction (max 83%). Moreover, total abatement of Klebsiella pneumoniae in AMB1 and Acinetobacter lwoffi in AMB2 has been seen, both on surfaces. Regarding air samplings, 89% moulds reduction has been seen, as observed on surfaces. Scaling up concentration to 2%, mesophilic bacteria reduction was ≥ 94%, both in air and on surfaces of the outpatient clinics. Same results have also been seen on moulds, whose maximum reduction was 97%. **Discussion**: Comparing results at different concentrations it has been observed that 2% KMPS induces an higher average reduction of mesophilic bacteria and moulds than 1%. Background : In this regard, microbial reduction percentage, either on surfaces or in the air, can be considered positive for outpatient clinics and healthcare settings indoor decontamination.

Riassunto

Background: Le infezioni correlate all'assistenza (ICA) sono strettamente correlate a diversi fattori, come la permanenza prolungata in ospedale in aree ad alto rischio e terapie intensive, potenzialmente favorite da condizioni sottostanti.

È stato inoltre dimostrato che l'incidenza di ICA può essere correlata al non rispetto di standard assistenziali, come strutture non adeguatamente sanificate oppure strumentario medico contaminato da batteri ambientali ed enterobatteri multidrug-resistant (MDR).

Objective: È stata portata avanti una valutazione di efficacia di un sistema di microionizzazione tramite perossimonosolfato di potassio (KMPS) per la disinfezione di ambienti indoor in contesto ambulatoriale. **Material and methods**: Sono stati analizzati due ambulatori (AMB-1 e AMB-2) trattati con KMPS alla concentrazione 1% e 2% al termine delle attività cliniche routinarie. Il campionamento microbiologico dell'aria passivo (piastre a caduta) e delle superfici (piastre a contatto) è stato effettuato prima e dopo la disinfezione, valutando la carica microbica totale a 37°C, patogeni opportunisti e muffe. **Results**: Alla concentrazione 1% di il sistema è stato efficiente nella riduzione dei batteri mesofilici (con un massimo dell'83%). Inoltre, è stato visto un abbattimento totale di Klebsiella Pneumoniae nell'AMB1 e di Acinetobacter Lwoffi nell'AMB2, entrambi su superfici. Per quanto riguarda il campionamento dell'aria, si descrive una riduzione dell'89% delle muffe, così come sulle superfici. Aumentando la concentrazione al 2%, la riduzione dei batteri mesofilici è stata del 94%, sia in aria che sulle superfici degli ambulatori. Gli stessi risultati sono stati rilevati sulle muffe, la cui riduzione massima è stata del 97%. **Discussion**: Comparando i risultati alle differenti concentrazioni, è stato visto che KMPS al 2% di concentrazione induce una maggiore riduzione di batteri mesofilici e muffe rispetto all'1% di concentrazione. **Conclusion**: A tal proposito, la riduzione microbica percentuale, sia su superfici che in aria, può essere considerata positiva per la decontaminazione di ambulatori e settings assistenziali indoor.

1. Introduction

Nowadays, infectious diseases have become a public health concern and major efforts are required to prevent and control them, mainly using disinfectants and sanitizers.

As studies keep going on, we're coming up with something more, witnessing new ways of understanding cleanliness.

Potassium peroxymonosulfate (KMPS) is a multi-purpose virucide and disinfectant aimed against pathogens affecting domestic and companion animals. It was produced and launched for farming and livestock production purpose.

As KMPS datasheet shows a wide range of antimicrobial activity and relative safety, it's widely used, even by UN-FAO and governments worldwide, to strengthen biosafety and prevent communicable diseases. KMPS is made with potassium peroxymonosulfate, sodium dodecylbenzenesulfonate, sulfamic acid and inorganic buffers. This solution is used for sanitization and cleaning in hospitals, laboratories, dental facilities and so on.

Many independent tests have shown that KMPS is able to inactivate viruses, including a strain of virus closely related to coronaviridae strains. In these tests, the inactivation was gained by a 1% concentration and a contact time of 10 minutes.

This formulation is diluted and sprayed on surfaces and equipment, both in hospitals and in public areas such as airports, shopping centers, etc. According to test conditions required by US Environmental Protection Agency (EPA), KMPS seems to offer a wide spectrum of action, combining cleaning and disinfection and avoiding pre-washing.

