The effect of disinfectants and line cleaners on the release of mercury from amalgam

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ABSTRACT

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Background. Dental practices use disinfectants or line cleaners to flush dental unit wastewater lines to minimize odor generation, remove solid waste particles and remove biofilms in dental unit water lines (DUWLs).

Methods. The authors evaluated 47 disinfectants or line cleaners for their potential to release mercury from amalgam waste. They prepared each product concentration according to the manufacturer's recommendations and gently agitated it along with one amalgam specimen for 24 hours. They filtered the combined decanted liquid and rinse and analyzed it for mercury using modified U.S. Environmental Protection Agency method 245.1.

Results. Six preparations released significantly more mercury from amalgam (about 17 to 340 times) than did the deionized water control ($P < .001$). The amount of mercury released by the other disinfectants/line cleaners was not statistically different from that released by the control. The pH values of all preparations ranged from 1.76 to 12.35.

Conclusion and Clinical Implications. This study and other published reports have demonstrated that preparations containing chlorine release more mercury from amalgam than did some other products and the deionized water control. As a result, the use of these products is not recommended for treating dental office wastewater lines or DUWLs.

Key Words. Disinfectants; line cleaners; dental unit water lines; amalgam wastewater.

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Dental practices use disinfectants or line cleaners to flush dental unit wastewater lines and wastewater plumbing to minimize odor generation and to remove solid waste particles. They also use these agents to remove biofilms in dental unit waterlines (DUWLs) and to maintain low microbial counts in dental unit water.

The release of mercury from amalgam occurs when some types of disinfectants and line cleaners come into contact with amalgam waste that has collected in chairside traps, dental unit waste line tubing, vacuum pump filters, amalgam separators (if installed) and wastewater plumbing. Because of growing environmental concerns, the U.S. Environmental Protection Agency (EPA) requires that publicly owned treatment works (POTWs)—that is, wastewater treatment facilities—meet increasingly stringent numeric limits for mercury in wastewater. In their compliance efforts, POTWs have identified dental office wastewater as a source of mercury in wastewater.[1]

Most mercury in dental office wastewater occurs in the form of dental amalgam[2-4] that is captured by POTWs in grit chambers and as biosolids.[4] However, dissolved mercury, which the EPA defines as mer-

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cury that can pass through a 0.45-micrometer filter, is too small to be captured by POTWs. As a result, dissolved mercury often appears in POTW effluent. Because disinfectants and line cleaners could react with amalgam waste to release dissolved mercury, choosing disinfectants and line cleaners that release little or no mercury from amalgam waste is a prudent approach.

Kielbassa and colleagues[5] and Kummerer and colleagues[6] reported that three of seven disinfectants caused more mercury release than water alone when either came in contact with amalgam waste in dental units. The investigators concluded that disinfectants containing oxidizing agents release mercury from amalgam. In an in vitro study, Rotstein and colleagues[7] reported that hypochlorite solutions released mercury from amalgam. Roberts and colleagues[8] reported that six of the eight disinfectants used in their laboratory study released more mercury from ground amalgam particles than did the water control. A disinfectant containing quaternary ammonium compounds released less mercury from amalgam than did water. Additionally, a combination of phenolic compounds released similar amounts of mercury from amalgam as did water. Disinfectants that contain chlorine, bromine, iodophor peroxide/peracetic acid and some phenolic compounds released more mercury from amalgam particulate than did the control (water). Stone and colleagues[9] reported that iodine, found in some DUWL treatment formulations, released mercury from amalgam. The American Dental Association's Best Management Practices for Amalgam Waste recommend against using chlorine-containing line cleaners.[10]

Our study involved the evaluation of 47 disinfectants or line cleaners for their potential to release mercury from amalgam waste. This report is intended to help dental professionals make product choices that minimize mercury release.

