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Research Article

Evaluation of the PotoClean® decontamination technology for reprocessing of water supply lines in dental units during routine work

Prüfung des PotoClean®-Verfahrens zur Dekontamination des wasserführenden Systems von Zahnarzteinheiten im laufenden Betrieb

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Abstract

Background: A frequent problem in dental units is the microbial contamination of water and biofilm formation in the water supply lines. After random identification of a bacterial contaminated dental unit (310 cfu/ml) in a practise with 3 dental units we implemented the present study to evaluate the efficacy of the PotoClean® technology, based on anodic oxidation.
Method: The efficacy of a regular low concentrated permanent decontamination (1 mg Cl/L) with an additional intensive decontamination by PotoClean® (three times 20 mg Cl/ml for 2 h) on three dental units was tested over 7 months. Microbial contamination, total chlorine concentration and redox potential have been analyzed. Dental unit A and B was 15 years old, unit C 5 years.
Results: After 3 intensive decontaminations, in dental unit A and B the number of bacteria and moulds could be reduced less than 7 d. Thereafter the bacteria counts increased again during the subsequent 7 month period and the amount of moulds was with some exceptions 300 cfu/ml, although PotoClean® was constantly added in the system (1 mg Cl/L). After further 7.5 month only with low concentrated permanent disinfection (1 mg Cl/L) both units were successful decontaminated. Dental unit C represented an object which was easier to decontaminate because of the advanced construction (prevention of water stagnation) and the shorter useful life. At the beginning of the decontamination it was no bacterial contamination, but moulds were contained (300 cfu/ml). Already after the first intensive decontamination, no further bacteria and moulds could be detected.
Discussion: An important factor for the efficacy of PotoClean® was the age of the units and their construction. For a new generation of dental units PotoClean® was effective during the whole period of monitoring. For two old types of dental unit with massive biofilm development the successful decontamination needed more than 7 month.
Conclusion: The PotoClean® technology has resulted in even old-type turbines with intensive biofilm formation to complete decontamination. In a recent turbine design already after the first intensive decontamination with PotoClean® and its continuous use (1 mg Cl/L) no more contamination by bacteria and moulds were detectable.

Keywords: dental unit, bacterial contamination, PotoClean® technology, decontamination

Zusammenfassung

Hintergrund: Ein häufiges Problem zahnärztlicher Einheiten ist die mikrobielle Kontamination des Kühlwassers und Biofilmbildung. Nach zufälliger Identifizierung einer bakteriell kontaminierten Dentaleinheit (310 KbE/ml) wurde die vorliegende Studie in einer Zahnarztpraxis mit

3 Dentaleinheiten implementiert, um die Wirksamkeit der auf der anodischen Oxidation beruhenden PotoClean® Technology zu evaluieren.
Methode: Für die Dauer von 7 Monaten wurde die Wirksamkeit des PotoClean® Verfahrens in der zur permanenten Dekontamination üblichen Verdünnung (1 mg Cl/L) in Verbindung mit zusätzlicher Intensivdekontamination (dreimal 20 mg Cl/ml für 2 h) bei drei Dentaleinheiten geprüft. Untersucht wurden die mikrobielle Kontamination, der Gesamtchlorgehalt und das Redoxpotential. Die Dentaleinheiten A und B waren 15 Jahre alt, Dentaleinheit C 5 Jahre.
Ergebnisse: Nach den 3 Intensivdekontaminationen konnte die Anzahl der Bakterien und Schimmelpilze in den Einheiten A und B nur für weniger als 7 d reduziert werden. Danach stieg die Gesamtkoloniezahl während des 7monatigen Untersuchungszeitraums wieder an und die Anzahl der Schimmelpilze betrug mit wenigen Ausnahmen 300 KbE/ml, obwohl PotoClean® (1 mg Cl/L) dem System permanent zugegeben wurde. Nach weiteren 7,5 Monaten Dauerdekontamination mit 1 mg Cl/L waren beide Einheiten erfolgreich dekontaminiert.
Dentaleinheit C war auf Grund ihrer moderneren Konstruktion (Verhinderung von Wasserstagnation) und kürzeren Nutzungsdauer problemlos dekontaminierbar. Zu Beginn der Dekontamination bestand keine bakterielle, sondern nur eine Kontamination mit Schimmelpilzen (300 KbE/ml). Schon nach der ersten Intensivdekontamination waren keine Schimmelpilze mehr nachweisbar.
Diskussion: Als ein wichtiger Faktor für die Wirksamkeit von PotoClean® stellten sich die Nutzungsdauer und die Konstruktion der Dentaleinheiten heraus. In der neuen Generation der Dentaleinheit war durch Einsatz von PotoClean® während des gesamten Untersuchungszeitraums Trinkwasserqualität gewährleistet. Für die veralteten Typen zweier Dentaleinheiten mit massiver Biofilmbildung wurden zur erfolgreichen Dekontamination mehr als 7 Monate benötigt.
Schlussfolgerung: Mit Hilfe der PotoClean® Technology war es möglich, sogar veraltete Turbinentypen mit starker Biofilmbildung zu dekontaminieren. In einer Dentaleinheit mit neuem Design war bereits nach der ersten Intensivdekontamination mit PotoClean® und anschließender permanenter Niedrigdosierung (1 mg Cl/L) zu keinem Zeitpunkt eine Kontamination mit Bakterien und Schimmelpilzen nachweisbar.

