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Adsorption of active ingredients of surface disinfectants depends on the type of fabric used for surface treatment

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SUMMARY

The disinfection of surfaces in the immediate surrounding of a hospitalised patient is considered to be an important element for prevention of nosocomial infection. The type of fabric in a mop, however, has to our knowledge never been regarded as relevant for an effective disinfection of surfaces. We have therefore studied the adsorption of benzalkonium chloride (BAC), glutardialdehyde and propan-1-ol from working solutions of three surface disinfectants to four different types of fabric (A: white pulp and polyester; B: viscose rayon; C: polyester; D: mixture of viscose, cellulose and polyester). The working solutions of each disinfectant were exposed to each fabric for up to 24 h. Before and after exposure, tissues were removed and squeezed in a standardised way. The eluate was used for determination of the concentration of the active ingredient in quadruplicate. The analysis of glutardialdehyde and BAC was performed using high performance liquid chromatography; the analysis of propan-1-ol was done using gas chromatography. BAC was strongly adsorbed to the tissues based on white pulp (up to 61% after 30 min), followed by the viscose rayon tissues (up to 70% after 30 min) and the mixed tissues (up to 54% after 7 h). The polyester fibre tissue adsorbed the smallest amounts of BAC with up to 17% after 15 min. Only with the polyester fibre tissue were BAC concentrations found in the range of the calculated BAC concentrations. Glutardialdehyde and propan-1-ol did not adsorb to any of the fibres. Effective surface disinfection also includes selection of an appropriate fabric.

Introduction

The long persistence of various nosocomial pathogens on inanimate surfaces together with the rather low compliance in hand hygiene are the key reasons why surface disinfection is considered to be a key element to prevent cross-transmission in hospitals especially on surfaces with recurrent and frequent contact to healthcare workers' hands.[1–4] For many infection control specialists, surface disinfection is considered to be something simple which does not require specific scientific attention for practical use. Failure to perform adequate surface disinfection, however, may result in preventable and serious nosocomial infections.[5]

Surface disinfectants are based on a variety of active ingredients such as aldehydes, aldehyde releasers, quaternary ammonium compounds, oxygen releasers, guanidines, alkylamines, alkylamine derivatives or alcohols.[6] For practical purposes, various aspects are considered to be relevant to perform an effective treatment of the surfaces, such as the stability of the working solution especially for oxygen releasing compounds, the exact dosage, using fresh cleaning utensils when dispensing from containers, and training of cleaning personnel.[6] Especially when cloths are presoaked and pulled off a wet roll for use some time after they were soaked, it is possible that the fabric interacts with the active ingredient resulting in adsorption of the active ingredient to the fabric. In this case the efficacy of the surface disinfectant may be lower or even abolished. The type of fabric in a mop, however, has to our knowledge never been regarded as

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relevant for an effective disinfection of surfaces. We have therefore studied the adsorption of the active ingredients benzalkonium chloride, glutardialdehyde and propan-1-ol from working solutions of three different surface disinfectants to four different types of fabric.

Methods

Test products

Three different surface disinfectants were used and diluted in the respective concentrations used:

- Surface disinfectant 1 (Mikrobac® forte, Bode Chemie GmbH, Hamburg, Germany), diluted to 0.5%; the concentration of benzalkonium chloride in this dilution will be 0.0995%.
- Surface disinfectant 2 (Kohrsolin® FF, Bode Chemie GmbH), diluted to 0.5%; the concentration of benzalkonium chloride in this dilution will be 0.015%, the concentration of glutardialdehyde will be 0.025%.
- Surface disinfectant 3 (Bacillol® AF, Bode Chemie GmbH), undiluted; the concentration of propan-1-ol in the ready-to-use product will be 45%.

Dilutions were done with tap water immediately before each experiment.

