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Handwipe Method for Removing Lead from Skin

ABSTRACT: Researchers at the U.S. National Institute for Occupational Safety and Health (NIOSH) developed a handwipe removal method for lead (Pb) after field studies showed that workers in lead-acid battery plants had significant risks for dermal-oral lead exposures, despite their attempts to remove the lead by washing with soap and water. Hand washing with soap and water remains the standard recommendation for workers (as well as the public) to clean skin known or believed to be contaminated with toxic metals, such as lead. Despite longstanding recommendations for workers to "wash hands with soap and water," no efficacy studies show this to be a completely effective removal method for lead. Removal of toxic metals such as lead from skin constitutes a decontamination procedure; it is not, in fact, a hand-washing step. NIOSH scientists conceived and developed a highly effective (nearly 100 %) method for removal of lead from skin. A systems approach was devised incorporating four components deemed necessary for effective metal removal: Surfaction, *p*H control, chelation, and mechanical effects. The handwipe removal method evolved from a previous NIOSH invention, the handwipe disclosing method for the presence of lead, in the interests of providing complementary techniques for dermal lead detection and

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decontamination. The method is a patented, award-winning, commercialized technology that has significant potential to prevent occupational and public exposures to lead.

KEYWORDS: isostearamidopropyl morpholine lactate (ISML), cleanser, citric acid, decontamination, dermal, lead, wipe, workplace

Introduction

Occupational and environmental exposure to metals (e.g., lead [1]) and other elements inherently toxic to biological systems (e.g., cadmium, arsenic, beryllium) implies (depending on the degree of exposure) a potential for adverse effects on workplace and public health. Exposure to such metals, especially lead, is a significant problem that affects a large and diverse segment of the population, and workers and their families are especially at risk [2–4]. Exposure to lead (Pb) may occur in a wide variety of locations, including the workplace, homes or schools, or the outdoor environment [1,2,4]. Skin contact is a significant route for transfer, and exposure to metals such as lead. While hand-to-mouth transfer is understood to be the most significant route of exposure; (a) several researchers have shown that lead ions may be absorbed through the skin [5–7]; (b) skin can act as a reservoir for metals [8,9]; (c) skin surface deposition can be an important source of secondary contamination [3,8,10]; and (d) impairment or loss of skin barrier function can occur [6,11]. Additionally, skin contact with some metals and their compounds (nickel, chromium, and beryllium among others) can cause sensitization and systemic allergic responses which can result in serious occupational disease and even loss of workers from the working population [12]. Unfortunately, many toxic metals are not easily washed off of the skin; finely divided metal particles not only lodge within the complex interstices of the stratum corneum but also bind to sulfhydryl, carboxyl, and other groups present in skin proteins [11]. Industrial hygiene workplace investigations conducted by NIOSH and other investigators have shown that lead and other metals remain on the hands of workers even after they report, or were known to have washed their hands before eating [13–16]. In industrial settings where lead poses exposure risks, significant metal contamination may remain even after washing [13,14,16,17].

Lead provides a particularly useful illustration of the exposure risks, detection and decontamination challenges posed by skin exposures. Lead exposure can occur to workers (and the public) during and after removal of lead-based paints and/or the renovation of structures containing lead-based paints [2], to workers in waste-to-energy plants, manufacture of lead-acid batteries, and other related industries (e.g., radiator repair work, welding, and construction work). Adults or children living within or visiting homes or schools containing deteriorated lead-based paints can be at risk for exposures [4,10]. Lead residues on the skin, especially on the hands, of industrial workers can be a significant health risk since such residues can be invisible and may be ingested during normal activities (e.g., eating, drinking, and smoking) [7–9,17,18]. Contaminated clothing (as well as automobiles) presents take-home toxics issues for workers and their families; lead is an especially important metal in this route of exposure [19].