About its chemical formulation, KMPS is based on an oxidizing agent which develops the optimal conditions with an acidic pH range (from 2.6 to 2.7), kept within optimal limits by organic acids and inorganic buffers. The oxidizing agent acts on the extra and intra-cellular chlorinated components to generate chlorine in situ.

Specifically, KMPS is made out of Hydrogen peroxide (that develops active oxygen), Active chlorine, Chloramine, Hypochlorous acid, Chlorine in situ.

As most traditional disinfectants could be inactivated by organic materials, KMPS contains an anionic surfactant that enhances a cleansing action, lowering the surface tension and letting the product penetrate inside the targeted microorganism.

KMPS is distributed as a powder, which dissolves in cold tap water obtaining a ready-to-use solution (1kg of product allows the preparation of 100 liters of solution). After its activation, the solution is stable for about 7 days.

Moreover, KMPS is biodegradable and the residues of the used solution can be normally disposed without any risk for the environment.

Studies have been carried on using KMPS at its recommended concentration (1%), demonstrating that it does not irritate [1], neither gives off toxic vapors or unpleasant odors.

It has also been tested by CDC and approved by US-EPA [2], with positive outcome and recently several trials were done evaluating its efficacy on different microorganisms.

For example, it has been seen [3] that KMPS (1%) at 2 hours contact time, is most efficient in killing *K.pneumoniae, E. coli, P. Mirabilis, A. baumanii, P. aeruginosa, S. aureus, MDR Enterococcus, B. subtilis*, etc.

Also, 1% KMPS killed *S. aureus, P aeruginosa*, and *C. albicans*, while 3% KMPS solution was required to kill *B. subtilis*.

KMPS has also shown excellent bactericidal and sporicidal efficacy. At 1% solution, all vegetative bacterial strains were effectively killed within 30 seconds exposure, while spores were killed after contact time of 2 hours. For this reason, it can be considered a fast-acting surface disinfectant and optimal for any practical use.

KMPS efficacy has been evaluated also on dental casts [4]: low toxicity and good environmental compatibility were shown, so it could be used as an antimicrobial agent for disinfection of dental stone casts as non-critical items. In fact, it was found out that *S. aureus*, *P. aeruginosa*, and *C. albicans* do not show significant difference between 1% KMPS and 0.525% sodium hypochlorite ($p > 0.05$). For *B. subtilis*, instead, the efficacy of 3% KMPS and 0.525% sodium hypochlorite was not significantly different ($p > 0.999$).

Moreover, KMPS has been tested on Novel avian influenza (H7N9) viruses [5]: further studies showed that it can be completely inactivated, although the virus presents a high tolerance to moderately acidic or higher alkali conditions. These results seem to be essential information for public health intervention of novel avian influenza H7N9 outbreaks.

Furthermore, KMPS destroys the Hepatitis B Surface Antigen (HBsAg) in ten minutes at the concentration of 1% [6].

According to some authors, it would not have irritant or toxic effects on animals and would not produce damage, at usual concentrations, on the materials utilized in hospital environments.

Further, Lawley et al. [7] found that 70% ethanol had no obvious or reproducible effect on the viability of the spores of *C. difficile*, whereas the sporicidal agent KMPS (1%) efficiently inactivated the spores.

The new disinfectant KMPS has been suggested as particularly suitable for the disinfection of hospital environments and surgical instruments which cannot undergo autoclave sterilization, such as endoscopes, which frequently act as carriers of pathogenic infectious agents and opportunists in immunologically weakened subjects.

It may be observed [8] that the sporicidal effect is greater and accelerated when using physiologic solution rather than distilled water. In fact, following only five minutes of contact, 99% of the spores of *B. subtilis* and *B. stearothermophilus* suspended in physiologic solution prove to be inactive, while at least ten minutes are required to inactivate approximately 60% of the spores suspended in distilled water.

Furthermore, its tolerability, biodegradability, safety of use and non-corrosiveness to metals make it suitable for use in hospitals to prevent the spread of nosocomial infection.