Four different types of fabrics were used:

- Fabric A (Wipex Fullpower; Nordvlies GmbH, Bargteheide, Germany) which contains mainly white pulp but also polyester. One role contains 90 tissues with a tissue size of 36×20 cm. The weight of 1 m^2 of the tissues is 60 g.
- Fabric B (Wipex Spezial; Nordvlies GmbH) which contains only viscose rayon. One role contains 90 tissues with a tissue size of 36×20 cm. The weight of 1 m^2 of the tissues is 75 g.
- Fabric C (BODE X-Wipes; Bode Chemie GmbH) which contains only polyester fibre. One role contains 90 tissues with a tissue size of 38×20 cm. The weight of 1 m^2 of the tissues is 60 g.
- Fabric D (zetClean; ZVG Zellstoff Vertriebs GmbH & Co. KG, Troisdorf, Germany) which contains a mixture of viscose, cellulose and polyester. One role contains 90 tissues with a tissue size of 29×29 cm. The weight of 1 m^2 of the tissues is 50 g.

Exposure of fabrics to disinfectants

The fabrics are available on a role in a specific box. The manufacturer of the fabrics recommends the volume of surface disinfectant which should be added to the fabrics to ensure a thorough moisture penetration of the tissues. For fabrics A, B and C it is 2.5 L per 90 tissues per box, for fabric D it is 1.5 L per 90 tissues per box. Once the tissues are soaked with the disinfectant solution they are usually left for 10 min in order to allow complete saturation. Tissues may then be pulled off the wet roll to be used in clinical practice.

The working solutions of each surface disinfectant were exposed to four different types of disposable fabrics in a standardised manner for 15 min, 30 min, 1 h, 3 h, 7 h, and 24 h. Before and after exposure to surface disinfectants 1 and 2, five tissues were removed and squeezed in a standardised way. For surface disinfectant 3, ten tissues were used. The eluate of 50 mL was used for determination of the concentration of the active ingredient in quadruplicate.

Determination of concentration of active agents from extracted fluid

The analysis of glutardialdehyde was performed using high performance liquid chromatography (HPLC) in the Agilent Technologies 1200 series (Agilent, Santa Clara, CA, USA). The Aminex HPX-87H Ion Exclusion Column (Bio-Rad Laboratories, Hercules, CA, USA) was used. The flow was adjusted to 0.7 mL per min, the column temperature was 45 °C, the pressure 121 bar. In the mobile phase 0.005 M sulphuric acid was used. The limit of detection of this method for glutardialdehyde was 0.003%. The separation takes place in a liquid chromatograph cation exchange column. The evaluation is done through an external standard and gives the concentration of glutardialdehyde.

The analysis of benzalkonium chlorides was also performed using HPLC but in the Agilent Technologies 1100 series. The CC 150/4.6 Nucleodur 100-5 C8 ec Column (Macherey-Nagel, Düren, Germany) was used. The flow was adjusted to 1.5 mL/min, the column temperature was 40 °C, the pressure 145 bar. In the mobile phase acetonitril supplemented with 0.1% phosphoric acid and bidistilled water supplemented with 0.1% phosphoric acid were used. The limit of detection of this method for benzalkonium chlorides was 0.0003%. The separation took place in a liquid chromatograph reversed-phase column. The analysis is based on the external standard method. The presence of benzalkonium chloride was determined for the four main components (C12, C14, C16 and C18) of benzalkonium chlorides.

The analysis of propan-1-ol was done using gas chromatography with the Clarus 500 and with the Autosystem XL (Perkin Elmer, Waltham, MA, USA) using an FID detector. The RTX 1701 column was used (Restek, Bellefonte, PA, USA). Helium with a pressure of 100 kPa was applied. The column temperature was set at 90 °C for 3 min before it was heated to 180 °C at a rate of 30 °C per min. The analysis was done by using an internal standard. It was calibrated with a five-fold injection of standards. All analyses were done in duplicate.

Statistics

The mean concentration and 95% confidence interval was determined for each active agent at each time point and for each type of fabric. The relative difference was determined by dividing the mean concentration at a specific time point by the mean baseline concentration.