Although screening methods for detecting the presence of lead in workplaces are available [20–22], validated methods, techniques, and products for highly effective (>99%) skin and surface decontamination are needed. In response to this gap, efforts have been directed to acknowledge the need and importance of detecting and removing lead from skin and other surfaces [6,7,23]. Lead desorption and removal from contaminated soil using surfactants has been investigated and described [24,25]. The physical properties of liquids and soil permit physical mixing of contaminated liquids or soils with decontaminating agents (such as surfactants) on a microscopic level that cannot be achieved with non-dispersible (such as, solid) matter. As a result, it may be more difficult to contact and remove metal contamination from a solid surface, especially where the surface has interstices where contaminants can lodge and bind (such as skin). Moreover, agents suitable for lead decontamination of liquids or soils may cause damage to solid surfaces and, in particular, may irritate or harm sensitive surfaces such as human skin [6,26,27].

Products that claim to remove lead and toxic metals from human skin often contain active ingredients such as the chelating agent ethylenediaminetetraaceticacid (EDTA) or anionic surfactants (fatty acid soaps) [28]. EDTA, while a good chelating agent, is a suspected persistent environmental pollutant and a skin irritant. EDTA may cause reddening or inflammation on prolonged skin contact [29]. Anionic surfactants such as sodium laurel sulfate (SLS) are used in many surfactant or soap mixtures but SLS may also cause skin irritation, including dryness and scaling [26,30]. Moreover, anionic surfactants due to their alkaline *p*H may not be fully effective in mobilizing and removing lead contamination [8,24,25,31]. Therefore, considering the disadvantages of EDTA and anionic surfactants for removing metals from human skin and surfaces, safe, reliable and effective compositions are needed for removing metals, notably lead. Of particular need are compositions and methods that do not substantially damage the treated surface, or unduly irritate, or sensitize biological surfaces, notably skin [32].

In this work we describe the development and evaluation of treated wipes for decontamination of lead and other metals from surfaces such as skin. Optimal wipe materials were found to be those that included a three-dimensionally highly textured absorbent support such a creped surface (a textured surface comprising a succession of ridges and groves; see Fig. 1) with isostearamidopropyl morpholine lactate (ISML) and citric acid in the absorbent, creped wipe. The amounts of ISML and citrate in the wipe medium were optimized in order to obtain the best metal-removing capability from dermal surfaces. The metal-removal performance of these wipes from the hands of the researchers as well as volunteers was compared to that of several other commercially available products and formulations, and also to hand washing with soap and water. We report herein the results of these investigations, which demonstrate the superior decontamination effectiveness of a textured (creped) wipe substrate containing the cationic surfactant ISML and chelating and *p*H adjusting agent, citric acid.

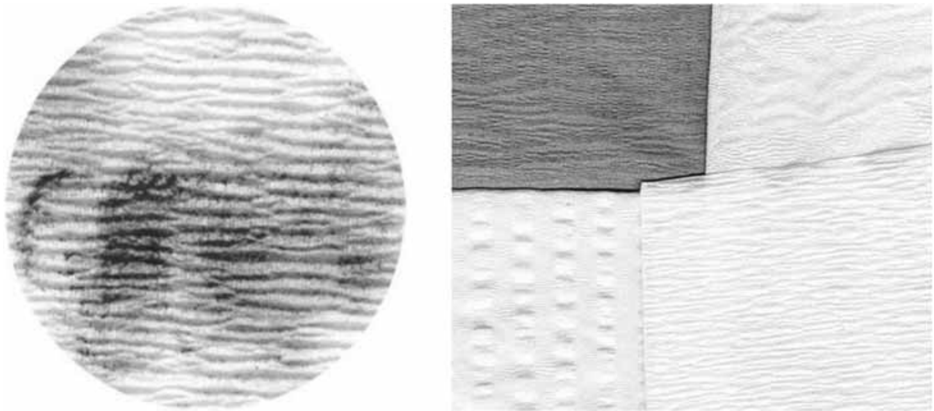

FIG. 1—*Creped wipe materials (a) Photo of creped wipe showing succession of ridges and groves and sample collection within a textured wipe. Photo courtesy of Micrex Corporation. Used with permission B) Photo of various creped textures that can be imparted into wiping materials. Photo courtesy of Micrex Corporation. Used with permission.*

