Journal of Occupational and Environmental Hygiene, 3: 428–434
ISSN: 1545-9624 print / 1545-9632 online
DOI: 10.1080/15459620600802754

A Comparison of Surface Wipe Media for Sampling Lead on Hands

Mark Boeniger

National Institute for Occupational Safety and Health, Cincinnati, Ohio

Hand contamination by toxic agents such as lead presents a potentially significant health hazard to workers if the contamination is transferred to the mouth by food, smoking, or touching the mouth. One method to sample the mass of contamination on hands is to wipe the skin and analyze the wipe media for the analyte. Several commercially available, prewetted wipe media were evaluated and compared. The Palintest and Wash'n Dri media are made of cellulose fiber; the Ghost wipe is made of a nonwoven polyvinyl alcohol fiber. ASTM test method E1792 for surface lead sampling provides some specified minimum requirements and some general, nonspecific criteria that these media should meet. However, no objective determination of the performance or characteristics of these different wiping media were found in the open literature for sampling lead on hands, particularly relating to typical collection efficiency. To test the recovery of lead oxide dust collected from two hands, two different loading levels were used for each wipe medium. Four successive wipes were collected and analyzed individually. The results of this study indicate that only about 52–62% of the total lead loading is recovered with the first wipe, but that up to 75% recovery could be obtained by combining all three successive wipes. This study also describes testing several physical aspects of these wipes that included tensile strength, wetness, and drying rate, which are characteristics that are not specified by ASTM E1792. The results indicate a higher fragility among the cellulosic wipes, less moisture content, and higher drying rates than the Ghost wipe. This information should be helpful when selecting a wipe material that is best suited for an environmental or industrial hygiene surface or skin sampling task and might also be useful for improving such media in the future.

Keywords hand wipes, lead, sampling

Address correspondence to: Mark Boeniger, 8380 Jakaro Dr., Cincinnati, OH 45255; e-mail: mfboeniger@worldnet.att.net.

Mention of company names or products does not constitute endorsement by the National Institute for Occupational Safety and Health (NIOSH). The findings and conclusions of this report are those of the author and do not necessarily represent the views of NIOSH.

INTRODUCTION

Surface sampling is a common and valuable tool for identifying the presence and quantity of toxic substances on environmental surfaces and on the skin. Substances on environmental surfaces can be sources for re-entrainment of dust into the air, for transfer to the skin where percutaneous absorption could occur, or for ingestion to occur if transferred to the mouth. Surface sampling is especially appropriate for toxic substances that are persistent, are solids or semivolatile, and are able to bioaccumulate once inside the body. Lead-containing dusts are an example of such agents.

Numerous types of media have been used over the years to collect samples for lead (and other elemental) analysis. Previous authors have commented that wipe media should conform to certain minimum requirements, such as low and consistent background concentrations of the analyte(s) of interest, ease of digestion during analysis, at least 80% recovery of lead from standard reference media spikes, and ease of use in the field.[1] From the recognition of the need for minimum and consistent performance requirements for lead sampling media, guidelines in the form of standard evaluation methods, and minimum performance criteria have evolved. The American Society for Testing and Materials Method E1792-03, "Standard Specification for Wipe Sampling Materials for Lead in Surface Dust,"[2] specifies that wipe media should be not less than 10 cm by 10 cm and not larger than 25 cm by 25 cm. The standard states that the wipes should be visibly wet and feel wet and have a moisture content that varies no more than 25%.

Furthermore, wipes should be sufficiently rugged to be used on a smooth surface without tearing. The standard also specifies that the minimum *absolute* collection efficiency for lead dust from a smooth surface shall be 75% or better for 95% of the wipes tested, as measured against a known mass of lead dust that was placed on the test surface. In an earlier version of this method (E1792-96a), the *relative* collection efficiency of the first wipe must have been at least 75%, as measured against the amount of lead determined from the combined amount of the first and a second wiping of the same surface.[3]

However, little attention has been directed to evaluating wipe media for sampling lead on the hands or for criteria related to sampling rough surfaces. ASTM 1792 describes the test to demonstrate sampling efficiency and "sufficient ruggedness" of the media by wiping a smooth vinyl-composite floor tile using a standard wiping procedure.[2,4] Skin on the human hand can have many topographical imperfections, including furrows, whorls, scars, and calluses. Environmental surfaces are often not smooth (e.g., old, painted windowsills) but nevertheless should be sampled. Sampling for lead on skin or environmental surfaces is not likely to be as efficient as for a smooth monolithic surface, such as linoleum, and textured surfaces are more likely to tear the wipe media more readily. These issues have not been well characterized or described. The dearth of comparison performance data on the most commonly used wipe sampling media makes selecting the best medium by a new user a challenging endeavor.

