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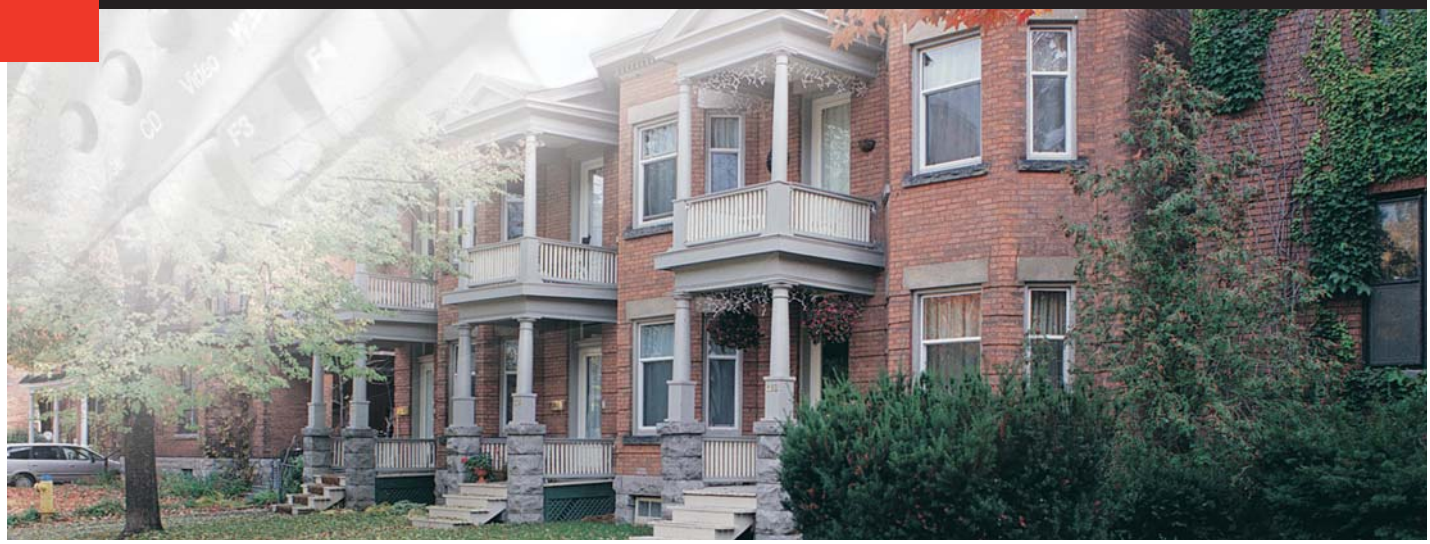

Evaluation of the Clean-up of Lead Paint Dust in Houses

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EVALUATION OF THE CLEAN-UP OF LEAD PAINT DUST IN HOUSES

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DISCLAIMER

This study was conducted for Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and recommendations are those of the consultant and do not necessarily reflect the views of Canada Mortgage and Housing Corporation or those divisions of the Corporation that assisted in the study and its publication.

ABSTRACT

A field research project was conducted to evaluate the effectiveness of various cleaning procedures for the clean-up of lead paint dust from floors. Twenty test rooms were identified in nine houses as having lead-based paint on walls, by X-ray fluorescence and chemical testing. The rooms were isolated, and sections of the walls were power-sanded to create lead paint dust. Four different cleaning protocols were used to clean floors in the rooms. Wipe samples were taken before and after cleaning to determine the level of lead contamination. The results of post-cleaning samples were compared to the current and proposed U.S. federal guidelines for acceptable cleanliness after lead abatement, of 2,150 micrograms per square metre, and 1,076 micrograms per square metre, respectively. Two cleaning methods, one that used a combination of sweeping and a utility vacuum, and another that used a utility vacuum followed by mopping with a household cleaner, did not meet the U.S. criteria. These two methods represent the cleaning procedures commonly available to householders. Two more elaborate methods, that used Ledizolv, a lead-specific cleaning agent, or trisodium phosphate, in combination with either a utility vacuum or a High Efficiency Particulate Air filtered vacuum, both met the criteria. Airborne dust concentrations during power sanding of leaded paint were shown to be up to 83 times the currently recommended industrial exposure limit of 50 micrograms per cubic metre of air. Airborne concentrations were also elevated during dry sweeping with a broom.

KEY WORDS

Lead abatement
Lead based paint
Lead paint dust
Renovations
X-ray fluorescence

EXECUTIVE SUMMARY

Pinchin Environmental Consultants Ltd. was retained by Canada Mortgage and Housing Corporation to conduct a field research project to evaluate the effectiveness of four cleaning methods used for the clean-up of lead paint dust from floors in houses. Renovation projects in older houses may disturb and release lead from lead paint, which will require effective clean-up. The criteria for adequate cleaning for the purpose of this study was the ability to meet the clearance standards set by the U.S. Department of Housing and Urban Development (HUD). There are no Canadian federal or provincial standards for lead dust clean-up.

A total of 20 test rooms were identified in 9 houses in Windsor, Ontario. The presence of lead in paint was determined by on-site X-ray fluorescence measurement and laboratory chemical analysis. The test rooms were isolated and areas of lead paint were power-sanded to create airborne dust containing lead paint. Following a settling period, the floors were cleaned of dust by one of four methods, which include commonly used household cleaning methods, as well as specialized cleaning agents and procedures developed for clean-up after lead paint abatement. The four cleaning methods were:

Cleaning Method 1:

Step 1. Sweep the floor dry with a corn broom.
Step 2. Vacuum the floor with a utility vacuum (shop vacuum).

Cleaning Method 2:

Step 1. Vacuum the floor with a household vacuum cleaner.
Step 2. Mop the floor with a commercial household cleanser.

Cleaning Method 3:

Step 1. Vacuum the floor with a utility vacuum.
Step 2. Mop the floor with a 2% solution of Ledizolv, a commercial lead-cleaning product.
Step 3. Rinse the floor with clean water.

Cleaning Method 4:

Step 1. Vacuum with a High Efficiency Particulate Air filtered (HEPA) vacuum.
Step 2. Mop with a Tri-Sodium Phosphate (TSP) cleaner, 2 tablespoons per gallon of water.
Step 3. Rinse the floor with clean water.
Step 4. Vacuum the floor with a HEPA vacuum.

The degree of lead contamination on the floors was determined by wipe samples taken before and after cleaning, following a HUD protocol for surface sampling and analysis.

The wipe samples showed that Cleaning Methods 1 and 2 were inadequate to meet the cleanliness criteria of the current or the proposed U.S. federal standards. This indicates that cleaning techniques as currently practiced in Canadian households are not adequate to meet U.S. national standards for clean-up of lead dust. Cleaning Methods 3 and 4 did meet both the current and proposed HUD criteria. However, the cleaning agent or type of vacuum cleaner used in these latter methods are not currently available to householders and small contracting firms. Householders and contractors should be advised to follow effective cleaning methods when lead dust is suspected.

Airborne lead measurements made during the power-sanding of leaded paint showed extremely high levels, up to 83 times the allowable exposure for the period of the disturbance. Uncontrolled power sanding, without effective locally-exhausted dust collection, should be discouraged. Airborne lead measurements made during cleaning showed excessive exposures only during the use of dry sweeping. Dry sweeping should also be discouraged.

RÉSUMÉ

La Société canadienne d'hypothèques et de logement a engagé Pinchin Environmental Consultants Ltd. afin de mener un projet de recherche qui consiste à évaluer l'efficacité de quatre techniques de nettoyage de la poussière de peinture à base de plomb. Lors des travaux de rénovation dans une vieille habitation, il est possible que la peinture à base de plomb libère du plomb. Une technique de nettoyage efficace est donc nécessaire. L'étude a pour objet d'établir une technique de nettoyage conforme aux normes du U.S Department of Housing and Urban Development (HUD). Il n'y a pas de normes fédérales ou provinciales en matière de nettoyage de la poussière de peinture à base de plomb.