Results

Exposure of disinfectant 1 to the four different types of fabrics revealed that most of the BAC was adsorbed to the tissues based on white pulp (up to 61% after 30 min), followed by the viscose rayon tissues (up to 59% after 30 min) and the mixed tissues (up to 27% after 7 h). The polyester fibre tissue adsorbed the smallest amounts of BAC with up to 7% after 1 h (Figure 1). Only with the polyester fibre tissue BAC were concentrations over a 24 h period found to be close to the calculated concentration of BAC in the working solution of disinfectant 1.

Disinfectant 2 showed a similar result with BAC. Most of the BAC was adsorbed to the viscose rayon tissues (up to 70% after 30 min), followed by the tissues based on white pulp (up to 62% after 3 h), and the mixed tissues (up to 54% after 7 h). The polyester fibre tissue adsorbed the smallest amounts of BAC with up to 17% after 15 min (Figure 2). Only with the polyester fibre tissue were BAC concentrations after 1 h found to be in the range of the calculated concentration of BAC in the working solution of disinfectant 2.

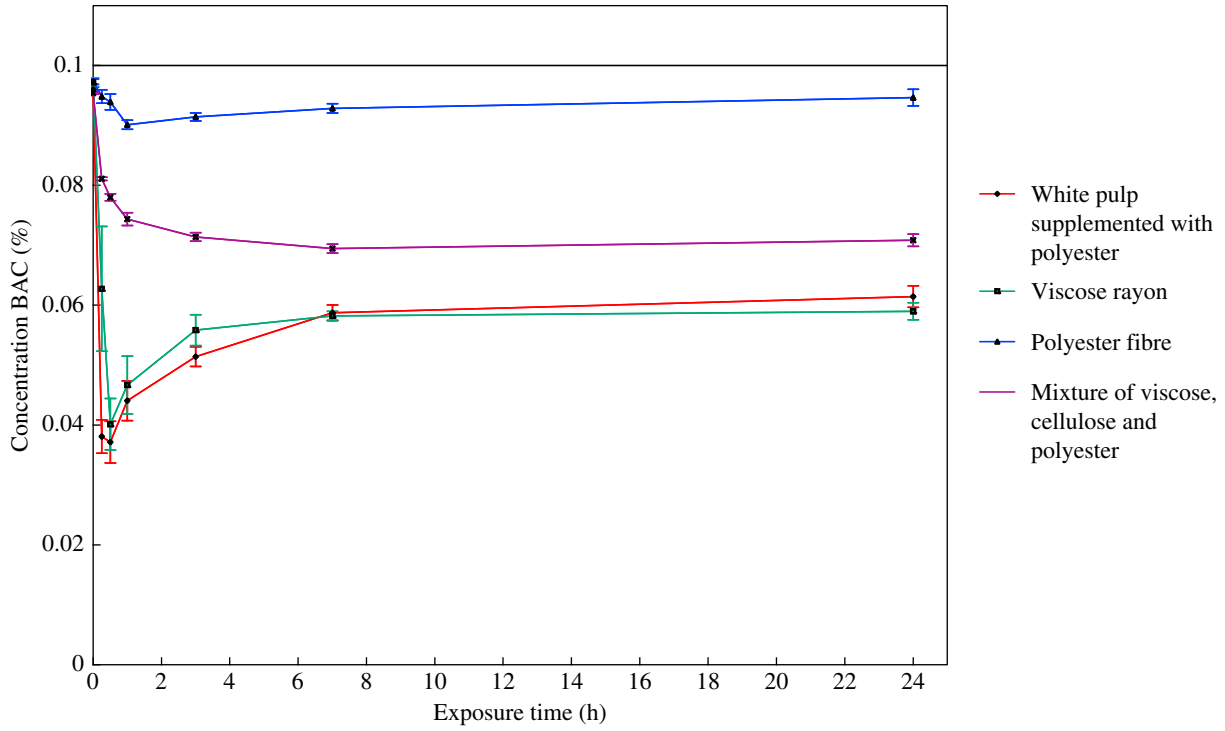

Figure 1. Mean concentration (with 95% confidence interval) of benzalkonium chloride (BAC) obtained from different types of fabric after various contact times to a 0.5% solution of surface disinfectant 1; the calculated concentration of BAC is indicated with the black line at 0.0995%.