Dry wipes are not likely to collect surface dust as readily as wet wipes, and how long wipes remain moist could affect collection efficiency.[5–8] The average amount of moisture that is initially present in the wipes, and the drying rate once exposed to air, are not specified by ASTM E1792. It is not clear whether moisture content is meant to refer only to water, so the rate of drying rate could be considerable if organic solvents, such as alcohols, are used.

The primary goal of this article is to describe results for three brands of commonly available wipes using an approach for measuring sampling efficiency when wiping hands contaminated with lead dust. However, certain additional comparisons of the physical aspects of the wipes are included. This work is intended to provide users of wipe sampling media with comparison information and data to make more informed decisions before sample collection, rather than find that the medium they chose (perhaps by default) was unsuitable for the sampling strategy they intended.

METHODS

Three brands of wipe sampling media–Palintest (PW), Wash'n Dri (WD), and Ghost Wipes (GW)–were chosen for evaluation because they meet the performance attributes of ASTM E1792, which primarily are low lead background concentration; acceptable analyte recovery from the media and from a smooth surface; size; and a prewetted state (Table I).

Ghost wipes have changed noticeably with each lot over the years, particularly in weight and texture. The original medium was thinner, and the 2002 lot was perforated and heavier. The most recent lot, Lot 2004, is not perforated but is relatively heavy and was used in these tests. Other available wipes include PaceWipe (13 × 15 cm), which are not presently available from LG Best & Associates, (Cary, N.C.) and Lead Wipes available from Aramsco (N.J.), but these appear very similar to Palintest wipes and, for this reason, were not evaluated.

The evaluation of lead dust recovery from the hands was conducted by first rubbing a mixture of lead oxide (PbO) and corn starch (baby powder) into the palms. Homogeneity of the mixture and assurance of analytical accuracy were confirmed by fortifying wipe media with weighed amounts. A "low" lead concentration and "high" lead concentration were used. The calculated analytical recovery from fortified wipes was 92% and 94%, and precision was good with a relative standard deviations of 3.1% and 3.6%, respectively. A 33.3 mg amount of the mixture, which had been carefully weighed to an accuracy of less than 0.1% of the weight of the measured amount, and containing either 6 mg or 90 mg PbO per gram corn starch, was carefully transferred to one palm from waxed weighing paper The amount of this mixture chosen to be applied was found to be easily distributed over the palms without loss of excess powder that could fall off and yet could be easily handled and seen.

The powder was carefully rubbed over the palmar area of both hands for 30 secs. This process deposited 200 μg (low loading) or 2979 μg (high loading) of PbO on the palms, which simulated a reasonable range of lead loadings that were previously reported in the literature and measured during NIOSH field surveys.[9–14] All experiments were performed on only the author's hands for sampling consistency. The two-dimensional surface area of both palms was approximately 1056 cm^2. Once the lead mix was deposited onto the palms, four consecutive wipe samples were used to sample both hands, wiping for 30 sec with each (palm sides only).[14]

After sample collection, each wipe was placed separately into a 50-mL polystyrene centrifuge tube for analysis. Analysis was performed by a laboratory accredited for proficiency in the analysis of lead using NIOSH NMAM Method 7300[15] (inductively coupled argon plasma-atomic emission spectroscopy). Results are reported as elemental lead (Pb), which has a lower limit of quantification of lead on wipes of about 2 μg.