Au total, on a choisi 20 salles de tests dans 9 maisons de Windsor, en Ontario. Un examen au rayon X et une analyse chimique en laboratoire ont permis de détecter la présence de plomb dans la peinture. Les salles de tests ont été isolées et la peinture à base de plomb a été sablée afin de libérer de la poussière plombifère en suspension dans l'air. Après que la poussière se soit déposée, on a nettoyé le plancher en employant une des quatre techniques, incluant les techniques habituelles de nettoyage, des produits de nettoyage et des méthodes d'enlèvement de la peinture à base de plomb. Les quatre techniques employées étaient les suivantes :

Technique de nettoyage n° 1 :

Étape 1. Balayer le plancher à l'aide d'un balai de jonc.
Étape 2. Se servir d'un aspirateur d'atelier.

Technique de nettoyage n° 2 :

Étape 1. Se servir d'un aspirateur domestique.
Étape 2. Se servir d'un balai laveur et d'un nettoyant ménager.

Technique de nettoyage n° 3 :

Étape 1. Se servir d'un aspirateur d'atelier.
Étape 2. Laver le plancher à l'aide d'un balai laveur et d'une solution à 2 % du nettoyant commercial Ledizolv.
Étape 3. Rincer à l'eau propre.

Technique de nettoyage n° 4 :

Étape 1. Se servir d'un aspirateur muni d'un filtre à particules à haute densité (HEPA).
Étape 2. Laver le plancher à l'aide d'un balai laveur et d'un nettoyant à base de phosphate trisodique, à raison de 2 cuillérées à thé par gallon d'eau.
Étape 3. Rincer à l'eau propre.
Étape 4. Se servir d'un aspirateur avec filtre HEPA.

Un prélèvement par épongeage avant et après le nettoyage, conformément aux règles du HUD en ce qui a trait à l'échantillonnage et à l'analyse, a permis de vérifier le degré de contamination des planchers.

Le prélèvement par épongeage montre que les techniques de nettoyage n° 1 et n° 2 ne répondent pas aux critères de propreté des normes fédérales américaines en vigueur ou proposées. Cela signifie que les techniques employées au Canada ne répondent pas aux normes américaines en matière de nettoyage de la poussière plombifère. Par contre, les techniques de nettoyage n° 3 et n° 4 répondent aussi bien aux critères HUD établis qu'à ceux proposés. Toutefois, le propriétaire d'une maison ou l'entrepreneur ne peut se procurer le nettoyant et le type d'aspirateur utilisés pour ces deux techniques. Il doit respecter les techniques de nettoyage lorsque l'on soupçonne la présence de poussière plombifère.

Le taux de poussière plombifère en suspension dans l'air lors du sablage de la peinture à base de plomb était 83 fois plus élevé que l'esposition admissible pour la période du dérangement. Le sablage sans surveillance et l'utilisation d'un appareil d'aspiration de la poussière inadéquat sont à déconseiller. Lors du balayage, le taux de poussière plombifère en suspension dans l'air était excessif. Le balayage est donc également à éviter.

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1. INTRODUCTION

Pinchin Environmental Consultants Ltd. was retained by the Research Division of Canada Mortgage and Housing Corporation to conduct a field research project to investigate the effectiveness of various methods for the clean-up of lead paint dust in houses. This document is the final report of this project.

1.1 *Background*

In the past, many types of consumer paints were formulated with lead compounds. Up until the 1940's, lead compounds were commonly used in paint as the hyde or blocking agent of the paint. Lead pigments were also used to provide the colour of the paint, especially where colour-fastness was required. Some lead compounds were added to oil-based paints and varnishes, as drying agents. The amount of total lead in consumer paints was limited by federal legislation in 1976, to no more than 0.5% by weight of the dried paint film (1).

Houses built before 1976 may contain lead paint on walls, wood and plaster trim, and on components, such as radiators, ironwork, doors, cupboards, etc. In houses built after the Second World War, lead paint may be found on walls, but is more likely limited to trim, exterior paint, and components. Older houses may have lead paint anywhere. The total amount of lead on surfaces can amount to levels as high as 20 milligrams per square centimetre of surface area (mg/cm^2).

Renovations to older housing may disturb lead paint through such common activities as sanding walls and trim for surface preparation, removal of paint for re-finishing, and demolition of walls and components. All these activities will release lead-containing dust to the household. In addition, deterioration of lead-based paint through weathering, water damage, or abrasion at friction surfaces (such as at windows) can release finely divided lead dust.

The chief concern regarding exposure to lead in houses is the possible exposure of young children, especially under 6 years of age. Young children can come in contact with lead paint and dust particles on floors, windowsills, furnishings, etc. During times of renovation, there is the potential for children to receive hazardous exposures to lead. In the United States, there have been many reports of severe lead poisoning to children

resulting from renovations in older houses. Sanding of leaded paint during a renovation can release sufficient lead dust to seriously harm children and the fetus carried by a pregnant woman (2).

There are no Canadian standards for the acceptable level of lead dust that could be used to evaluate the significance of lead contamination in houses. The United States Department of Housing and Urban Development (HUD), which sets housing policy in the United States, has set a clearance criteria for lead abatement work. That criteria requires floor surfaces to have less than 2,150 micrograms of lead per square metre (ug/m^2), before the residents can return to the house (3). Samples are collected by wiping known areas of surfaces with a moistened tissue to collect the loose, available surface contamination. In 1994, the U.S. Environmental Protection Agency recommended a criteria of 1,076 ug/m^2 for surface dust in houses following lead abatement work (4). HUD will adopt this lower standard in the 1995 revisions to the Guidelines for Lead-Based Paint Hazard Identification and Abatement (5).

1.2 *Project Objectives*

The objective of this project was to evaluate the effectiveness of various cleaning methods as applied to the clean-up of lead paint dust present on the floors of houses. The project required the identification and supply of 20 test houses or rooms with known lead paint, the controlled disturbance of lead-based paint to produce lead-containing dust on the floors, and the clean-up of this dust by one of four cleaning methods. Surface contamination tests were taken before and after the cleaning. The residual contamination levels were compared to the current and proposed HUD clearance criteria. In addition, airborne lead measurements were made to evaluate the possible hazard during lead paint disturbance, and during vacuum and wet-cleaning.

1.3 *Cleaning Methods*

Four cleaning methods were set by CMHC and Pinchin, to cover a wide range of complexity from the simplest, commonly used household methods, to the specialized cleaning method recommended by the HUD Guidelines. These are as follows:

Cleaning Method 1:

Step 1. Sweep the floor dry with a corn broom.
Step 2. Vacuum the floor with a utility vacuum (shop vacuum).

Cleaning Method 2:

Step 1. Vacuum the floor with a household vacuum cleaner.
Step 2. Mop the floor with a commercial household cleanser.

Cleaning Method 3:

Step 1. Vacuum the floor with a utility vacuum.
Step 2. Mop the floor with a 2% solution of Ledizolv, a commercial lead cleaner.
Step 3. Rinse the floor with clean water.

Cleaning Method 4:

Step 1. Vacuum with a High Efficiency Particulate Air filtered (HEPA) vacuum.
Step 2. Mop with Tri-Sodium Phosphate (TSP), 2 tablespoons per gallon of water.
Step 3. Rinse the floor with clean water.
Step 4. Vacuum the floor with a HEPA vacuum.

2. TESTING PROCEDURES

2.1 *Schedule*

An initial trial of four rooms, cleaned by the four different methods, was conducted in August 1994. The initial trial allowed the team to evaluate the isolation methods and worker protection. A few minor changes were made to the procedures, and these are discussed below. The remaining 16 rooms were tested in the period of late October to mid November, 1994. Detailed information on the tests performed in each room, environmental factors, room descriptions, etc. are given on a room-by-room basis, in Appendix 1.