The glutardialdehyde concentrations of disinfectant 2 revealed an interesting picture. None of the fabrics adsorbed relevant amounts of glutardialdehyde. Exposure of disinfectant 2 to the tissues based on white pulp supplemented with polyester and to the tissues based on the mixture of viscose, cellulose and polyester showed over a 24 h period concentrations of glutardialdehyde in the range of the calculated concentration of glutardialdehyde in the working solution of disinfectant 2. With the polyester fibre the

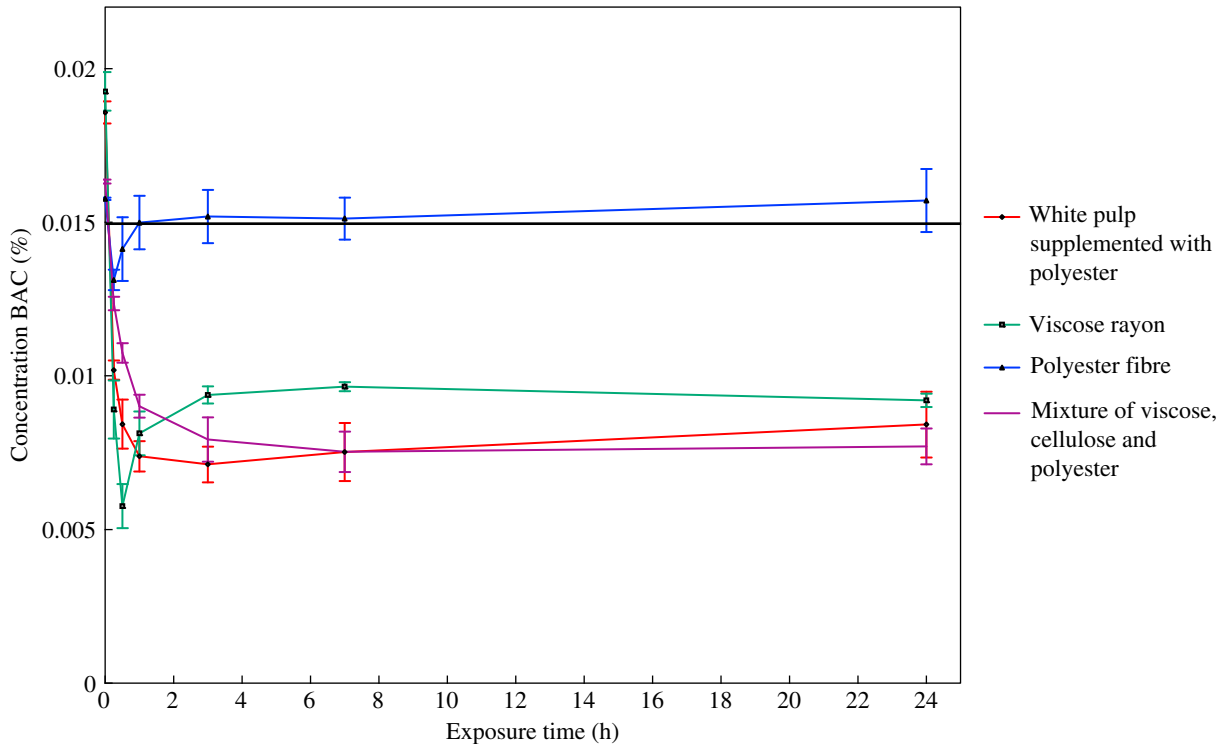

Figure 2. Mean concentration (with 95% confidence interval) of benzalkonium chloride (BAC) obtained from different types of fabric after various contact times to a 0.5% solution of surface disinfectant 2; the calculated concentration of BAC is indicated with the black line at 0.015%.

concentration of glutardialdehyde was higher after 15 min (up to 10%) and fell again close to the calculated concentration of glutaraldehyde. Exposure to the viscose rayon fibre tissue led to an increase in the concentration of glutardialdehyde of 38% after 15 min, which also fell close to the calculated concentration of glutardialdehyde after 3 h (Figure 3).

