Foil Backing Used in Intraoral Radiographic Dental Film: A Source of Environmental Lead

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Abstract

The lead content of the foil backing of 4 types of intraoral film commonly used by dentists was 69% to 85%. An environmental issue exists because these foils are typically thrown out with regular refuse, even though recycling programs exist. For a new adult patient, a full-mouth radiographic series would generate 11.2 g of waste lead; for a 6-month checkup, waste lead would only be produced if radiographs were required. In an experiment that simulated the acidic conditions that might be expected in a landfill site, 3.5–4.4 mg of lead was released during 17-hour incubation in dilute acetic acid. When distilled double-deionized water replaced the acid, 1.0–2.2 mg of lead was released by the same types of foils. Human health concerns also exist when dental assistants handle lead foil while developing radiographs and fail to change their gloves or wash their hands before handling instruments and dental paraphernalia used in the mouth. Although the amount of lead introduced into the oral cavity would be relatively small, the elimination of sources of lead exposure, especially for children, is important.

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The proper disposal of potentially toxic waste material (e.g., mercury) generated during routine procedures in dental practice has been a contentious issue for at least the last 2 decades.[1] On June 6, 2000, the Canadian Council of Ministers of the Environment accepted a national target of a 95% reduction in mercury amalgam waste being discharged into the environment.[2] Environment Canada recognized that the standard was based on the precautionary principle because few data exist concerning the environmental consequences of mercury amalgam waste.[3] In contrast, we know of no Canadian legislation governing the disposal of dental lead, another waste generated by radiography in dental offices, even though numerous studies have shown that lead is detrimental to the environment and human health.[4]

Intraoral films are packaged with a sheet of lead foil to protect the film from backscatter and secondary irradiation.[5] Although recycling services exist,[6] dentists typically discard lead foil with regular refuse, which is typically deposited in landfills. In addition, if dental assistants do not wash their hands or change their gloves after processing intraoral films, lead oxide might adhere to the gloves or hands and be introduced onto instruments and dental paraphernalia used in the mouths of patients. This is important because inorganic lead is easily dissolved in human saliva.[7]

Mounting evidence suggests that the current level of concern about blood lead may be inadequate in protecting the health of children.[4,8] The potential for lead exposure in patients visiting the dental office has also recently been reported by the United States Food and Drug Administration's Center for Devices and Radiological Health. Dental films stored in certain lead-lined film containers were identified as a potential source of lead exposure for patients and practitioners because of a white layer of approximately 80% lead that covered the dental film.[9] No mention was made of the problem of the lead foil itself.

In this study, we examined the potential for patients' exposure to lead related to the handling of lead foil by dental health professionals. We also determined the lead concentration of lead foils recovered from radiographic film commonly used in the dental profession and examined whether these films would

Table 1 **Average weight of lead foils and lead content of 4 common types of dental film**

Film type[a]	*n*	Weight of lead foil; g ± SD	Average lead content; % ± SD[b]
Size 0	10	0.438 ± 0.002	81 ± 15
Size 1	10	0.533 ± 0.002	85 ± 14
Size 2	10	0.733 ± 0.013	84 ± 18
Occlusal[c]	10	2.920 ± 0.008	69 ± 13

[a]*Sizes 0 and 1 are Kodak Insight film; size 2 is Kodak EKTASPEED Plus; and occlusal is Kodak Ultra-speed D Safety 1 Film, occlusal large.*
[b]*One or 2 outliers were excluded from the average. The very large dilution factor of 125,000–150,000 was likely one of the reasons for the rather low reproducibility, as both manual and spectrometer-activated dilutions were involved.*
[c]*This film type had a thin paper backing that could not be removed.*

be of any environmental consequence under conditions that might be expected in a landfill site. The fate of toxic metals in landfill sites has not been adequately characterized.[10,11] Briefly, the degradation process begins with a short initial aerobic phase, followed by an anaerobic phase (anaerobic acid and methane production subphases), and finally the humic phase.[10,11] Because waste materials are not homogeneously distributed in landfill sites, different parts of a site will be at different stages of degradation.[10,11] The acetic acid leaching experiment incorporated into the present study accelerated the degradation of the lead foil in an effort to simulate the anaerobic acid subphase.