2.2 *Selection of Houses*

For this project, 20 test rooms were to be identified. To be included, the test rooms had to meet the following criteria:

- Have a significant concentration of lead paint on at least one wall, of approximately 3 mg/cm^2 or more.

- Be of residential construction, ie. a house or apartment.

Based on the XRF measurements, 9 houses were selected for this study, providing 20 test rooms. The houses, all in Windsor, Ontario, were scheduled for demolition and were made available for this research program. The houses all dated from the 1930's and 1940's.

2.3 *Measurements of Lead in Paint*

A Scitec Corporation MAP-3 spectrum-based X-ray fluorescence (XRF) analyser was used to measure lead paint concentrations on-site. The Scitec instrument is specifically designed and calibrated to measure the lead content of paint, on a variety of substrates. The analyser measures the sum of lead present, in all paint layers, to a depth of at least 6 mm. The response of the XRF analyser was checked several times per day, against a reference paint block.

In addition to the XRF measurements scrapings of paint were taken from the Test Rooms 1-4, by knife collection, and were analysed by acid digestion and chemical analysis, at Entech Laboratories, Mississauga.

For Test Rooms 5-16, a more detailed chemical testing procedure was used. The purpose of this procedure was to give chemical test data that could be compared to the results of the XRF instrument. An XRF measurement was first made, and the footprint of the instrument was marked on the wall. Then known areas of paint, of a minimum area of 16 square centimetres, were removed from within the footprint of the XRF instrument, using a heat gun with built-in scraper blade. At the time of the testing, it appeared that the heat gun procedure removed all layers of paint effectively. However, as is discussed below in Results, there was a very poor correlation between the XRF

results and chemical testing, suggesting that the heat gun method for removal of paint samples was not effective in removing all layers of paint.

2.4 *Test Room Preparation*

Preparation of the rooms started with removal of furniture, boxes, or any other loose articles. Temporary power and lighting was provided. Cupboards, built-in cabinets, and other items that could not be removed, and which would collect dust during the paint disturbance, were sealed over with 6 mil polyethylene and tape, to prevent the possible transfer of dust from these surfaces to the floor during cleaning. Any openings to the room, ie. broken windows, vents, transfer grilles, etc., were sealed with polyethylene and tape. Double flap doors were built at the entrance to the room, by attaching two sheets of polyethylene sheeting to the two sides of the door casing, and affixing the plastic at the headers and to the alternate jambs. The double flap doors served to minimize air movement on entry or exit from the test room. If carpeting was present, it was removed, and the underlying floor cleaned of debris and staples, to allow effective cleaning.

2.5 *Paint Disturbance*

The paint disturbance consisted of sanding a known amount of paint off a wall, plus the removal of some painted wood trim. A 6" angle grinder fitted with a medium abrasive pad and rubber backing pad was used to grind off the wall paint, in all rooms except Test Room 1. In Test Room 1, a belt sander was used to remove the paint, but this method was ineffective, and tended to gouge the plaster; this method was abandoned after the first room. In disturbing the paint, the angle grinder was held in light contact with the paint, so that the paint was feathered off the plaster, and the minimum amount of plaster was removed.

A known area of wall paint was disturbed (0.44 square metres in Test Room 1, and 0.36 square metres in all other rooms). This area of disturbance was adequate to give a considerable coating of dust, equivalent to about 0.1 mm to 1 mm of settled dust. In most rooms, the paint was disturbed at one 60 cm by 60 cm location. In a few larger rooms, the area to be disturbed was split between two locations, to assist in producing a more uniform level of dust on the floors.

The technician performing the grinding wore disposable coveralls with attached hood and boot covers, and was protected with a full-facepiece powered air purifying respirator equipped with a high efficiency filter cartridge. Based on the maximum airborne concentration measured during the testing, this respiratory protection was adequate. The dust levels during the sanding were very high; visibility across the rooms was limited. After completing the sanding, which took approximately 20-40 minutes per room, the room was left undisturbed for a minimum of 16 hours, to allow the airborne dust to settle.

The paint disturbance also included the removal of some trim components, commonly painted with lead paint. In Test Rooms 1-4, this was the removal of the longest piece of baseboard. However, when the baseboard was removed, this allowed considerable amounts of airborne dust to be transferred out of the test room and into adjacent areas. To prevent the inadvertent tracking of contamination into the test rooms, from supposedly clean areas, the removal of baseboard was not performed in Test Rooms 5-20. Rather, the casing trim at one door was removed as part of the paint disturbance. However, it should be noted that this disturbance released a very small amount of paint debris compared to the sanding of the wall paint.

2.6 *Cleaning Procedures*

A few minor changes were made in the cleaning procedures and surface testing protocol, based on the initial experience. In the initial trial TSP was used as the cleaning agent in Method 3, rather than Ledizolv, due to the latter product being unavailable at that time. For the subsequent tests, Ledizolv was used.

The cleaning of the floors in all four methods was preceded by a vacuum cleaning of settled dust on vertical surfaces within the test room (except for the floor), including the tops of baseboards, window sills, polyethylene sheeting over articles, etc. The purpose of this pre-clean was to eliminate a possible source of paint dust contamination that might later contaminate the cleaned floor. For Test Rooms 1-4, this cleaning was performed with a HEPA vacuum. For the remaining test rooms, the vacuum assigned to the cleaning method was used.

For consistency, the same two technicians performed all of the cleaning tasks; in fact at least 80% of the cleaning was performed by the same technician.

The four cleaning methods were performed as follows:

Method 1:

1. The floor was swept with a corn broom, in one direction only.

2. The floor was vacuumed, first in one direction, and then in the perpendicular direction, with a utility vacuum (Model 500 Wet/Dry Utility Vacuum, Shop Vac Canada, 4 gallon canister, 1.25 HP peak, 165 Watts peak air power). This vacuum was selected as one of the most economical utility vacuums available (under $50 retail price), and would be typical of the basic utility vacuum present in many households or used by small contractors. The vacuum was used with the liner bag available for this model, which would provide some increased collection efficiency, compared to operation without the liner bag. The vacuum had been pre-loaded to at least 10% capacity with dust and debris prior to use in the test rooms, by vacuuming existing debris in the apartment.

Method 2:

1. The floor was vacuumed, in one direction and then in the perpendicular direction, with a household vacuum cleaner fitted with a floor brush (Filterqueen Model 700). This vacuum was chosen to be typical of the equipment commonly used in household cleaning. The vacuum had been fitted with a new filter prior to this work, and was pre-loaded with some debris. This model discharges air upwards from the top of the vacuum body.

2. The floor was mopped, in one direction and then in the perpendicular direction, with the same solution of a common household cleaner (Mr. Clean), mixed with water according to the recommendations on the container. This product was chosen as representative of a common household cleanser that does not require a rinse step. The cleaning solution was held in a plastic household-type bucket and applied with a sponge mop. The dirty sponge mop was rinsed and squeezed out into the cleaning solution, as is typical of common household cleaning.

Method 3:

1. The floor was vacuumed, in one direction and then in the perpendicular direction, with the utility vacuum described above.

2. The floor was mopped, in one direction and then in the perpendicular direction, with the same solution of a specific lead-cleaning detergent (Ledizolv, Hin-Cor Industries, Charlotte, North Carolina; available from Southern Safety Express, Mississauga). The Ledizolv was mixed to form a 2% solution, as recommended by the manufacturer (8 fluid ounces to 2.5 Imperial gallons). The cleaning solution was held in a plastic household-type bucket. The sponge mop was wrung out into the bucket, as is typical of household cleaning.

3. The floor was rinsed, in one direction and then in the perpendicular direction, with the same clean rinse water held in a clean bucket. The same mop-head as had been used for the Ledizolv wash, was used for the rinse stage.

Method 4:

Method 4 is the cleaning procedure recommended by the HUD Guidelines.

1. The floor was vacuumed with a wet-dry HEPA vacuum (Tiger Model B-5 DS, TigerVac Inc., Montreal, 1200 Watts total power), in one direction and then in the perpendicular direction operated without a collection bag.