Experimental

Materials

Initial formulations of the decontamination wipes were made in NIOSH laboratories in Cincinnati, OH and Denver, CO. Several rolls of DuPont™ Sontara® were creped by Micrex® (Walpole MA) and provided to NIOSH as the absorbent substrate for the initial experimental trials. ISML (Mackalene™ 426 and Incromate® ISML) were obtained from McIntyre Group Ltd. (University Park, IL USA) and CRODA Inc. (Edison, NJ, USA), respectively. Citric acid solutions were made in-house (NIOSH, Cincinnati, OH, USA). A pre-commercial version of the invention (MEDTOX® Wipe Lot # 0807) of LeadTech™ Wipes was provided for evaluation by MEDTOX® Diagnostics (Burlington, NC, USA). The final formulation of wipes contained between 0.3 and 2 g (g) of ISML and between 0.01 and 0.1 g citric acid per gram of absorbent support (exact formulations are proprietary). Sampling wipes (Palintest™ and Ghost Wipes™) meeting international voluntary consensus performance standards were obtained from Palintest® (Gateshead, Tyne and Wear, U.K.) and Environmental Express (Mt. Pleasant, SC, USA), respectively [33]. D-Lead™ cleansers, both with and without scrubbers, were obtained from Esca Tech (Milwaukee, WI, USA). Clean-All Heavy Metals Soap™ cleanser came from Sasha International (Miami Beach, FL, USA). Kresto Select™ cleanser with scrubber, and Kresto Kwik™ wipes, were purchased from Stockhausen (Greensboro, NC, USA). GoJo Multigreen™ cleanser with scrubbers was obtained from GoJo Corp. (Akron, OH, USA). Waxed kitchen paper, paper towels, and food grade corn starch (Safeway brands, Pleasanton, CA, USA), as well as Pampers Baby Wipes™ and Ivory™ Liquid Soap (Procter & Gamble Co., Cincinnati, OH, USA), were purchased at a neighborhood grocery store. Disposable nitrile laboratory gloves came from Fisher Scientific (Fair Lawn, NJ, USA). Acetic acid (reagent grade) came from Sigma Aldrich. Industrial hand soap used was Smart & Final™ Liquid Soap (Los Angeles, CA, USA).

Red lead monoxide powder (PbO; $> 99.9\ \%$, particle size <10 micrometer[μm]) was obtained from Sigma-Aldrich (Milwaukee, WI, USA) and was mixed uniformly into corn starch (used as a mixing diluent) by rotary tumbling to yield a concentration of 90.9 mg (mg) Pb/gram. Aliquots of this mixture were weighed into samples of 33 mg each (to ± 1 mg) on an analytical balance (Mettler model AE163, Greifensee, Switzerland). Lead-containing dust (consisting primarily of PbO collected from a lead-acid battery manufacturing plant in Texas, USA [14]) was also weighed into samples of approximately 3000 μg each. Polyethylene centrifuge tubes (Elkay™, 50 mL) were obtained from Life Sciences Products (Denver, CO, USA).

Procedures

The evaluation of lead dust decontamination from human hands (the researchers as well as volunteers) was approved through NIOSH human subjects review board [34]. Skin was contaminated by spiking both palmer surfaces with weighed quantities of leaded dust (either lead monoxide powder and corn starch, or straight PbO from a lead-acid battery plant). Skin sampling was performed in accordance with NIOSH Method 9105 [35]. To establish if significant lead might have been present as background contamination, an initial 30-s hand wipe sample was collected on every subject (researcher or volunteer) before each of the experimental trials. Both Ghost Wipes™ and Palintest™ brand wipes were used for skin sampling. To collect skin samples for the presence of lead, the investigator (wearing clean nitrile gloves) opened a wipe packet and offered the folded wipe to the subject. The volunteer was asked to completely unfold the wipe and then carefully wipe to sample the palmer surfaces of both hands for 30 s to collect an initial background sample for the presence of lead. After 30 s, the subject was requested to stop wiping and fold the wipe with the soiled surface facing inward. The volunteer was asked to place the folded wipe into a 50-mL plastic centrifuge tube that was used for sample containment and laboratory transport. After sample collection, the centrifuge tube was tightly capped and labeled with a discrete sample identification number using an indelible marker.