In an attempt to account for the possible loss of the PbO powder during application and the rub-in process, the hands were held over a large wax paper sheet (approx. 1.3 ft × 2.0 ft) to which an open Ghost wipe was placed in the middle and positioned directly underneath the hands. After all consecutive hand wipe samples were collected, in half the sample runs the wax paper was wiped with the open wipe medium with a gloved hand. In the other half of the runs only the Ghost wipe was recovered without wiping the paper. By quantifying the

TABLE I. Description of Wipe Media Selected for Evaluation

Name Identity	Manufacturer	Material	Size (cm)	Total (cm^2)
PW	Palintest USA, Erlanger, Ky.	Cellulosic	17.9 × 12.7	227
WD	Colgate-Palmolive, New York	Cellulosic	14 × 20	280
GW	Environmental Express, Mount Pleasant, S.C.	Proprietary nonwoven, noncellulosic filament	15 × 15	225

TABLE II. Mean Lead Recovery Fraction Obtained with Each Successive Wipe

Media	Wipe 1	Wipe 2	Wipe 3	Wipe 4	Total
PW low	0.561 (8.9)	0.133 (42.3)	0.070 (49.1)	0.037 (38.4)	0.786 (3.8)
PW high	0.581 (2.9)	0.101 (23.5)	0.041 (21.5)	0.024 (2.9)	0.740 (2.7)
WD low	0.625 (10.3)	0.078 (3.7)	0.032 (19.8)	0.019 (49.7)	0.747 (7.3)
WD high	0.600 (7.8)	0.087 (24.5)	0.035 (25.4)	0.017 (12.4)	0.730 (7.8)
GW low	0.574 (11.6)	0.085 (10.6)	0.035 (8.6)	0.027 (10.4)	0.707 (12.5)
GW high	0.522 (15.3)	0.114 (11.4)	0.047 (19.3)	0.032 (9.0)	0.699 (10.4)

Notes: Low (200 Fg) loading, high (2979 Fg) loading of PbO with (% relative standard deviation, RSD). Sample sizes for each value, n = 4.

amount of lead in the wipe media and the surface beneath the hands separately (from either waxed paper or media wipe), an indication of the amount of dispersion of lost lead was obtained.

Because it is generally known that wet media are more effective than dry media for surface sampling, moisture content might seem to be an important characteristic of these premoistened wiping media.[5,6] It has also been demonstrated that there may be an optimal moistened state for obtaining analyte collection efficiency.[7] To evaluate moisture content, the initial weights and dry weights of the wipes were measured so that the moisture content (by weight) could be determined. In addition, the drying rate of the wipes was measured. This was done by opening a wipe from its package, unfolding it completely, and immediately placing it on an analytical balance capable of weighing to less than 1 mg. Weight was recorded over several predetermined times. Because it was assumed, based on experimental experience, that a wipe sample could be performed in less than 3 min, weight loss was monitored only for that duration.

Two simple tests of physical ruggedness were devised to test each of the three wipe materials. The first was to measure the capacity of each of the three wipes to resist separating while applying an increasing pulling force. To evaluate this, uniform 3-cm widths of each moist medium were quickly cut and attached between a spring scale (#3001003; Edmund Scientific, Tonawanda, N.Y.) and a fixed clamp. With the strip of wipe medium attached, the spring scale was then slowly pulled while observing the resistance measured until the wipe medium tore. This was repeated eight times with fresh wipe media and the mean and standard error calculated.

A second simple test of ruggedness was devised in which each wiping medium was rubbed over very fine grit sandpaper in a semiuniform manner. This choice of wipe surface was intended to mimic a surface that might be more like a manual laborer's hands or a painted surface. A 2.5 $\times$ 12.5 cm strip of grit #320 sandpaper (413Q Wetordry; 3M, St. Paul, Minn.) was mounted on a digital laboratory platform scale. Using the gloved index finger, the wiping medium was pressed onto the platform scale while applying various amounts of force as the medium was rubbed over the length of the sand paper. After rubbing, each wipe was observed for evidence of tearing or holes that went completely through the medium. This process was repeated until the approximate tear force could be identified. Wipes were then repeated five times at that force. If at least four out of five wipes failed to tear, this force was recorded as the maximum "no tear" value. The objective of this test was to determine the maximum applied force that each wipe material could withstand without tearing apart.

RESULTS

The results of the hand wipe evaluation of lead dust recovery are listed in Table II and displayed in Figure 1. The means and percent coefficients of variation are presented. For all practical purposes, the three brands of wipe media collected similar amounts of lead. The total mean fractional recovery (fraction percent of total mass loaded on the skin) for each wipe media (both low and high loadings) for PW, WD, and GW were for the low loading: 0.79, 0.75, and 0.71, and for the high loading: 0.74, 0.73, and 0.70, respectively. The Ghost wipe recoveries were slightly lower than for the other two wipes, but for the high loading test the differences were not statistically significant (one-way ANOVA $\rho = 0.15$ or Mann-Whitney U test, $\rho > 0.12$ all comparisons). However, the total recovered by the Ghost wipes with the low loading tests was significantly different compared with both the cellulosic wipes (Mann-Whitney U test, $\rho = 0.04$). There was more variation between tests within each group than between the different brands of wipes. Also, the variance of the total mass recovered as the sum of four successive wipes was less than the variance within each successive wipe in four out of the six test scenarios.