2. The floor was mopped, in one direction and then in the perpendicular direction, with a solution of tri-sodium phosphate (TSP) in water. The TSP solution was made up to the concentration suggested on the product container for heavy duty cleaning (2 tablespoons per gallon of water). The cleaning solution was applied to the floor by a garden-type water sprayer, and the mop-head was wrung out into a dirty water bucket. In this HUD-specified procedure, the clean TSP wash solution is not contaminated by the dirt collected by the mop-head.

3. The floor was rinsed, in one direction and then in the perpendicular direction, with water. The rinse water was applied to the floor by a garden-type water sprayer, and the mop-head was wrung out into a dirty rinse water bucket.

4. The floor was vacuumed again with the wet-dry HEPA vacuum.

A number of steps were taken to prevent transfer of contamination into the rooms:

- The vacuums were inspected before each use.
- New mop-heads and brooms were used for each test room.
- New coveralls and boot covers were donned for each entry into a test room.
- All equipment was vacuumed and wet-cleaned after work was complete in each house.

2.7 *Surface Contamination Testing*

Pre-cleaning and post-cleaning surface contaminant tests were taken by wiping known areas of the floor with the HUD recommended surface sampling procedure. The technician donned new latex gloves, and wiped a marked location of known area with a moistened baby wipe (Huggies Unscented Baby Wipes, Kimberley Clark, Neenah, Wisconsin; alcohol-free and aloe-free). The test area was wiped once in one direction with overlapping S-strokes; the wipe was folded; the area was re-wiped in the perpendicular direction; the wipe was folded once again; the area was wiped once again, in the original direction. The wipe was then placed into a sterile 60 mL specimen jar. The wipes were analysed for lead at Entech Laboratories, Mississauga, by acid digestion and either Atomic Absorption or Inductively-Coupled Plasma Emission spectroscopy. A total of three field blank wipes were collected by donning new gloves, folding a clean wipe three times, and placing into a sample container.

The test area wiped was 30 cm X 30 cm for all samples taken, except for the pre-clean sample taken in Test Room 2, for which an area of 20 cm X 20 cm was sampled.

In Test Rooms 1-4, there was one pre-clean wipe test taken, and 5 post-clean samples taken. The pre-clean wipe was collected at the centre of the room. The post-clean samples were taken, one at the centre of the room, and the remaining 4 samples half-way along the 4 diagonals between the centre and each of the 4 corners.

In Test Rooms 5-20, there were 2 pre-clean wipe tests taken, and 4 post-clean samples. The pre-clean samples were taken at 1/3 and 2/3 of the distance along a line running down the middle of the room, in the longest direction. The post-clean samples were taken half-way along the 4 diagonals between the centre and each of the 4 corners.

The amount of damage to the floor was noted, both generally across the floor, and at each specific test location.

Two samples of wall contamination were taken in Test Rooms 2 and 3, in order to measure the amount of lead dust on the walls that might be released to the floors either during or after the cleaning.

2.8 *Personal Airborne Exposure Measurements*

Task-based measurements of airborne lead concentrations were made during the paint disturbance in 3 rooms, and during the cleaning operations in 18 rooms. Samples of airborne lead were collected by drawing known volumes of air through cellulose ester filters held in closed-face sampling cassettes. A battery-operated pump, flow-calibrated before the work, was worn by the technician, with the sampling cassette clipped on their shoulder. In this way, the personal exposure was estimated. Analysis was performed at Entech Laboratories. The air sampling and analysis followed the U.S. National Institute for Occupational Safety and Health (NIOSH) Method 7300. The sampling data is given in the room-by-room field information of Appendix 1.

3. RESULTS AND DISCUSSION

Tables 1 to 4 present the detailed results for this project, organized by Cleaning Methods 1 to 4 respectively. For each test room, the following results are given:

- Average lead concentration in paint on walls, by XRF (mg/cm^2)
- Average lead concentration in paint on walls, by chemical testing (%)
- Floor type
- Floor condition
- Pre-cleaning lead surface concentrations on floors (ug/m^2)
- Post-cleaning lead surface concentrations on floors (ug/m^2)

Figure 1 presents the post-cleaning floor concentrations, plotted by cleaning method, and in relation to the current and proposed HUD criteria for floor cleanliness.

3.1 *Lead Concentrations in Paint*

The concentrations of lead paint disturbed in the 20 Test Rooms, as measured by the XRF procedure, ranged from 2.0 mg/cm^2 to 10.3 mg/cm^2, and averaged 3.9 mg/cm^2. The percentages of lead in paint as measured by scraping or heat gun removal, were from 0.01% to 1.13%.

For Test Rooms 5 - 20, there was an effort made to produce data that would allow a test of the correlation between the XRF results and the chemical tests. The samples for chemical analysis were taken from known areas, with a heat gun procedure, so that it might be possible to compare the XRF and chemical test results on a mass per unit area basis. Figure 2 shows the relationship between the XRF concentrations and the chemical tests, both taken at the same location. There is a very poor correlation, with the results of the chemical tests all appearing to be lower than the XRF results. Yet, the surface concentrations showed that there was a large amount of lead dust deposited on the floors, so it appears unlikely that the chemical tests were correct. The under-reporting of lead by the chemical tests is likely caused by an under-sampling of the paint by the heat gun method. It is likely that the lowest (and therefore oldest) paint layers, the layers most likely to contain high concentrations of lead, were not effectively collected in this test. It is recommended that correlation testing of this type involve the collection of a bulk sample well into the substrate material.

3.2 *Lead Surface Contaminations Before Cleaning*

The amount of lead contamination on the floors before cleaning is given in Tables 1 to 4. For Test Rooms 8 and 10, the degree of lead contamination on the floor was considerably lower than the remainder of the rooms (1,290 ug/m^2 and 4,220 ug/m^2, respectively). Since the pre-cleaning lead concentrations were too low, the post-cleaning data for these rooms is considered suspect, and therefore these 2 data sets are rejected. These data sets are not included in the discussion of the remaining 18 data sets.

The surface lead concentrations on the floors before cleaning, for the 18 acceptable data sets, ranged from 33,900 ug/m^2 to 228,000 ug/m^2, and averaged 103,000 ug/m^2. The

highest surface contamination concentrations corresponded to the highest XRF measurements of lead in paint.

Figure 3 shows the relationship between the amount of lead in the paint that was disturbed, as measured by X-ray fluorescence, and the average pre-cleaning lead concentration on the floor. It should be noted that the pre-cleaning floor concentration data is relatively imprecise, as only one or two samples were collected, and the bulk distribution of dust on the floor was visibly non-uniform. Nevertheless, Figure 3 shows a good positive correlation between the amount of lead in the paint that was disturbed, and the floor lead concentration. The XRF results did appear to properly measure the relative amount of lead in the paint. This supports our belief that the poor correlation between the XRF concentrations and the chemical tests was not due to inaccurate XRF measurements, and instead was due to the ineffectiveness of the heat gun sample collection procedure.

Two measurements were made of lead contamination on the walls, prior to cleaning. The purpose of these tests was to determine the amount of lead on the walls relative to the level on the floors, so that if dust collected on the walls were to be transferred to the floors during the cleaning, whether this would represent a significant risk to the validity of the data. The two concentrations were 800 ug/m^2 (Test Room 2) and 2,530 ug/m^2 (Test Room 3). These concentrations are much lower than the pre-cleaning contamination levels measured on the floors, and represent about the same contamination level as the floors after cleaning. Therefore, since there was not a gross transfer of dust from the walls, and the lead content of this dust was low, there is very little chance that the contamination on walls affected the post-cleaning floor concentrations.

Three field blank wipes were taken, and gave results of <1 ug, $<$ 1 ug, and 2 ug of lead. These concentrations, even if an averaging calculation assumes the concentration to be at the detection limit, represent a surface concentration measurement of 15 ug/m^2, which is very much below the lowest post-cleaning concentration reported.