To apply the leaded dust to the skin of each volunteer, the investigator (wearing clean nitrile gloves) carefully unfolded the sample weighing paper and poured each pre-weighed leaded dust sample into the volunteers' cupped hands while they were held over a clean sheet of wax paper. The wax paper was placed below the subjects' hands to capture any leaded dust that fell off the hands during the application, enabling a mass balance to be established. Subject individuals were asked to carefully rub the leaded dust into the skin of their hands for 30 s, being careful to keep as much lead dust on their hands as possible.

After the leaded dust was applied to the skin, the investigator changed gloves, removed a decontamination wipe from its container and handed it to each volunteer. Each subject was asked to cleanse his/her hands for a period of 30 s. Following the 30-s decontamination step, the volunteer was asked to rinse their hands for 30 s under a laboratory sink with flowing, tepid water to remove the surfactant. After rinsing, the investigator gave the volunteer two flat paper towels and instructed the volunteer to carefully pat dry their hands, taking care not to rub their hands with the paper towel.

Two serial handwipe samples were then collected to evaluate the volunteers' (or researchers') hands for the presence of lead on skin. The investigator (wearing a fresh pair of nitrile gloves) again opened packets of Ghost Wipes^{TM} or Palintest^{TM} wipes and offered the folded wipes to the volunteers. The volunteers were asked to unfold the wipe and wipe the palmer surfaces of both hands for 30 s and then to fold the wipe together with the "soiled" or sample side facing in. The volunteers placed the wipes into 50-mL centrifuge tubes, which were then capped and labeled. Skin sampling was repeated twice and the samples combined in a single tube for analysis. A surface wipe sample was collected from the wax paper that was placed on the laboratory bench below the volunteers' hands during application of leaded dust to the hands. This sample was used to account for any lead-containing dust that might have not been rubbed into the volunteers' hands or somehow spilled through their fingers during the application process.

Similar protocols as described above were employed to evaluate hand washing with soap and water as well as various liquid soaps, solutions, wipes and cleanser formulations.

Wipe samples were analyzed at Bureau Veritas North America, (Novi, MI, USA), a facility accredited by the American Industrial Hygiene Association Laboratory Accreditation Programs, LLC. Analyses were carried out using NIOSH method 9102 with modifications: lead in collected wipe samples was determined by means of nitric/perchloric acid hot block digestion and inductively coupled plasma-atomic emission spectrometry (ICP-AES). Each wipe sample was removed from the centrifuge tubes and placed in a clean beaker to which 2.5 mL of 12.1*M* perchloric acid was added and allowed to stand for 30 min. The beakers were placed in a hot block and heated at 95°C for 15 min. Samples were removed from the hot block, left to stand, and allowed to cool to room temperature, and 2.5 mL of 15.6*M* nitric acid was then added. The samples were placed back in the hot block and again heated at 95°C for 15 min. The samples were then removed, left to stand, and allowed to cool to room temperature and diluted to a final volume of 25 mL with deionized water. Quality assurance/quality control samples (blank samples, spikes and spike duplicates) were digested and analyzed in the same manner. All samples were analyzed using a Perkin Elmer Optima 3200 XL ICP-AES instrument (Boston, MA, USA). The ICP-AES limits of detection and quantitation for lead (0.3 and 0.86 μg per sample, respectively) were estimated in accordance with ASTM E1613 [36].

Results and Discussion

In initial experiments, the researchers compared the efficacy of a combination of liquid surfactant and acids alone, with no wipe (i.e., ISML and acetic or citric acids) against ISML and citric acid added to a lightly textured "creped" wipe, against common industrial soap and water to remove leaded dust from the researcher's skin. Fig. 2 shows the amount of lead (in μg) remaining on the palmer surfaces of the skin after an initial 3000 μg Pb loading (using the PbO–corn starch mixture) following the four different methods of cleansing: (1) Common industrial soap and water alone (S&W); (2) liquid only mixtures of citric acid and ISML (C-I liquid); (3) liquid mixtures of acetic acid and ISML (A-I liquid); and, (4) an aqueous mixture of citric acid and ISML (C-I on wipe) applied onto a commercially available lightly textured (Pampers® brand) baby wipe. In these trials, five replicates were run for each of the above four experiments.