From the tabletop samples, the amount of lead found on the entire waxed paper or the opened wipe media was not statistically different (Mann-Whitney U-test, $\rho = 0.47$ low loading; $\rho = 0.20$ high loading), although the entire waxed paper area tended to have slightly less lead than the wipe placed directly under the hands while rubbing. Specifically, for the low loading level, the mean amounts of lead (and %RSD) found directly under the hands on the opened wipe and on the table top were 5.5 (1.3) and 4.2 (2.4) μg, respectively, whereas for the high loading level there were 39.8 (9.1) and 26.3 (8.3) Fg measured.

The mean initial weights of the wipe media, their dry weight, the calculated moisture weight, and percent relative standard deviation for each type wipe media are presented in Table III.

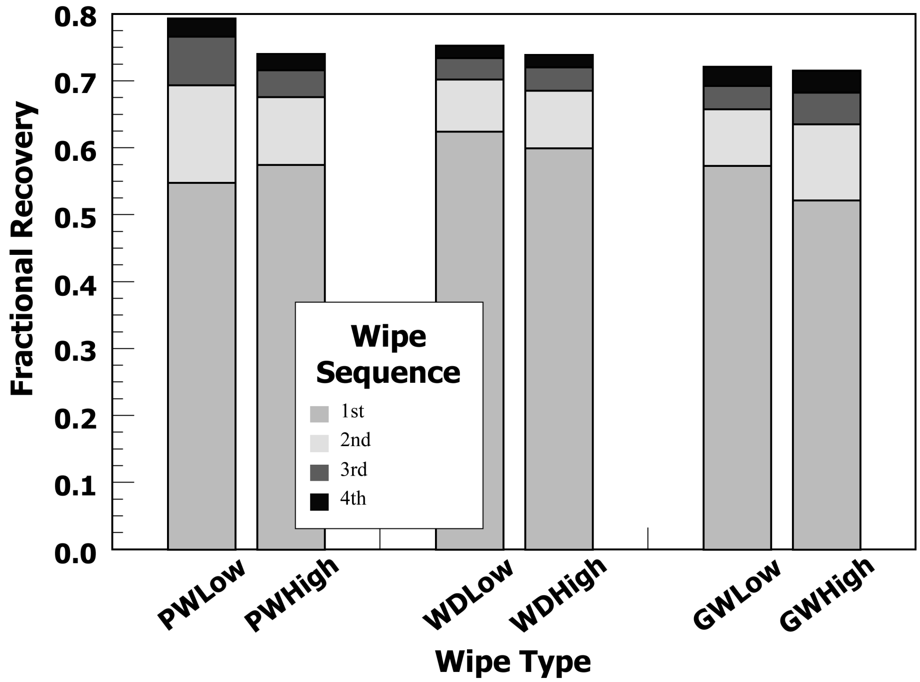


FIGURE 1. Lead recovery for three types of wipe media at two lead loading levels (200 and 2979 μg PbO) for each type of wipe. Mean results of three replicate samplings, each involving four successive wipes from the hands, are shown in each stacked bar.

The dry weights of the three media are not appreciably different. However, compared with the Ghost wipes, the Palintest and Wash'n Dri wipes have 47% and 55% the moisture content of Ghost wipes. Moisture variation was highest for Wash'n Dri at 16% but still lower than the criteria set by the ASTM E1792 Method (25%).

Differences in the weight loss rates of the three media were evident (Figure 2). Both cellulosic media appeared to dry more rapidly than the synthetic media, especially at first. This might have practical relevance during sampling, especially since the cellulosic wipes contained less moisture content to begin with.

In the tensile strength tests, all wipes were statistically significantly different by all pair-wise comparisons (Mann-Whitney U-test; $\rho = <0.05$). Ghost wipes were most resistant to separating, whereas Wash'n Dri wipes were least resistant (Figure 3).

