PROBLEM DRYWALL ASSESSMENT AND INDOOR ENVIRONMENTAL QUALITY EVALUATION 144 GROESBEEK STREET AND 4 DARDEN STREET FORT BRAGG, NORTH CAROLINA

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF APPENDICES

LIST OF TABLES

TABLE OF CONTENTS (Continued)

LIST OF TABLES (Continued)

LIST OF FIGURES

LIST OF ABBREVIATIONS AND ACRONYMS

A $30d^{-1}$	angstroms per 30 days
AHU	air handling unit
ASTM	American Society for Testing and Materials
cfm	cubic feet per minute
cfu/m^3	colony forming units per cubic meter
CID	U.S. Army Criminal Investigation Division
CO	carbon monoxide
CO_2	carbon dioxide
CV	coefficient of variation
DNPH	2,4-dinitrophenylhydrazine
DRIFT	diffuse reflectance infrared Fourier transform
EH&E	Environmental Health & Engineering, Inc.
EPA	U.S. Environmental Protection Agency
FTIR	Fourier transform infrared
GC/ECD	gas chromatography/electron capture detector
GC/MS	gas chromatography/mass spectrometry
GC/SCD	gas chromatography/sulfur chemiluminescence detector
HUD	U.S. Department of Housing and Urban Development
HVAC	heating, ventilating, and air-conditioning
ICP/MS	inductively coupled mass spectrometry
IEQ	indoor environmental quality
IR	infrared
MCL	maximum contaminant level
MEA	malt extract agar
mg/kg	milligrams per kilogram
ml/min	milliliters per minute
ng/g	nanograms per gram
OSHA	U.S. Occupational Safety and Health Administration
QA/QC	quality assurance and quality control
$PM_{2.5}$	particulate matter that is 2.5 micrometers or smaller in size
PM_{10}	particulate matter that is 10 micrometers or smaller in size
ppm	parts per million
psig	pounds per square inch gauge
RBC	risk-based concentration
RPD	relative percent difference
S_8	orthorhombic sulfur (elemental sulfur)
SMCL	secondary maximum contaminant level
spores/m^3	spores per cubic meter
TICs	tentatively identified compounds
VOC	volatile organic compound
XRF	X-ray fluorescence
$\mu g/m^3$	micrograms per cubic meter
°C	degrees Celsius
°F	degrees Fahrenheit
% WME	percent wood moisture equivalent

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

Under contract with the U.S. Consumer Product Safety Commission (CPSC), Environmental Health & Engineering, Inc. (EH&E) concluded its investigation of the indoor environmental quality (IEQ) of two homes that are part of the housing provided to families of military personnel stationed at Fort Bragg, North Carolina. The homes are located at 144 Groesbeek Street (Ardennes neighborhood), Fort Bragg, North Carolina, and 4 Darden Street (Linden Oaks neighborhood), Cameron, North Carolina (collectively "the homes"). This environmental investigation was conducted in support of the U.S. Army's investigation of several infant deaths from undetermined causes in Fort Bragg military housing. Initial reports inferred that the homes potentially contained problem drywall.[1]

This comprehensive environmental and building investigation had two primary objectives:

1) Determining whether problem drywall was present in either, or both, of these homes, and, if so, determining its potential impacts on the indoor environment.
2) Performing a detailed investigation of the indoor environment and associated building systems at each home to examine other possible environmental causes that may have contributed to the infant deaths.

1.2 INVESTIGATION OVERVIEW

From October 4, 2010, to October 7, 2010, a four-person research team from EH&E conducted in-home inspections and testing at the homes. EH&E's investigation consisted of the following elements, which are described in full in corresponding sections in the Report:

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[1] Problem drywall is defined here as drywall that meets the case definition criteria established by the CPSC/HUD (CPSC/HUD 2010) and contributes to elevated rates of corrosion in homes. The issue of drywall-related problems initially and commonly was referred to as the 'Chinese Drywall' issue because many of the homes with this issue were built with drywall imported from the People's Republic of China.

- Assessment of the potential for either of the Fort Bragg homes to be impacted by problem drywall. The assessment focused on parameters that were found previously to be indicative of homes with problem drywall (EH&E 2010a; EH&E 2010b), including: concentrations of elemental sulfur (S_8), strontium, and carbonate in the drywall material; hydrogen sulfide and other reduced sulfur compounds in indoor air; and elevated rates of corrosion observed and measured in the homes.

- Indoor environmental profile, including a visual assessment of the homes; review of previous reports and testing done in and around the homes; and informational interviews to solicit input from Army CID and CPSC investigators on their observations.

- Heating, ventilating, and air-conditioning (HVAC) system assessment, including evaluation of overall system hygiene and system performance as it relates to in-service operation, zoning, and the identification of conditions that could potentially result in an adverse impact to IEQ.

- Ventilation assessment, including measurements to quantify home ventilation rates.

- Indoor environmental measurements and analyses, including carbon monoxide (CO), volatile organic compounds (VOCs), aldehydes, fungal growth, airborne fungal spores, water quality, pesticides, metals, and allergens.

Section 1.3 provides a summary of the major findings from the evaluation. Detailed explanations of all methods, findings, analyses, and conclusions are included in the body of the Report.

1.3 SUMMARY OF FINDINGS

1.3.1 Problem Drywall Assessment

Neither Fort Bragg home met the criteria for identification of homes with problem drywall as defined by the CPSC/U.S. Department of Housing and Urban Development (HUD) interim guidance document (CPSC/HUD 2010). The identification method, based on extensive testing of problem drywall in homes and in laboratory settings (EH&E 2010a;

EH&E 2010b; LBNL 2010), involves two steps: 1) threshold inspection of the home; and 2) verification of the presence of corroborating evidence. A summary of the steps and criteria are provided in Table 1.1. Briefly, a positive result for Step 1 includes the observation of blackening of the copper materials found in the home and verification that drywall was installed in the home during the relevant time period (2001–2008). Positive results for both criteria are a prerequisite to any further consideration. Once the Step 1 criteria are met, confirmation of the presence of several pieces of corroborating evidence is also necessary to properly identify the home as having problem drywall. Depending on the date of drywall installation, the number of pieces of corroborating evidence will vary. For homes built/renovated between 2001 and 2004, at least four of the Step 2 criteria must be met. For homes built/renovated between 2005 and 2008, at least two of the Step 2 criteria must be met.

Table 1.1 Summary of the CPSC/HUD Interim Guidance for Identification of Homes with Corrosion from Problem Drywall, August 27, 2010

Step 1 – Threshold Inspection	a) Blackening of copper electrical wiring and/or air conditioning evaporator coils.
	-- AND --
	b) The installation of drywall (for new construction or renovations) between 2001 and 2008.
Step 2 – Corroborating Evidence[a]	a) Elemental sulfur levels in samples of drywall core found in the home exceeding 10 mg/kg.
	b) Corrosive conditions in the home, demonstrated by the formation of copper sulfide on copper coupons (test strips of metal) placed in the home for a period of two weeks to 30 days or confirmation of the presence of sulfur in the blackening of the grounding wires and/or air conditioning coils.
	c) Confirmed markings of Chinese origin for drywall in the home.
	d) Elevated levels of hydrogen sulfide, carbonyl sulfide, and/or carbon disulfide emitted from samples of drywall from the home when placed in test chambers.
	e) Corrosion of copper metal to form copper sulfide when copper is placed in test chambers with drywall samples taken from the home.

CPSC U.S. Consumer Product Safety Commission
HUD U.S. Department of Housing and Urban Development
mg/kg milligrams per kilograms

[a] For homes built/renovated between 2001 and 2004, at least four of the Step 2 criteria must be met. For homes built/renovated between 2005 and 2008, at least two of the Step 2 criteria must be met.

The following observations were made in relation to the CPSC/HUD guidance criteria:

- Visual inspections of 150 copper ground wires in the two homes (144 Groesbeek Street and 4 Darden Street) did not identify any locations where there was evidence of significantly corroded copper electrical wiring. The copper ground wires in these homes exhibited little to no evidence of visible corrosion.

- Both homes had drywall installed during the relevant time period.

- Elemental sulfur was not detected in the analysis of 10 drywall samples from each home. There was no evidence of elevated rates of copper sulfide formation on copper classification coupons (i.e., metal strips) deployed in multiple locations in either 144 Groesbeek Street or 4 Darden Street over a 14-day test period.

- Markings of Chinese origin were not observed on the drywall in either home.[2]

In addition, EH&E evaluated several other relevant factors that are useful for aiding in the determination of the presence or absence of problem drywall in a home. The following is a summary of those observations:

- There was no evidence of elevated rates of silver sulfide formation on silver classification coupons (i.e., metal strips) deployed in multiple locations in each home for the 14-day test period.

- Hydrogen sulfide was not detected in any indoor air samples collected from either 144 Groesbeek Street or 4 Darden Street. In addition, measurements for an expanded list of 19 additional reduced sulfur compounds in air were made on each floor of the homes. None of these compounds were detected in the homes.

- Elevated levels of strontium combined with elevated levels of carbonate in drywall can be used as an indicator to aid in the screening of homes for problem drywall. This indicator was not found in any of 223 samples analyzed (103 for 144 Groesbeek

[2] Note that the presence of non-English character printing on drywall was reported in a previous investigative report for the 4 Darden Street home (CPSC IDI. 2010b). However, these markings were later confirmed through evaluation by a Chinese linguist as being not of Chinese origin.

Street and 120 for 4 Darden Street). In addition, multiple locations on every wall and ceiling in each home were screened for strontium, and elevated levels were not observed.

1.3.2 Indoor Environmental Quality Assessment

- Visual inspection identified no evidence of water damage on floors, walls, or ceiling surfaces in 4 Darden Street. Minor evidence of water damage was noted in 144 Groesbeek Street, including an area under the window of the second floor bedroom and the floor of the second floor utility room. At the time of inspection, building materials in these areas were dry. For both homes, no evidence of visible mold growth or the presence of mold-like odors was noted in any area inspected.

- Visual inspection of both air handling units identified no unusual sources of air contaminants or conditions that could have a negative impact on IEQ.

- Assessment of the HVAC systems showed them to operate in a manner consistent with the overall operational intent of systems of similar design. EH&E field investigators identified the potential for functional problems caused by frost buildup on the indoor cooling coil at 144 Groesbeek Street that could result in decreased airflow through the system and a potential fire hazard. This information was conveyed to the CPSC upon discovery.

- The findings from the investigation indicate that combustion sources inside the homes are not negatively impacting IEQ, even under extreme conditions that could potentially lead to back-drafting of combustion gases (e.g., carbon monoxide) into the home.

- The average ventilation rate measurements suggest that the homes are on the lower end of the distribution of typical air exchange rates found in North America and may reflect that the homes are of relatively tight construction.

- Air sampling did not identify any unusual levels of aldehydes or VOCs in either of the homes.

- Dust characterization of both homes is consistent with typical residential dust.

- The concentrations of various metals measured in surface dust from each home were found to be acceptable and well below the available screening level, health-based benchmarks.

- Low (trace) amounts of cat allergen (Fel d 1) were identified in the return air duct at 144 Groesbeek Street.