3.3 *Lead Surface Contaminations After Cleaning*

Table 1 gives the results for Cleaning Method 1, which is the broom sweeping and utility vacuum procedure. Three of the 5 data sets met the current HUD clearance criteria, and none of the 5 data sets met the proposed clearance criteria. Test Room 5,

which had a floor in poor condition, had a much higher post-cleaning surface contamination than the other rooms.

Table 2 gives the results for Cleaning Method 2 (household vacuum, household cleaner). Only one of the 5 data sets met the current HUD criteria, and none met the proposed criteria. There was more variation in results than seen with Method 1, and again the highest level of post-cleaning contamination was measured in a room with vinyl tiles in poor condition.

Table 3 gives the results for Cleaning Method 3 (utility vacuum, mop with Ledizolv, rinse). All of the 4 acceptable data sets met both the current and the proposed HUD criteria. This included two rooms that were reported as having 3% damage to sheet flooring and 25% of vinyl floor tiles as surface-cracked.

Table 4 gives the results for Cleaning Method 4 (HEPA vacuum, TSP wash, rinse, HEPA vacuum). Of the four acceptable data sets, 4 of 4 met the current HUD criteria, and 3 of 4 met the proposed criteria. All of the floors, including sheet flooring, strip hardwood, and vinyl tile, were in good condition.

The data for the cleaning methods was also analysed by determining the percentage of lead dust remaining after cleaning, by dividing the average post-cleaning concentration by the pre-cleaning concentration. This analysis would tend to compensate for any possible inverse relationship between the amount of pre-cleaning lead, and the degree of effectiveness, especially when comparing test rooms with considerably different starting contaminant levels. The average percentage of lead remaining after Cleaning Methods 1, 2, 3 and 4 was 6.7%, 14.9%, 1.5%, and 0.8%, respectively. This analysis again shows that Methods 3 and 4 are much more effective in removing lead paint dust, than Methods 1 and 2.

Figure 4 shows the relationship between post-cleaning floor concentrations and the condition of the floor, ranked as Good, Fair or Poor. A ranking of Poor meant a visual estimate of damage of more than 5%; Fair was any amount of damage, up to 5%; Good meant no damage. Note that the cleaning method assignment did not consider the floor condition, so that all methods were not equally challenged by floors in good and poor condition. The test rooms for Methods 3 and 4 had fewer floors in poor condition. As illustrated in Figure 4, there is a strong association between the ability to clean

satisfactorily, and the condition of the floor. Floor surfaces in Poor condition could not be satisfactorily cleaned, with any method. This conclusion matched the field observations that the wet cleaning methods tended to continually transfer dust held in cracks, crevices, areas of missing floor, and under cupped floor tiles, back onto the cleaned floor surfaces. Floors that are in poor condition should be protected with plastic sheeting or other cleanable surface, before any paint disturbance, or if contaminated with lead dust, should be removed or permanently covered, for example, with a new layer of underlay and a new finished floor.

3.4 *Airborne Lead Measurements*

Table 5 gives the results of the task-based airborne lead measurements. During disturbance of the lead paint by power sanding, personal exposures ranged from 1,600 ug/m^3 to 4,320 ug/m^3. For reference, the occupational exposure limit, which represents the maximum exposure recommended for industrial workers averaged over an 8 hour work period (and does not provide adequate protection for children, pregnant women, or men wishing to conceive a child), depending on the jurisdiction, is 50 ug/m^3 to 150 ug/m^3. The highest airborne exposure measured during this work was 83 times over the 50 ug/m^3 limit.

Table 5 also gives the results of personal exposures measured during the cleaning of the floors. Exposures during Cleaning Method 1 averaged 105 ug/m^3, above the most recently recommended industrial exposure limit. This high concentration is probably due to the broom sweeping performed in Method 1, and not the use of the utility vacuum, as airborne concentrations during Cleaning Method 3, which used the same utility vacuum, were not excessive.

The personal concentrations measured during cleaning by Methods 2, 3, and 4 averaged 30 ug/m^3, 22 ug/m^3, and 17 ug/m^3, respectively. All these methods employ a vacuum cleaning followed by wet cleaning. Interestingly, the average concentration during Method 3, which used the $50 utility vacuum, was not higher, and in fact was lower than during Method 2, which used a much more expensive household vacuum. Although it is good industrial hygiene and public health practice to require HEPA vacuums for removal of toxic materials, this advice may not be required for lead dust arising from sanding. We caution that this finding may not apply to lead dust from other sources, ie. environmental dust, fumes arising from hot work, or dust from chalking of paint.

Airborne concentrations measured by Cleaning Method 4, at 17 ug/m^3, averaged the lowest of the 4 methods. This may be due to the use of the HEPA vacuum, or the discharge pattern of the HEPA vacuum blower, or the higher air exchange rate with the HEPA vacuum, or possibly even the longer measurement period for Method 4, allowing a longer settling and filtration period.

The results for Method 3 indicated that Ledizolv, as applied thoroughly, first in one direction, and then in the opposite direction, using the same cleaning solution, followed by a similar bidirectional rinse, gave surface concentrations that met current and proposed HUD standards. While these findings reflect favourably on this product, it is possible that other cleaning products not tested in this project, if applied as carefully, might also have given acceptable results.

4. CONCLUSIONS

The following conclusions are made, based on the data collected in this project.

4.1 Cleaning of lead paint dust by either i) a utility vacuum followed by Ledizolv and rinsing, or ii) HEPA vacuum cleaning, TSP cleaning, rinsing, and HEPA vacuuming, will likely reduce floor concentrations of lead to levels below both the current and proposed HUD clearance criteria.

4.2 Cleaning of lead paint dust by either i) broom cleaning and a utility vacuum, or ii) household vacuum, followed by mopping with a household cleaner, will not meet either the current or proposed HUD clearance criteria.

4.3 Power sanding of leaded paint produces extremely high and dangerous airborne dust exposure levels, and should be prohibited, without adequate protection.

4.4 Dry sweeping of leaded dust produces high concentrations of airborne dust, and should be discouraged.

4.5 The use of heat guns to collect paint samples for lead determination may not adequately collect all layers of paint, and thereby may under-represent the extent of lead in paint.

4.6 The cleaning of lead dust from floors with major damage is ineffective, in the rooms tested. We recommend that significantly damaged floors be covered with polyethylene sheeting or other protection prior to lead paint disturbance, or the flooring be removed or permanently covered.

4.7 TSP cleaning solution, as tested in this study, was able to achieve the required level of cleanliness on floors at a much lower concentration than recommended in the HUD guidelines.

5. REFERENCES

1. Regulation Respecting the Advertising, Sale and Import of Liquid Coating Materials; made under the Hazardous Products Act, (Canadian federal government) 1976 (as amended)

2. Marino, P.E., et al; A Case Report of Lead Paint Poisoning during Renovation of a Victorian Farmhouse; American Journal of Public Health; October 1990; 10:1183-1185

3. Prepublication Copy: Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing; prepared for U.S. Department of Housing and Urban Development, February 1995.