The rub resistance test results paralleled the tensile strength tests. The maximum applied weight measured when pressing the medium while rubbing it over the abrasive surface without tearing were as follows: Ghost wipes, 4.89 newton (1.1 lbs); Palintest wipes, 0.445 newton (0.1 lbs); Wash'n Dri, <0.445 newton (<0.1 lbs). Because the Wash'n Dri wipes could barely be touched to the sandpaper without tearing, it was difficult to get accurate readings.

DISCUSSION

In every evaluation of the lead wipe media, the greatest amount of lead was recovered in the first wipe. The relative percentage recovery of the first wipe, relative to the first and second wipe, was typically better than 75%, suggesting a moderately efficient sampling method. More importantly, the absolute recovery of lead from the hands relative to the amount applied was substantially less than the minimum acceptable recovery of 75%, as specified by ASTM Method E1792-03 for smooth surfaces. Overall, the best absolute recovery found in the first wipe of the three media was only 62% (WD, low loading). In fact, only when three consecutive hand wipe samples were combined did the total recovered lead mass approach 75% of the applied mass. The continued detection of lead on the hands in the second through fourth wipes indicates a residual contamination that is difficult to remove. This should not be surprising given the topography of the palms, which is crisscrossed with whorls and furrows and may be callused.

These results agree well with previous reports on lead dust recovery using hand wipes. Vostal et al.[16] conducted hand wiping with Wash'n Dri wipes to recover lead containing dust from six children's hands and reported recovery of 68.7% ±1.49 (SEM) from the first wipe, and 31.3% ± 1.39 in the second wipe. However, it was not clear if the actual amount of lead used to contaminate the skin was known, or if this simply represented the relative recovery found in a total of six consecutive wipes. Que Hee et al.[17] also reported hand wipe recovery results for lead for several media that were available at that time. They evaluated absolute and relative recovery after contaminating the hands with 50 mg of a house dust containing a known amount (~1200 μg Pb/g) of lead. The investigators used one sampling wipe per hand, up to five consecutive times, and analyzed each wipe individually.

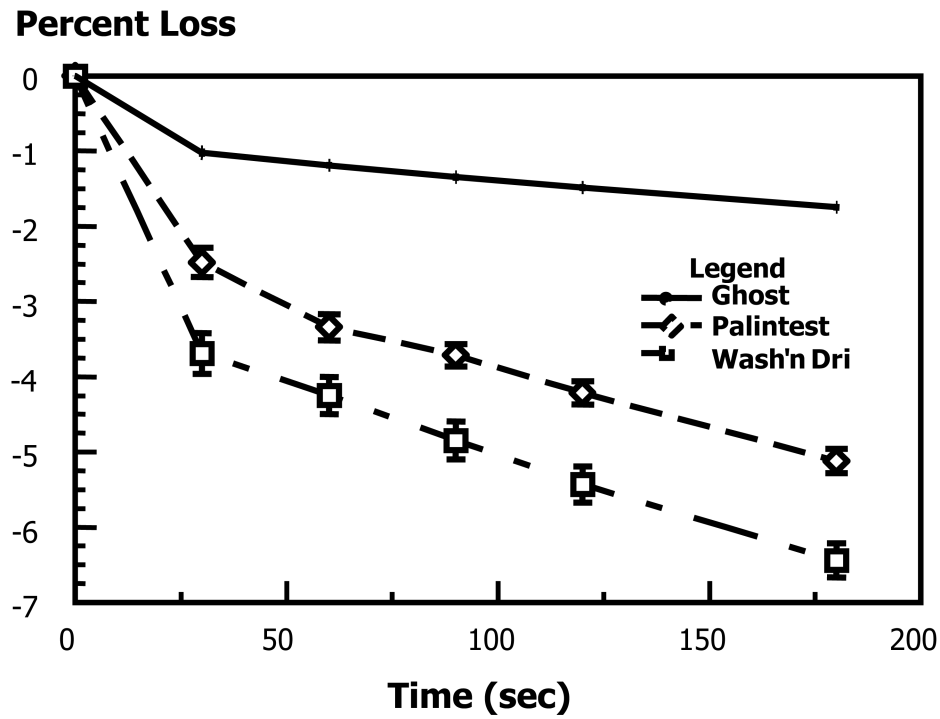


FIGURE 2. Mean moisture loss as a percentage of initial moisture content ± coefficient-1 of variation (n = 4)