- Significant concentrations of dog allergen (Can f 1) and a low level of dust mite allergen (Der f 1) were found in the master bedroom at 4 Darden Street. In addition, a low to significant concentration of dust mite allergen (Der f 1) was measured in the northwest corner of bedroom 1.

- Pesticide concentrations in dust obtained from the two homes were consistent with typical ranges reported in the peer-reviewed literature, except for permethrin and cypermethrin at 144 Groesbeek Street.

- The screening tests determined that permethrin and cypermethrin concentrations in a dust sample obtained from the air return duct from 144 Groesbeek were at the high end of the distribution of values found in the peer-reviewed literature (i.e., the high end of normal). As this sample may not reflect exposure conditions in the living area of the home, EH&E recommends analyzing archived dust samples from 144 Groesbeek Street for pesticides in order to fully characterize possible exposure concentrations.

- Both surface and air fungi concentrations in the two homes were typical. Results do not indicate the presence of fungal contamination in either home.

- There were no contaminants found at levels of concern in the drinking water of either home.

1.4 CONCLUSIONS

Based on the observations of the EH&E field staff and analysis of the results of the in-home sampling and testing, as well as interviews with CID and CPSC field investigators and a review of previously conducted testing of drywall from the homes, EH&E concludes that 144 Groesbeek Street and 4 Darden Street do not contain problem drywall. Further, the investigation included measurements for a series of parameters that are considered indicators of IEQ conditions in homes generally and also included a number of measurements to provide a more comprehensive assessment of potential environmental issues. All testing was conducted in accordance with standard or published methodologies that are widely used for assessing IEQ conditions in indoor environments. Based on these measurements, the indoor environmental and building systems investigation did not identify any issues or contaminants in the air, dust, or water of either home at levels that would potentially pose a health concern to residents of the homes. One dust sample collected at 144 Groesbeek Street that was screened for pesticide content was observed to have concentrations of permethrin and cypermethrin in dust from the air duct, which were above the median concentrations reported in the literature and are similar to concentrations at the 95^{th} percentile of reported values. Although the concentrations measured in this sample are not considered hazardous, EH&E recommends analyzing additional dust samples collected from other locations at 144 Groesbeek Street for pesticides in order to characterize further the range of potential exposure conditions in this home.

2.0 BACKGROUND

2.1 PURPOSE AND SCOPE

Under contract with the U.S. Consumer Product Safety Commission (CPSC), Environmental Health & Engineering, Inc. (EH&E) concluded its investigation of the indoor environmental quality (IEQ) of two homes that are part of the housing provided to families of military personnel stationed at Fort Bragg, North Carolina. The homes are located at 144 Groesbeek Street (Ardennes neighborhood), Fort Bragg, North Carolina, and 4 Darden Street (Linden Oaks neighborhood), Cameron, North Carolina (collectively "the homes"). This environmental investigation was conducted, in support of the U.S. Army's investigation of several infant deaths from undetermined causes in Fort Bragg military housing. Initial reports inferred that the homes potentially contained problem drywall.[3]

This comprehensive environmental and building investigation had two primary objectives:

1) Determining whether problem drywall was present in either, or both, of these homes, and, if so, determining its potential impacts on the indoor environment.
2) Performing a detailed investigation of the indoor environment and associated building systems at each home to examine other possible environmental causes that may have contributed to the infant deaths.

2.2 HOME PROFILES

The home located at 144 Groesbeek Street is a two-story, single family, slab on grade structure with an attached garage. The home, constructed circa 2005, is situated within the Fort Bragg Military complex in the Ardennes neighborhood and is constructed as part of a townhouse complex. The home occupies a footprint of approximately 1,100 square feet, including the 275 square foot garage. Total living floor area for the home is

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1,800 square feet and comprises four bedrooms on the second floor, a living room, family room, and kitchen on the first floor, and three bathrooms.

Figure 2.1 144 Groesbeek Street

The home at 4 Darden Street was constructed circa 2007, and is located approximately 10 miles outside of the Fort Bragg Military complex in the Linden Oaks neighborhood. The home is also constructed as part of a townhouse complex and comprises a two-story, single family, slab on grade structure with an attached garage. The home is situated on a footprint of approximately 1,000 square feet, including the 275 square foot garage. Total floor area for the home is 1,800 square feet and comprises four bedrooms on the second floor, a living room, family room, and kitchen on the first floor, and three bathrooms.

Figure 2.2 4 Darden Street

3.0 STUDY DESIGN

3.1 OVERVIEW

On September 28, 2010, investigators from EH&E and the CPSC met with U.S. Army CID representatives at Fort Bragg to review background information related to the homes. The team conducted an initial site visit at the homes and spoke with Fort Bragg officials.

From October 4, 2010, to October 7, 2010, a four-person research team from EH&E conducted in-home inspections and testing at the homes. The research team comprised of two senior scientists, one senior engineer, and one technical specialist was organized to include expertise in the following fields: building systems and performance, exposure assessment, risk assessment, and industrial hygiene. Each member of the four-person field team had extensive experience conducting in-home testing for problem drywall as well as experience conducting general IEQ investigations. The on-site research team was supported by principal scientists, senior scientists and senior engineers from EH&E's main office.

3.2 FIELD ACTIVITIES

Field activities were designed and carried out to address the study objectives. These activities are outlined in Table 3.1 and are described in detail in the Methods section.

The assessment of the potential for either of these homes to be impacted by problem drywall focused on parameters that were previously found to be indicative of homes with problem drywall (EH&E 2010a; EH&E 2010b). These parameters include: 1) elevated rates of corrosion observed and measured in the home; 2) elevated concentrations of elemental sulfur (S_8), as well as elevated levels of strontium and carbonate in the drywall material; and 3) elevated levels of hydrogen sulfide and other reduced sulfur compounds in indoor air.

The composition of the drywall was assessed in each home and in laboratory analysis of drywall samples removed from the home by EH&E investigators. The in-home screening was performed by obtaining measurements of the strontium concentration of the drywall on multiple locations of every wall and ceiling in the home. Multiple bulk samples of drywall were taken from behind the electrical outlet cover on each wall (i.e., at least one sample was taken per wall in each room). These samples are referred to as "core samples" in this report. Additionally, larger bulk (6 inch by 6 inch) drywall samples were taken from multiple ceilings and rooms in the home. The bulk and core samples were analyzed in the laboratory for strontium and carbonate content. Both two-week integrated and discrete air samples were obtained to characterize the indoor and outdoor air of each of the homes (see Table 3.1, Parameter Monitored). The characterization of the potential for the indoor environment to be associated with corrosion was determined by: 1) visual inspection and rating of copper ground wires at electrical outlets and copper components in building systems (e.g., cooling coils); and 2) determination of copper and silver corrosion rates on pristine corrosion classification coupons over a two-week period.

The building systems in each home were evaluated by examining mechanical systems and their performance, assessing thermal control and zoning, and quantifying the ventilation rate within the homes.

The environmental assessment also included obtaining measurements of a broad suite of potential indoor environmental contaminants in air, dust, and water, including: volatile organic compounds, aldehydes, fungi, allergens, pesticides, and metals.

Table 3.1 Overview of Field Activities Performed to Address Study Objectives

Objective	Focus	Parameter Monitored	Sample Type
Problem drywall assessment	Source characterization	Elemental sulfur (S_8)	Core sample
		Strontium	In situ and core sample
		Carbonate	Core sample
	Air	Hydrogen sulfide (H_2S)	2-week integrated measure
		Reduced sulfur compounds	Discrete sample
	Corrosion	Copper grounding wires	Visual assessment
		Copper and silver corrosion classification coupons	2-week integrated measure
Environmental and Building Investigation	Systems Performance	Mechanical systems	Visual inspection and monitoring
		Ventilation	Air exchange rate
		Building envelope	Blower door test
		Temperature/relative humidity	Short-term and 2-week continuous monitoring
	Air	Volatile organic compounds (VOCs)	Discrete samples
		Aldehydes	Discrete samples and 2-week integrated samples
		Fungi	Discrete sample
	Dust	Metals	Dust collection
		Allergens	Dust collection
		Pesticides	Dust collection
		Fungi	Surface wipes and dust collection
	Water	Hydrogen sulfide	Discrete sample
		Metals	Discrete sample
		VOCs	Discrete sample
		Polychlorinated biphenyls	Discrete sample
		Pesticides/herbicides/ insecticides	Discrete sample
		Organic compounds	Discrete sample
		General chemistry	Discrete sample
		Perchlorate	Discrete sample
		Coliform bacteria	Discrete sample

4.0 METHODS

4.1 INTRODUCTION

The following sections describe the sampling and analytical procedures used to collect data in each home, the procedures used to process and analyze the data, and the quality assurance and quality control (QA/QC) procedures implemented by EH&E.

4.2 SOURCE DRYWALL MEASUREMENTS

Material characteristics of representative sections of drywall from the two homes were determined using gas chromatography/electron capture detector (GC/ECD), x-ray fluorescence (XRF), and Fourier transform infrared (FTIR) spectrometry. These methods have been assessed previously and validated for analysis of markers in problem drywall (EH&E 2010b). As described below, analysis for strontium content was conducted using XRF in the field at each home. More detailed analyses, using a combination of GC/ECD, XRF, and FTIR, subsequently were obtained in the laboratory from the bulk samples of drywall collected and archived from each home.

4.2.1 Elemental Sulfur (S_8) Analysis by GC/ECD

In each home, a total of 10 drywall samples were analyzed for S_8 content. The samples selected for analysis were chosen in a manner that maximized the likelihood of detecting S_8 and also ensured representative samples were analyzed. This was done by first selecting the drywall samples with the highest strontium samples determined by XRF because strontium and S_8 have been found to be positively correlated in problem drywall (EH&E 2010b). Once samples with the highest strontium levels were selected, additional samples were selected by choosing drywall boards across the full distribution of strontium concentrations as determined by XRF.

Drywall samples were sent to an independent laboratory (Columbia Analytical Services, Inc., Simi Valley, California) for analysis of orthorhombic cyclooctasulfur (S_8) using GC/ECD. A detailed description of this method can be found in a previous report (EH&E 2010b). The laboratory achieved a reporting limit of 5.0 mg/kg for the S_8 analysis.

4.2.2 Strontium Analysis by X-Ray Fluorescence

An XRF Spectrometer (Innov-X ALPHA™ Handheld XRF, Innov-X Systems, Inc., Woburn, Massachusetts) provided on-site and laboratory metals analysis in this study. This device is a handheld portable XRF analyzer and was used to identify and quantify the elements in representative wall surfaces in each home as well as in the bulk samples collected from each home.

Multiple XRF measurements were obtained on each wall and ceiling surface in each of the two homes included in the study. In-home measurements were taken through any wall coatings, such as paint or plaster. The elemental scanning profile for each location was stored on the internal flash memory card of the XRF. The location of each measurement was marked on a floor plan and recorded in the master field log binder. Data files were downloaded daily and saved on a central file server. In addition, drywall bulk samples collected from each of the homes were scanned, analyzed, and downloaded with the XRF software package in EH&E's main facility. More than 100 (n=103 at 144 Groesbeek Street; n=120 at 4 Darden Street) samples of drywall were collected from each test house and analyzed using XRF at EH&E's facility. Analysis of the drywall samples removed from the home was conducted on the bulk material and not through paint or paper layers.