The compound was found to be effective against tested *Salmonella* strains dried on stainless steel [9]. There was also a tendency to be more active against Salmonella rather than the dominating non-spore-forming microbiota, found in both fish feed and animal feed factories. Consequently, these results suggest that its use may reduce the Salmonella populations, while leaving the majority of the other bacterial populations less affected.

Another study [10] conducted in Portugal demonstrated its efficiency in eliminating all bacteria tested, such as *Enterococcus spp, E. coli, Pseudomonas spp, S. pseudintermedius* and so on.

Masia et al. [11], in their air samplings in Operating Rooms (OR), isolated *Pseudomonadaceae*, *Enterobacteriaceae*, *Staphylococcus aureus* and coagulase-negative staphylococci. Due to its high capacity to survive and spread in hospital environments, Pseudomonadaceae detected in air and surfaces might be a threat for patient health, especially leading to surgical site infections (SSI).

Prevention of SSI is complex and requires integrated preventive measures before, during and after surgery. Since this prevention is not standardized worldwide, guidelines are necessary to face this issue. In its Global Guidelines for the Prevention of Surgical Site Infection [12], defined the factors contributing to the risk of SSI during the patient's stay in the surgery ward. Therefore, the prevention of SSIs is complex and requires the integration of multiple preventive measures before, during and after surgery. In fact, the incidence density of in-hospital SSIs per 1000 post-operative patient-days varied from 0.1 to 5.7, depending on the type of surgical procedure. [13]

Even more specifically, efficacy of KMPS has been tested on S. iniae [14], that is able to form resilient biofilms for its persistence in the environment which increase its survivability, especially in aquatic environments, eradicating all isolated biofilms.

Moreover, KMPS has been tested even in addition of alginate acid beads for water disinfection [15]. In this case, it turned out that KMPS has been helpful in the elimination of MRSA, MSSA and *E. coli*, in order of strength of action.

Besides its antibacterial activity, KMPS seems to be quite efficient even as a virucide. For example, a study [16] was aimed to validate the use of 1% KMPS over African Swine Fever Virus (ASFV), disinfecting surfaces in containment laboratories.

Likewise, this action has been seen against Epizootic Epitheliotropic Disease Virus (EEDV) in aquatic environment by treating EEDV-contaminated nets with 1% KMPS Aquatic [17]. In susceptible host species as trouts, there were no signs of virus, no signs of disease, not EED-associated mortality.

About food supply chain, a study [18] was carried out evaluating efficacy of various disinfectants on the elimination of Tomato brown rugose fruit virus (ToBRFV) and Cucumber green mottle mosaic virus (CGMMV), both harmful for fruits and vegetables. They have seen positive effects with KMPS at 2% concentration and it was useful on Tobacco mosaic virus (TMV) of Petunias, too.

Infection control is also important when speaking about Healthcare Associated Infections (HAIs). Among them, Surgical Site Infections are

Mainly, this work is aimed to evaluate KMPS effectiveness (1% and 2% concentration) in hospitals and healthcare facilities. As literature shows efficacy of KMPS 1% and 2% on reduction of microbial load even after few minutes of exposure, our research tests the germicide and sporicide power of this tool in healthcare setting, e.g. outpatient clinic.

2. Materials and Methods

Efficacy of KMPS has been evaluated mainly on surfaces and air, from May to June 2021, collecting samples in outpatient clinics of a local healthcare facility of Pisa Province, Italy.

Microbial load reduction was evaluated using contact plates (UNI EN ISO 14698-1), with Rodac plate Ø55 mm, containing Plate Count Agar (PCA) and Sabouraud Dextrose Agar (SDA), both from Oxoid Ltd, Basingstoke, UK. After every sample collection, surfaces were cleaned by 70% alcohol wipes, in order to remove agar remains from surfaces.

After collection, plates have been delivered to the Hygiene laboratory, on temperature-controlled transport.

Totally, 128 samples of surfaces and 64 air samples were collected. Each air and surface point of sampling was taken at different height, in order to evaluate cleansing efficacy on the entire volume, so measured:

- outpatient clinic no.1 (AMB1), 15m2 surface, 50m3 volume
- outpatient clinic no.2 (AMB2), 13m2 surface, 40m3 volume.

Sampling points are shown in Table 1.