4. Goldman, L.R.; Guidance on Residential Lead-Based Paint, Lead-Contaminated Dust, and Lead-Contaminated Soil; U.S. Environmental Protection Agency; July 1994

5. Jonathan Wilson; National Centre for Lead-Safe Housing; Columbia, Maryland; Personal communication, March 1995.

FIGURE 1:
Evaluation of Cleanup of Lead Paint Dust in Houses

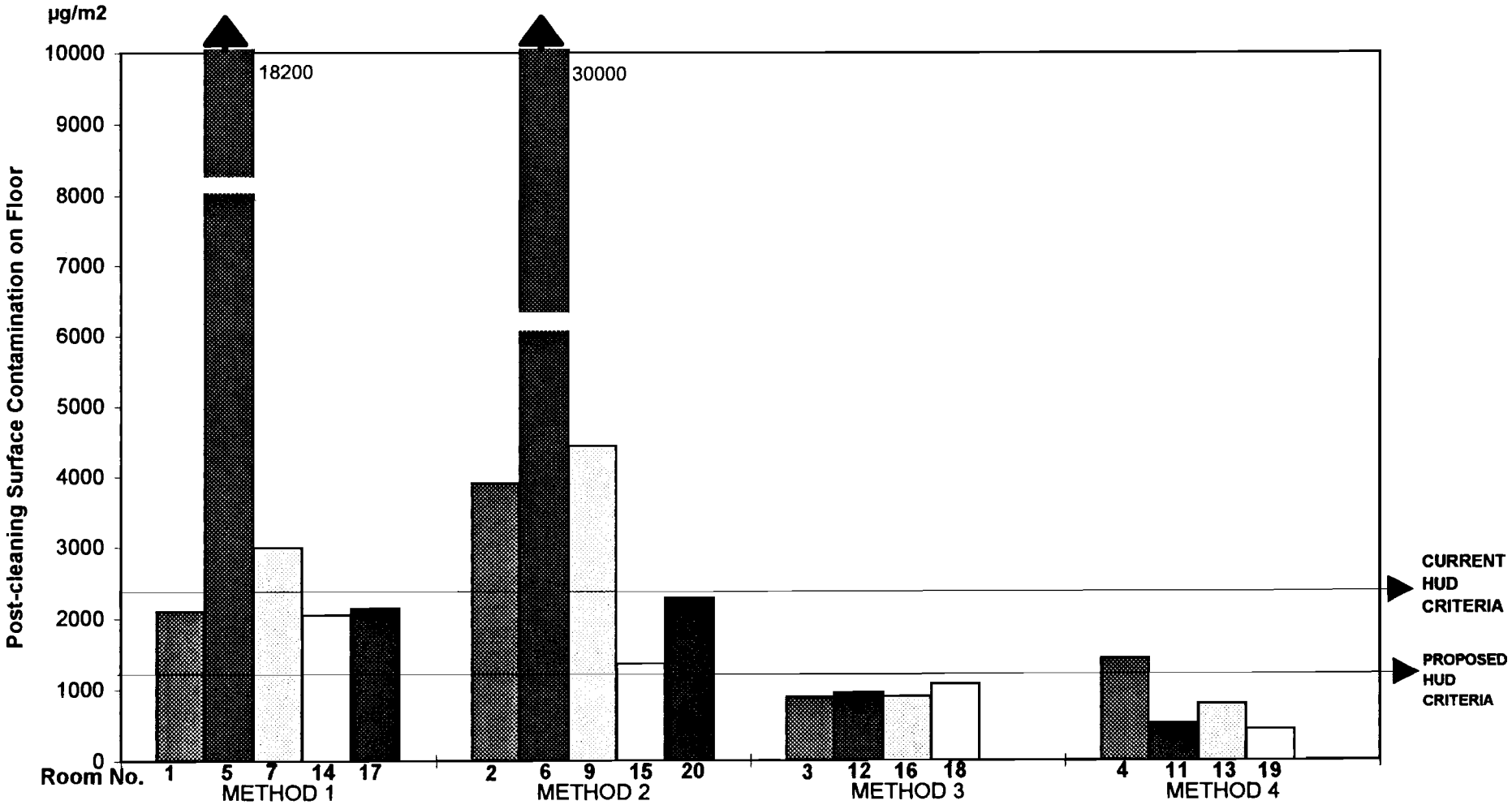

FIGURE 2: XRF Lead in Paint Measurements vs. Heat Gun Scraping and Chemical Analysis

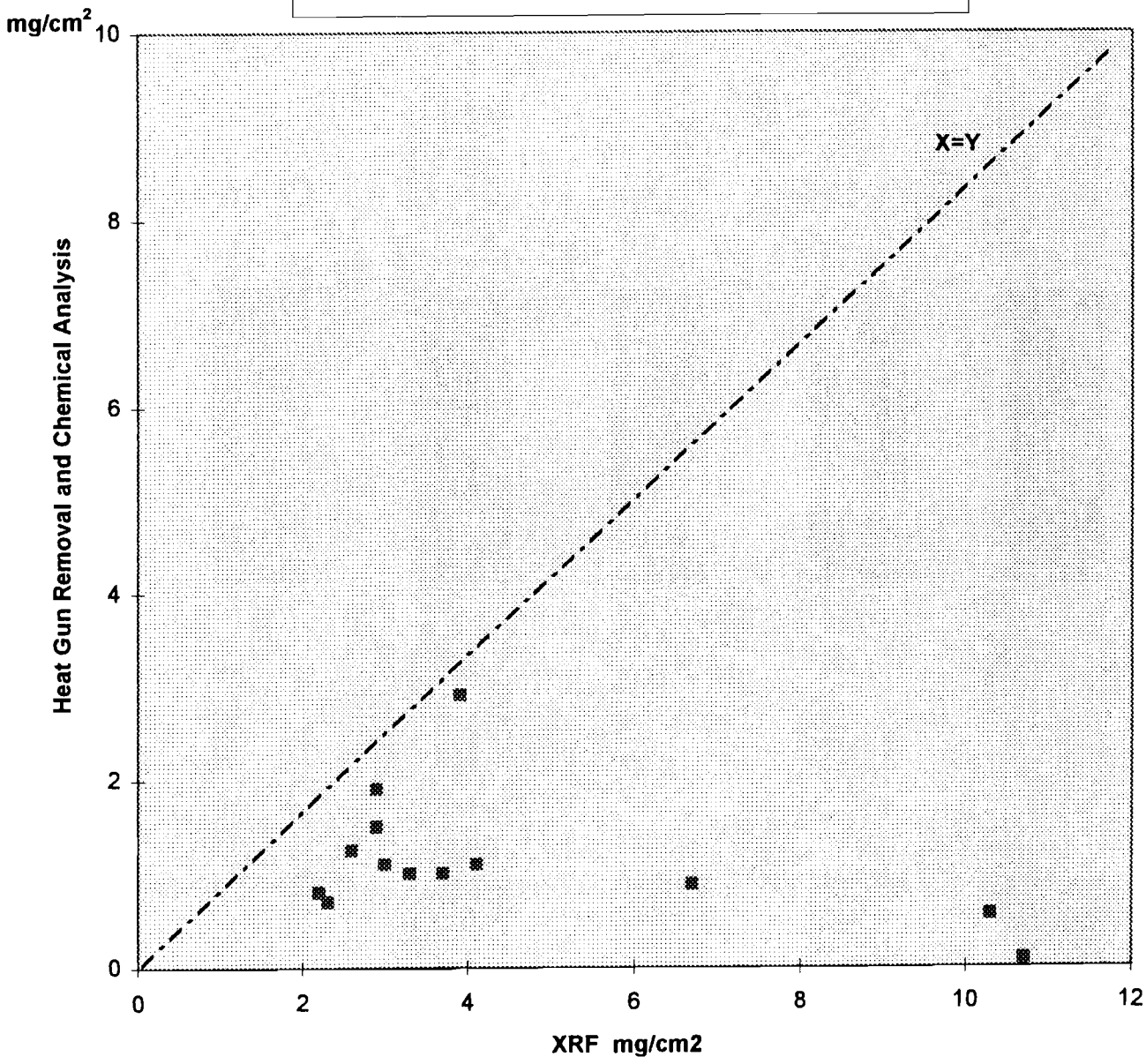

FIGURE 3:
Pre-Cleaning Floor Lead Contamination vs. XRF Lead in Paint Concentration

