A Pilot Study of the Measurement and Control of Deep Dust, Surface Dust, and Lead in Ten Old Carpets Using the 3-Spot Test While Vacuuming (7-6-04)

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Abstract. This pilot study measured and examined the relationship between surface dust, deep dust, lead (Pb), and the 3-spot test during vacuuming of carpets. The 3-spot test measures the total time in seconds for the indicator light on a Hoover vacuum with dirt detector (HVDD) to turn from red to green on three spots three feet apart at least four feet from an entrance door. Ten older carpets were sampled in the Seattle area by using: 1. A 3-spot test to estimate the deep dust, 2. Measuring the surface dust in g/m^2 with a High Volume Small Simplified Surface Sampler (HVS4); 3.Vacuuming with a HVDD to extract a portion of the deep dust in g/m^2; and 4. Repeating the above cycle of a 3-spot test, surface dust sample, and deep dust sample until the clean carpet criteria was reached. Dust particles smaller than 150 microns were analyzed for Pb. The surface dust, deep dust, and dust collection rate (g/min) dropped rapidly at first and then much more slowly as vacuuming continued. The initial 3-spot test ranged from 12 to 110 seconds, median 40 seconds. The starting surface dust loading was 0.7 to 21.1 g/m^2, median 2.9 g/m^2, decreased by 84 to 99% when the deep dust was removed. Total dust, the sum of the

surface dust and deep dust, ranged from 8.3 to 465 g/m^2, median 63.2 g/m^2. It took from 2.3 to 92 min/m^2, median of 7.5 min/m^2, to remove the total dust. The starting dust collection rate of 3.8 to 37 g/min dropped to final rates of 0.5 to 4.3 g/min. The 3-spot test (seconds) correlated with total dust (g/m^2) ($r = 0.51$, $p= 0.11$), and cleaning time (min/m^2) ($r = 0.40$, $p= 0.23$) when the data was log transformed. This study confirms the utility of the 3-spot test. It provides families and professional carpet cleaners with a quick and low-cost estimate of the deep dust and the time required to clean carpets as well as indicating when the carpet is clean. Deep dust tends to accumulate in older carpets and becomes surface and airborne dust after activity on a carpet. Monitoring and removing the deep dust in old carpets may reduce the exposure of infants and sensitive adults to Pb, allergen, and other pollutants in house dust.

Introduction

The goal of this pilot study was to measure and show the relation between surface dust, deep dust, total dust, and lead (Pb) during vacuuming, and to confirm the utility of the 3-spot test in estimating total dust and the time to remove this dust from carpets. Can the 3-spot test be used to estimate the effectiveness of dirt removal, the Pb exposure of infants living in an old house, or the exposure of asthmatics to asthma triggers in carpet dust?

Lead (Pb), chromium (Cr), pesticides, fungi, other allergen, bacteria, and benzo-a-pyrene (BaP) tend to accumulate in house dust (Takaro et al. 2004, Lioy et al. 2002, Roberts el al. 1999, Ott and Roberts 1998). BaP is a strong probable human carcinogen that comes from burning oil, gas, wood, coal, food, etc. (Collins and Alexeeff 1994).

Measuring surface dust and deep dust may be required to estimate and control the exposure and health risks from such pollutants in house dust. Controlling house dust may be very important for the health of small children and other sensitive populations (Battelle 1997, Lanphear 1996, Roberts and Dickey 1995). The loading of dust and pollutants in carpet dust in g/m^2 tends to be related to the concentration of particles, pesticides, fungi, and bacteria found in indoor air (Camann et al. 1991, Leese et al. 1997).

Much progress has made in the last 15 years understanding the exposures of children and adults to Pb, allergen, and pesticides found in house dust (Takaro et al. 2004, Lioy et al. 2002, Lewis et al. 2001, Roberts et al. 1999, Platts-Mills et al. 1997, Battelle 1997). A number of studies have found that Pb loadings in old carpets, and on surfaces where toddlers play are some of the best predictors of blood Pb, especially in pre 1950 homes (Davies et al. 1990, Hilts 1994, Lanphear 1996, Battelle 1997).