Schlüsselwörter: Dentaleinheit, bakterielle Kontamination, PotoClean® Technology, Dekontamination

Introduction

A common problem in water supply lines of dental units is the formation of a biofilm and the microbial contamination of the water [1], [2], [3], associated with it. In some units, thin, moist plastic tubes, pipes and stagnant sections instead of a ring system provide an ideal environment for biofilm formation, which is encouraged by water stagnation when the equipment is not in use [1], [4], [5], [6]. One source of contamination by biofilm formation is the supply lines of the public water system, so-called background contamination. In addition to that, retrograde contamination is also possible via leaky valves and the suck-back effect at the turbine, through contact with hands or cleaning utensils which have been contaminated, for example by aerosols from the siphon of the dental unit or the flow limiter of the hand basin when people wash their hands, may also be sources [7], [8], [9], [10].

Upwards of >100 *Legionella pneumophila*/ml there is a high risk of disease by arising dental water aerosol, and it is possible for legionellae from a water supply system to cause unrecognised individual infections [11] repeatedly over years. The significantly higher incidence of IgG and IgM antibodies against 6 strains of *Legionella pneumophila* in dental clinic staff as compared with the general population also indicates that the team is potentially at risk [12].
After the inhalation of dental aerosols contaminated with *P. aeruginosa* there is above all also the risk of persistent colonisation of the respiratory tract. For example pneumonia may develop as a secondary infection in the wake of influenza. In many cases it has been possible to attribute chronic sinusitis among dental staff to contaminated water supply lines and regular exposure to aerosols containing pathogens.
Both the removal of the biofilm and the prevention of its renewed formation are important, particularly with a view

to the growing number of immunosuppressed patients. There is a choice from among various approaches such as purging, chlorination, decontamination with hydrogen peroxide or chlorine dioxide, though so far none of these methods has established itself as a 'gold standard'. For one-off decontamination, the decontaminant CARELA®BIODES, a two-component product based on active O_2, is effective.

Permanent decontamination is only permitted with chemicals approved for the purpose. Heed needs to be paid to the formation of decontamination by-products. According to the German Drinking Water Ordinance (TrinkwV), only decontamination with chlorinated lime, chlorine, chlorine dioxide and ozone and with methods based on exposure to ultraviolet light and electrolytic decontamination in situ are approved in Germany. If chlorine or hypochlorite is to be added, up to 6 mg/l Cl_2 are permitted. Residues of up to 0.6 mg/l Cl_2 are disregarded after reprocessing if this is the only way decontamination can be guaranteed [13].

In recent years electrolytic methods for continuous decontamination have been gaining importance. In the electrolysis of water containing NaCl the largest fractions produced apart from free chlorine are chlorine dioxide, hydrogen peroxide and other short-lived oxidants [14]. With the so-called MIOX method, Venczel et al. [15] showed that the electrolytically produced mixture is more effective in terms of decontamination than free chlorine alone. Further advantages are its low cost, the possibility of producing it in situ, the broad spectrum of its anti-microbial activity and its low toxicity. A disadvantage is that it promotes the corrosion of metals including stainless steels and may damage polyurethanes [16]. Another problem is the composition of the reaction products, variable within certain limits, on account of the varying quality of the drinking water.