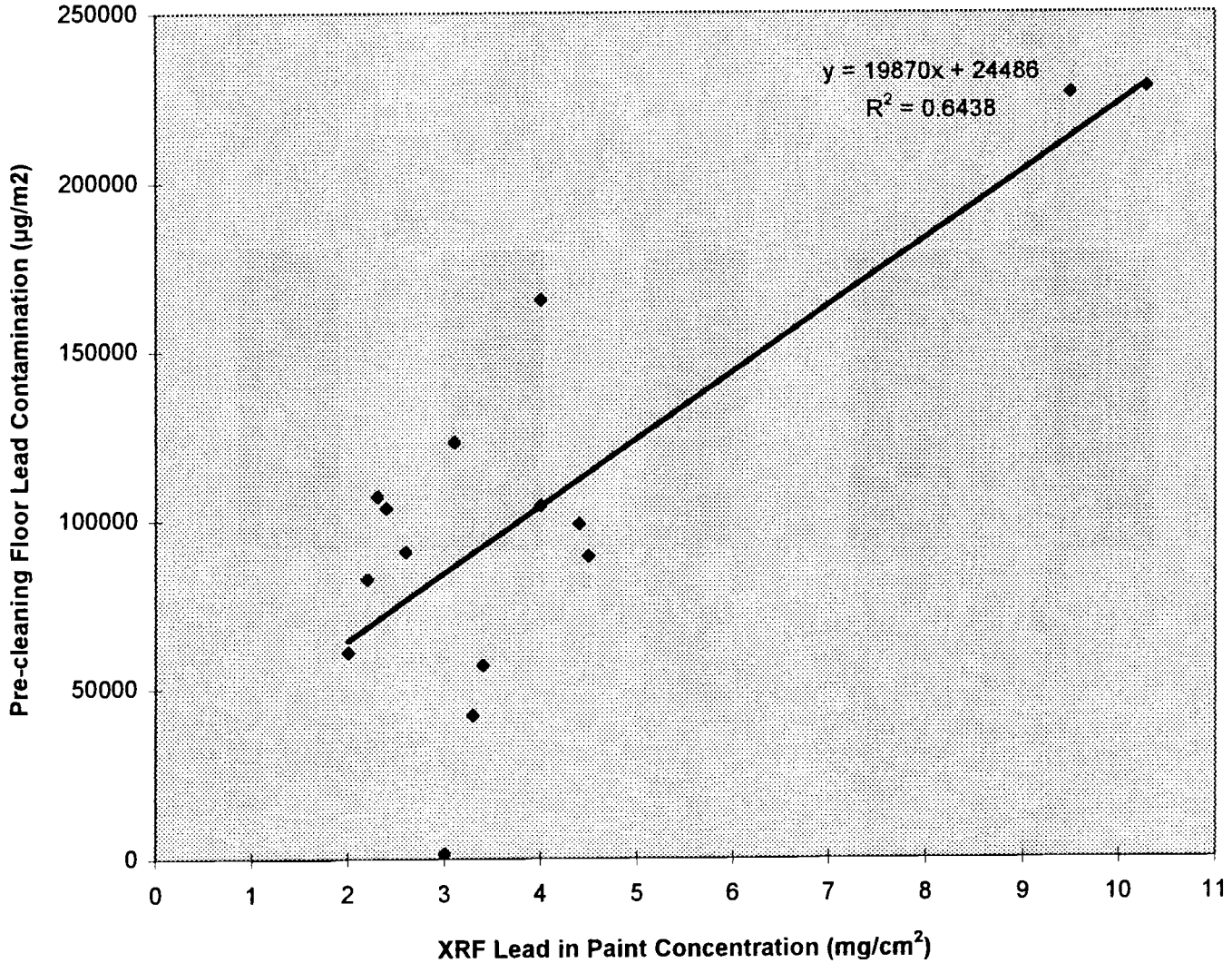

FIGURE 4:
Post-Cleaning Lead Contamination on Floor vs. Floor Condition

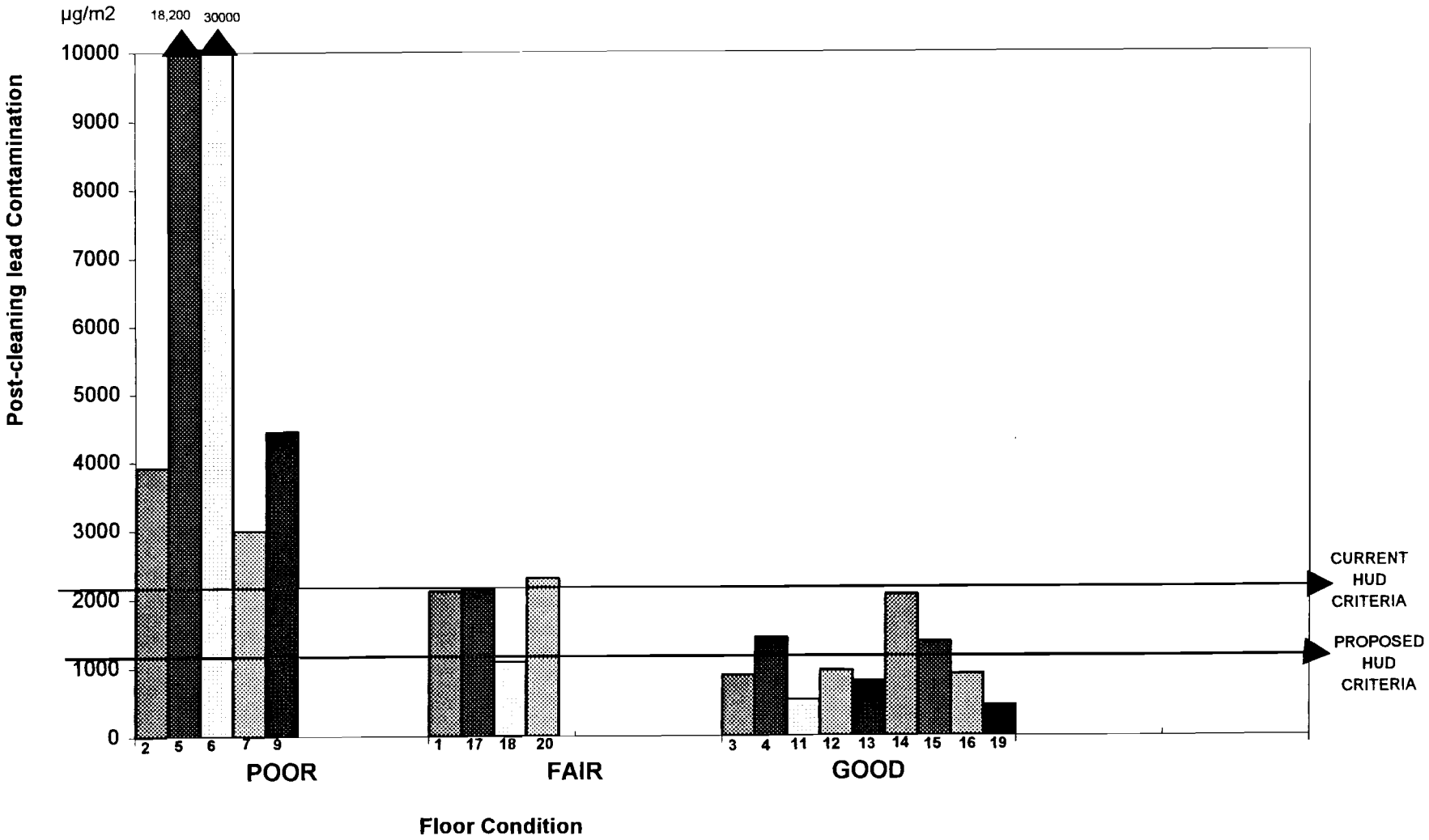

TABLE 1

EFFECTIVENESS OF FLOOR CLEANING BY CLEANING METHOD 1

(DRY SWEEP, UTILITY VACUUM)