Most house dust and related pollutants appear to be tracked into the house (Adgate et al. 1998). However, the concentration of Pb, and BaP in house dust may be up to seven times higher than the concentrations of these pollutants in yard soil or similar to or higher than the concentrations found in road dust from the street in front of the house (Solomon et al. 1974, Roberts et al.1992). This may be due to generation of Pb and BaP inside the house or to the preferential track-in of small particles, which have a higher surface area and toxicity per unit mass (Roberts et al.1996). Organic pollutants may last longer in house dust than similar organic compounds in outdoor soil because there is much less direct sunlight to degrade the organic pollutants in house dust (Lewis et al. 2001). The higher concentration of toxic metals in house dust may also reduce the degradation of organic pollutant in house dust (Sandrin and Maier 2003).

There are several methods used to measure surface dust on carpets but few to measure deep or total dust. The High Volume Small Surface Sampler (HVS3) was developed for the U.S. Environmental Protection Agency, validated, and recognized in ASTM Method 5438-00 as a standard method for sampling pollutants in surface dust on carpets and bare floors (Roberts et al. 1991). Also, a low-cost wipe method was adopted by the U.S. Environmental Protection Agency (2001) to determine if a carpet or bare floor meets the standard of 40 μg Pb/ft^2 for Pb loading to protect the health of 95% of small children but cannot be used for measuring deep dust. Both of these methods require weighing and/or lab analysis of the collected samples for lead.

A method of assessing the total dust in carpets has been developed in Denmark by Kildeso et al. (1998). A falling weight resuspends dust particles from the carpet, which collect on the sticky surface of foil. The particles on the foil are measured with a laser light. This instrument, named the STEPP Tester, can compare the ability of different carpets to hold back particles from resuspension, compare cleaning methods, and assess potential exposure from carpet dust.

Anyone with an upright vacuum and digital scale with a sensitivity of 0.1 g can determine deep dust in g/m^2 by weighing the vacuum bag before and after vacuuming a measured section of the carpet 132 times (Roberts et al. 1995). However, the methods listed are not practical for the people who clean carpets every day. A quicker and lower cost method is needed for carpet cleaners and families to estimate the dust in carpets. The introduction of vacuums with dirt detectors around 1994 to 1996 made the 3-spot test method possible. The 3-spot test makes it clear to the home user what vacuum manufacturers and carpet cleaners have long known that some carpets take longer to

clean. The tight knit flat and level loop carpets make it more difficult for the dirt to penetrate and are easier to clean. Carpets with short plush are next easiest, followed by medium plush, and deep plush, with shag carpets being the hardest to clean (Tucker 2002).

The results of an unpublished 1998 study conducted by one of the authors (Roberts) are shown in Table 1. The 3-spot test, deep dust and cleaning time were measured in 12 carpets in the Pacific Northwest. Although similar methods were used in the collection of the data, these 12 samples were not combined with the data in this study since only six of the seventeen factors were measured, more level loop carpets were included, and there were other differences in the samples. However the correlations between the 3-spot test and deep dust as well as cleaning time were ? and ? respectively. The 1998 study provided the data that needed to be confirmed.

Materials and Methods

The study was explained and an informed consent form was also obtained from all the participating families. Related information including the age of the carpet and house was collected with a questionnaire which was filled out with the help of the occupants. Families were given $20 for completing the study. The 3-spot test is used to measure the total time in seconds for the indicator light on a Hoover vacuum with dirt detector (HVDD) to turn from red to green on three spots three feet apart at least four feet from an entrance door. The HVDD is held in one spot without motion. The HVDD and a stopwatch are started at the same time on the first spot and moved quickly to a second spot three feet away when the light turns green and moved to a third spot when the light

turns green. The HVDD and stopwatch are stopped when the third green light appears. The three spots form an equilateral triangle and are usually located in the center of the room. The dirt detector on the HVDD consists of a microphone attached to the impact plate at the top of the dirt tube. When the sound of the particles hitting the impact plate goes below a given level the green light comes on. The air sweeping over the impact plate tends to remove any particles and allows the dirt detector to maintain its calibration. A proprietary method is used by the Hoover Company in calibrating the dirt detector.