4.2.3 Carbonate Analysis by Fourier Transform Infrared Spectrometry

Bulk samples of drywall collected from the two homes were tested using FTIR at EH&E's main facility. FTIR measurements were obtained using the A2 Technologies Exoscan instrument, a full scanning Fourier transform mid-infrared spectrometer, equipped with a Michelson interferometer and non-hydroscopic optics. The diffuse reflectance Exoscan was configured for porous and rough surfaced materials. It has an optical design that focuses an infrared light beam perpendicular to the sample surface, resulting in diffusely scattered infrared light. This scattered infrared light interacts with the sample and is subsequently reflected back to the detector in the Exoscan. This diffuse reflectance configuration provides spectra for drywall analysis. The diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy technique has been widely accepted as a highly sensitive means of measuring inorganic compounds. DRIFT spectra of pure non-diluted minerals are different in appearance from more traditional FTIR spectra due to several very intense absorbance bands that appear as negative peaks (specular) and multiple weaker absorbance bands, which are observed as positive peaks (diffuse). DRIFT technology was used in this study to obtain FTIR measurements.

The representative drywall bulk samples collected from the homes (n= 103 at 144 Groesbeek Street, n=120 at 4 Darden Street) were analyzed using FTIR. Each sample was scanned, analyzed, and the results downloaded with the A2 Technologies Microlab PC software package.

4.3 AIR SAMPLING METHODS

Air samples were collected in representative areas at each home (master bedroom, secondary bedroom, living room, and outdoors) and analyzed using standard reference methods. The following sections summarize the air sampling methods used, the analytes or groups of analytes quantified in each sample, and the specific analytical methods employed.

4.3.1 Reduced Sulfur Gases

Grab air samples were collected and analyzed for a suite of 20 reduced sulfur gases according to validated procedures (CAS reduced sulfur analysis method; American Society for Testing and Materials [ASTM] Method D5504 *Standard Test Method for Determination of Sulfur Compounds in Natural Gas and Gaseous Fuels by Gas Chromatography and Chemiluminescence)*. Whole air samples were collected into Foil Flex bags (SKC Cat. No. 245-01) using the SKC Vac-U-Chamber™. Gases collected using these bags, including hydrogen sulfide, are stable for at least two days or longer in single stainless steel-fitted FlexFoil bags (SKC Publication 1796 Rev 0912). The Vac-U-Chamber is a rigid box that allows air sampling bags to be filled directly (without sample air passing through a pump) from ambient atmospheres through use of negative pressure differentials; all surfaces that came in contact with sample air were constructed of stainless steel or Teflon tubing (SKC Cat. No. 231-940). The sampling pumps used to fill/evacuate the chambers were adjusted to a nominal flow rate of 1.0 liter per minute, and each grab sample was collected for approximately 30 seconds, for a total volume of approximately 0.5 liters for each sample.

Air samples were collected at three indoor locations and one outdoor location per test house. In addition, one duplicate sample was collected per sample set at each home (the analytical laboratory was blinded to all sample designations, including duplicate samples). Due to the reactive nature of many reduced sulfur gases, the reference method (ASTM Method D5504) recommends that sample analysis occur within 24 hours of collection. To satisfy this requirement, the reduced sulfur samples were collected at each test home and shipped to the analytical laboratory via first priority overnight delivery.

ASTM D5504 is a gas chromatography method with a sulfur chemiluminescence detector (GC/SCD). The chemical analyses were conducted by Columbia Analytical Services, Inc., Simi Valley, California. Table 4.1 shows the reduced sulfur compound analytes and the laboratory reporting limits for each analyte. Analysis of duplicate samples is discussed further in Section 4.9.2.

Table 4.1 Targeted Reduced Sulfur Gases and Laboratory Reporting Limits

Compound	Laboratory Reporting Limit ($\mu g/m^3$)
2,5-Dimethylthiophene	23
2-Ethylthiophene	23
3-Methylthiophene	20
Carbon disulfide	7.8
Carbonyl sulfide	12
Diethyl disulfide	12
Diethyl sulfide	18
Dimethyl disulfide	9.6
Dimethyl sulfide	13
Ethyl mercaptan	13
Ethyl methyl sulfide	16
Hydrogen sulfide	7
Isobutyl mercaptan	18
Isopropyl mercaptan	16
Methyl mercaptan	9.8
Tetrahydrothiophene	18
Thiophene	17
n-Butyl mercaptan	18
n-Propyl mercaptan	16
tert-Butyl mercaptan	18

$\mu g/m^3$ micrograms per cubic meter

4.3.2 Volatile Organic Compounds (SUMMA Canister Method)

Whole air samples for VOCs were collected with individually cleaned and certified SUMMA canisters obtained from Columbia Analytical Services, Inc. located in Simi Valley, California. Each flow controller used to fill the SUMMA canisters during sampling was also calibrated and conditioned by Columbia Analytical Services, Inc. prior to use. Flow controllers were calibrated to achieve 4-hour sample durations. Canisters were protected from radiant heat, as well as moisture, prior to, during, and after sampling.

In the two homes, SUMMA canister samples were collected at three indoor locations and at one outdoor location. One duplicate sample was collected in each home and sent to the analytical laboratory as a blinded sample. Also, one field blank sample was sent to the laboratory for analysis. These procedures were used to assess potential canister contamination during shipping, preparation, or analysis of the samples. Analysis of blank and duplicate samples is discussed further in Section 4.9.2.

Whole air VOC samples were analyzed using gas chromatography/mass spectrometry (GC/MS). The analyses were performed according to EPA Method TO-15 from the EPA's Second Edition *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. The whole air samples were analyzed for 75 specific VOCs reported as part of the laboratory's standard TO-15 analysis. In addition to the 75 standard target VOCs, the laboratory reported the estimated concentrations of an additional 23 VOCs present in the samples as tentatively identified compounds (TICs). The standard list of 75 analytes includes compounds for which the method has been validated in accordance with laboratory QA/QC standards, while TICs are compounds that are likely present, but the method has not been comprehensively validated for its capacity to identify these compounds. The laboratory identifies TICs by examining the mass spectrograph from each sample and identifying responses that do not correspond to the known signature peaks associated with the 75 target compounds. TICs (and their concentration) are then estimated based on a review of spectral information in the laboratory's internal library. Table 4.2 shows the list of 75 standard VOCs targeted by the laboratory and the corresponding laboratory reporting limits for this study.

Table 4.2 Targeted Volatile Organic Compounds (VOCs) by Canister Method and Laboratory Reporting Limits

Compound	Laboratory Reporting Limits ($\mu g/m^3$)
1,1,1-Trichloroethane	0.12 – 0.17
1,1,2,2-Tetrachloroethane	0.12 – 0.17
1,1,2-Trichloroethane	0.12 – 0.17
1,1,2-Trichlorotrifluoroethane	0.12 – 0.17
1,1-Dichloroethane	0.12 – 0.17
1,1-Dichloroethene	0.12 – 0.17
1,2,4-Trichlorobenzene	0.61 – 0.83
1,2,4-Trimethylbenzene	0.61 – 0.83
1,2-Dibromo-3-chloropropane	0.61 – 0.83
1,2-Dibromoethane	0.12 – 0.17
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	0.61 – 0.83
1,2-Dichlorobenzene	0.12 – 0.17
1,2-Dichloroethane	0.12 – 0.17
1,2-Dichloropropane	0.12 – 0.17
1,3,5-Trimethylbenzene	0.61 – 0.83
1,3-Butadiene	0.24 – 0.33
1,3-Dichlorobenzene	0.12 – 0.17
1,4-Dichlorobenzene	0.12 – 0.16
1,4-Dioxane	0.61 – 0.83
2-Butanone (MEK)	6.1 – 8.3
2-Hexanone	0.61 – 0.83
2-Propanol (isopropyl alcohol)	1.2 – 1.6
3-Chloro-1-propene (allyl chloride)	0.12 – 0.17
4-Ethyltoluene	0.61 – 0.83
4-Methyl-2-pentanone	0.61 – 0.83
Acetone	6.1 – 8.3
Acetonitrile	0.61 – 8.3
Acrolein	2.4 – 3.3
Acrylonitrile	0.61 – 0.83
Benzene	0.12 – 0.17
Benzyl chloride	0.61 – 0.83
Bromodichloromethane	0.12 – 0.17
Bromoform	0.61 – 0.83
Bromomethane	0.12 – 0.17
Carbon disulfide	6.1 – 8.3
Carbon tetrachloride	0.12 – 0.16
Chlorobenzene	0.12 – 0.17
Chloroethane	0.12 – 0.17
Chloroform	0.12 – 0.17
Chloromethane	0.24 – 0.33
Cumene	0.61 – 0.83
Cyclohexane	0.61 – 0.83
Dibromochloromethane	0.12 – 0.17
Dichlorodifluoromethane (CFC 12)	0.61 – 0.83
Ethanol	6.1 – 8.3
Ethyl acetate	0.61 – 0.83
Ethylbenzene	0.61 – 0.83

Table 4.2 Continued

Compound	Laboratory Reporting Limits ($\mu g/m^3$)
Hexachlorobutadiene	0.61 – 0.83
Methyl methacrylate	0.61 – 0.83
Methyl tert-Butyl ether	0.12 – 0.17
Methylene chloride	0.61 – 0.83
Naphthalene	0.61 – 0.83
Propene	0.61 – 0.83
Styrene	0.61 – 0.83
Tetrachloroethene	0.12 – 0.17
Tetrahydrofuran (THF)	0.61 – 0.83
Toluene	0.61 – 0.83
Trichloroethene	0.12 – 0.17
Trichlorofluoromethane	0.12 – 0.17
Vinyl acetate	6.1 – 8.3
Vinyl chloride	0.12 – 0.17
alpha-Pinene	0.61 – 0.83
cis-1,2-Dichloroethene	0.12 – 0.17
cis-1,3-Dichloropropene	0.61 – 0.83
d-Limonene	0.61 – 0.83
m,p-Xylenes	0.61 – 0.83
n-Butyl acetate	0.61 – 0.80
n-Heptane	0.61 – 0.83
n-Hexane	0.61 – 0.83
n-Nonane	0.61 – 0.83
n-Octane	0.61 – 0.83
n-Propylbenzene	0.61 – 0.83
o-Xylene	0.61 – 0.83
trans-1,2-Dichloroethene	0.12 – 0.17
trans-1,3-Dichloropropene	0.61 – 0.83

$\mu g/m^3$ micrograms per cubic meter

4.3.3 Volatile Organic Compounds (Sorbent Tube Method)

Active air samples were collected and analyzed according to EPA Method TO-17 for selected VOCs using individually cleaned sorbent media containing Tenax TA. This method was selected to ensure that a broad range of VOCs were targeted during the study. The sorbent tubes were provided by the analytical laboratory that performed the analysis (Columbia Analytical Services, Inc.).