To identify a method which would be effective in the long term, the PotoClean® technology was evaluated under practice conditions. The reason for the evaluation was that the threshold values prescribed in the TrinkwV had been exceeded in a dental practice. The method was approved in 2007 in accordance with Worksheet W229 Section 6.5.2 issued by the German Technical and Scientific Association for Gas and Water (DVGW) [13]. The liquid itself is also approved in accordance with DIN EN 901 [17]. Once degraded, PotoClean® leaves no residues except for some traces of NaCl. Furthermore, no toxic substances are detectable.

Method

Manufacture

In an electrolytic cell with a diaphragm separating the anode and the cathode, the highly oxidative PotoClean® (anolyte) is produced at the anode and the reducing catholyte solution at the cathode from salt water by selective ion exchange. The anolyte has a redox potential of approx. 1100 mV. Generating available chlorine (predominantly hypochlorous acid), it is highly effective in antimicrobial terms. As the tube diameters in the water supply system of the dental unit were comparatively small, it was not possible to produce the solution in situ using a device of our own. For this reason, PotoClean® delivered by the marketing company was used at weekly intervals. According to the safety data sheet (WaterClean GmbH, Kirkel, Germany) the product has the following composition: sodium chloride <1%, sodium hypochlorite 0.02%, ozone 0.009%, hydrogen peroxide 0.00005% and oxygen 0.0013%.

PotoClean® was introduced into the dental unit after the softener with a metering pump at the main inlet of the practice's drinking water network. During daily routine operation at the practice the pump ran at 1 impulse/L/min (flowmeter), with 5 ml of PotoClean® being pumped per impulse. At a content of 200 mg Cl/L, this meant that the diluted solution in the system had a concentration of 1 mg Cl/L.

PotoClean® was metered in as from 19.12.2008, initially as a shock decontamination. On two other dates (02.02.2009, 25.03.2009) further shock decontaminations were carried out for a period of 2 h each. For the shock decontamination the impulse rate of the pump was increased from 1 to 60 impulses/L/min. Metering was discontinued once the max. mV values (~720 mV) had been reached. After that, the high concentrations were flushed out of the supply network, until according to the redox and chlorine measurements the value of 1 mg Cl/L had once again been achieved. No-one was allowed to take any drinking water from the system until this value had been reached.

Sampling dates

Following the initial findings of the official spot-check inspection, 310 cfu/ml in the turbine water of Unit A – in Unit C the values of the TrinkwV were complied with, whilst Unit B was not sampled – samples were taken from the 3 units prior to the use of PotoClean® on 29.10.2008, 5.11.2008 and 13.12.2008 in order to determine the initial contamination.

During the use of PotoClean® the water in the turbines of the 3 units was analysed weekly for a period of 7 months and the redox potential and the total chlorine content determined. 8 months after the last weekly samples a final control measurement was carried out (23.02.2010).

Sampling and analysis

The water samples were taken aseptically after the turbine casings had been disinfected by wiping (with 70% ethanol), with the water first being allowed to run for 30 s. The samples were taken directly in autoclaved, cooled sampling container with 0.5 ml 0.1 M sodium thiosulphate solution to neutralise any residual chlorine. The quantity of water sampled was 50 ml.