MATERIALS AND METHODS

We used deionized water as the control. The table lists the products, manufacturers, intended use, active ingredients and recommended concentration for use. We prepared each product concentration according to the manufacturer's recommendations. We measured the pH of each preparation using an Accumet Model 15 pH meter and Accumet pH electrode (Fisher Scientific International, Hampton, N.H.). We prepared cylindrical amalgam specimens measuring 4 × 7 millimeters using Tytin (lot no. 3-2239, Kerr, Orange, Calif.) according to American National Standards Institute/American Dental Association Specification No. 1-2003.[11] We aged the amalgam cylinders for seven days in air at 25 ± 2 C. We measured the diameter and height of each specimen using a micrometer (Mitutoyo Model no. CD-6 in. CS, Mitutoyo USA, Aurora, Ill.) and calculated the surface area of each amalgam cylinder (113.10 ± 1.03 square millimeters). We placed each amalgam specimen in a polypropylene vial measuring 76 × 20 mm (Sarstedt, Newton, N.C.), containing 5.5 milliliters of disinfectant or line cleaner preparation. We prepared five samples of each disinfectant or line cleaner. We placed the vials on a rocking platform (Rocking Platform, Model 100, VWR Scientific, Philadelphia) and gently agitated them for 24 hours. We decanted the solution and separated the amalgam cylinder and rinsed the empty vials with 2.5 mL of 10 percent nitric acid/0.02 percent potassium dichromate. We combined the decanted liquid and rinse, filtered the mixture through 0.45-µm Teflon filters (National Scientific, Rockwood, Tenn.) and analyzed it for mercury using modified EPA method 245.1. We analyzed every disinfectant or line cleaner and calculated the amount of mercury released per unit surface area each time.

We performed statistical analysis using a one-way analysis of variance and multiple comparisons (Student-Newman-Keuls), and we determined the correlation coefficient (r^2) for pH versus the mean amount of mercury released.

RESULTS

The table summarizes the amounts of mercury released per unit surface area of amalgam after 24 hours and the pH values of the disinfectant or line cleaner preparations. Six preparations released significantly more mercury from amalgam (about 17 to 340 times) than did the deionized water control ($P < .001$). The amount of mercury released by the other line cleaners or disinfectants was not statistically different from that released by the control. The pH values of all preparations ranged from 1.76 to 12.35.

DISCUSSION

In this study, six disinfectant or line cleaner preparations released significantly more mercury from amalgam than did the control, which was deionized water. Three of these disinfectant or line cleaner preparations contained sodium

TABLE

Mercury released from disinfectants and line cleaners.

LINE CLEANER/ DISINFECTANT BRAND NAME	MANUFAC-TURER	INTENDED USE	ACTIVE AGENTS (MANUFACTURER-REPORTED)	LINE CLEANER/ DISINFECTANT PREPARATION	pH	MEAN MERCURY RELEASED ng/mm²* (SD†)	DIFFER-ENCE BETWEEN PRODUCTS‡
Compliance	Metrex Research (Orange, Calif.)	Disinfectant	7.35% hydrogen peroxide, 0.23% peracetic acid	No dilution	1.76	471.69 (13.46)	NA§
Clorox (Ultra)	Clorox (Oakland, Calif.)	Disinfectant/ cleaner	6% Sodium hypochlorite	200 to 1,800 milliliters DI¶ water	10.72	46.42 (21.97)	NA
Discide TB	Palmero Health Care (Stratford, Conn.)	Disinfectant/ cleaner	0.154% Quaternary ammonium chloride, 0-5% EDTA#	No dilution	11.96	33.81 (0.00)	A
Vac Attack	Premier Dental (Plymouth Meeting, Pa.)	Line cleaner	< 10% Sodium dichloroisocyanate dihydrate	16.9 grams to 2,000 mL DI water	11.05	29.93 (8.41)	A
Sanogene	Biocide International (London)	Disinfectant	Sodium chlorite, chlorine dioxide	12.5 mL and 0.75 g activator to 500 mL DI water	2.59	23.73 (1.56)	A,B
Dispatch	Caltech Industries (Midland, Mich.)	Line cleaner	<1 % Sodium hypochlorite	No dilution	12.35	23.63 (21.00)	A,B
DentaPure DP90	MRLB International (River Falls, Wis.)	DUWL** cleaner	Iodine 2-6 ppm††	Filtrate from Denta Pure DP90	6.95	15.00 (0.15)	B,C
Maxicide Plus	Henry Schein (Melville, N.Y.)	Disinfectant	3.4% Glutaraldehyde	Activator added to 3.785 liters of Maxicide Plus	8.00	5.05 (0.005)	C
Biocide G30	Biotrol (Earth City, Mo.)	Disinfectant	2.65% Glutaraldehyde	No dilution	6.17	4.68 (0.76)	C
MicroClear	Rowpar Pharmaceuticals (Scottsdale, Ariz.)	DUWL cleaner	Chlorine dioxide	50 mL to 500 mL DI water	6.65	4.58 (0.15)	C
Bi-Arrest III	Infection Control Technology (Woods Cross, Utah)	Disinfectant/ cleaner	0.06% o-phenyl phenol, 0.05% p-tertiary amyl phenol	2 mL to 500 mL DI water	10.09	4.45 (0.01)	C
Banicide	Pascal (Bellevue, Wash.)	Disinfectant	3.5% Glutaraldehyde	As is	6.21	4.40 (0.29)	C
Metricide Plus	Metrex Research	Disinfectant	3.4% Glutaraldehyde	Add activator to 3.8 L of Metricide Plus	7.99	4.07 (0.08)	C
Microstat2	Septodont (New Castle, Del.)	Line cleaner	Sodium bromide, dimethylhydantoin, potassium bicarbonate, sodium bisulfate	2 tablets of 2A and 2 tablets of 2B to 1892.8 mL DI water	6.83	3.23 (0.90)	C
Sterilex Ultra	Sterilex (Owings Mills, Md.)	DUWL cleaner	Quaternary ammonium chloride, sodium carbamate peroxide	5.5 bottles of solution 1 to 5.5 bottles of solution 2	10.10	1.48 (0.02)	C
Water (Deionized)	None	Control	N/A	N/A	4.93	1.36 (0.21)	C