The High Volume Small Simplified Surface Sampler (HVS4) using ASTM Method 5438-00 was used to collect surface dust. The HVS4 is an improved version of the HVS3 and draws 9.5 L/s (20 cubic feet per minute) through a 5-inch nozzle and cyclone. The collection efficiency of the cyclone on the HVS3 and HVS4 is over 99% for house dust and 99.4% for Pb (Roberts et al. 1991). The Pb and dust is then collected in a clean cyclone bottle. Deep dust is defined as the dust remaining after surface dust is removed and picked up by the upright Hoover Wind Tunnel Vacuum (Model U 6445-900) with dirt detector (HVDD). Total dust is defined as deep dust plus the surface dust. Ten carpets over eight years of age in eight single-family homes, one townhouse, and one small office were tested in the Seattle area. Only carpets with a 3-spot test of 12 seconds or above were selected for sampling. Two samples were taken from home No. 5 to allow a comparison for areas with different traffic and distance from the entrance.

The relation between surface dust, deep dust, total dust, Pb and the 3-spot test was examined by sampling the carpets by: 1. Laying out an area of one to three square meters on a carpet in the living room with masking tape; 2. Completing a 3-spot test in this area to measure the time in seconds to get a green light on three spots three feet apart with an

HVDD; 3. Measuring the surface dust with the HVS4 using ASTM Method 5438-00; 4. Vacuuming with the HVDD from one to 16 minutes in a series of sequential steps. Longer periods of vacuuming were used for carpets with heavier dust loadings. The sequential vacuuming was conducted until the green light came on. Both the HVS4 collection cup and the vacuum bag of the HVDD were weighed before and after each sequential test to measure the surface dust and deep dust removed, and 5. Repeating the above cycle of a 3-spot test, HVS4 surface dust, and HVDD deep dust samples until nearly all of the deep dust was removed. The criteria for a clean carpet and termination of the tests on a carpet were 3-spot test of 11 seconds or less for the green light to come on, or the HVS4 loading of 0.4 g/m^2 or less. The first two HVS4 samples from house No. 10 were individually analyzed for Pb and Cr. All of the rest of the HVS4 samples were analyzed for Pb as an integrated sample. The HVDD vacuum bags for each carpet were analyzed for Pb. The dust from the HVDD vacuum bags was collected by cutting apart the bag and brushing the dust slowly into a sieve. Dust from the 13 HVS4 and 11 HVDD samples were sieved through stacked 50 and 100 mesh sieves so that dust less than 150 microns was analyzed for Pb. This dust size was selected in the ASTM Method 5438-00 because it tends to stick to the hands and skin.

All samples were analyzed for Pb with Cr being added for House No. 10 using a Spectro X-lab 2000 X-ray Fluorescence Spectrometer. Samples were quantitated against standard reference materials using the Compton K alpha peak normalization technique. The spectrometer was calibrated at the beginning and end of each sample run. The standard reference materials were obtained from the National Institute for Standards and Technology. The precision was + or - 10% and the accuracy was estimated to be + or -

20%. The precision was estimated by running blind duplicate samples. The accuracy was estimated by running two different standards at the beginning and end of each run. Duplicate blind reference samples were analyzed for Pb with a true value of 1162 ppm and a found value of 1150 and 1160 ppm. Reference Cr samples with a true value of 130 showed 119 ppm on the Fluorescence Spectrometer. The limit of detection for Pb was estimated to be 5 ppm and was calculated by diluting SRM 2709 with clean sand so the level of Pb is approximately 5 ppm. The manufacturer's calculated limit of detection for the Spectro X-lab 2000 for Pb is one ppm.