Propan-1-ol did not adhere to any of the fabrics in substantial amounts. The largest deviation of the propan-1-ol concentration was found after exposure of disinfectant 3 to the viscose rayon tissues (increase of 8%). With all other types of fabrics the concentration of propan-1-ol was close to its calculated concentration (Figure 4).

Discussion

Exposure of diluted surface disinfectants to various types of fabrics resulted in a substantial adsorption of active ingredients. BAC from product 1 was, for example, adsorbed up to 61% after 30 min on to a fabric consisting mainly of white pulp, or from product 2 up to 62% after 3 h on to a viscose rayon fabric. Surface adsorption of benzalkonium chloride has been described before. In 1977 Richardson *et al*. found in contact lens solutions that up to 80% of the antibacterial preservative BAC was lost by surface adsorption.[7] Due to the strong adsorption the surface disinfectant loses its antimicrobial activity. In particular, BAC is more or less neutralised by some of the fabrics. As a result the surface disinfection does not take place at the intended time, which may put patients unnecessarily at risk. We see the interaction between BAC and different types of fabrics as critical because the active ingredient will no longer be available in the disinfectant solution to be active against nosocomial pathogens on surfaces.

With 1-propanol no substantial absorption to any of the fabrics was found. An interesting observation, however, was found with glutardialdehyde. With the fabric based on viscose rayon the concentration of glutardialdehyde increased by 38% within 15 min and fell again to baseline levels within 3 h. With fabric C a similar but remarkably weaker effect was found with a maximum increase of 10%. With fabrics A and D no such effect was noticed.

The relevance of fabrics has also been recently identified for the removal of nosocomial pathogens from surfaces with some advantages for a cloth consisting of polyamide and polyester fibre.[8] But cleaning alone without a disinfectant component can also enhance the spread of nosocomial pathogens.[9] And a detergent solution without a disinfectant component may become contaminated which may potentially result in the spread of nosocomial pathogens by cleaning.[10]

The role of surface disinfection for prevention of transmission of nosocomial pathogens has been discussed controversially in many countries especially in the USA and Germany.[11–15] Some scientists see clear benefits and mainly refer to a successful control of outbreaks.[16] Other scientists see no real benefit and refer to a study by Maki *et al*.[17] and a systematic review by Dettenkofer *et al*. who conclude that infection rates are not lower when surface disinfection is done routinely.[18] But how solid is the evidence behind this conclusion in the light of our data on absorption?

In one study Dharan *et al*. used a surface disinfectant based on a quaternary ammonium compound (QAC) for floor disinfection which was diluted to 0.5%.[19] It was distributed with 'Taski mops' but the type of fabric is not mentioned. For furniture disinfection a local preparation was used based on an unknown concentration of an unknown alcohol and 0.028% aldehydes. For disinfection of bathrooms, toilets and isolation rooms, a surface disinfectant based on