Each tube was connected to a personal sampling pump adjusted to a nominal flow rate of 100 milliliters per minute (ml/min) that ran for approximately 40 minutes. Pumps were inspected and batteries conditioned (i.e., charged) before each sampling period in order to reduce the possibility of faults during sampling. Pump flows were verified by a calibrated flow meter (Drycal® flow meter, Bios International Corporation) at the start and end of the sampling period. The flow rates measured at the start and end of sampling were averaged in order to calculate the total volume of air sampled. Start and end flows used to calculate the sample volumes were within 1.5% on average.

In the two homes, VOC samples were collected on the sorbent tubes at three indoor locations and at one outdoor location. One duplicate sample was collected in each home and sent to the analytical laboratory as a blinded sample. One field blank was collected for the sample set. Analysis of blank and duplicate samples is discussed further in Section 4.9.2.

Active VOC samples were analyzed using thermal desorption/gas chromatography/mass spectrometry. The analyses were performed according to EPA Method TO-17 from the EPA's Second Edition *Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air*. The active air samples were analyzed for 52 specific VOCs for which the method has been validated and met laboratory QA/QC standards. In addition to the standard list of target VOCs, the laboratory reported the estimated concentrations of 20 additional VOCs likely present in the samples as TICs, using a similar methodology discussed in Section 4.3.2. Table 4.3 shows the list of the 52 standard VOCs reported by the laboratory and the laboratory reporting limits for each.

Table 4.3 Targeted Volatile Organic Compounds (VOCs) by Active Air Sampling Method and Laboratory Reporting Limits Based on 4 Liters of Air Sampled

Compound	Laboratory Reporting Limits ($\mu g/m^3$)
1,1,1-Trichloroethane	0.12 – 0.13
1,1,2,2-Tetrachloroethane	0.12 – 0.13
1,1,2-Trichloroethane	0.12 – 0.13
1,1-Dichloroethane	0.12 – 0.13
1,1-Dichloroethene	0.12 – 0.13
1,2,4-Trichlorobenzene	0.12 – 0.13
1,2,4-Trimethylbenzene	0.12 – 0.13
1,2-Dibromo-3-chloropropane	0.12 – 0.13
1,2-Dibromoethane	0.12 – 0.13
1,2-Dichlorobenzene	0.12 – 0.13
1,2-Dichloroethane	0.12 – 0.13
1,2-Dichloropropane	0.12 – 0.13
1,3,5-Trimethylbenzene	0.12 – 0.13

Table 4.3 Continued

Compound	Laboratory Reporting Limits ($\mu g/m^3$)
1,3-Dichlorobenzene	0.12 – 0.13
1,4-Dichlorobenzene	0.12 – 0.13
1,4-Dioxane	0.25
2,2,4-Trimethylpentane (isooctane)	0.12 – 0.13
2-Butanone (MEK)	0.25
2-Hexanone	0.12 – 0.13
2-Propanol (isopropyl alcohol)	0.49 – 0.50
4-Methyl-2-pentanone	0.25
Acetone	1.2 – 1.3
Benzene	1.2 – 1.3
Bromodichloromethane	0.12 – 0.13
Bromoform	0.12 – 0.13
Carbon disulfide	0.49 – 0.50
Carbon tetrachloride	0.12 – 0.13
Chlorobenzene	0.12 – 0.13
Chloroform	0.12 – 0.13
Cumene	0.12 – 0.13
Cyclohexane	0.12 – 0.13
Dibromochloromethane	0.12 – 0.13
Ethylbenzene	0.12 – 0.13
Hexachlorobutadiene	0.12 – 0.13
Methyl tert-Butyl ether	0.12 – 0.13
Methylene chloride	0.49 – 0.50
Naphthalene	0.12 – 0.13
Styrene	0.25
Tetrachloroethene	0.12 – 0.13
Tetrahydrofuran (THF)	0.25
Toluene	0.12 – 0.13
Trichloroethene	0.12 – 0.13
Trichlorofluoromethane	0.12 – 0.13
Trichlorotrifluoroethane	0.49 - 0.50
cis-1,2-Dichloroethene	0.12 – 0.13
cis-1,3-Dichloropropene	0.12 – 0.13
m,p-Xylenes	0.25
n-Heptane	0.12 – 0.13
n-Hexane	0.12 – 0.13
n-Octane	0.12 – 0.13
o-Xylene	0.12 – 0.13
trans-1,2-Dichloroethene	0.12 – 0.13
trans-1,3-Dichloropropene	0.12 – 0.13

$\mu g/m^3$ micrograms per cubic meter

4.3.4 Aldehydes (Active Air Sampling)

Active air samples were collected and analyzed according to EPA Method TO-11A for aldehydes, including formaldehyde, using 2,4-dinitrophenylhydrazine (DNPH) coated sorbent tubes with a built-in ozone scrubber (SKC Cat. No. 226-120). Each tube was connected to a personal sampling pump adjusted to a nominal flow rate of 500 ml/min that ran for approximately 200 minutes. Pump filters were inspected and batteries conditioned (i.e., charged) before each sampling period in order to reduce the possibility of faults during sampling. Pump flows were verified by a calibrated flow meter (Drycal® flow meter, Bios International Corporation) at the start and end of the sampling period. The flow rates measured at the start and end of sampling were averaged in order to calculate the total volume of air sampled. Start and end flows used to calculate the sample volumes were within 2.7% on average.

Active aldehyde samples were collected at three indoor locations and one outdoor location at each house. At one indoor station per house, duplicate samples for aldehyde analysis were collected. In addition, one field and one shipping blank were collected for the sample sets from each home. All aldehyde samplers were refrigerated before and after sample collection, and during shipment. Duplicate and blank samples were sent to the analytical laboratory in a blinded fashion. Statistical analysis of blank and duplicate samples is discussed further in Section 4.9.2.

In the EPA Method TO-11A, aldehydes in the sample air react with DNPH to form stable hydrazones, which are extracted from the silica gel and analyzed by high performance liquid chromatography coupled with an ultraviolet detector (HPLC-UV). The aldehyde analyses were conducted by Columbia Analytical Services, Inc., Simi Valley, California. Table 4.4 lists the 12 aldehyde compounds assessed during the study and the associated laboratory reporting limits for each aldehyde.

Table 4.4 Targeted Aldehydes and Laboratory Reporting Limits

Compound	Laboratory Reporting Limits (μg/m^3)*
2,5-Dimethylbenzaldehyde	1.0
Acetaldehyde	1.0
Benzaldehyde	1.0
Butyraldehyde	1.0
Crotonaldehyde, Total	1.0
Formaldehyde	1.0
Isovaleraldehyde	1.0
Propionaldehyde	1.0
Valeraldehyde	1.0
m,p-Tolualdehyde	2.0 – 2.1
n-Hexaldehyde	1.0
o-Tolualdehyde	1.0

μg/m^3 micrograms per cubic meter

* Calculated based by using the reporting limit in μg/sample and the nominal air sampling volume of 0.5 cubic meter.

4.3.5 Passive Diffusive Sampling

Passive monitors were utilized to collect two-week integrated samples for hydrogen sulfide and aldehydes using Radiello Diffusive Sampling Systems (Buzica et al. 2008; Cocheo et al. 1996; Sigma-Aldrich 2006; Swaans et al. 2007).

The various analytes collected by each type of passive system are summarized in Table 4.5, which also lists the laboratory reporting limits achieved for the analysis.

Table 4.5 Passive Sampling, Targeted Analytes and Laboratory Reporting Limits

Compound	Laboratory Reporting Limits ($\mu g/m^3$)*
Aldehydes	
Acetaldehyde	0.12 – 0.48
Acrolein	0.15 – 0.61
Benzaldehyde	0.06 – 0.22
Formaldehyde	0.20 – 0.81
Hexanal	0.28 – 1.1
Isopentanal	0.08 – 0.33
Methyl Ethyl Ketone/Butyraldehydes	0.46 – 1.8
Pentanal	0.19 – 0.74
Propanal	0.13 – 0.52
Other	
Hydrogen sulfide	0.59 – 0.63

$\mu g/m^3$ micrograms per cubic meter

* Reporting limits provided by the laboratory in $\mu g/m^3$, based on the analyte-specific sampling rate and a nominal sampling time for each sample batch.

Passive air samples have been demonstrated as a valid tool in residential exposure assessment (Pellizzari et al. 2001; WHO 2000). For each analyte there is a specific chemiadsorbing cartridge and sampling protocol. The diffusive sampler is composed of two surfaces, a diffusive surface and an adsorbing surface. The sampling process is driven by the concentration gradient as the gaseous molecules cross the diffusive surface towards the adsorbing surface. The molecules are trapped by the selected adsorbing material in each type of passive diffusion sampler (Sigma-Aldrich 2006). The specific passive sampling system and the analytical technique used for each class of analyte are shown in Table 4.6.

Table 4.6 Summary of Target Parameters, Passive Air Sampling

Analyte	Radiello Badge Type	Analytical Method*
Aldehydes	165	Aldehydes by Radiello 165, HPLC-UV
Hydrogen sulfide	170	Hydrogen sulfide by Radiello 170 Spectrophotometer at 665 nm

HPLC-UV high performance liquid chromatography with ultraviolet detector
nm nanometer

* Analytical methods provided by Fondazione Salvatore Laboratory, Radiello Manual, Supelco Edition.

Three indoor locations and one outdoor sampling location were selected in each home. At one indoor station per house, a duplicate sampling device for each analyte was used to assess repeatability of these methods. To begin sampling, the adsorbent cartridge was transferred from the sealed storage tube into the diffusive body and was screwed onto the supporting plate. Field personnel recorded the start time and date on the field log sheet, and the assembled device was attached to the sampling tripod at a sampling height of approximately four feet. To achieve the desired limit of detection, the sampling devices were deployed for 14 days in each of the test homes. Upon completion of the sampling period a field investigator retrieved the sampling device, sealed the chemiadsorbing cartridge into the storage tube and shipped the sample to the analytical laboratory. All samples were temperature controlled before and after the sampling period and QA/QC samples were sent to the analytical laboratory in a blinded manner.

Statistical analysis of blank and duplicate samples is discussed further in Section 4.9.2.

The concentrations of H_2S and several aldehydes measured in each study home were calculated using Equation 4.1:

$$C = \frac{m}{Q_k * t} * 1{,}000{,}000 \qquad \text{(Equation 4.1)}$$

where:

C	=	concentration in micrograms per cubic meter ($\mu g/m^3$)
m	=	mass in μg
Q_k	=	analyte-specific sampling rate, adjusted for temperature at the sampling site, in ml/min
t	=	sample duration in minutes
1,000,000	=	conversion factor, ml/m^3

Where appropriate, sampling rates for indoor samples were adjusted to account for different temperatures and their potential effect on the sampling rate by using the mean indoor temperature measured in each home. For outdoor samples, the sampling rates were adjusted using the mean outside air temperature over the sampling period.[4] The reported passive sampling results were adjusted for temperature in accordance with

[4] Outside air temperatures were obtained from the nearest National Weather Service weather station.