Two sample t-test and correlations were used to compare the 3-spot test in seconds to the total dust collected per square meter and to the cleaning time per square meter. Since the distribution for these comparisons were non-normal, the data used was log transformed. Correlations and P values were calculated using a Pearson's correlation in the STATA 7.0 statistical package (STATA Corporation, College Station, Texas).

Results

Table 2 shows the age of the house and carpet, time for the 3-spot test, surface dust loading (g/m^2), carpet type, and cleaning rate (g/min) at the start and end of vacuuming. The percent reduction in surface dust, deep dust, total dust, Pb in ppm, and cleaning time and rate (min/m^2) are also shown for samples 1 through 11 (home No. 5 had two samples) for this study. Surface dust, deep dust in g/m^2, and the dust collection rate (g/min) dropped rapidly at first, and dropped much more slowly as vacuuming proceeded. An average of 16.4% of total dust was picked up on five carpets with the first two passes of the vacuum. The starting 3-spot test ranged from 12 to 110 seconds,

median 40 seconds. Starting surface dust ranged from 0.7 to 21.1 g/m^2, median 2.9 g/m^2 was reduced 84 to 99% by removing deep dust. The total dust ranged from 8.3 to 465.3 g/m^2 , median 63.2 g/m^2. The time to remove deep dust ranged from 2.3 to 92 minutes, median of 7.5 min/m^2. The initial dust collection rate was from 3.8 to 37 g/min, and ended at 0.5 to 4.3 g/min.

Using log transformed data, the correlation of the initial 3-spot test with carpet dust loading (g/m$^{2)}$ for homes 1-10 was r = 0.51, (P = 0.11) using data only from the 2000 collection year. The log transformed correlation results for the 3-spot test and cleaning time (min/m^2) was r = 0.40, (P = 0.23) using data from the 2000 tests. The plot of 3-spot test vs. total dust and 3-spot test vs. cleaning time is shown in Figures 1 and 2 respectively.

The 3-spot test tells you when the carpet is clean and when very little dust can be removed by added vacuuming. The 3-spot test, surface dust, and surface Pb and Cr loading and concentration increased during the vacuuming process on individual samples. Figure 3 shows the sharp drop in collection rate as carpet No 4 was vacuumed. While carpet No.4 had the highest total dust loading and change in collection rate with time, the shape of the curve is typical of most of the other samples.

In carpet No. 10 the surface dust was monitored for Pb and Cr at the end of the first and second sequential sample during removal of deep dust. The first surface dust sample measured 190 ppm Pb and 150 ppm Cr. Concentrations in the second sample of surface dust were more than 59,800 ppm Pb (exceeding the calibration range of the instrument) and 500 ppm Cr in the fine dust. Table 2 shows the deep dust Pb loading of

carpet No. 10 in a 50 year old house was 35,854 µgPb/m^2 and 32,228 µgPb/m^2 in the 25 year old house No. 4.

Discussion

The deep dust and Pb remaining in a carpet is a major source of surface dust and Pb. Normal vacuuming will remove surface dust but walking or other activity on the carpet tends to bring up deep dust that remains in the carpet. The HVS4 collects much less surface dust after vacuuming even though there is a large amount of deep dust still left in the carpet. This may explain why there is a higher correlation between the 3-spot test and deep dust than with surface dust. The surface dust is loosely related to deep dust but is influenced by time since the last vacuuming, the intensity of the vacuuming, and the activity on the carpet, location, and track-in. The 3-spot test shows areas of the carpet that are closer to the entrance door may take twice as long to clean as shown by the results from the two samples taken from home No. 5. Areas that get more wear and are also harder to clean (Lewis 2002).).