	Outpatient clinic no.1 (AMB1)		**Outpatient clinic no.2 (AMB2)**	
	Surfaces	**Air**	**Surfaces**	**Air**
1	Right wall on the window side	Right corner on the door side	Windowed wall on the right side	Right corner on the door side
2	Right wall	Left corner on the door side	Right wall on cabinet side	Left corner on the door side
3	Left wall on the door side	Room center	Radiator wall	Room center
4	Wall under the desk	Under the desk	Desk	Under the desk
5	Wall above the desk	-	Under the desk	-
6	Windowsill	-	Left wall	-
7	Right wall (3 meters of height)	-	Stool	-
8	Desk	-	Windowsill wall	-

Table 1: *Surface and air sampling classification of outpatient clinic no.1 (AMB1) and clinic no.2 (AMB2)*

Disinfectant was dissolved in sterile water for a concentration of 1% (10g/L) or 2% (20 g/L) of product in a clean tank, which was ultimately in the nebulizer device.

In both disinfections the two different concentrations were applied; nebulization processes took place 45 min for AMB1 and 35 min for AMB2.

Environmental samplings on surfaces and air were taken at two different times, at the beginning of the procedure (unclean room) and 15 min after the treatment.

Microbiological monitoring was performed on air and surfaces matrices measuring the total microbial counts at 37°C and moulds.

In each air monitoring, passive method (settle plates) was chosen, leaving plates exposed for about an hour, at 4 different points, in order to collect data about the Microbial Air Index.

Like surface sampling, air sampling was conducted with Plate Count Agar (PCA) and Sabouraud Dextrose Agar (SDA) plates, both from Oxoid Ltd, Basingstoke, UK.

Surface microbial load is stated in CFU/24cm2 and air microbial load is stated in CFU/plate/h.

microbial load was evaluated counting the number of colonies formed, estimating the decrease of microbial load, due to cleansing procedure. Any relevant colony was subjected to biochemical typing tests through Gallerie mini-API (Biomérieux, Italy), isolating any pathogens.

3. Results

1% KMPS

The test performed in clinic 1 (AMB.1), regarding the bacterial load on surfaces at 37 °C, showed a mean reduction of 69% between the bacterial loads obtained before and after the treatment. 1% KMPS concentration was effective in reaching total abatement of *Klebsiella pneumoniae*, which was isolated only before treatment.

A mean reduction of 80% was observed for moulds.

In air samples, an average reduction of 81% and 90% was observed for the bacterial load at 37 °C and moulds, respectively (Figure 1).

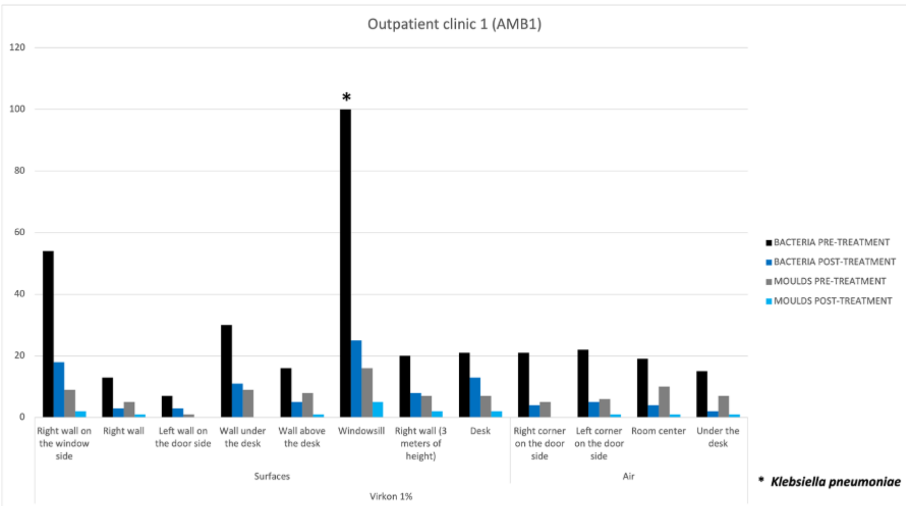

***Fig.1**: Surface (CFU/24cm2) and air (CFU/plate/h) mean results of outpatient clinic no.1 (AMB1) before and after treatment with 1% KMPS.*

In the second outpatient clinic (AMB-2), the surface samples showed a 74% reduction of bacterial load and a 83% reduction of moulds load. 1% KMPS concentration was effective in the total abatement of *Acinetobacter lwoffi*, which was isolated only before treatment.