TEST ROOM	TEST CONDITIONS	PRE-CLEANING (ug/m^2)	POST-CLEANING (ug/m^2)
1	Average XRF: 5.6 mg/cm^2 Lead %: 0.9%, 2.5% Floor Type: Sheet flooring Floor Condition: 3% damage	46,000 Average = 46,000	1,310 2,480 2,110 2,530 2,070 **Average = 2,100**
5	Average XRF: 2.6 mg/cm^2 Lead %: 1.95% Floor Type: Vinyl tile Floor Condition: Poor	58,700 122,000 Average = 90,400	10,000 18,200 33,200 11,400 **Average = 18,200**
7	Average XRF: 2.2 mg/cm^2 Lead %: 0.44% Floor Type: Sheet flooring Floor Condition: 15% damaged	88,400 76,200 Average = 82,300	3,170 3,480 3,670 1,640 **Average = 2,990**
14	Average XRF: 2.0 mg/cm^2 Lead %: 1.57% Floor Type: Vinyl tile Floor Condition: Good	65,700 55,600 Average = 60,700	1,140 3,130 1,030 2,890 **Average = 2,050**
17	Average XRF: 2.3 mg/cm^2 Lead %: 1.91% Floor Type: Sheet flooring Floor Condition: 5% damage	21,300 194,000 Average = 107,000	2,220 2,440 2,110 1,780 **Average = 2,140**

NB: For reference, the current HUD cleanliness criteria for floors is 2,150 ug/m^2. HUD proposes to reduce this criteria to 1,076 ug/m^2.

TABLE 2

EFFECTIVENESS OF FLOOR CLEANING BY CLEANING METHOD 2

(HOUSEHOLD VACUUM, MOP WITH HOUSEHOLD CLEANSER)

TEST ROOM	TEST CONDITIONS	PRE-CLEANING (ug/m^2)	POST-CLEANING (ug/m^2)
2	Average XRF: 3.9 mg/cm^2 Lead %: 0.2% Floor Type: Sheet flooring Floor Condition: 10% damaged	145,000 Average = 145,000	5,380 4,000 2,380 3,100 4,680 **Average = 3,910**
6	Average XRF: 3.0 mg/cm^2 Lead %: 1.40% Floor Type: Vinyl tile Floor Condition: Poor	91,600 288 Average = 45,900	21,300 60,900 20,200 17,600 **Average = 30,000**
9	Average XRF: 4.0 mg/cm^2 Lead %: 0.60% Floor Type: Sheet flooring Floor Condition: 20% damaged	86,600 122,000 Average = 104,300	2,670 10,900 2,670 1,530 **Average = 4,440**
15	Average XRF: 4.5 mg/cm^2 Lead %: 0.60% Floor Type: Sheet flooring Floor Condition: Good	116,000 62,200 Average = 89,100	1,530 1,230 1,740 977 **Average = 1,370**
20	Average XRF: 10.3 mg/cm^2 Lead %: 1.68% Floor Type: Strip hardwood Floor Condition: 3% damaged	166,000 290,000 Average = 228,000	1,210 1,710 3,700 2,520 **Average = 2,290**

NB: For reference, the current HUD cleanliness criteria for floors is 2,150 ug/m^2. HUD proposes to reduce this criteria to 1,076 ug/m^2.

TABLE 3

EFFECTIVENESS OF FLOOR CLEANING BY CLEANING METHOD 3

(UTILITY VACUUM, MOP WITH LEDIZOLV, RINSE)

TEST ROOM	TEST CONDITIONS	PRE-CLEANING (ug/m^2)	POST-CLEANING (ug/m^2)
3	Average XRF: 2.9 mg/cm^2 Lead %: 1.7%, 1.6 % Floor Type: Sheet flooring Floor Condition: Good **(TSP was used for wash rather than Ledizolv)**	33,900 Average = 33,900	1,120 622 756 878 1,067 **Average = 889**
8	Average XRF: 3.1 mg/cm^2 Lead %: 0.01% (?) Floor Type: Sheet flooring Floor Condition: 3% damaged	1,680 900 ****	222 200 344 644 ****
12	Average XRF: 3.1 mg/cm^2 Lead %: 0.76% Floor Type: Strip hardwood Floor Condition: Good	220,000 26,700 Average = 123,000	1,020 1,010 989 767 **Average = 947**
16	Average XRF: 3.4 mg/cm^2 Lead %: 2.64% Floor Type: Vinyl tile Floor Condition: Good	2,970 111,000 Average = 57,000	1,030 1,200 722 633 **Average = 896**
18	Average XRF: 2.4 mg/cm^2 Lead %: 0.75% Floor Type: Vinyl tile Floor Condition: 25% surface cracks	188,000 19,300 Average = 103,650	1,240 1,030 833 1,200 **Average = 1,076**

NB: For reference, the current HUD cleanliness criteria for floors is 2,150 ug/m^2. HUD proposes to reduce this criteria to 1,076 ug/m^2.

**** Insufficient lead dust was created in Test Room 8 for a valid test of cleaning ability. The results for Test Room 8 were not included in the overall analysis.

TABLE 4

EFFECTIVENESS OF FLOOR CLEANING BY CLEANING METHOD 4

(HEPA VACUUM, TSP WASH, RINSE, HEPA VACUUM)

TEST ROOM	TEST CONDITIONS	PRE-CLEANING (ug/m^2)	POST-CLEANING (ug/m^2)
4	Average XRF: 4.4 mg/cm^2 Lead %: 1.3%, 1.3% Floor Type: Sheet flooring Floor Condition: Good	98,700 Average = 98,700	1,580 1,760 1,410 1,510 890 **Average = 1,430**
10	Average XRF: 1.6 mg/cm^2 Lead %: 0.27% Floor Type: Vinyl tile Floor Condition: Good	4,220 4,220 ****	311 289 1,560 1,110 ****
11	Average XRF: 3.3 mg/cm^2 Lead %: 1.16% Floor Type: Vinyl tile Floor Condition: Good	40,000 44,400 Average = 42,200	422 422 811 444 **Average = 525**
13	Average XRF: 4.0 mg/cm^2 Lead %: 0.93% Floor Type: Strip hardwood Floor Condition: Good	207,000 122,000 Average =165,000	678 911 798 822 **Average = 797**
19	Average XRF: 9.5 mg/cm^2 Lead %: 1.02% Floor Type: Strip hardwood Floor Condition: Good	370,000 82,800 Average = 226,400	233 622 489 411 **Average = 439**

NB: For reference, the current HUD cleanliness criteria for floors is 2,150 ug/m^2. HUD proposes to reduce this criteria to 1,076 ug/m^2.

**** Insufficient lead dust was created in Test Room 10 for a valid test of cleaning ability. The results for Test Room 10 were not included in the overall analysis.

TABLE 5

AIRBORNE LEAD CONCENTRATIONS DURING LEAD PAINT DISTURBANCE AND CLEANING OF DUST

ACTIVITY	TEST ROOM	SAMPLE NUMBER	EXPOSURE PERIOD (minutes)	AIRBORNE CONCENTRATION (ug/m^3)
Paint disturbance	12	70164	19	1,600
	15	70161	21	1,220
	19	70169	26	4,320
			Average:	**1,990**
Cleaning by Method 1	5	70157	35	126
	7	70160	29	193
	14	70172	14	79
	17	70174	30	22
			Average:	**105**
Cleaning by Method 2	6	70156	42	21
	9	70162	48	<5
	15	70154	20	33
	20	70165	26	60
			Average:	**30**
Cleaning by Method 3	3	54070	29	17
	8	70152	30	45
	12	70173	28	16
	16	70153	28	24
	18	70166	30	<7
			Average:	**22**
Cleaning by Method 4	4	54064	44	11
	10	70159	66	<4
	11	70168	50	4
	13	70158	39	11
	19	70176	42	53
			Average:	**17**

NB: For reference, the current occupational exposure limit for industrial exposure to airborne lead is a concentration of 50 - 150 ug/m^3, depending on the jurisdiction. Children, pregnant women and males wishing to conceive a child are encouraged to maintain exposures below the industrial exposure limit.