The difference of the correlations between the 3-spot test and cleaning time as well as deep dust reported in this study and the 1998 (Tables 1 and 2) are difficult to explain on the basis of available data. The increase in the percentage of level loop carpets in the 1998 study is one hypothesis to explain the higher correlations. Five of the 12 carpets (A to L) on table 1 were level loop, which are easier to clean unlike the 2000 study in which there were no level loop carpets. The 1998 study had three types of carpets while the 2000 study had five. However the results of the two studies tend to reinforce each other and add weight to these findings

This study and the 3-spot test have limitations. The carpets were not randomly selected and some were rejected because they were too clean for this study. In this study the 3-spot test was repeated a number of times on the same section of carpet and may have been done in or near the same spot in later tests. This may cause subsequent 3-spot tests to be reduced in that spot and with the next 3-spot test being higher. Subsequent 3-spot tests were higher in 23 out of 95 3-spot tests. The surface dust loading in g/m^2 was observed to increase in around 10 percent of the tests. These increases tended to be small and occur at the end of the removal of the deep dust. The 3-spot test is not as accurate as the HVS4 and HVDD for measuring surface dust and total dust. Because of the variation in surface dust that has been previously discussed, there is little correlation between the 3-spot test and surface dust. The time to get three green lights on the 3-spot test with a clean carpet dropped from 10 to six sec when the HVDD (Model 6446-900) vacuum with a higher dust removal rate was used in a separate experiment. The user would need this added information to make comparison between 3-spot test results for vacuums with different dust collection rates. Vacuums in poor condition will take longer to get a green light.

The evidence suggests that deep dust and Pb risks in carpets are common. The common practice of taking two passes over a carpet with an upright vacuum each week allows deep dust to build up. This practice is far better than doing nothing even though the deep dust and Pb exposure may gradually increase. The first two strokes get more dust than any other two strokes and if they were not taken the risks from Pb, deep, and surface dust would increase at a faster rate. The dust build-up would also be larger if a poor vacuum is used, the bag is full, or the belt and brush are worn. A similar dust build-

up may occur in a carpet if it is cleaned with a canister vacuum without a power head. A nationally representative survey of 1984 homes suggests that in 15% of such dwellings there was no evidence of cleaning. Some 16% of the homes built before 1940 had house dust on carpets or bare floors that exceeded the health-based Pb standard of 40 ΦgPb/ft^2 (Clickner et al. 2001). The children of poor families face environmental injustice in that there is less access to effective vacuums, good doormats, and homes that are easy to clean. Remodeling by a middle class family in a pre 1940 home can cause the loading in carpets to exceed 3200 ΦgPb/ft^2 and increases the importance of monitoring and controlling for Pb and deep dust (Roberts 1998).

It is estimated that over 50% of 374 low income families with asthmatic children did not have an effective vacuum at the start of the Seattle King County Healthy Home study (Takaro et al. 2004). After 74 families were given a lower cost HVDD, allergy control bedding covers, quality door mats, cleaning supplies, and training from an outreach worker, the average 3-spot test dropped 61%, from 59 to 23 sec, and the median dropped 23% from 15 to 11.5 sec. A reduction in the average surface dust loading of 64% (2.64 to 0.96 g/m^2) was measured in the carpets of 195 families involved in this study where the surface dust was measured with the HVS3 before and after intervention. These families have made progress in reducing dust in carpets. However this study and the 1999 study by Roberts et al. suggest the 3-spot test can be under 10 sec and the surface loading would be near 0.1 g/m^2 in a clean carpet. The red and green light on the vacuum dirt finder appears to motivate the user to get the deep dust out. The 3-spot test is very popular with outreach workers because it is simple, can be done in one minute, and can be seen and done by the client who has a HVDD.

There appears to be unmixed layers of dust in some old carpets that can be brought to the surface as the deep dust is removed. Previous cleaning studies may have been confounded if the deep dust was not removed and higher amounts of Pb were found in surface dust after cleaning. This study and previous studies by Lewis (2002), Roberts et al. (1999), and others show that higher loadings of Pb, Cr, and dust mite allergen may be brought to the surface during the vacuuming process if deep dust is not removed. Ewers et al. (1994) also found that HEPA vacuuming may increase the Pb loading on the surface of carpets by a factor of four if the cleaning is not conducted for a sufficient time. Hilts (1994) reported that surface Pb loading increased in 5% of the 55 carpets of all ages after HEPA vacuuming in a larger study in Trail, B.C. Remodeling had been done at some earlier date in home No.10 in this study. Paint sanding or other remodeling activities may have left Pb and Cr in a dust layer in the carpet. Carpet shampooing may have left a crust in the deep dust, which prevented mixing during the first cycle of vacuuming. Cole et al. (1996) showed an initial increase in surface dust loading using the HVS3, after hot water extraction of a carpet.