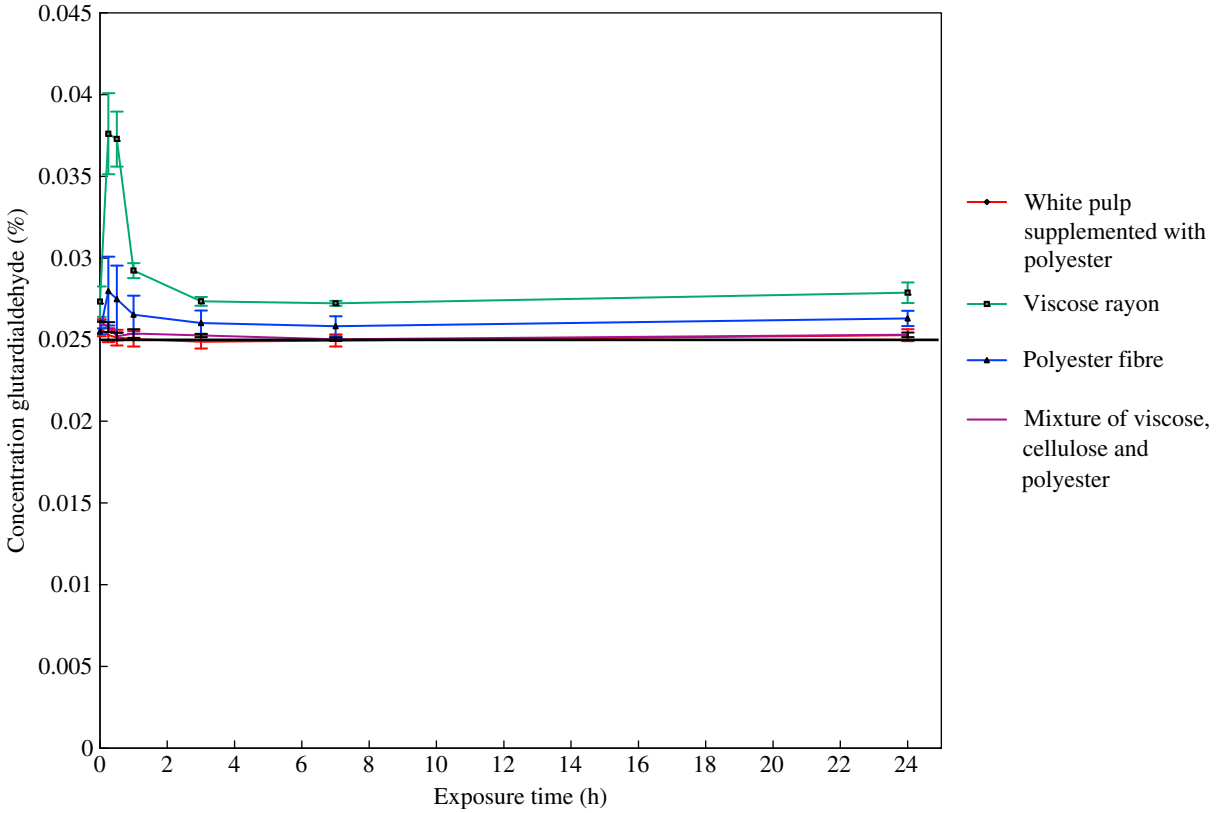

Figure 3. Mean concentration (with 95% confidence interval) of glutardialdehyde obtained from different types of fabric after various contact times to a 0.5% solution of surface disinfectant 2; the calculated concentration of glutardialdehyde is indicated with the black line at 0.025%.