Equation 4.2, which is provided by the supplier of the passive diffusion samplers (Sigma-Aldrich 2006).

$$Q_k = Q_{298} * \left(\frac{K}{298} \right)^{\exp} \quad \text{(Equation 4.2)}$$

where:

- Q_k = analyte-specific sampling rate, adjusted for temperature at the sampling site, in ml/min
- Q_{298} = analyte-specific sampling rate at 298 K (25 °C) in ml/min
- K = temperature at the sampling site, in degrees kelvin
- exp = diffusion sampler-specific factor (provided by manufacturer)

Analyte-specific sampling rates at 298 K (Q_k) and the sampler-specific factor (exp) are listed in Table 4.7, and are all provided by the manufacturer, based on a standard temperature of 298 K (Sigma-Aldrich 2006). No sampling rate adjustments for relative humidity or wind speeds are recommended because rates have been shown to be constant over wide ranges of relative humidity and wind speed conditions (Sigma-Aldrich 2006).

Table 4.7 Sampling Rates for Targeted Analytes for Passive Sampling

Compound	CAS #	Sampling Rate in ml/min at 298 K (Q_{298})	exp
Acetaldehyde	75-07-0	84	0.35
Acrolein	107-02-8	33	0.35
Benzaldehyde	100-52-7	92	0.35
Formaldehyde	50-00-0	99	0.35
Hexanal	66-25-1	18	0.35
Isopentanal	590-86-3	61	0.35
Butanal*	123-72-8	11	0.35
Pentanal	110-62-3	27	0.35
Propanal	123-38-6	39	0.35
Hydrogen sulfide	7783-06-4	69	3.8

CAS # Chemical Abstract Service number
ml/min milliliters per minute
K degrees kelvin
exp sampler-specific factor provided by manufacturer

* Butanal coelutes with isobutanal and methyl ethyl ketone. The corresponding peak was reported by the laboratory as butanal.

All analysis of the diffusive sampling media was conducted by Air Toxics Ltd. located in Folsom, California.

4.3.6 Total Culturable Airborne Fungal Spores (Viable)

Sampling for analysis of total culturable airborne fungal spores was conducted at six indoor locations at 4 Darden Street and at seven locations at 144 Groesbeek Street. In addition, a replicate sample was collected and analyzed at one indoor location. For comparison purposes, two outdoor samples were collected prior to indoor sampling and two outdoor samples were collected after indoor sampling at each home. One field and one shipping blank were included in the sample sets from each home.

Sampling for culturable airborne fungal spores was carried out using Andersen N-6 impactors connected to a vacuum pump. The samplers were swabbed with alcohol prior to each use, and air dried. Samples were collected on malt extract agar (MEA) for five minutes each at a flow rate of 28.3 liters per minute. Pump flows were verified by a calibrated rotameter at the start and end of the sampling period.

The samples were sent to EMLab P&K (Cherry Hill, New Jersey) for culturing and analysis. MEA plates were incubated at 25 degrees Celsius (°C) for seven days. MEA serves as a diagnostic media for the identification of fungal species, and it also selects against the growth of most bacteria. Fungi were identified to the species level and reported as colony forming units per cubic meter (cfu/m^3) of air sampled; the laboratory reporting limit was 7 cfu/m^3.

4.3.7 Total Airborne Fungal Spores (Viable and Non-viable)

Sampling for analysis of total viable and non-viable airborne fungal spores was conducted at six indoor locations at 4 Darden Street and at seven locations at 144 Groesbeek Street. In addition, a replicate sample was collected and analyzed at one indoor location. For comparison purposes, two outdoor samples were collected prior to indoor sampling and two outdoor samples were collected after indoor sampling at each home. One field and one shipping blank were included in the sample sets from each home. This sampling method reflects the total numbers of spores present in the air sample, not just those that are viable and may proliferate in indoor environments. Samples for analyses of levels of viable and non-viable fungi spores in the air were collected with an Air-O-Cell Volumetric Spore Sampler (SKC Inc., Eighty-Four, Pennsylvania). Samples were collected onto Air-O-Cell air sampling cassettes for five minutes. All cassettes were sent to EMLab P&K (Cherry Hill, New Jersey) for analysis by light microscopy. Pump flows were verified by a calibrated rotameter at the start and end of the sampling period. Results were reported as spores per cubic meter of air sampled. The laboratory reporting limit was 13 spores per cubic meter (spores/m^3); for example, a total count of 13 spores/m^3 indicated that, based on the volume of air sampled, one spore was present in the sample analyzed.

4.4 SURFACE SAMPLING METHODS

Dust samples were collected from various surfaces in each home and analyzed for a wide range of parameters. The following sections describe the surface sampling methods and the analytical methods used.

4.4.1 Allergens

Bulk samples of settled dust from selected floor surfaces in the two homes (n=4 for 144 Groesbeek Street, n=3 for 4 Darden Street) were collected using a Eureka Mighty-Mite canister vacuum cleaner (The Eureka Co., Bloomington, Indiana) modified to collect dust in a DustChek™ thimble (EML P&K Products, San Bruno, California). At each sample location, a measured surface area was vacuumed; sample areas were measured with rulers or tape measures. After sampling, the sample thimbles were sealed in a clean plastic bag and transported, under chain-of-custody, to EMLab P&K (Phoenix, Arizona) for analysis. One field blank was also submitted for quality assurance purposes.

The settled dust samples were analyzed for cat antigen (Fel d 1), dog antigen (Can f 1), cockroach antigen (Bla g 1) and two types of dust mite antigens (*Dermatophagoides pteronyssinus* [Der p 1] and *Dermatophagoides farinae* [Der f 1]) using standard enzyme-linked immunosorbent assay (ELISA) methods. The results are expressed in µg of antigen per gram of dust sampled, except for cockroach allergens, which are reported as units of allergen per gram of dust. The detection limits achieved by the laboratory are listed in Table 4.8.

Table 4.8 Laboratory Reporting Limits for Allergens in Bulk Dust Samples

Allergen	Laboratory Reporting Limit	Units
Cat (Fel d 1)	0.16	μg/g
Cockroach (Bla g 1)	1.6	U/g
Dog (Can f 1)	0.39	μg/g
Dust mite (Der f 1)	0.39	μg/g
Dust mite (Der p 1)	0.39	μg/g

μg/g micrograms per gram
U/g units per gram

4.4.2 Surface Mold Growth

Representative surface samples were collected from selected HVAC-system surfaces (diffusers and duct interiors) in the two homes (n=5 for 144 Groesbeek Street, n=8 for 4 Darden Street) for evaluation of the presence of fungal spores and growth structures. Two field blanks were also collected during the study for quality assurance purposes. Surface sampling differentiates mold from dust or other non-biological debris. It is also useful for identifying the presence of types of mold that indicate elevated moisture conditions. Results for tape samples provide an assessment of whether there is growth on the surface (indicated by the presence of growth structures), the density of the growth (indicated using a 1 to 4 numerical ranking), the type of growth, and the presence of spores.

The surface samples were collected by applying clear adhesive tape to the surface being tested and then affixing the tape to a glass slide. All slides were sent to EMLab P&K (Cherry Hill, New Jersey) for examination by light microscopy.

4.4.3 Viable Surface Fungi

Representative surface samples were collected from selected HVAC-system surfaces (diffusers and duct interiors) in the two homes (n=5 for 144 Groesbeek Street, n=11 for 4 Darden Street) for analysis of viable spores. Note that a greater number of samples were collected at 4 Darden Street given differences in the overall configuration of the return air duct systems in that home. Two field blanks were also collected during the study for quality assurance purposes. Surface samples for viable spores were collected by wiping a specified area with sterile rayon-tipped swabs. At each sample location, a measured surface area was sampled (approximately one square inch); sample areas were measured with rulers. First, the sterile swab tip was dipped into sterile Stuart's medium to moisten the tip. Afterwards, the swab samples were immersed into modified Stuart's medium to preserve the viability of the spores during transport to the laboratory.

The samples were labeled, sealed, and shipped to EMLab P&K laboratory located in Cherry Hill, New Jersey, for culture and analysis. The material collected on each swab was cultured on three types of culture media including cornmeal agar (CMA), MEA, and dichloran glycerol-18 agar (DG18) prior to microscopic analysis for culturable (viable) fungi; viable fungi are identified to the species level. The laboratory prepared the samples for analysis by suspending the collected material in distilled water at a 1:10 dilution. The samples are cultured using a serial dilution approach, where dilutions of 1:10, 1:100, 1:1,000 and 1:10,000 are prepared and 0.1 milliliter of each dilution is inoculated (spread) onto 100-millimeter diameter petri dishes containing the three types of culture media and incubated at 25 °C for 7 to 10 days. Results are reported as cfu/sample by counting the number of colony forming units of each fungal species present on each culture media at the lowest dilution; the results reported for each fungal species represent those found in the highest number among the three media types and then multiplying the raw colony forming units count by the dilution.

4.4.4 Dust Composition (Qualitative Analysis)

Bulk samples of settled dust from selected floor and HVAC-system surfaces in the two homes (n=4 in each Home) were collected using a Eureka Mighty-Mite® canister vacuum cleaner (The Eureka Co., Bloomington, Indiana) modified to collect dust in a DustChek™ thimble (EML P&K Products, San Bruno, California). At each sample location, a measured surface area was vacuumed; sample areas were measured with rulers or measuring tapes.

The surface samples were transported, under chain of custody, to MicroVision Laboratories, Inc. (Chelmsford, Massachusetts), for examination by microscopy. The laboratory prepared the samples for analysis by homogenizing a portion of the collected dust using a clean mortar and pestle. A portion of the homogenized dust was then mounted on a glass slide with optical immersion oil with a refractive index of n=1.515 and examined with polarized light microscopy for determination of the types of particles present and determination of a percentage estimate for each. Another portion of the homogenized dust was placed on an aluminum analysis stub with double-sided adhesive tape, coated with evaporated graphite and examined by energy-dispersive scanning electron microscopy (SEM-EDX) to obtain elemental data in the form of EDX spectra. The elemental data are reported qualitatively in the laboratory discussion of the results.

4.4.5 Trace Metals

Bulk samples of settled dust from selected floor and HVAC-system surfaces in the two homes (n=3 in each home) were collected using a Eureka Mighty-Mite® canister vacuum cleaner (The Eureka Co., Bloomington, Indiana) modified to collect dust in a DustChek™ thimble (EML P&K Products, San Bruno, California). At each sample location, a measured surface area was vacuumed; sample areas were measured with rulers or measuring tapes and where irregular surfaces were sampled “best estimates” were used.

The surface samples were transported, to Liberty Mutual Industrial Hygiene Laboratory (Hopkinton, Massachusetts), an American Industrial Hygiene Association-accredited laboratory, and analyzed using inductively coupled plasma (ICP) analysis via U.S. Occupational Safety and Health Administration (OSHA) Method ID-121 for a suite of 20 trace metals. Table 4.9 lists the targeted metals reported by the laboratory and the laboratory reporting limit for each as both mass of metal per mass of dust (based on the sample weights reported by the laboratory) and as mass of metal per surface area sampled.