From air samples, the bacterial load reduction was 84% while the reduction of moulds was 86% (Figure 2).

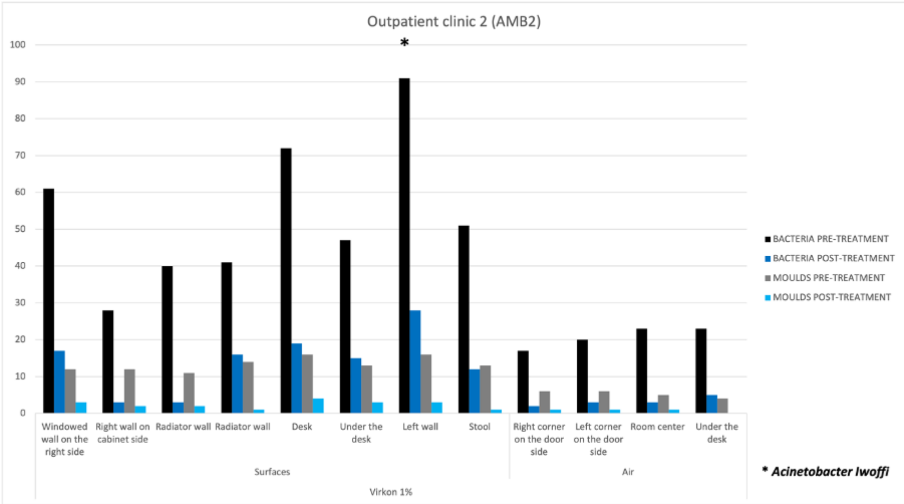

Fig.2: *Surface (CFU/24cm2) and air (CFU/plate/h) mean results of outpatient clinic no.2 (AMB2) before and after treatment with 1% KMPS.*

2% KMPS

The bacterial load at 37 °C, measured after the test with 2% KMPS on surfaces of AMB-1, a mean reduction of 92% was found after the treatment. A 95% mean reduction was observed for moulds.

In the air samples, a mean reduction of 93% was detected for the bacterial load at 37 °C and a 90% mean reduction was obtained for moulds (Figure 3).

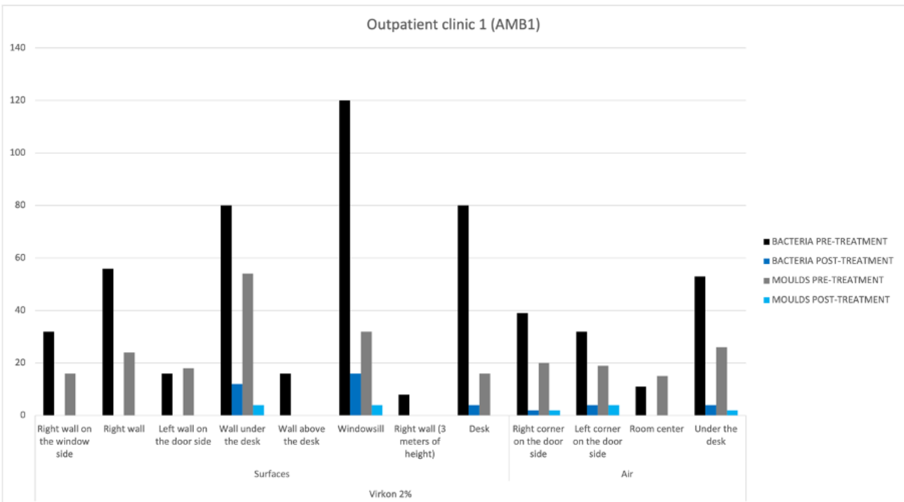

Fig.3: *Surface (CFU/24cm2) and air (CFU/plate/h) means results of outpatient clinic no.1 (AMB1) before and after treatment with 2% KMPS.*

In the second clinic (AMB-2), 89% mean reduction was achieved for the bacterial load at 37°C of surfaces, while the mean moulds reduction was 94%.

As for the air, a mean microbial reduction was 93% both for bacteria and moulds (Figure 4).