Materials and Methods

Four types and sizes of intraoral dental film commonly used in Canada were examined: Kodak Insight, size 0 (Eastman Kodak Co., Rochester, NY); Kodak Insight, size 1; Kodak EKTASPEED Plus, size 2; and Kodak Ultra-speed D Safety 1 Film, occlusal large. Ten foils from each type of film were weighed (**Table 1**). Stainless steel scissors were used to cut a 15-mg sample (approximately) from each piece of dental foil. The samples were placed in labelled test tubes and 2.0 mL of ultra-pure nitric acid (HNO_3) and 2.0 mL of distilled double-deionized water (DDW) were added to each sample. Samples were digested overnight (about 17 hours) at room temperature, then vortexed and placed into cylindrical heating blocks on hot plates. The samples were digested for 5–6 hours at 120°C, until dry. They were then dissolved in 5.0 mL of 0.1% HNO_3 and diluted 150,000-fold with 0.1% ultra-pure HNO_3 to bring the lead concentrations within a readable range. The samples were placed in a test tube rack and refrigerated until determination of lead by electrothermal atomic absorption spectroscopy (EAAS).

Size 0 and 2 lead foils, 10 each, were used in the acetic acid leaching experiment. Lead foils were loosely folded and placed individually in 2-mL cryovials containing 1.5 mL of 0.01% acetic acid. An additional 10 cryovials containing only 1.5 mL of 0.01% acetic acid served as controls. All samples were rotated using a vertical rotator (16-cm diameter, 20 rpm) for 17 hours at room temperature. The leachate and control samples were then diluted to 5 mL with 0.1% ultra-pure HNO_3. The foil leachates were further diluted 125,000-fold with 0.1% HNO_3. All solutions were placed in the refrigerator until determination of lead levels by EAAS. The experiment was repeated with DDW as the bathing solution.

Ghost Wipes for testing lead in dust (Environmental Express, Mount Pleasant, S.C.) were used in the lead foil handling experiment. Each of 10 wipes was torn into matching halves. One half of each was used to wipe a lead foil (size 0) 3 times using gentle pressure. Experimental and control halves were placed in individual test tubes containing 6 mL of ultra-pure HNO_3 and allowed to dissolve for 8 hours at room temperature. The mixture was then diluted to 5 mL with 0.1% ultra-pure HNO_3, followed by another 50-fold dilution with 0.1% HNO_3. The diluted digests were stored as described above until analysis.

Approximately 1 mL of each digest was poured into a cup and placed in the spectrometer carousel. The samples were analyzed using a Spectra AA 220 EAAS (Varian, Inc., Palo Alto, Calif.) with a graphite furnace. Before analysis and after every 10 samples, calibration curves were recorded to ensure that the spectrometer was accurate (± 10%). One blank sample and a certified reference standard (multi-element water standard, SRM 1640, National Institute of Standards and Technology, Gaithersburg, Md.) were run after every 10 samples. Reference standards were within 10% of the certified concentration. Duplicates of 10 samples were also measured and, on average, were within 5% of the original readings. All controls were below the detection limit of 0.3 µg/L.

Data for the acetic acid and DDW experiments were log transformed to equalize the variance of the data. Variation in lead levels between groups was assessed by analysis of variance (ANOVA) and a post-hoc test (Student-Newman-Keuls [SNK]).

Results

The average lead content of the 4 types of dental foil ranged from 69% to 85% (**Table 1**). Substantial lead was released during leaching of the foils in dilute acetic acid and DDW. ANOVA revealed significant differences ($p < 0.001$) between the 4 experimental groups. The amount of leached lead was significantly higher ($p < 0.05$) in the dilute acetic acid than DDW: 4.4 ± 2.0 mg versus 2.2 ± 0.2 mg (size 0), corresponding to 0.80 ± 0.40% and 0.41 ± 0.04%, respectively; and 3.5 ± 0.5 mg versus 1.0 ± 0.5 mg (size 2), respectively, corresponding to 0.4 ± 0.06% and 0.12 ± 0.06% (**Table 2**). Although lead levels were significantly lower ($p < 0.05$) in the DDW experimental groups compared with the acetic acid groups, the SNK test indicated that lead levels were not signif-

Table 2 **Leaching of lead foils with dilute acetic acid and distilled-deionized water**

Sample	*n*	Amount of lead leached	
		mg ± SD[a]	%
Size 0			
Acetic acid (0.01%)	10	4.4 ± 2.0*	0.80 ± 0.40
Distilled-deionized water	10	2.2 ± 0.2†	0.41 ± 0.04
Size 2			
Acetic acid (0.01%)	10	3.5 ± 0.5*	0.41 ± 0.06
Distilled-deionized water	9	1.0 ± 0.5‡	0.12 ± 0.06

[a]*Numbers in this column that are followed by the same symbol are not significantly different (*p > 0.05; ANOVA, SNK); *different letters indicate a significant difference (*p < 0.05).