The 3-spot test may be useful in giving an estimate of exposure to Pb, allergen, and other pollutants, especially when used with a questionnaire and in areas where pollutants are known to exist at significant levels. These conditions exist by definition at many if not most Superfund sites in which residential pollutant soil concentrations exceed preliminary remediation goals (PRGs), which trigger a risk assessment. BaP (median = 1.1 ppm) was found in 89% of the 372 Midwest homes in a childhood Leukemia study (Camann et al. 1994). The PRG for BaP at an industrial outdoor soil at a Superfund site is 0.26 ppm (Smucker, 1995). It may be prudent at some Superfund sites to provide a

vacuum with dirt detector to families to monitor and reduce exposure to house dust. However, for pesticides such as chlorpyrifos, which has a higher vapor pressure of 2.7 x 10^{-6} Pa, the 3-spot test is not adequate to give an estimate of exposure even though there is a correlation between the pollutant concentration in indoor air and surface dust loading (Camann et al. 1991, British Crop Protection Council 1995). Less than 10% of the total carpet pollutant loading for Pb, BaP, and pesticides is usually found in the total dust that can be extracted from a carpet. It appears that over 90% of these pollutants are found in the fibers, backing, and pad (Roberts et al. 1995, Fortune et al. 2000, Lewis et al. 2001). Carpet pollutants with low vapor pressure (Pb and BaP) in the carpet present much less risk for children and adults breathing indoor air when the total dust is removed. BaP has a vapor pressure of around 7.3 x 10^{-10} Pa (Lewis Publishers 1992). However, the pesticides and other pollutants with a higher vapor pressure, which are in the backing, may continue to degrade indoor air quality for a number of months after the total dust is removed. Mass balance studies which considered air exchange rates could not explain the source of the continued presence of chlorpyrifos in indoor air in some homes long after the pesticide was applied, until this large source was discovered in the carpet fibers, backing, and pad (Camann et al. 1991).

We suggest that the removal of deep dust from old carpets and use of commercial grade doormats may result in a 90 to 94% average reduction in risks from the pollutants in surface dust. It is estimated that the average fine surface dust loading in 372 Midwest carpets, which included newer carpets, was 1.4 g/m^2 when measured with the HVS3 (Camann et al. 1994). This surface dust loading can be reduced to less than 0.1 g/m^2 when the green light shows steady on the HVDD as shown in this study and the earlier

study by Roberts et al. (1999). We showed that this large reduction in surface dust loading could be achieved in a few hours with a vacuum with dust detector for nearly all carpets (Roberts et al. 1999). This reduction in surface dust was measured one week after the deep dust was removed after normal activity in the home.

Families have two ways to get clean carpets. It may require one to six hours spread over a week to clean all the carpets in some homes when using the HVDD. The same results can be achieved in most cases in three months with a vacuum in good condition by making 25 passes over areas near entrance doors, 16 passes over high traffic areas, and 8 passes over other areas of the carpet each week with the vacuum. The vacuum with the dirt sensor will save time by eliminating vacuuming after an area is clean and provide evidence that most of the deep dust has been removed. The dirt detector allows use of the precautionary approach to reduce exposure by removing all the deep dust from one small area of the carpet before doing other areas. This eliminates the risk of having more pollutants on the surface of the carpet than when you started. The League of Women Voters of Seattle (2002) has produced a leaflet titled; Get the Deep Dust Out of Carpets, to educate families on effective cleaning.