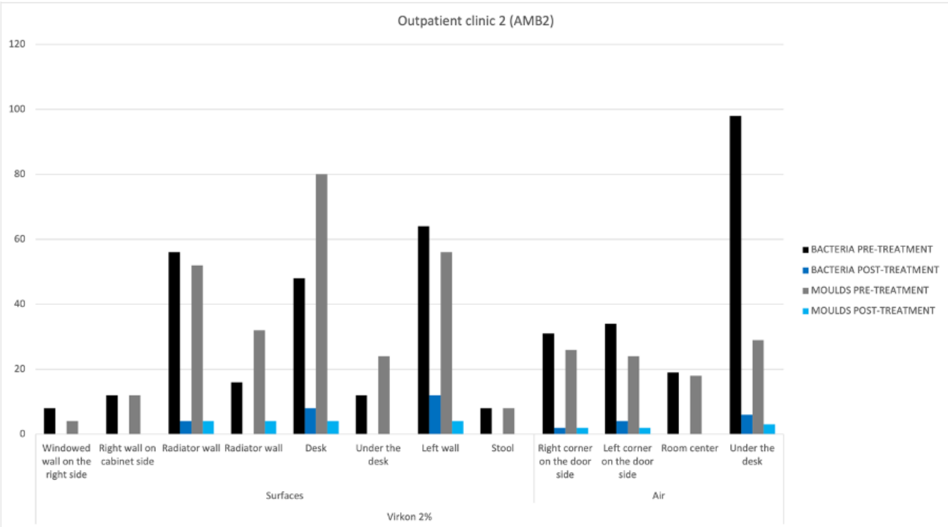

Fig.4: *Surface (CFU/24cm2) and air (CFU/plate/h) means results of outpatient clinic no.2 (AMB2) before and after treatment with 2% KMPS.*

4. Discussion

In conclusion, 1% KMPS system proved effectiveness in the reduction of mesophilic bacteria and moulds.

Furthermore, it has been proved that 1% KMPS system is sufficient to achieve total abatement of Gram-negative pathogens such as *Klebsiella pneumoniae* and *Acinetobacter lwoffii*.

Klebsiella pneumoniae is a Gram-negative bacterium, an opportunistic pathogen responsible for relevant clinical manifestations such as pneumonia, urinary infections, sepsis. It can easily infect immunosuppressed patients, especially after prolonged antibiotic treatments. It's transmitted by contact and is mainly localized in the respiratory mucosae and gut. Hospitalization, surgical interventions and prolonged use of invasive medical devices predispose to contagion [19-20]. This shows the importance of using the KMPS system in clinical and hospital settings.

The risk of development of the antibiotic-resistance phenomenon is also extended to *Acinetobacter lwoffii*, an opportunistic pathogen. *Acinetobacter lwoffii* is a non-fermenting lactose-negative gram-negative bacillus. It can cause nosocomial infections, particularly associated with central venous and urinary catheters. Due to its ability to survive in low water conditions (it survives up to one month on dry surfaces) and acid pH, it is resistant to many disinfectants or mild biocidal treatments. [21-22]

As for the 2% KMPS, the results were certainly more favorable in bacterial and moulds reduction (over 95%) (Table 2).

		Surface	Air
Bacteria reduction	1% treatment	69%	83%
	2% treatment	95%	94%
Moulds reduction	1% treatment	82%	89%
	2% treatment	97%	95%

Table 2: *Bacteria and moulds mean percentage reduction after KMPS treatment (1% and 2% concentrations)*

Comparing the results of the two systems at different concentrations, 2% KMPS has a higher average reduction of mesophilic bacteria and moulds than 1% KMPS.

As to air quality, on all tests carried out, 2% KMPS is significantly more effective than the 1% concentration, especially on bacterial load.

At 2%, an average reduction of 93% of mesophilic bacteria was observed, while at 1% this reduction was 80%.

5. Conclusion

Considering that the experimentation was carried out through in vivo tests, the percentages of microbial reduction, both on surfaces and in the air, can be considered favorable for the purpose of decontamination of indoor environments intended for clinical-outpatient and health activities in general.

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Igiene e Sanità Pubblica 2023; 81 (1):1-12

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