* ng/mm²: Nanograms per square millimeter.
† SD: Standard deviation.
‡ There was no significant difference between products with the same letters.
§ N/A: Not applicable.
¶ DI: Deionized
# EDTA: Ethylenediaminetetraacetic acid.
** DUWL: Dental unit waterline.
†† ppm: Parts per million.

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TABLE (CONTINUED)

Mercury released from disinfectants and line cleaners.

LINE CLEANER/ DISINFECTANT BRAND NAME	MANUFACTURER	INTENDED USE	ACTIVE AGENTS (MANUFACTURER-REPORTED)	LINE CLEANER/ DISINFECTANT PREPARATION	pH	MEAN MERCURY RELEASED ng/mm²* (SD†)	DIFFERENCE BETWEEN PRODUCTS‡
Envirocide	Envirosafe Manufacturing (West Melbourne, Fla.)	DUWL cleaner	Quaternary ammonium, chloride, 17-2% isopropyl alcohol, ethylene glycol	No dilution	11.45	1.05 (0.00)	C
Vacusol Ultra	Biotrol	Line cleaner	Quaternary ammonium, EDTA, sodium meta silicate	40 mL to 2,000 mL DI water	10.54	1.01 (0.36)	C
BirexSE	Biotrol	Line cleaner	Tertiary amyl phenol	7.8 mL to 2,000 mL DI water	1.98	0.77 (0.21)	C
SRG Evacuation System Cleaner	Icon Laboratories (Farmingdale, N.Y.)	Line cleaner	15% Phosphoric acid, 10% glycolic acid	60.6 mL to 2,000 mL DI water	3.27	0.72 (0.43)	C
Asepti TB	Ecolab (St. Paul, Minn.)	Disinfectant/ cleaner	< 1 % Quaternary ammonium chloride	No dilution	5.58	0.55 (0.77)	C
E-Vac Evacuation System Cleaner Concentrate	L&R Manufacturing (Kearny, N.J.)	Line cleaner	20-30% Ortho phosphoric acid, 1-5% isopropyl alcohol, 60-70% water, 0.5% sodium butoxy ethoxy acetate	64.5 mL to 2,000 mL DI water	1.85	0.51 (0.41)	C
GC Spray-Cide	GC America (Alsip, Ill.)	Line cleaner	21% Isopropyl alcohol, alkyl dimethyl benzyl ammonium chloride, ethylene glycol mono ethyl ether	No dilution	5.75	0.47 (0.52)	C
Madacide-FD	Mada Medical (Carsltadt, N.J.)	Disinfectant/ cleaner	0.308% Quaternary ammonium chloride, 21% isopropyl alcohol	No dilution	6.55	0.46 (0.36)	C
ProE-Vac	Certol International (Commerce City, Colo.)	Line cleaner	< 10% Phosphoric acid, < 10% glycolic acid, < 10% isopropyl alcohol	64.5 mL to 2,000 mL DI water	1.93	0.41 (0.19)	C
Patterson Brand	Patterson Dental (St. Paul, Minn.)	Line cleaner	15% Phosphoric acid, 10% glycolic acid	31.7 mL to 2,000 mL of DI water	2.15	0.37 (0.13)	C
Turbo-Vac	Pinnacle Products (Lakeville, Minn.)	Line cleaner	Hydrochloric acid, glutaraldehyde	60.6 mL to 2,000 mL DI water	2.60	0.31 (0.08)	C
Cavicide	Metrex Research	Line cleaner	17-20% Isopropyl alcohol, 3% ethylene glycol monoethyl ether, 0.3% quaternary ammonium chloride	No dilution	10.54	0.30 (0.03)	C
Vacuum Clean	Palmero Health Care	Line cleaner	40% Dimethyl benzyl ammonium chloride	20 tablets to 1,892.8 mL DI water	6.59	0.26 (0.10)	C
Sani-Treet Plus	Enzyme Industries (Heath, Ohio)	Line cleaner	Enzyme	60.6 mL to 2,000 mL DI water	4.29	0.23 (0.17)	C
Lines (Bio-2000)	Micrylium Laboratories (North York, Ontario, Canada)	DUWL cleaner	12% Ethanol, 0.12% chlorhexidine gluconate	No dilution	6.87	0.16 (0.09)	C