As is illustrated in Fig. 2, use of common industrial soap and water alone was not effective in completely removing deposited lead from human skin, as nearly 300 μg of lead remained after hand washing. The alkaline (pH 8–9) nature of common industrial soap and water, absence of a low pH surfactant and chelating agent, and lack of mechanical removal effects are understood to be the main reasons for less complete removal of lead from skin. In contrast, a citric acid and ISML formulation on a lightly textured "creped" wet wipe was the most effective in this trial, as evidence by the least amount of remaining lead recovered ($<$ 75 μg) after skin decontamination. Mixtures of citric or acetic acids and ISML applied without a wipe (C-I liquid and A-I liquid) were also

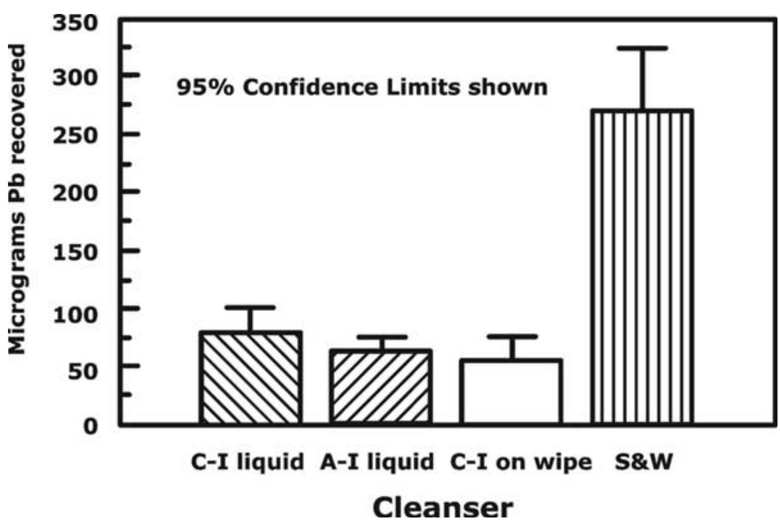

FIG. 2—*Amount of lead (in µg) remaining on human hands after cleansing with a liquid mixture of citric acid and ISML ("C-I liquid"), a liquid mixture of acetic acid and ISML ("A-I liquid"), a mixture of citric acid and ISML on a wipe ("C-I on wipe"), and plain soap and water ("S&W"); n=5 for each cleanser method.*

effective at removing lead (Fig. 1). The finding that the wipe formulation with citric acid and ISML is somewhat more effective than ISML/citric acid liquid only indicates that the mechanical action of even a lightly textured wiping material contributed to the lead-removal process.

In another initial set of experiments also conducted on the researchers' hands, several variations on the use of a highly textured "creped" wipe containing aqueous solutions of citric acid and ISML were tested for efficacy at removing lead from skin. Different cleansing protocols utilizing Micrex® (highly textured, creped) Dupont Sontara wiping material were employed after application of 3000 μg Pb in leaded dust on hands, as described previously. These six protocols and hand washing with common soap and water (which is the most commonly used cleansing protocol) are outlined in Table 1. Each protocol was done in replicates of five.

As shown in Fig. 3, Protocols A and B (using two different concentrations of citric acid and ISML) were essentially equally effective at removing lead from skin, with $\approx$15 μg Pb of an initial 3000 μg Pb load measured on the hands after cleansing in this manner. With Protocol C, (same as A&B but without a water rinse) about 100 μg Pb remained on the hands, indicating that a final water rinse is recommended for removal of solubilized lead. Protocol D (use of a second citrate/ISML creped wipe) illustrates that use of a second citric acid and ISML treated wipe removes almost all lead, with only 2.5 μg Pb remaining on skin. Use of a second wipe but without a final water rinse (Protocol T) indicates that lead removal is effective ($\approx$35 μg Pb remains after the cleansing protocol). Protocol T could be used in remote locations where water for rinsing is not available.