Table 4.9 Targeted Trace Metals in Surface Dust and Laboratory Reporting Limits

Trace Metal	Laboratory Reporting Limit (μg/m^2)
Aluminum	40 – 430
Antimony	1.1 – 12
Arsenic	0.60 – 6.5
Beryllium	0.01 – 0.14
Cadmium	0.05 – 0.52
Calcium	11 – 120
Chromium	0.91 – 9.9
Cobalt	0.08 – 0.82
Copper	0.89 – 9.7
Iron	2.2 – 24
Lead	0.26 – 2.8
Magnesium	1.6 – 17
Manganese	0.38 – 4.1
Nickel	0.30 – 3.2
Selenium	1.1 – 12
Thallium	0.50 – 5.4
Tin	0.20 – 2.2
Titanium	0.13 – 1.4
Vanadium	0.20 – 2.2
Zinc	1.8 – 19

μg/m^2 micrograms per square meter

4.4.6 Pesticides

Analysis for organochlorine pesticides in surface dust samples (vacuum samples) was conducted by isotope dilution high resolution gas chromatography and high resolution mass spectrometry (HRGC/HRMS). AXYS Analytical Services Ltd. (AXYS) of Sidney, BC, Canada, conducted the analysis by AXYS Method MLA-028 for determination of the organochlorine pesticides in solids. Soxhlet extraction with dichloromethane was the extraction method used by the laboratory for the solid sample matrix. Column chromatography cleanup was conducted on a Florisil column.

Instrumental analysis at AXYS is performed on a DB-5 capillary chromatography column coupled to a high-resolution mass spectrometer (HRMS). The HRMS is operated at a static (8000) mass resolution (10% valley) in the electron ionization (EI) mode using multiple ion detection (MID). Two masses from the molecular ion cluster are used to monitor each of the target analytes and 13C-labelled surrogate standards.

Analysis for multi-residue pesticides in surface dust samples (vacuum samples) was also conducted by HRGC/HRMS according to AXYS Method MLA-035 for determination of multi-residue pesticides in solids. Soxhlet extraction with dichloromethane was the extraction method used by the laboratory for the solid sample matrix. Column chromatography cleanup was conducted with automated gel permeation chromatography, an aminopropyl column, and a microsilica column.

For this method, instrumental analysis is performed on a DB-17 MS capillary chromatography column coupled to a HRMS. The HRMS is operated at a static (8000) mass resolution (10% valley) in the electron ionization (EI) positive ion mode using multiple ion detection (MID) acquiring two characteristic ions, where available, for each target analyte and surrogate standard. Selected PFK ions are used as a reference for mass lock. Analytes are acquired in two separate instrumental runs.

Initial calibration is performed using a minimum of five calibration solutions that encompass the working range of the instrument. The initial calibration is used to determine response factors for target analytes and labeled standards. The calibration is verified at least once every 12 hours by analysis of a mid-level calibration solution (CAL/VER). The mean relative response factors, determined from the initial calibration, or from the mid-level calibration run at the beginning and end of the analysis run, are used for the quantification of target analytes.

A chromatographic peak is identified as a target compound if the laboratory criteria are met for the quantification ion and concentrations and detection limits for the pesticide.

4.5 DRINKING WATER SAMPLING METHODS

Samples of drinking water were collected from the kitchen sinks in each of the two homes. The samples were analyzed for multiple parameters, including the presence of hydrogen sulfide, trace metals (total), VOCs and other organic compounds, total coliform bacteria, polychlorinated biphenyls (PCBs), perchlorate, pesticides/herbicides/fungicides, and a number of general water-quality parameters. In addition, field blank samples of distilled water were submitted to the laboratory for quality control.

The samples were collected using specially cleaned bottles containing preservatives specified by the reference method provided by the analytical laboratory. Prior to sample collection, the faucet was flushed for approximately one to two minutes. Samples were placed on ice in a cooler for transport via overnight shipping to the analytical laboratory. All water samples were analyzed in accordance with reference EPA methods for drinking water analysis. Sulfide analysis was performed by Columbia Analytical Services (Kelso, Washington), and analysis for all other parameters was performed by Groundwater Analytical, Inc. (Buzzards Bay, Massachusetts). Table 4.10 lists the targeted analytes in the sampled drinking water, the analytical methods used, and the laboratory reporting limits for each.

Table 4.10 Drinking Water Samples, Targeted Analytes, Analytical Methods, and Reporting Limits

Analyte Group	Analyte	Method	Laboratory Reporting Limit	Units
Metal	Calcium, Total	EPA 200.71	0.50	mg/L
Metal	Copper, Total	EPA 200.71	0.03	mg/L
Metal	Iron, Total	EPA 200.71	0.10	mg/L
Metal	Magnesium, Total	EPA 200.71	0.10	mg/L
Metal	Manganese, Total	EPA 200.71	0.05	mg/L
Metal	Potassium, Total	EPA 200.71	1.0	mg/L
Metal	Sodium, Total	EPA 200.71	1.0	mg/L
Metal	Lead, Total	EPA 200.82	0.001	mg/L
VOC	1,1,1,2-Tetrachloroethane	EPA 524.2	0.0005	mg/L
VOC	1,1,1-Trichloroethane	EPA 524.2	0.0005	mg/L
VOC	1,1,2,2-Tetrachloroethane	EPA 524.2	0.0005	mg/L
VOC	1,1,2-Trichloroethane	EPA 524.2	0.0005	mg/L
VOC	1,1-Dichloroethane	EPA 524.2	0.0005	mg/L
VOC	1,1-Dichloroethene	EPA 524.2	0.0005	mg/L
VOC	1,1-Dichloropropene	EPA 524.2	0.0005	mg/L
VOC	1,2,3-Trichlorobenzene	EPA 524.2	0.0005	mg/L
VOC	1,2,3-Trichloropropane	EPA 524.2	0.0005	mg/L
VOC	1,2,4-Trichlorobenzene	EPA 524.2	0.0005	mg/L
VOC	1,2,4-Trimethylbenzene	EPA 524.2	0.0005	mg/L
VOC	1,2-Dibromo-3-chloropropane	EPA 524.2	0.0005	mg/L
VOC	1,2-Dibromoethane (EDB)	EPA 524.2	0.0005	mg/L
VOC	1,2-Dichlorobenzene	EPA 524.2	0.0005	mg/L
VOC	1,2-Dichloroethane	EPA 524.2	0.0005	mg/L
VOC	1,2-Dichloropropane	EPA 524.2	0.0005	mg/L
VOC	1,3,5-Trimethylbenzene	EPA 524.2	0.0005	mg/L
VOC	1,3-Dichlorobenzene	EPA 524.2	0.0005	mg/L
VOC	1,3-Dichloropropane	EPA 524.2	0.0005	mg/L
VOC	1,4-Dichlorobenzene	EPA 524.2	0.0005	mg/L
VOC	2,2-Dichloropropane	EPA 524.2	0.0005	mg/L
VOC	2-Chlorotoluene	EPA 524.2	0.0005	mg/L
VOC	4-Chlorotoluene	EPA 524.2	0.0005	mg/L
VOC	4-Isopropyltoluene	EPA 524.2	0.0005	mg/L
VOC	Benzene	EPA 524.2	0.0005	mg/L
VOC	Bromobenzene	EPA 524.2	0.0005	mg/L

Table 4.10 Continued				
Analyte Group	**Analyte**	**Method**	**Laboratory Reporting Limit**	**Units**
VOC	Bromochloromethane	EPA 524.2	0.0005	mg/L
VOC	Bromodichloromethane	EPA 524.2	0.0005	mg/L
VOC	Bromoform	EPA 524.2	0.0005	mg/L
VOC	Bromomethane	EPA 524.2	0.0005	mg/L
VOC	Carbon Tetrachloride	EPA 524.2	0.0005	mg/L
VOC	Chlorobenzene	EPA 524.2	0.0005	mg/L
VOC	Chloroethane	EPA 524.2	0.0005	mg/L
VOC	Chloroform	EPA 524.2	0.0005	mg/L
VOC	Chloromethane	EPA 524.2	0.0005	mg/L
VOC	Dibromochloromethane	EPA 524.2	0.0005	mg/L
VOC	Dibromomethane	EPA 524.2	0.0005	mg/L
VOC	Dichlorodifluoromethane	EPA 524.2	0.0005	mg/L
VOC	Ethylbenzene	EPA 524.2	0.0005	mg/L
VOC	Hexachlorobutadiene	EPA 524.2	0.0005	mg/L
VOC	Isopropylbenzene	EPA 524.2	0.0005	mg/L
VOC	Methyl tert-butyl Ether (MTBE)	EPA 524.2	0.0005	mg/L
VOC	Methylene Chloride	EPA 524.2	0.0005	mg/L
VOC	Naphthalene	EPA 524.2	0.0005	mg/L
VOC	Styrene	EPA 524.2	0.0005	mg/L
VOC	Tetrachloroethene	EPA 524.2	0.0005	mg/L
VOC	Toluene	EPA 524.2	0.0005	mg/L
VOC	Trichloroethene	EPA 524.2	0.0005	mg/L
VOC	Trichlorofluoromethane	EPA 524.2	0.0005	mg/L
VOC	Vinyl Chloride	EPA 524.2	0.0005	mg/L
VOC	cis-1,2-Dichloroethene	EPA 524.2	0.0005	mg/L
VOC	cis-1,3-Dichloropropene	EPA 524.2	0.0005	mg/L
VOC	meta-Xylene and para-Xylene	EPA 524.2	0.0005	mg/L
VOC	n-Butylbenzene	EPA 524.2	0.0005	mg/L
VOC	n-Propylbenzene	EPA 524.2	0.0005	mg/L
VOC	ortho-Xylene	EPA 524.2	0.0005	mg/L
VOC	sec-Butylbenzene	EPA 524.2	0.0005	mg/L
VOC	tert-Butylbenzene	EPA 524.2	0.0005	mg/L
VOC	trans-1,2-Dichloroethene	EPA 524.2	0.0005	mg/L
VOC	trans-1,3-Dichloropropene	EPA 524.2	0.0005	mg/L
Pest/herb/fung	1,2-Dibromo-3-chloropropane (DBCP)	EPA 504.1	0.00002	mg/L
Pest/herb/fung	Ethylene Dibromide (EDB)	EPA 504.1	0.00002	mg/L
Pest/herb/fung	Toxaphene	EPA 505	0.001	mg/L
Pest/herb/fung	2,4,5-TP (Silvex)	EPA 515.3	0.0003	mg/L
Pest/herb/fung	2,4-D	EPA 515.3	0.001	mg/L
Pest/herb/fung	Dalapon	EPA 515.3	0.001	mg/L
Pest/herb/fung	Diacamba	EPA 515.3	0.0002	mg/L
Pest/herb/fung	Dinoseb	EPA 515.3	0.0005	mg/L
Pest/herb/fung	Pentachlorophenol	EPA 515.3	0.0001	mg/L
Pest/herb/fung	Picloram	EPA 515.3	0.001	mg/L
Pest/herb/fung	3-Hydroxycarbofuran	EPA 531.1	0.001	mg/L
Pest/herb/fung	Aldicarb	EPA 531.1	0.001	mg/L
Pest/herb/fung	Aldicarb Sulfone	EPA 531.1	0.001	mg/L
Pest/herb/fung	Aldicarb Sulfoxide	EPA 531.1	0.001	mg/L
Pest/herb/fung	Carbaryl	EPA 531.1	0.001	mg/L
Pest/herb/fung	Carbofuran	EPA 531.1	0.0009	mg/L
Pest/herb/fung	Methiocarb	EPA 531.1	0.001	mg/L
Pest/herb/fung	Methomyl	EPA 531.1	0.001	mg/L