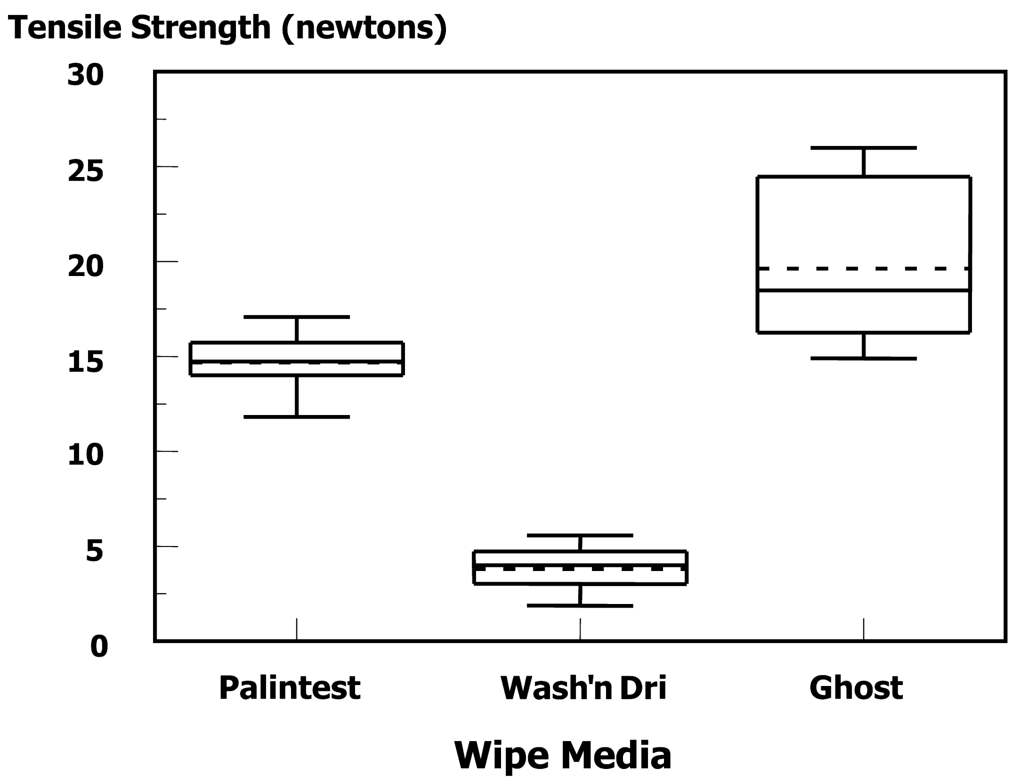


FIGURE 3. Tensile strength (n = 8) of three types of wipes. The percentile box plots show the lowest data, the lowest 25th percentile, 50th percentile, upper 75th percentile and upper values. The dotted line represents the mean.

Regarding the relative recovery when using Wash'n Dri wipes, for five consecutive wipes the recovery relative to total mass recovered of lead was 60%, 20%, 8%, 8%, and 4%, respectively. The absolute recovery of lead from all five wipes was reportedly 89%. Thus, the absolute recovery when combining each consecutive wipe can be calculated as 53%, 71%, 78%, 85%, and 89%. However, these researchers apparently evaluated Wash'n Dri wipes on only one person in one test trial.[17] When these authors tested several other wipe media using this same protocol, similar recoveries were obtained.

A possible way of improving the absolute sample recovery for hand wipe sampling would be to composite three consecutive wipes from the same surface area for a single sample analysis. In addition to improving recovery, it might seem rational that precision should be improved with multiple wipes of the same area by averaging out the random operator variability in each wipe, such as amount of pressure applied, quickness of wiping, etc. In fact, improved precision was generally seen within these test runs when the sum of the consecutive wipes were compared with only the first (Table II). The coefficients of variation for the composite wipe recovery results for each wipe group were all between 3–12%, which is good for surface sampling methods in general. But this data set represents results from only one individual, which was intentionally chosen for the design to minimize interpersonal imprecision so that the media, rather than the user influences, could be evaluated. Therefore, precision issues might be more pronounced among a mixed group of individuals. The only additional costs to obtain several consecutive wipes and an improvement in recovery, and possibly precision, are for the additional wipes used and the minimal time it takes to collect multiple wipes compared with a single wipe. The analytical laboratory should be made aware of the submission of multiple wipes so that appropriate modifications and precautions are taken.