In contrast to each of the protocols involving one or more citrate/ISML wipes, the use of a wetted, creped wipe with no surfactant or citric acid (i.e., Protocol E) was less effective for lead removal from skin, with nearly 200 μg Pb remaining (see Fig. 3) indicating that the mechanical action of the creped wipe has an effect in dislodging lead from skin. Use of common industrial hand soap

TABLE 1—*Cleansing protocols tested in evaluating efficacies of treated, textured wipes.*

Protocol	Description
A	Wipe containing 10 mL of 0.5 % citric acid and 12.5 % ISML solution and a final water rinse
B	Wipe containing 10 mL of 0.25 % citric acid and 18.75 % ISML solution with a final water rinse
C	Protocol B but without a final water rinse
D	Protocol B but with use of a second wipe prior to rinsing with water
E	Use of a wipe wetted with water only, followed by a water rinse
T	Protocol B followed by a second citric acid/ISML wipe, but with no water rinse
S&W	Soap and water hand washing

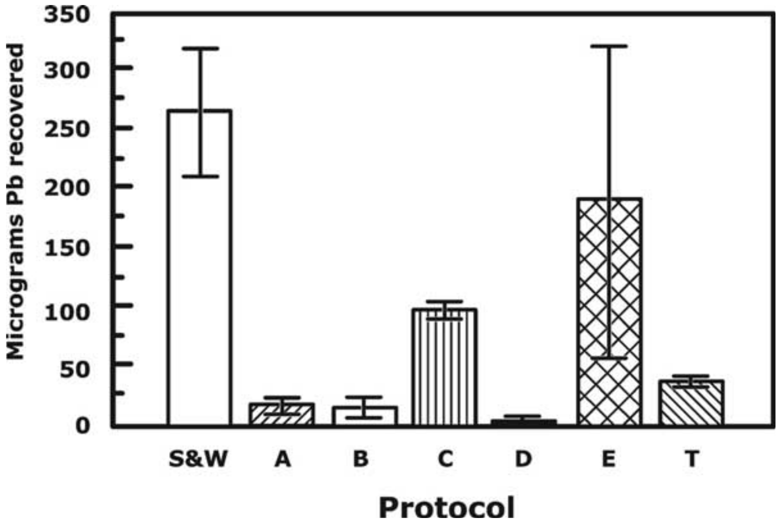

FIG. 3—*Amount of lead (in μg) remaining on human hands after cleansing protocols involving one or more citrate/ISML wipes, as described in Protocols A, B, C, D and T; or a wipe wetted only with water (Protocol E); or hand washing with soap and water (S&W). 95 % confidence limits are shown (n=5). (See text and Table 1 for description).*

and water as cleaning agents (S&W) resulted in over 250 μg Pb remaining on the hands thereby demonstrating the relative ineffectiveness of this widely used method for lead removal from dermal surfaces.

The efficacy of lead removal using textured creped wipes containing citric acid and ISML was compared side-by-side with other commercial products in described in Fig. 4. In this set of experiments, Dupont Sontara™ creped by Micrex® (20 cm × 20 cm) were fortified with 10 mL of aqueous solution containing 0.5 % citric acid and 12.5 % ISML. Fourteen volunteer's hands were spiked with 3000 μg leaded dust prior to cleansing. Commercial products tested included those listed in Table 2. These comparison products were selected as among the most widely used on the commercial market for lead and other heavy metal decontamination. The scrubbers in some of these products may consist of ground walnut shells, plastic beads, or crystalline silica (comparable to the consistency of beach sand).

The citric acid/ISML wipe (Cleanser A) provided statistically significant superior lead cleansing from human hands when compared to Cleansers F, U, N, H, and G (cleansers listed in Table 2). The citric acid/ISML wipe also removed more lead from skin than did Cleanser I (16 μg Pb versus 27 μg Pb remaining on hands: Fig. 3), but this difference was not statistically significant. It is noted that scrubbers contained in some of the commercial products may irritate the skin with repeated use [32].