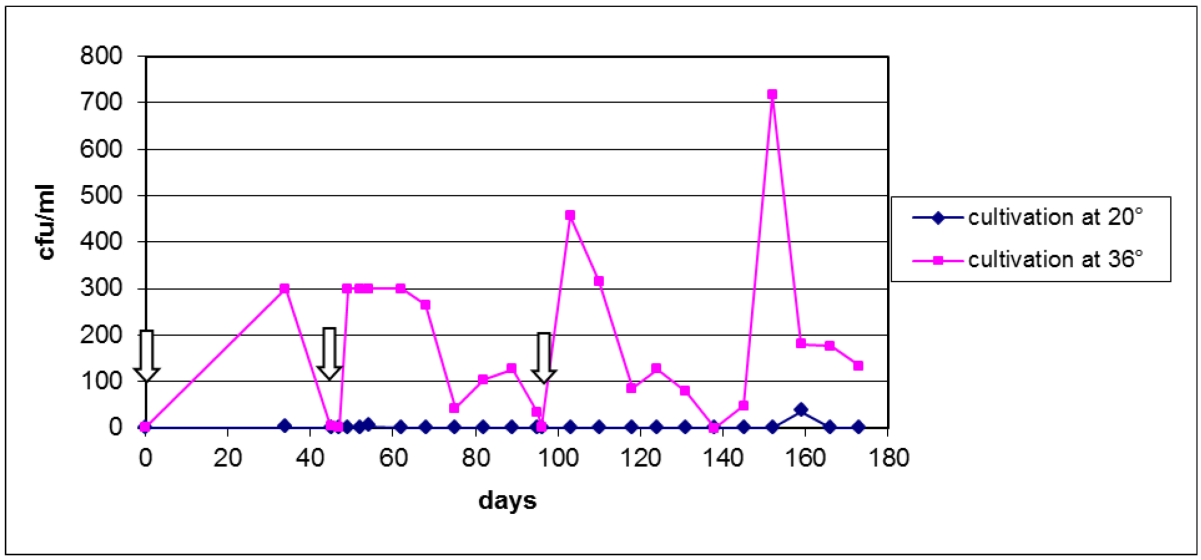

Figure 1: Colony count in Unit A (white arrows = shock decontamination)

The water samples were processed within 1 h of sampling at the latest. First the total colony count (cfu/ml) was determined at 20 °C and 36 °C incubation, as were molds (cfu/10ml), coliforms/*E. coli*/*P. aeruginosa* (cfu/100ml) and *Legionella* spp. (cfu/1000ml) in accordance with [18], [19], [20], [21], [22]. Since there is no standard for determining molds in drinking water, the filtration was carried out analogously to that of *E. coli* and coliforms, the filter being placed on malt extract agar and incubated at 30 °C for 5 d. The colonies were then counted. Since neither coliforms, *E. coli, P. aeruginosa* nor *Legionella* spp. were detectable at any time prior to the use of PotoClean®, they were not determined during the trial period.

Electrochemical diagnostics

Chlorine content was determined with the LANGE cuvette test LCK310 [23]. A test tube charged with DPD (N,N-diethyl-p-phenylenediamine) is filled with sample water up to 1 cm below the rim, sealed with a plug and shaken for 2 min. Three drops of potassium iodide are then added and the tube shaken for 2 further min. The potassium iodide releases the bound chlorine and the total chlorine content can then be measured. The proportion of bound chlorine is the difference between total and free chlorine, determined before the addition of potassium iodide [23]. Subsequently the total chlorine value [mg/ml] was measured with the LASA 100 (HACH LANGE GmbH, Düsseldorf). The process of determining the chlorine content was not begun until after the 2nd shock decontamination. The redox values [mV] were determined by means of a calibrated measuring electrode with the GPRT 1400 AN (GREISINGER electronic GmbH, Regenstauf).

Results

Colony count

In the control tests prior to the commencement of PotoClean® use (29.10., 5.11., 13.12.2008) Unit A at 20 °C did not reveal any abnormal values (Figure 1). At 36 °C the values were higher, though they did not, at a maximum of 39 cfu/ml, – as in the official inspection carried out previously where a value of 310 cfu/ml was measured – exceed the maximum permissible threshold value in drinking water of 100 cfu/ml. After the first shock decontamination (day 0) the colony count dropped to 2 cfu/ml, rising in the subsequent weekly checks up to day 34 after shock decontamination to 300 cfu/ml on average, and dropped again after that in some cases to below 100 cfu/ml. After the 2nd shock decontamination contamination was reduced to 4 cfu/ml, and after the 3rd to 2 cfu/ml. On day 152 after the beginning of the study 716 cfu/ml were counted, on day 159 181 cfu/ml and on day 166 176 cfu/ml. In the follow-up check on 23.02.2010 the colony count at 20 °C was 0 cfu/ml, and at 36 °C 13 cfu/ml, which is to say that the values had returned to normal without a repeat of the shock decontamination in the interim.