Besides sampling performance, there are additional aspects of wipe sampling media that might be worthy of consideration, including versatility to use in the field on various surfaces and under various conditions. Those considerations that might relate to their performance, which are not included in ASTM Method E1792, include the initial wipe moisture content, drying rate, and ruggedness for sampling any surface other than one that is smooth. Whereas these physical aspects were measured for comparison, how they actually might affect sampling efficiency under various field situations was not specifically tested in this study. Under the uniform laboratory conditions of the protocol described here for sampling hands, sampling efficiencies for all three wipes seemed little affected by the differences in the measured physical aspects.

TABLE III. Mean Initial Weight, Dry Weight, Moisture Weight, and % RSD of Wipe Media (n = 5)

Media	Initial Wt. (g)	Dry Wt. (g)	Moisture Wt.
Palintest	2.87 (1.4)	1.11 (0.8)	1.76 (2.8)
Wash'n Dri	3.26 (9.9)	1.21 (1)	2.05 (16)
Ghost	5.09 (1.9)	1.35 (6)	3.75 (2.0)

The major difference that emerged between the three media was in their physical ruggedness. The cellulosic wipes were more delicate, which could make them more difficult to use when collecting samples from textured surfaces, including soiled hands. Samples collected on rough surfaces could easily result in tearing of the wipe, sample loss, user frustration, and incomplete sample collection by the user. ASTM Method E1728 does not provide guidance on how much pressure should be applied to a wipe when sampling a surface.[4]

Objective tests of wipe media ruggedness for sampling nonsmooth surfaces should be considered part of the wipe performance and selection criteria. The simple tests described here were quick and inexpensive to perform. There are several more sophisticated methods to measure tensile strength and tear resistance of fabrics (ASTM D1117-01; ASTM D4966-98; ASTM D4158-01) and paper (ASTM D689-03), but these require special equipment that can be expensive. To improve rub resistance testing, perhaps a modification of the device that Lioy et al.[18] developed of a sliding, constant pressure wiping jig, could be adapted to wiping abrasive surfaces to test ruggedness.

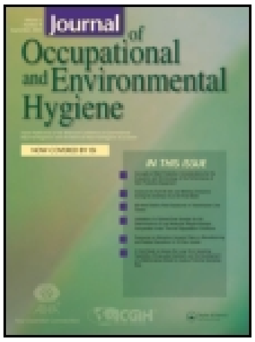
The samples of the tabletop collected directly underneath the test runs suggest that only a minor amount of lead was lost from the hands during the application or rubbing period. On average, the most that could be recovered from the surface below the hands was 2.5% of the low loading and 1.3% of the high loading tests. Generally, most of this lead (76–66%, respectively) was found on the wipe media that was located directly beneath the hands during the application and rubbing process. This might suggest that most of the lead that was lost during the rub-in procedure would deposit directly under the hands and not be widely distributed.

Additional loss due to incomplete transfer of the lead-containing powder from the weighing paper to the hands is unlikely because recovery was essentially complete when lead powder was transferred directly to wiping media, and the waxed paper appeared clean after transferring the powder to the hands. The implications then are that the lead that was not recovered by the hand wipes and from the tabletop is presumed to be still on the skin. That relatively significant amounts of lead were still being recovered with the fourth wipe compared with the third supports this. At the high loading level, the amount of lead collected on the fourth wipe compared with the third wipe was between 49% (WD) to 67% (GW), indicating that recovery efficiency had not changed much compared with the first wipe, and sampling continued to be only moderately efficient.

Objective evaluations of the performance of environmental sampling methods are always needed in order for the user to fully understand the capabilities and limitations of each collection process. This information can provide guidance toward improving the sampling strategy used during sample collection, and the interpretations of the results later on. The data presented here are directed specifically to those persons involved with collecting wipe samples for occupational and environmental lead contamination and probably other toxic elements, which continue to remain a significant public health issue.