As a follow-on to the previous investigations, a blind comparison between citric acid/ISML wipes and representative liquid cleansers was also conducted using another fourteen volunteer participants. In this investigation, the

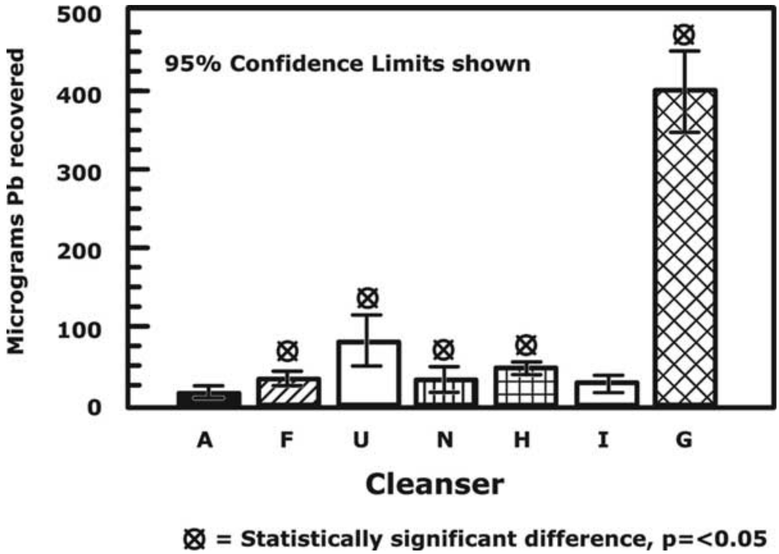

FIG. 4—*Amount of lead remaining on hands following 3000 μg Pb initial loading and after cleaning with a citric acid/ISML wipe (Cleanser A) and various commercially available industrial hand cleansers (Cleansers F, U, N, H, I and G), as described in text and Table 2;* $n = 5$ *for each cleanser method.*

participants were not informed of the identities of the test products. Each subject was provided with a randomly selected cleanser, and each product was used twice by each participant. As in previous trials, volunteers' hands were spiked with 3000 μg Pb leaded dust prior to cleansing. The liquid cleansers that were compared to the citric acid/ISML wipe (Cleanser A) included: 1. D-Lead® liquid soap without scrubbers (Cleanser B); 2. Clean-All Heavy Metal™ liquid soap (Cleanser C); and 3. Ivory® liquid soap (Cleanser D). In carrying out these tests, 2 mL of each of the liquid soaps were applied to the palms.

TABLE 2—*Cleansing products tested in comparison study with treated, textured wipes containing citric acid and ISML.*

Cleanser	Product Description
A	Wipe containing 10 mL of 0.5 % citric acid and 12.5 % ISML solution
F	Clean-All Heavy Metal Soap
G	Kresto Kwik Wipes
H	Kresto Select with scrubber
I	GoJo Multigreen with scrubbers
N	D-Lead with scrubbers
U	D-Lead without scrubbers

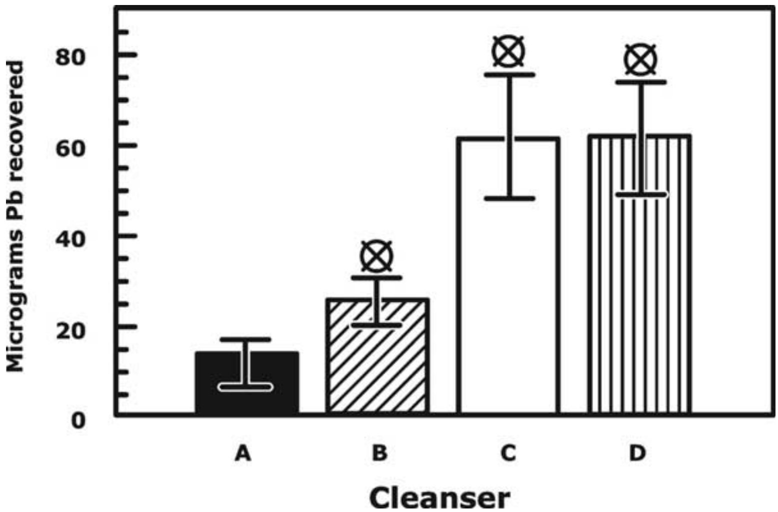

FIG. 5—*Amount of a 3000 μg Pb initial load remaining on the hands of 14 blinded study participants after using a citric acid/ISML wipe ("Cleanser A"), D-Lead liquid soap without scrubbers ("Cleanser B"), Clean-All liquid soap ("Cleanser C"), or Ivory liquid soap ("Cleanser D").*

The results from these comparisons are shown in Fig. 5. It is demonstrated that the citric acid/ISML wipe system removed more lead from the hands than each of the other products; these results are statistically significant. One of the products advertised to be effective for removal of lead as well as other toxic metals (Clean-All Heavy Metal Soap™) in fact did not decontaminate hands any better than (the non-industrial) Ivory® liquid soap.