In the control tests (29.10., 5.11., 13.12.2008) in Unit B at both incubation temperatures a maximum of 3 cfu/ml was detectable. After the beginning of decontamination Unit B developed in a way similar to Unit A (Figure 2). In the control measurement on 23.02.2010 the colony count at 20 °C was 0 cfu/ml, at 36 °C 62 cfu/ml.

By contrast, the method in Unit C already proved to be highly effective after the 1st shock decontamination and the values remained constant at 0 cfu/ml.

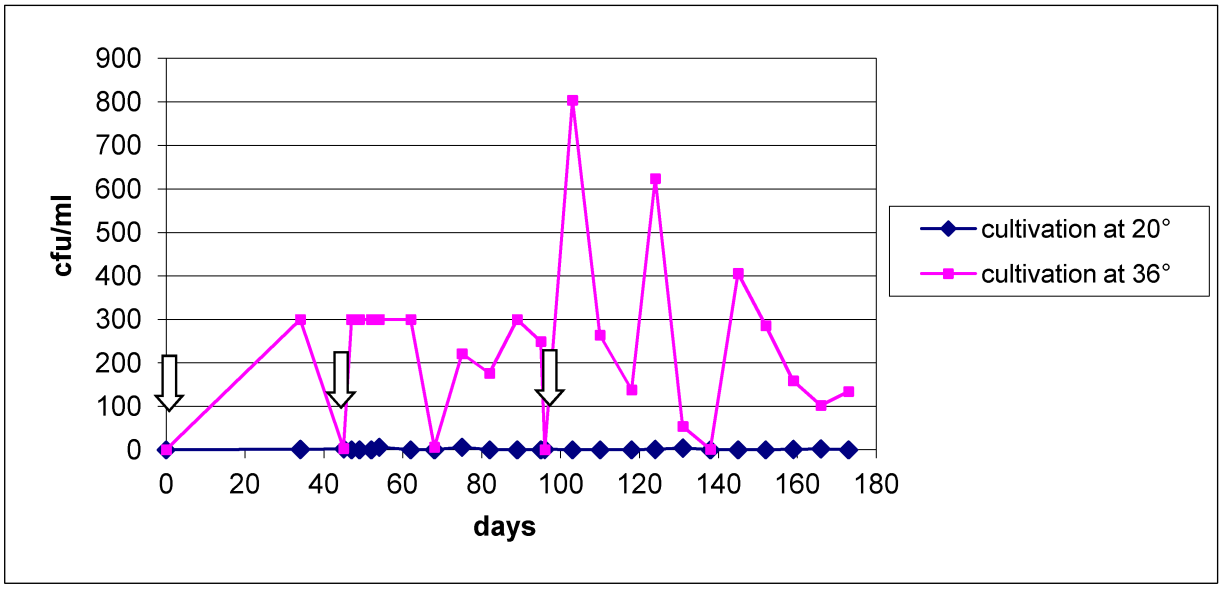

Figure 2: Colony count in Unit B (white arrows = shock decontamination)