TABLE (CONTINUED)

Mercury released from disinfectants and line cleaners.

LINE CLEANER/ DISINFECTANT BRAND NAME	MANUFACTURER	INTENDED USE	ACTIVE AGENTS (MANUFACTURER-REPORTED)	LINE CLEANER/ DISINFECTANT PREPARATION	pH	MEAN MERCURY RELEASED ng/mm²* (SD†)	DIFFERENCE BETWEEN PRODUCTS‡
Prospray	Certol International	Disinfectant	0.28% o-phenyl phenol, 0.03% o-benzyl p-chlorophenol	No dilution	9.06	0.15 (0.02)	C
Stay Clean	Midmark (Versailles, Ohio)	Line cleaner	10-15% Phosphoric acid, 1-5% glycolic acid,1-5% isopropyl alcohol	60.6 mL to 2,000 mL DI water	1.86	0.14 (0.02)	C
VistaClean	Vista Research (New York)	DUWL cleaner	Diphenol hydroxy-benzene, USP glycerin	0.09 mL to 500 mL DI water	4.35	0.12 (1.08)	C
Pure Vac	Sultan Chemists (Englewood, N.J.)	Line cleaner	10-15% Phosphoric acid, 1-5% glycolic acid	60.6 mL to 2,000 mL DI water	1.81	0.12 (0.02)	C
Green and Clean	Metasys (Miami, Fla.)	Line cleaner	Quaternary ammonium, defoamer, enzymes	19.8 mL to 2,000 mL DI water	5.63	0.11 (0.04)	C
Cidex	Advanced Sterilization Products (Miami, Fla.)	Disinfectant	2.4% Glutaraldehyde	Activator added to 3.785 L of Cidex	8.00	0.10 (0.06)	C
Iodofive	Certol International	Disinfectant/ cleaner	1.75% Iodine, 21.34% phosphoric acid	2.4 mL to 500 mL DI water	2.24	0.09 (2.02)	C
Zerosil	National Surtrex (Paterson, N.J.)	DUWL cleaner	7.5% Hydrogen peroxide	134.8 mL to 500 mL DI water	2.56	0.08 (3.42)	C
Fresh-Vac	Ecolab Healthcare Division (St. Paul, Minn.)	Line cleaner	Protease enzyme	62.5 mL to 2,000 mL DI water	5.93	0.07 (0.02)	C
Mint-A-Kleen	Anodia Systems (Danville, Ky.)	DUWL cleaner	8.5% Ethanol, 0.12% chlorhexi-dine gluconate	No dilution	4.99	0.03 (0.04)	C
Ecotru	Envirosystems (Santa Clara, Calif.)	Disinfectant/ cleaner	0.20% Parachlorometa-xylenol	No dilution	8.72	0.03 (0.64)	C
ZPC-11	Sultan Chemists	Line cleaner	Quaternary ammo-nium chloride	15.2 mL to 500 mL DI water	9.20	0.01 (0.01)	C
Multicide Ultra	Biotrol	Disinfectant/ cleaner	9.09% o-phenylphenol, 7.66% p-tertiary amyl phenol	3.9 mL to 500 mL DI water	10.26	0.00 (0.02)	C
Sporicidin	Sporicidin (Rockville, Md.)	Disinfectant	2.01% Phenol, 0.01% sodium phenate	42.7 mL activator added to 0.9037 L of Sporicidin	7.45	0.00 (0.09)	C
ProhenePlus	Certol International	Disinfectant/ cleaner	9% o-phenyl phenol, 1% o-benzyl p-chlorophenol	15.6 mL to 500 mL DI water	9.63	0.00 (0.06)	C
DRNA Vac	Dental Recy-cling North America (New York City)	Line cleaner	Nonionic alkoxylate	666.6 mL to 2,000 mL DI water	9.11	0.00 (0.00)	C
Biocide	Biotrol	Line cleaner	75% Phosphoric acid, iodine	No	2.37	0.00 (0.00)	C