In a final evaluation, the efficacy of lead removal using straight, lead-acid battery plant dust (as 99 % PbO), of a licensed, converted (commercially manufactured and packaged), Beta version of the invention was evaluated using nine volunteers. Results from these experiments are summarized in Table 3. The spiking, sampling, and decontamination investigative protocol was similar to the previous investigations but Palintest™, rather than Ghost Wipes™ were used for skin sampling. Differences in sampling efficiency using Ghost Wipes™ and Palintest™ brand wipes has been investigated and no significant sample collection efficiency differences were found [37]. Not unexpectedly, all background handwipe samples revealed some lead, likely from handling lead-containing brass keys, or touching other brass/lead containing environmental surfaces. Dermal lead concentrations ranged from trace levels (detectable but not quantifiable) to 2.6 μg Pb/handwipe. An average of 670 μg of lead was recovered in surface wipe samples from the wax paper suggesting the application technique varied considerably in the successful loading of lead dust onto the skin. The average calculated amount of Pb applied to the skin was $\approx 2,300$ μg. Calculated percent removal for pre-commercial lot 0807 ranged from 99.7 to 99.9 %, indicating that the MEDTOX™ Wipe (which uses a slightly

TABLE 3—*Lead dust removal efficacy (hands) from a pre-commercial lot of textured citric acid/IMSL wipes.*

Volunteer No.	Background Handwipe Pb (μg)	Initially Weighed Pb Amount (μg; as PbO)	Pb (μg) Recovered from Wax Paper	Calculated Pb Mass (μg) Applied to Hands	Final Pb (μg) Collected After 2 Serial Handwipes	Calculated % Pb Removed[a]
1	2.5	2868	830	2038	4.6	99.7
2	0.31[b]	2978	310	2668	6.6	99.7
3	2.0	3238	1500	1738	2.1	99.8
4	2.5	2830	660	2170	2.7	99.8
5	0.65[b]	3146	270	2876	3.3	99.8
6	2.6	2960	600	2360	1.8	99.9
7	0.77[b]	3006	790	2216	1.9	99.9
8	1.2	2997	470	2527	1.6	99.9
9	0.71[b]	3053	600	2453	3.5	99.8

[a]Accounts for initial hand contamination measured (background) and losses onto wax paper that occurred during loading of lead oxide dust onto hands.

[b]Estimated amount: Above detection limit but below quantitation limit.

different but highly textured wipe material from that supplied to NIOSH by Micrex®) was as effective as the original citric acid/ISML creped wipes evaluated previously (creped DuPont™ Sontara® wipe material supplied by Micrex®). Similar experiments using Hygenall® brand licensed and commercialized wipes have also demonstrated 99.2 % lead removal efficiency with five trials using 6,000 μg palmer skin loadings and of straight PbO (99 %) from a lead-acid battery plant.

Conclusion

A novel and highly effective method for removing toxic metals (notably lead) from skin has been conceived, developed, evaluated, patented and licensed from the government to the private sector. The technology consists of a three-dimensionally textured absorbent wipe treated with proportions of a cationic surfactant (ISML) and a weak organic acid (citric acid). Published research has shown that the method does not damage the skin [6]. The technology design criteria involved developing a system of metal removal incorporating contributing effects of surfaction, chelation, *p*H adjustment and mechanical removal. This technology was developed to complement a previous NIOSH invention involving colorimetric chemistry that detects lead collected from skin and workplace surfaces. Used serially, the two technologies are envisioned to “close the loop” on detection and decontamination of skin contaminated with lead. Decontamination of workers’ skin should improve with the use of this technology and the commercial versions of these wipes, which have been shown to be more effective than hand washing using soap and water.

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