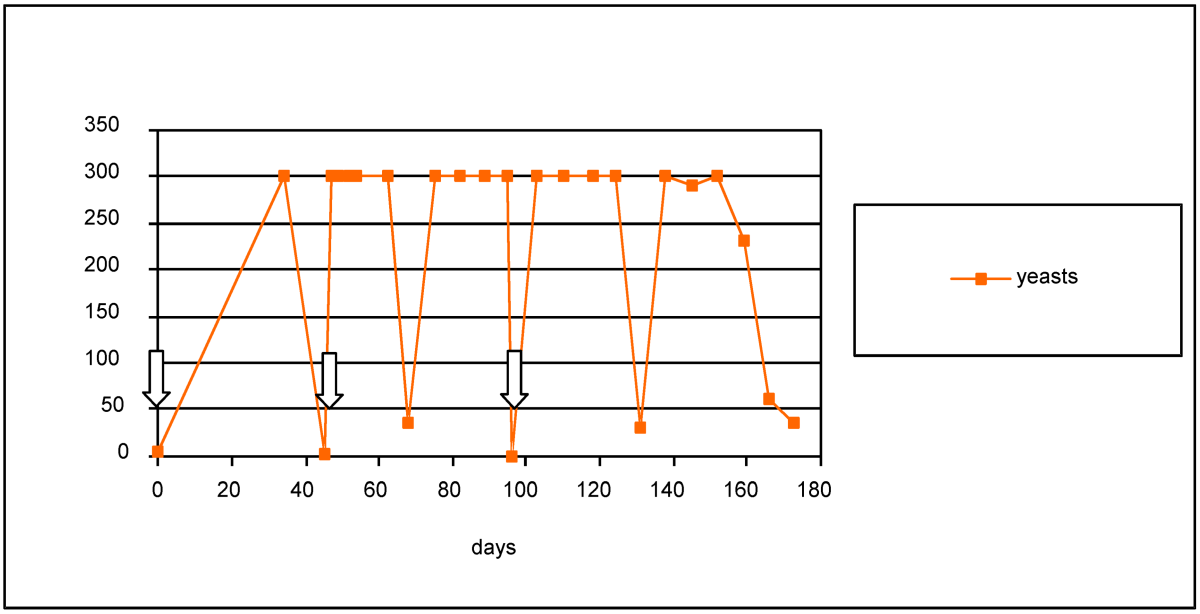

Figure 3: Colony count in Unit A for molds (white arrows = shock decontamination)

Molds

The number of molds in Unit A remained more or less constant at 30 cfu/ml (Figure 3). Only after the shock decontaminations was there a marked drop (day 0: 6 cfu/ml, day 45: 3 cfu/ml, day 96: 0 cfu/ml). In the follow-up check on 23.02.2010 the colony count was still 30 cfu/ml. In Unit B the picture was similar (Figure 4), whereby the colony count in the follow-up check on 23.02.2010 was also 30 cfu/ml.

In Unit C, by contrast, with the same initial findings, the effectiveness of Potoclean® against molds was analogous to its effectiveness against bacteria.

Redox potential and chlorine content

The redox value measured in undiluted PotoClean® was approx. 1200 mV, in untreated turbine water 240 mV on average. After shock decontamination there was an increase in redox potential to 710–800 mV. In the subsequent permanent constant decontamination the values dropped to 210 mV on average until the 2nd shock decontamination, and after the 3rd shock decontamination further to 189 mV, with some fluctuations around 220 mV. The chlorine values increased after the 2nd and 3rd shock decontamination to 1.58 mg/L (Unit A), 1.19 mg/L (Unit B) and 4.72 mg/L (Unit C) respectively.