We do not have enough data to predict how often the surface dust Pb, dust mite, BaP, or other pollutant concentrations or loadings will increase during the vacuuming process. Hilts (1994) found this increase in 5% of carpets when new carpets were included in his survey. This percentage may increase in surface Pb when only old carpets are studied. Since Pb in deep dust is the main source of Pb in surface dust and is more stable than measures of surface dust Pb, the current U.S. Environmental Protection Agency standard for surface dust of 40 Φg Pb/ft2 may protect more children if a cost-

effective standard for deep dust is added. This addition is more important when the carpet is retained after lead remediation in a residence. If you are paying workers, the 3-spot test may be useful in making the decision as to whether to clean or replace a carpet. The past use of pesticides inside or outside the home may add weight in favor of replacing the carpet.

Conclusions and Applications

The utility of the 3-spot test was confirmed in this study. It provided an useful estimate of the time to clean and the amount of removable dust in carpets. The 3-spot tells when the carpet is clean and when very little dust will be removed by added vacuuming. Measuring deep dust makes it possible to efficiently control exposure from this source. The 3-spot test can be done in one minute and can be used to evaluate the effectiveness of carpet cleaning. There is a need to assess the effectiveness of commercial carpet cleaning and extraction methods on the deep dust that remains in the carpet. The 3-spot test when used with a questionnaire, may identify carpets in old homes with potentially high risks for Pb and carpets in homes of any age for high risks for asthma triggers (dust, dust mites, mold, animal dander, and cockroach allergen) pesticides, BaP, and other pollutants. Controlling deep dust in bedroom carpets is more important for people with allergies or asthma because the high concentration of skin scales provides food for dust mites (Pope et al. 1993).

Families and carpet cleaning companies who vacuum old carpets an estimated 0.5 to 2 min/m^2 on the average cannot guarantee that the carpet is clean with the deep dust removed, or that children who crawl on the carpet are relatively safe from exposure to Pb

allergen, and other pollutants found in carpet dust. The Institute for Inspection Cleaning Restoration and Certification=s (IICRC) has done much to improve the cleaning profession. However, the new IICRC 2002 S100 standard for cleaning does not include a measurement to determine if the carpet is clean and the deep dust removed as part of the cleaning process. They suggest frequency of cleaning guidelines depending on usage. For example one min/m^2 each day is recommended for cleaning carpets in school hallways. Following the guidelines recommended by the S100 standard will reduce surface and deep dust and related pollutants as well as provide progress toward a clean carpet most of the time. However, the data presented here and in other studies suggest that these cleaning frequency guidelines are not adequate to protect sensitive populations from the pollutants in carpets all of the time. Sensitive people include the 20% of the population with allergies or asthma (Pope et al. 1993), those who have been sensitized to a pollutant, people with AIDS, people undergoing chemo or radiation therapy, people with lowered immune protection, pregnant women, the elderly, and people with cancer, heart, or lung disease. We believe this large group of people can reduce their exposure to particles, allergen, Pb, pesticides, carcinogens, bacteria, fungi, and many other pollutants by monitoring and removing the deep dust in carpets with a vacuum with a dirt sensor.

This is a pilot study which needs to be repeated on a larger representative sample. We recommend the following:

1. Develop a standard ASTM method for measuring total removable dust in carpets.
2. Develop a model to show the relation of the 3-spot test to particles and pesticides in indoor air, to these pollutants in carpet deep dust, surface dust, and carpet backing as well as to carpet construction, soil type, and use of pesticides in and near the home.

3. Develop and validate charts and methods to allow carpet cleaners to estimate the time required for removing deep dust different types of carpets and to bid on cleaning jobs.

4 Further validate the 3-spot test on a larger probalistic sample of residential carpets.

5. Test the cost-effectiveness of using the 3-spot test with a questionnaire to provide greater protection from deep dust for sensitive adults and children with asthma or a high risk for exposure to Pb.

6. Determine if the addition of the 3-spot test to the current Pb surface wipe standard for carpets will show a higher level of correlation to the blood lead of young children.