Table 4.10 Continued

Analyte Group	Analyte	Method	Laboratory Reporting Limit	Units
Pest/herb/fung	Oxamyl (Vydate)	EPA 531.1	0.001	mg/L
Pest/herb/fung	Propoxur (Baygon)	EPA 531.1	0.001	mg/L
PCBs	Aroclor 1016	EPA 504.1	0.0002	mg/L
PCBs	Aroclor 1221	EPA 505	0.0002	mg/L
PCBs	Aroclor 1232	EPA 505	0.0002	mg/L
PCBs	Aroclor 1242	EPA 505	0.0002	mg/L
PCBs	Aroclor 1248	EPA 505	0.0002	mg/L
PCBs	Aroclor 1254	EPA 505	0.0002	mg/L
PCBs	Aroclor 1260	EPA 505	0.0002	mg/L
Organic	Chlordane	EPA 505	0.0002	mg/L
Organic	Alachlor	EPA 525.2	0.0001	mg/L
Organic	Aldrin	EPA 525.2	0.0001	mg/L
Organic	Atrazine	EPA 525.2	0.0001	mg/L
Organic	Benzo(a)pyrene	EPA 525.2	0.0001	mg/L
Organic	Butachlor	EPA 525.2	0.0001	mg/L
Organic	Di(2-ethylhexyl)adipate	EPA 525.2	0.0006	mg/L
Organic	Di(2-ethylhexyl)phthalate	EPA 525.2	0.003	mg/L
Organic	Dieldrin	EPA 525.2	0.00004	mg/L
Organic	Endrin	EPA 525.2	0.0001	mg/L
Organic	Heptachlor	EPA 525.2	0.00004	mg/L
Organic	Heptachlor Epoxide	EPA 525.2	0.00006	mg/L
Organic	Hexachlorobenzene	EPA 525.2	0.0001	mg/L
Organic	Hexachlorocyclopentadiene	EPA 525.2	0.0001	mg/L
Organic	Lindane	EPA 525.2	0.00007	mg/L
Organic	Methoxychlor	EPA 525.2	0.0001	mg/L
Organic	Metolachlor	EPA 525.2	0.0001	mg/L
Organic	Metribuzin	EPA 525.2	0.0001	mg/L
Organic	Propachlor	EPA 525.2	0.0001	mg/L
Organic	Simazine	EPA 525.2	0.0001	mg/L
General chemistry	Total hardness	EPA 200.71	2.0	mg/L
General chemistry	Chloride	EPA 300.0	0.60	mg/L
General chemistry	Sulfate	EPA 300.0	3.0	mg/L
General chemistry	Sulfide	SM 4500-S2-D	0.05	mg/L
General chemistry	Nitrate (as nitrogen)	Lachat 10-107-04-1-C	0.02	mg/L
General chemistry	Nitrite (as nitrogen)	Lachat 10-107-04-1-C	0.02	mg/L
General chemistry	Ammonia (as nitrogen)	Lachat 10-107-06-1-B	0.20	mg/L
General chemistry	Turbidity	SM 2130 B	0.20	N.T.U.
General chemistry	Specific conductance	SM 2510 B	2.0	umhos/cm
Perchlorate	Perchlorate	EPA 314.0	0.0003	mg/L
Perchlorate	Specific conductance	SM 2510 B	1.0	umho
Coliform bacteria	Coliform bacteria	SM 9223 B	0	colonies/ 100 mL
Sulfides	Total sulfide	SM 4500-S2- D	0.05	mg/L

EPA — U.S. Environmental Protection Agency
mg/L — milligrams per liter
VOC — volatile organic compound
Pest/herb/fung — pesticides/herbicides/fungicides
PCB — polychlorinated biphenyl
NTU — nephelometric turbidity units
umhos/cm — micromhos per centimeter
mL — milliliter

4.6 ADDITIONAL ASSESSMENT PARAMETERS

A series of inspections and physical measurements were performed in the two homes to aid EH&E's environmental assessment. The homes were inspected for evidence of historical moisture intrusion through surveys utilizing moisture meters and infrared thermographic analyzers, in addition to visual assessment for indications of water-stained and/or mold-impacted materials. Characterization of the HVAC systems serving the homes was also conducted, including visual assessment of system hygiene, evaluation of system operation, and investigation of possible HVAC-related sources, including the potential for back-drafting of flue gases into the homes. In addition, overall home air exchange rates were measured at multiple locations in each home as well as other indicators of building and HVAC system performance, including dry-bulb and dew point temperature. The specific methods employed for these additional assessment parameters are provided in Sections 4.6.1 through 4.6.3

4.6.1 Visual Inspection and Moisture Survey

As part of the assessment in each of the two homes, all accessible interior areas as well as representative interior and exterior components of the HVAC systems were inspected by EH&E's field investigators to identify potential sources or conditions that may affect indoor environmental conditions. This inspection included a visual survey of building material and HVAC-system components to identify staining, efflorescence, or other visible signs of water damage.

In addition, a moisture assessment was conducted in accessible locations in each of the homes to identify materials with elevated moisture content that may indicate wet materials. This survey was performed in conjunction with the visual inspection to identify evidence of water damage (such as staining or peeling paint) and included the use of an infrared thermographic camera to screen for evidence of wet building materials. Suspect materials were evaluated for moisture content using a moisture meter.

The moisture meter used during the evaluation was a GE Protimeter® Surveymaster (GE Infrastructure Sensing, Inc., Billerica, Massachusetts). This instrument displays readings as percent moisture content, referenced to a wood standard. When non-wood materials such as wallboard are measured, the results are expressed as percent wood moisture equivalent (% WME). Moisture levels in building materials, such as gypsum wallboard, are considered elevated when they were higher than levels measured in similar materials in unaffected areas. Moisture measurements obtained from wallboard in the homes were less than approximately 15% WME, a moisture content that was considered dry.

EH&E also used infrared (IR) thermography to identify building materials with potentially elevated moisture content. The IR camera used during the evaluation was a ThermaCAM™ B20 (FLIR Systems, Inc., North Billerica, Massachusetts). IR cameras display relative surface temperatures of materials in the visual field. Under most conditions, building materials that contain higher liquid moisture are relatively cooler than dryer materials and can be differentiated in the camera display. Where possible, a moisture meter was used to confirm IR camera findings.

4.6.2 Relative Humidity/Temperature

Real-time temperature and relative humidity measurements were collected in each home using U10-003 HOBO® Temperature Relative Humidity Data Loggers manufactured by Onset Computer Corporation (Bourne, Massachusetts). The temperature sensor is a thermistor, and relative humidity is measured by a thin-film capacitive sensor. The temperature sensor has a range of -20 °C to 70 °C (-4 to 158 degrees Fahrenheit [°F]) with accuracy of ± 0.4 °C at 25 °C (± 0.7 °F at 77 °F). The temperature sensor is factory rated to achieve a resolution of 0.1 °C at 25 °C (0.2 °F at 77 °F). The relative humidity sensor has a range of 25% to 95% with accuracy of ± 3.5% from 25% to 85%. The humidity sensor is factory rated to achieve a resolution of 0.07%. As recommended by the manufacturer, the accuracy of the temperature and relative humidity sensors is verified annually. The data loggers were programmed to record five minute average measurements with a sampling rate of five seconds. A minimum of three temperature and humidity monitoring locations were selected in each of the homes: one in the central living room of the house and two in bedrooms. Temperature and relative humidity measurements were collected for 17 days in each home.

4.6.3 Air Exchange Rate

The air exchange rates in each test home were assessed using the method outlined in ASTM Standard E741-00, *Standard Test Method for Determining Air Change Rate in a Single Zone by Means of a Tracer Gas Dilution*. Air exchange rate determinations used high concentration carbon dioxide (CO_2) as a tracer with decay being measured using portable real-time instruments. The tests were conducted by introducing approximately five pounds of CO_2 throughout the home, allowing the gas to mix, and recording the decaying part of the tracer curve over time.

CO_2 concentrations were measured continuously at multiple locations inside the home using a Q-Trak Model 8551 Indoor Air Quality Monitor manufactured by TSI, Inc. (St. Paul, Minnesota). The CO_2 sensor utilized by this monitor is non-dispersive infrared (NDIR) and is accurate within 3% (or 50 parts per million [ppm]) at 25 °C (78 °F) of the reading. Prior to each air exchange rate test, the sensors were calibrated at zero using hydrocarbon free air and spanned to approximately 1,000 ppm of CO_2. Air exchange rates were calculated from the CO_2 decay results using the regression method.

4.7 CORROSION ASSESSMENT

In order to evaluate corrosion of metal building components, EH&E conducted a detailed inspection of each home to determine qualitatively the extent of corrosion found on specific surfaces as well as to deploy devices to measure quantitatively the corrosion rate in each home over time.

4.7.1 Visual Inspection

Detailed visual inspections were performed on the electrical grounding wires, air handling units (AHUs), plumbing components, and appliances. Notes also were made regarding other home contents that possibly could show visible evidence of corrosion.

Grounding wires were evaluated on a three-point scale. A score of one indicated no visible corrosion; two indicated moderate visible corrosion; and three indicated significant visible corrosion. Examples of grounding wires and the associated rating are provided in Figure 4.1. Field team members performed cross-reference evaluations during training to ensure consistency between teams in the field. Visual corrosion ratings were recorded in the master field log binder.

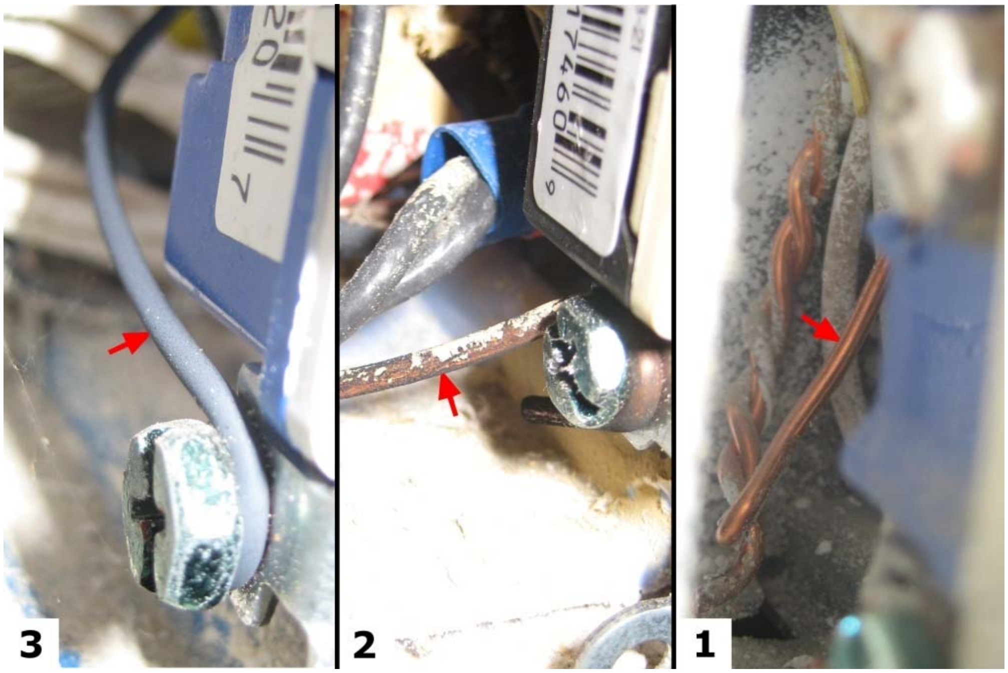

Figure 4.1 Example of Visual Corrosion Ratings, Electrical Ground Wire
(3—Significant Visible Corrosion, 2—Moderate Visible Corrosion, 1—No Visible Corrosion)

AHU inspection focused on the cooling coils and associated copper refrigerant lines. Representative surfaces were photographed and all locations were logged into the master field log binder. Appliances and fixtures, including accessible refrigerator components, hot water heaters, faucets, plumbing lines, and other items indicating patterns of corrosion were logged and photographed.