Table 3 **Lead content of Ghost Wipes before and after being wiped on size 0 lead foil**

Sample	*n*	Amount of lead; µg ± SD[a]
Wiped on lead foil	10	6.8 ± 3.0[b]
Unwiped	10	0.8 ± 0.7[b]

[a]*Detection limit is 0.01 µg.*
[b]*Lead contents of the wiped and unwiped samples were significantly different at the* p < 0.05 *level.*

icantly different ($p > 0.05$) between the 2 acetic acid experimental groups. In the Ghost Wipes experiment, lead concentrations in the experimental samples (6.8 ± 3.0 µg) and the matched controls (0.8 ± 0.7 µg) were also found to be significantly different ($p < 0.05$).

Discussion

In the last 30 years, significant progress has been made in decreasing sources of environmental lead; however, as old sources are eliminated or regulated, new sources become apparent.[7,12] The lead foils used in oral radiography are typically discarded directly into waste containers and end up in landfill sites. We are unaware of any restrictions concerning the proper disposal of these lead foils in Canada. Furthermore, the lead contained in the foil can be leached from the landfills if no leachate collection system is in place. During the anaerobic acid subphase of the degradation process, microorganisms break down organic material, producing organic acids such as acetic acid that may result in a drop in pH.[11,13] Our acetic acid experiment clearly illustrates how mild acidification can cause significant dissolution of lead from radiographic foil in only 17 hours. This experiment is a simplification of what occurs at landfill sites; the alkalinity of waste material (e.g., carbonate minerals, silicate minerals, aluminium, iron) may be sufficient to buffer acid-producing processes (e.g., oxidation of sulfides, degradation of organic matter) and acidic precipitation.[11] Nevertheless, lead levels as high as 2.6×10^3 µg/L have been reported in leachate samples originating from closed landfill sites.[14]

The amount of lead waste produced by a dental office can be significant. For a new patient examination (adult), a full-mouth series of films may include 14 periapical radiographs using size 2 film and 2–4 bitewing radiographs with size 2 film.[15] Based on data from the current study, as much as 11.2 g of lead waste would be produced in the course of examining one new patient. The amount of lead waste produced (if any) at a recall appointment will vary because the need for radiographs varies from patient to patient.[16] However, the amount of lead produced annually by the dental profession may be substantial.

In addition to environmental concerns, human health issues may also arise. Results from the handling experiment clearly show that patients may be exposed to lead if dental assistants processing radiographs do not change their gloves or wash their hands before handling instruments and dental paraphernalia used in the mouth. The amount of lead available would be proportional to the number of films processed and the amount of handling of the lead foil before handling instruments and dental paraphernalia and patient interaction. Although the amount of lead transferred to a patient may be minimal (about 6 µg; **Table 3**), it is of concern especially with respect to children, who have been reported to absorb approximately 35% of the lead they ingest.[17] The level of lead in children's blood that is of medical concern is constantly being lowered.[4,8] Thus, the dental profession is morally obligated to minimize exposure to such toxicants. Further, environmental lead may be a factor in the disproportionately high dental caries burden reported in the economically disadvantaged portion of North American society.[18,19] The former president of the Canadian Dental Association has stated that "as a group, we [dentists] want to act responsibly to minimize the environmental impact of the dental practice"[20] while protecting human health. This objective can be achieved.

Conclusions

Reducing patient exposure can be achieved effectively by changing gloves or washing one's hands after processing intraoral radiographs. With respect to the environmental issue, lead foil recycling programs exist, but must be used by dentists. Moreover, the use of direct digital radiography would eliminate both the need for intraoral dental film with lead foil and

the subsequent wet processing of the film using chemicals (note, developer and fixer are typically dumped into the drain after use).[21]

Dentists have a moral and professional responsibility toward the dental as well as general health of patients in their care. This should extend beyond the radiation safety procedures normally adopted within the dental office for specific procedures to a more generalized consideration of the environmental impact of the potentially hazardous waste products from these procedures. The various national dental associations, worldwide, should engage in a voluntary movement toward more environmentally friendly alternatives with regard to the disposal of dental lead foil, as was seen with the mercury amalgam waste issue in Canada and elsewhere. ➧

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