hypochlorite as the active ingredient; the other three contained sodium dichloroisocyanate, ethylenediaminetetraacetic acid (EDTA), or hydrogen peroxide and peracetic acid as active ingredients. The results we obtained with sodium hypochlorite and sodium dichloroisocyanate preparations agree with those of previously reported studies.[5,6,8] However, the results for the preparation that contained hydrogen peroxide and peracetic acid as active ingredients differed from those obtained by Roberts and colleagues.[8] Those authors found no significant difference in mercury release with the hydrogen peroxide/peracetic acid preparations or distilled water. Interestingly, in our study, a preparation based on hydrogen peroxide without peracetic acid did not release significantly more mercury from amalgam than did deionized water. The results of our study also differ from those reported by Rotstein and colleagues'[7] study of preparations containing EDTA.

Disinfectants or line cleaners that contained phenols, glutaraldehyde or quaternary ammonium compounds did not release more mercury from amalgam than did deionized water, a finding noted in other studies.[6,8]

In our study, we used standardized amalgam cylinders to provide a consistent surface area to react with the chemical preparations. Our approach differed from that of other studies that used ground amalgam particles.[6,8] Even when the researchers in the other studies controlled particle size by sieving, the surface areas of each batch could have varied more substantially than would be the case with standardized amalgam cylinders, the surface area of which can be determined easily. Standardized cylinders, which other studies have featured,[7,12] also provided a more controlled comparison of mercury release from the preparations.

The reaction kinetics between the preparations and the amalgam cylinders influences the amount of mercury released in a specified contact time. It is important to use the same contact time and the same surface for all preparations, because it provides a controlled basis for comparing the amount of mercury released from the amalgam cylinders. For all preparations in this study, we used a contact time of 24 hours and a surface area of 113.10 mm^2. The results of our report can be compared more easily with those of Kummerer and colleagues,[6] who used a contact time of 18 hours for their study. In contrast, Roberts and colleagues[8] used contact times based on the manufacturers' recommended times for disinfection, and those times ranged from two to 10 minutes. Also, they used milled amalgam with particle sizes between 710 and 900 µm. The milled amalgam that passed through the standard sieves of 710 and 900 µm varied in particle size because their irregular shape could vary substantially in surface area. In our study, we used amalgam cylinders of consistent surface area and a uniform contact time of 24 hours. The differences in contact times between the studies and the surface areas of amalgam samples may explain the observed differences in the relative amount of mercury released from amalgam.

Our results showed that pH is not a good predictor (correlation coefficient [r^2] = 0.0236) of mercury release from amalgam; the six preparations that released more mercury from amalgam than deionized water were either highly acidic (pH 1.76-2.59) or highly alkaline (pH 10.72-2.35). However, some preparations had similar acidity levels (for example, pH 1.8) or alkalinity (for example, pH 11.4) that did not release significantly more mercury from amalgam than did deionized water. Soh and colleagues[12] reported that a citric acid buffer at pH 2.5 released more mercury from amalgam than did a citric acid buffer at pH 7.0. Although the components of the buffers were mostly identical, the relative amounts of components used to achieve the different pH values differed between the two buffers. Thus, our study did not address the more complex differences in chemical composition of the disinfectants or line cleaners.

Our study suggested that the chemical compositions of some disinfectants or line cleaners primarily caused the release of mercury from amalgam. The intended use of each product determined its active ingredients (Table), according to manufacturers' information. However, the list of active ingredients may not identify chemicals that are not active in disinfection or line cleaning, but these chemicals may contribute to the reaction kinetics and influence the type of reaction products. This may explain why our study results differ from those of Rotstein and colleagues'[7] study on disinfectants containing EDTA or EDTA and sodium hypochlorite solutions. Thus, the information on active ingredients provided by a product's manufacturer does not predict the potential of that product to release mercury from amalgam.

The aim of our study was to compare the effect of disinfectants and line cleaners on mercury release from amalgam in a highly controlled condition by using the same surface area for the amalgam samples. The heterogeneous nature of amalgam particles in clinical wastewater makes it difficult to quantify the release of mercury. Thus the use of clinical wastewater would introduce a hard-to-control factor into a comparison of the effect of disinfectants and line cleaners on mercury release from amalgam. Therefore, in our study, we used amalgam cylinders of consistent surface area and a uniform contact time of 24 hours.

CONCLUSION

This study and other published reports have demonstrated that preparations containing chlorine release more mercury from amalgam than some other products and the deionized water control. As a result, the use of these products is not recommended for treating dental office waste lines or DUWLs.[10] ■

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