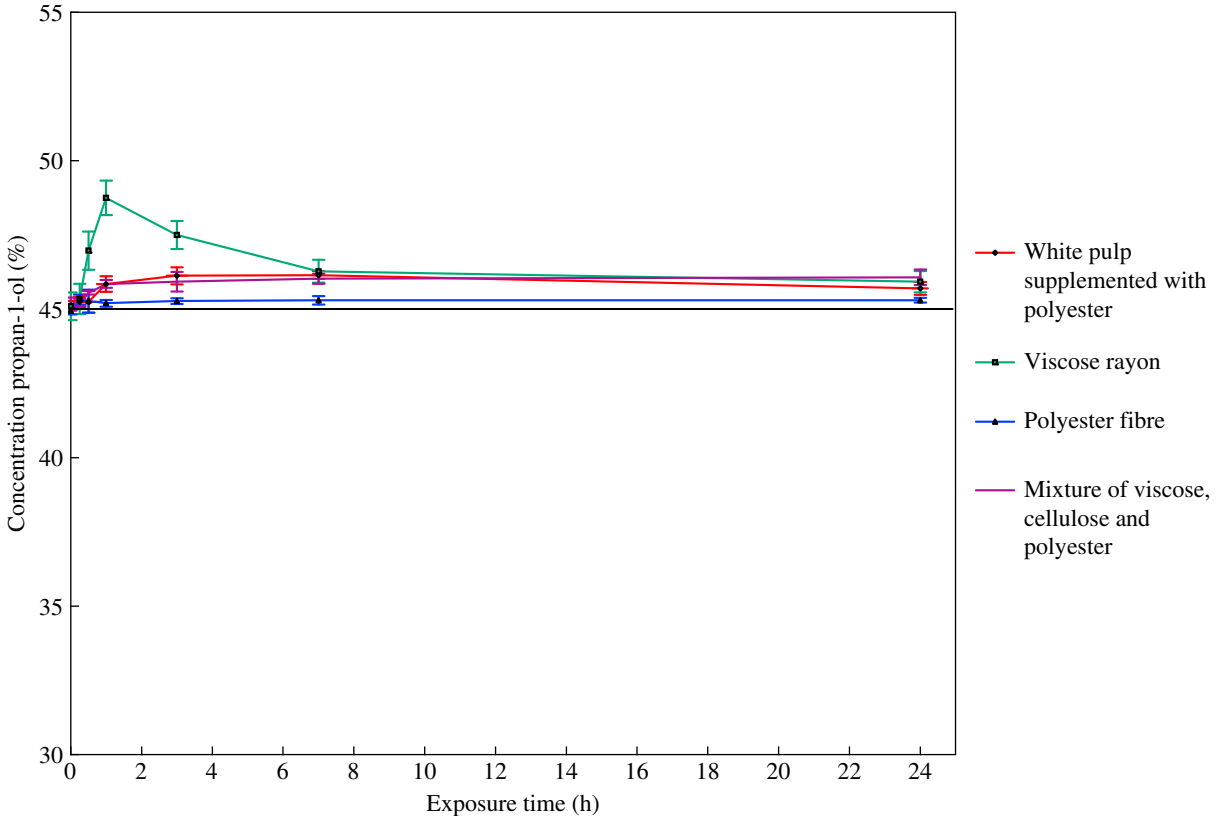

Figure 4. Mean concentration (with 95% confidence interval) of propan-1-ol obtained from different types of fabric after various contact times to surface disinfectant 3; the calculated concentration of propan-1-ol is indicated with the black line at 45%.

active oxygen and diluted to 1% was used. The surface disinfectant based on QAC yielded no significant reduction of the bacterial surface contamination on the ward floor (−0.6 cfu per 24 cm^2). On bathroom and toilet floors the bacterial surface contamination even increased (+50 cfu per 24 cm^2). The most likely explanation for their finding is that the QAC was bound to the fabric of the mops resulting in a solution which is more like water than a surface disinfectant solution. Dharan *et al.* describe the in-use concentration of the QAC as inadequate. It is more likely that the chosen mop was inadequate.

In another study Danforth *et al.* used a surface disinfectant based on orthobenzyl parachlorophenol which was described as a 'germicidal cleaning agent' in an unknown concentration and an unknown exposure time.[20] It was distributed every two days by a mop of an unknown company with an unknown type of fabric; the disinfectant solution was changed after every second room. The effect of the 'germicidal cleaning agent' was compared with that of a soap product. The overall nosocomial infection rates were not significantly different between the two types of surface treatment.

In 1980 Daschner *et al.* reported that a surface disinfectant based on aldehyde and diluted to 0.5% and applied three times per day reduced the mean number of cfu on the floor by 84% but did not change the rate of nosocomial infections in intensive care units.[21]

If the study groups had performed surface disinfection with a different type of fabric, they probably would have found a different result especially with the surface disinfectant based on QAC.

Overall, in clinical practice we strongly recommend that disinfectant solutions based on QAC are made up to concentrations appropriate for specific types of fabric, especially when cloths are presoaked. The combination of QAC with an inappropriate type of fabric will more or less abolish its antimicrobial activity. In this case, the intended disinfection process may only be a cleaning process and may put the patients unnecessarily at risk.

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Conflict of interest statement

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