REFERENCES

1. **Millson, M., P.M. Eller, and K. Ashley:** Evaluation of wipe sampling materials for lead in surface dust. *Am. Ind. Hyg. Assoc. J. 55*:339 (1994).
2. **American Society for Testing and Materials (ASTM):** *Standard Specification for Wipe Sampling Materials for Lead in Surface Dust* (E 1792-03). [Standard] West Conshohocken, Pa.: ASTM, 2003.
3. **American Society for Testing And Materials (ASTM):** *Standard Specification for Wipe Sampling Materials for Lead in Surface Dust* (E 1792-96a). [Standard] West Conshohocken, Pa.: ASTM, 1996.
4. **American Society for Testing And Materials (ASTM):** *Standard Specification for Collection of Settled Dust Samples Using Wipe Sampling Methods for Subsequent Lead Determination* (E 1728-03). [Standard] West Conshohocken, Pa.: ASTM, 2003.
5. **Klein, R.C., I. Linins, and E.L. Gershey:** Detecting removable surface contamination. *Health Phys. 62*:186–189 (1992).
6. **Campbell, J.L., C.R. Santerre, P.C. Farina, L.A. Muse:** Wipe testing for surface contamination by tritiated compounds. *Health Phys. 64*:540–544 (1993).
7. **Klein, R.C., I. Linin, and E.L. Gershey:** Detecting removable surface contamination. *Health Phys. 62*:186–189 (1992).
8. **Santerre, C.R., J.L. Campbell, P.C. Farina, L.A Muse:** Assessing tritium contamination on three surfaces. *Appl. Radiat. Isot. 46*:261–267 (1995).
9. **Esswein, E.J., M.F. Boeniger, R.M. Hall, and K. Mead.:** *NIOSH Health Hazard Evaluation Report, HETA 94-0268-2618, Standard Industries, San Antonio Texas*. Cincinnati, Ohio: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 1996.
10. **Burr, G., J.B. Nemhauser, and R. L. Tubbs:** *Interim Health Hazard Evaluation Report, Yuasa Inc., Sumpter South Carolina, HETA # 99-0188.* Cincinnati, Ohio: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 2000. Available at Health Hazard Evaluation and Technical Assistance Branch.
11. **Esswein, E.J., and A. Tepper:** *NIOSH Health Hazard Evaluation Report, Delaware County Resource Recovery Facility, Chester, Pennsylvania, HETA 91-0366-2453*. Cincinnati, Ohio: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 1992.
12. **Mattorano, D.A.:** *NIOSH Health Hazard Evaluation Report, Bruce Mansfield Power Station. Shippingport, Pennsylvania, HETA 94-0273-2556.* Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, 1996.
13. **Piacetelli, G., and C. Rice:** Lead contamination in radiator repair shops. *Appl. Occup. Environ. Hyg. 8*:434–438 (1993).
14. **Schlecht, P.C., and P.F. O'Connor (eds.):** Method 7300: Elements by ICP. In *NIOSH Manual of Analytical Methods (NMAM)*, 4th ed. DHHS (NIOSH) Pub. No. 94–113, 1994.
15. **Schlecht, P.C., and P.F. O'Connor (eds.):** Method 9100: Lead in surface wipe samples. In *NIOSH Manual of Analytical Methods (NMAM)*, 4^{th} ed. DHHS (NIOSH) Pub. No. 94-113, 1994.
16. **Vostal, J., E. Taves, J.W. Sayre, and E. Charney:** Lead analysis of house dust: A method of the detection of another source of lead exposure in inner city children. *Environ. Health Perspect. 7*:91–97 (1974).
17. **Que Hee, S., B. Peace, S.C. Clark, J.R. Boyle, R.L. Bornschein, and P.B. Hammon:** Evolution of efficient methods to sample lead sources, such as house dust and hand dust, in the homes of children. *Environ. Res. 38*:77–95 (1985).
18. **Lioy, P.J., T. Wainman, and C. Weisel:** A wipe sampler for the quantitative measurement of dust on smooth surfaces: Laboratory performance studies. *J. Exp. Anal. Environ. Epidemiol. 3*:315–330 (1993).



Journal of Occupational and Environmental Hygiene

ISSN: 1545-9624 (Print) 1545-9632 (Online) Journal homepage: https://www.tandfonline.com/loi/uoeh20

A Comparison of Surface Wipe Media for Sampling Lead on Hands

Mark Boeniger

To cite this article: Mark Boeniger (2006) A Comparison of Surface Wipe Media for Sampling Lead on Hands, Journal of Occupational and Environmental Hygiene, 3:8, 428-434, DOI: 10.1080/15459620600802754

To link to this article: https://doi.org/10.1080/15459620600802754

Published online: 23 Oct 2007.