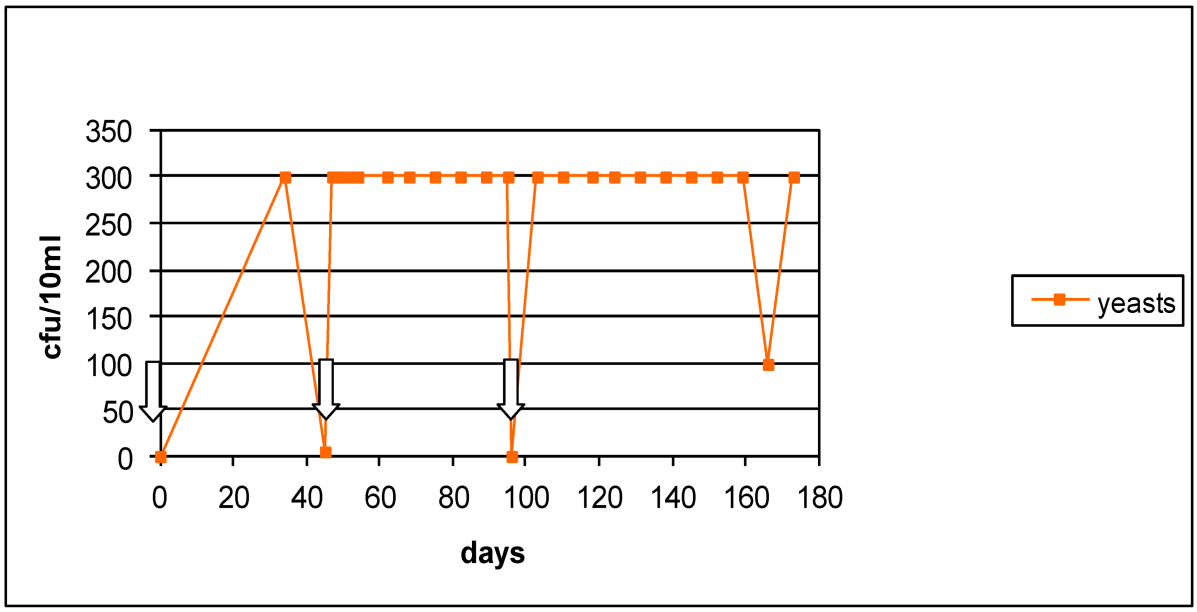

Figure 4: Colony count in Unit B for molds (white arrows = shock decontamination)

Discussion

In view of the fact that neither coliforms, *E. coli*, *P. aeruginosa* nor *Legionella* spp. were detectable at any time prior to the use of PotoClean®, it was ethically justifiable to examine the decontamination performance of the method without closing off Units A and B.

The increase in the colony counts of bacteria and molds which began in Units A and B after each shock decontamination suggests that Potoclean® had been instrumental in detaching parts of the biofilm, which subsequently led to an intermittent discharge of micro-organisms from the residual biofilm into the turbine water. It was not possible to decontaminate Units A and B within the sampling period of 7 months. Having said that, both units proved to have been decontaminated by the time of the follow-up check after 14.5 months. Since there had been no sampling in the 7.5-month interim phase, decontamination may have been achieved much earlier.

On the other hand, in Unit C the colony count for molds was already at a constant zero after the 1st shock decontamination. In view of the fact that this unit was not purchased until 5 years ago, whilst Units A and B were already purchased 15 years ago, it may be assumed that the Unit C was easier to decontaminate for reasons of improved design (fewer stagnant sections) and that the decontamination in Units A and B simply took longer on account of the strong biofilm formation caused by their having been in use for a long time. If the Potoclean® solution is installed directly in situ and not introduced into the system via a metering pump as in this study, it is possible with the aid of a microbiological examination of effectiveness to carry out shock decontaminations at short intervals so that decontamination can be achieved more swiftly.

There is no threshold value for molds in drinking water. To that extent, these values only hint at the existence of biofilms. With the method selected, decontamination was only successful in Unit C. In view of the fact that after each shock decontamination there was a clear drop in the mold count, it can be expected that more frequent shock decontamination would also be more effective against molds.

The redox potential, which fluctuated somewhat over the period of application, was within the expected range of measurement.

In January 2011, in another dental practice, instead of having PotoClean® solution delivered from outside, the equipment used to make the solution was installed directly in the main water supply, so that all the drinking water supply points were decontaminated. The reason for this was that in the context of an official inspection the total count of colony-forming units was found to exceed the threshold value for drinking water in the cooling water of a dental unit. Decontamination was begun with a shock decontamination (10 mg Cl/L) and continued with a constant dose of 0.3mg Cl/L (final dilution in the network). The initial contamination with cultivation at 20 °C was 4800 cfu/ml, at 36 °C 422 cfu/ml. In the first follow-up check 34 d after commencement of operation of the PotoClean® unit, the initial contamination already showed a marked decrease, at 6 cfu/ml at 20 °C and 115 cfu/ml at 36 °C. In the 2nd follow-up check one month later, the requirements of the TrinkwV were found to have been met with a comfortable safety margin, the results being 6 cfu/ml at 20 °C and 1 cfu/ml at 36 °C.

Conclusion

Even in turbines of older design with intensive biofilm formation, the PotoClean® technology brings about a decontamination in which the threshold values of the TrinkwV are met. In a turbine of more recent design, no

bacterial contamination of the water was detectable in any of the samples after an initial shock decontamination with PotoClean® followed by its continued use at the concentration of 0.1 mg Cl/L intended for long-term application.

Notes

Competing interests

The authors declare that they have no competing interests.

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