7. Assess surface and deep dust following standard commercial cleaning methods such as vacuuming, shampooing, chem-dry extraction, hot-water extraction, and steam extraction.

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Table 1. Age home and carpet, 3-spot test, deep dust, total dust, and cleaning time

House	Age in Years	Carpet age in years	Carpet type	3-spot test		Surface Dust Loading			Deep Dust g/m^2	Total Dust g/m^2	Deep Dust Lead Concentration ug/g	Surface Dust Lead Concentration ug/g	Deep Dust Lead Loading ug/m2	Starting Surface Dust Lead Loading ug/m2
				Initial (seconds)	Final (seconds)	Start g/m^2	End g/m^2	Percent Reduction						

A	25	25	MP	6	-	-	-	-	1.1	-	-	-	-	-	
B	71	5	MP	11	-	-	-	-	12.7	-	-	-	-	-	
C	41	20	LL	12	-	-	-	-	18.7	-	-	-	-	-	
D	93	23	LL	22	-	-	-	-	23	-	-	-	-	-	
E	43	25	LL	22	-	-	-	-	23.7	-	-	-	-	-	
F	48	21	LL	32	-	-	-	-	94.7	-	-	-	-	-	
G	-	-	LL	36	-	-	-	-	74.6	-	-	-	-	-	
H	70	-	FW	48	-	-	-	-	80.7	-	-	-	-	-	
I	71	30	LW	6	-	-	-	-	6.3	-	-	-	-	-	
J	25	25	MP	8	-	-	-	-	4.7	-	-	-	-	-	
K	25	25	MP	11	-	-	-	-	4	-	-	-	-	-	
L	-	-	P	45	-	-	-	-	52.4	-	-	-	-	-	

Carpet Type: MP = medium plush; DP = deep plush; LP = low plush; ML = multilevel; S = shag; FW=Flat wool; LL = Level loop; NA = Not avai

Table 2. 3-spot test, surface dust before and after vacuuming, percent reduction, deep dust, total dust, and cleaning time

House	Age in Years	Carpet age in years	Carpet type	3-spot test		Surface Dust Loading			Deep Dust g/m^2	Total Dust g/m^2	Deep Dust Lead Concentration ug/g	Surface Dust Lead Concentration ug/g	Deep Dust Lead Loading ug/m2	Starting Surface Dust Lead Loading ug/m2	Cleaning Time & Rate		
				Initial (seconds)	Final (seconds)	Start g/m^2	End g/m^2	Percent Reduction							Cleaning time min/m^2	Start in g/min	End in g/min
1	60	23	MP	40	10	NA	0.12	NA	74.4	77.5	540	590	40,176	NA	6	27.3	1.1
2	25	8	DP	30	NA	4.2	0.4	90%	70.1	81.5	32	29	2,243	122	6.7	37	NA
3	25	10	LP	45	9	2.1	0.2	90%	37.1	42.2	59	62	2,189	130	19.3	3.8	0.5
4	25	25	S	95	9	21.1	0.3	99%	429.7	465.3	75	69	32,228	1,456	92	16.6	0.8
5-1	25	17	LP	26	7	0.7	0.11	84%	60.6	63.3	82	78	4,969	55	15.2	9.3	1.9
5-2	25	17	LP	12	10	2.1	0.13	94%	36.7	41.6	87	78	3,193	164	7.5	6.1	2.7
6	73	8	MP	34	10	4.4	0.16	96%	42.3	48	76	120	3,215	528	6.8	13.4	1.8
7	25	12	ML	13	10	0.8	0.06	93%	6.7	8.3	62	73	415	58	2.3	5.7	1.8
8	80	28	S	35	9	0.9	0.09	90%	97.2	89.3	300	420	29,160	378	12.9	13.3	2.9
9	61	5	MP	110	10	2.9	0.16	94%	50.3	54.3	87	120	4,376	348	4.8	14.2	2.1
10	50	8	ML	44	11	7.6	0.21	97%	256.1	268.1	140	190	35,854	1,444	26.7	26.9	4.3