4.7.2 Corrosion Classification Coupons

Corrosion classification coupons were used to determine the corrosion rate present in the study homes. The corrosion coupons used in this study contained copper and silver metal and were supplied by the Purafil, Inc. Research and Development Laboratory (Doraville, Georgia). Pre-cleaned copper and silver corrosion coupons were placed at four indoor locations at 4 Darden Street, at five indoor locations at 144 Grosbeek Street, and at one outdoor location at each home for a two-week period. In addition, one duplicate and one field blank sample were collected and analyzed for each home.

At the end of the sampling period, the corrosion coupons were collected, placed in sealed containers, and returned to Purafil, Inc. for analysis. The laboratory measured the thickness of several copper and silver compounds, including silver sulfide (Ag_2S), silver chloride (AgCl), Ag "unknown,"[5] copper sulfide (Cu_2S), copper oxide (CuO), and Cu "unknown" present in the sample corrosion coupons. The laboratory normalized the data, using the actual period of exposure, and reported the result in units of "angstroms per 30 days of exposure." For the 14-day period of exposure in this study, the laboratory reporting limit for the analysis was 32 angstroms. Corrosion rates were compared with reference values contained in the Instrumentation, Systems, and Automation Society (ISA) standard ISA-71.04-1985, *Environmental Conditions for Process Measurement and Control Systems: Airborne Contaminants*.

According to ISA, the use of corrosion coupons and measurement of corrosion accumulation is referred to as "reactivity monitoring," and the method provides a quantitative measure of the overall corrosion potential of an environment. Copper has been selected by ISA as a primary standard because extensive data exist that correlate copper film formation with reactive (corrosive) environments. Four levels of corrosion severity have been established for this standard.

G1 Mild—Defined as an environment sufficiently well-controlled such that corrosion is not a factor in determining equipment reliability. Less than 300 angstroms corrosion build up per 30 days of exposure.

G2 Moderate—Defined as an environment in which the effects of corrosion are measurable and may be a factor for determining equipment reliability. Less than 1,000 and greater than 300 angstroms corrosion build up per 30 days of exposure.

G3 Harsh—Defined as an environment in which there is a high probability that a corrosive attack will occur on metallic equipment surfaces. These harsh levels should prompt further evaluation resulting in environmental controls or specially designed and packaged equipment. Less than 2,000 and greater than 1,000 angstroms corrosion build up per 30 days of exposure.

5 "Unknown" refers to a corrosive layer where the laboratory was able to quantify thickness in angstroms but was unable to determine the compound.

GX Severe—Defined as an environment in which only specially designed and packaged equipment would be expected to survive. Specifications for equipment in this class are a matter of negotiation between user and supplier. Greater than or equal to 2,000 angstroms corrosion build up per 30 days of exposure.

4.8 PROCEDURES FOR STATISTICAL ANALYSIS OF DATA

All statistical analyses of the study data were performed using SAS statistical software, version 9.1 (Cary, North Carolina). Field blank samples (discussed in Section 4.9) were analyzed to determine if field samples should be blank corrected. Based on statistical analysis of the field and shipping blank data (refer to Section 4.7.9) samples did not require blank correction. Values obtained that fell below the laboratory reporting limit, generally defined as three times the method detection limit, were substituted using one-half of the reporting limit in statistical analyses. As described in Section 4.9.2, good agreement was observed between paired primary samples and duplicates; samples and duplicates were averaged for all statistical analyses.

4.9 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

This section describes the overall project QA/QC measures used to design, implement, analyze, and report the results of the study. Every effort was made in each phase of the project to ensure completeness and accuracy of data collection, analytical methods, data entry, calculation procedures, and reporting of results.

As described in this report, EH&E conducted a series of inspections and environmental measurements in the two homes. All sampling and analytical procedures for the project utilized appropriate and valid monitoring procedures approved and recommended in relevant published sources, either from regulatory agencies, such as the EPA, OSHA, other relevant governmental organizations, such as National Institute for Occupational Safety and Health, consensus standard organizations such as ASTM, or the peer-reviewed scientific literature. The following sections describe specific measures and procedures implemented to assure quality of the data collected and reported.

4.9.1 Project Organization(s) and Responsibilities

EH&E's project manager was responsible for overall implementation, documentation, and delivery of the project and had the responsibility of ensuring the accuracy, precision, and completeness of all data presented. The project executive and two technical directors were responsible for technical oversight of the overall project and for ensuring that high data quality objectives were met by the project manager and the project team. Prior to release, all deliverables at EH&E were reviewed and approved by qualified senior level staff, with relevant qualifications and expertise, whose responsibilities include ensuring the accuracy and appropriateness of technical information presented. All members of the project team were trained in, and responsible for, data validation and quality control checks during each of their tasks.

4.9.2 Quality Assurance and Quality Control Samples

As detailed above, in addition to the primary samples collected during the study, a number of quality control samples were collected and analyzed in each sample set to evaluate the quality and reasonableness of the data collected during the study. The types and frequency of QA/QC samples collected during the study are outlined in Table 4.11.

Table 4.11 Quality Assurance and Quality Control Samples Collected During the Project

Sample Type	Frequency	Definition
Duplicate sample	Minimum of one per sample set	A sample collected concurrently with a primary field sample to assess repeatability of methods.
Field blank	Minimum of one per sample set	A sample prepared by the field team that represents the procedure for preparing for integrated sampling, and is handled as such, but is not actually used for sampling. This is sent in a blinded fashion to the laboratory. The results of the field blanks can be used to determine whether there was any contamination in the preparation, handling or shipping process in the field, or during the analysis of the samples by the laboratory.
Media Blank	Minimum of one per sample set	An unused sample that is not handled in the field other than to have it incorporated into a regular sample shipment and sent in a blind fashion to the laboratory. The results of shipping blanks can be used to determine whether there was any contamination during the shipping process.

In addition to the use of different QA/QC samples in the field, QA/QC of integrated air samples included verification of pump flows by use of calibrated flow meters at the start and end of each sampling period. The start and stop flow rates were then averaged to obtain an average flow rate. Sample duration was also calculated from the start and stop times recorded on the field data sheets. Total sample volumes then were calculated using the average flow rate and the duration of sampling as follows:

Total Sample Volume (L) = Average Flow Rate (L/min) x Total Sample Time (minutes)

4.9.3 Sample Handling

EH&E followed the requirements for holding times and sample preservation outlined in the respective reference sampling methods used. Samples were stored under appropriate conditions and shipped to the laboratory via overnight express delivery within the holding time specified by the analytical method. The reduced sulfur air samples were shipped immediately after sampling via first priority overnight express delivery.

4.9.4 Sample Custody

All project samples were handled in accordance with appropriate chain-of-custody procedures. Compliance was overseen by the field team leader. The field team leader was also responsible for ensuring that all unused sample media, as well as collected samples, were properly cared for before, during, and after sampling. At the time of use, each sample was assigned a unique sample identification label. Each sample label was recorded on the field sample log sheets prior to sample collection. All log sheets were stored in a master field binder during the study.

4.9.5 Calibration Procedures

All measuring, monitoring, and sampling instrument calibrations, except those requiring factory calibrations, were performed in EH&E's Field Operations Support Center (FOSC) prior to shipment of instruments to the field. All instruments that are factory calibrated are checked periodically in the FOSC by comparing them against other, recently calibrated instruments. Prior to use in the field, each instrument was zeroed and span-checked with appropriate gases, or flow-checked with rotameters to insure that they were operating within specification (and adjusted as necessary). Table 4.12 summarizes the calibration procedures for instruments used in the study.

Table 4.12 Calibration Procedures

Parameter	Instrument Type	Instrument	Calibration Method	Frequency
Air temperature	Thermistor, data logger	HOBO® U10-003 (Onset Computer Corp)	Calibrations performed by the manufacturer	Annual
Relative humidity	Thin-film capacitive sensor, data logger	HOBO® U10-003 (Onset Computer Corp)	Calibrations performed by the manufacturer	Annual
Carbon dioxide	Non-dispersive infrared sensor	Q-Trak Model 8551 Indoor Air Quality Monitor	Multipoint with standard gas mixtures ranging from 0 to 1,000 ppm along linear response curve.	Pre and post field measurements
Active air sampling	Air-sampling pump	Gilair-3/5 (Sensodine, Inc.) SKC Inc.	Compared against calibrated flow meter.	Pre and post measurements
Active air sampling	Flow meter	Dry-Cal DC-Lite, Bios International Corp.	Annual factory calibration	Pre and post measurements
Volatile organic compounds	SUMMA canister flow controller	6-liter SUMMA canister	Provided pre-calibrated by laboratory	Each canister

4.9.6 Recordkeeping

4.9.6.1 Written Documentation

All data and documentation generated during the study, except that generated in electronic formats (raw data files, digital photographs), was transcribed into the appropriate collection forms, which are subsequently stored in a single data collection binder. Hardcopies of final analytical laboratory reports (and the completed chains of custody) were also received and retained in EH&E's central filing system. Any changes in data entries are done in a manner that does not obscure the original entry. The reason for the revision is indicated, dated, and signed at the time of change. All original hardcopy records for the project are retained (together) in a central file system at EH&E's main office.

4.9.6.2 Electronic Documentation

Electronic documentation generated in the field during the study included: digital photographs, XRF data files, CO_2 measurements, and temperature and relative humidity data files. All files generated during the field phases of the study were downloaded and stored temporarily on a field computer under the control of the field team leader. Electronic files then were transferred from the field computer onto EH&E's central server at the completion of the study. In order to track the various electronic data files, a standardized filing and naming system was used to clearly differentiate between files by type and the home in which they were collected. Also, field personnel documented the location of digital photographs, XRF measurements, and real-time data monitor deployments on the appropriate field forms.

4.9.7 Data Reduction, Validation, and Reporting

A systematic, standardized approach was implemented by EH&E to analyze, validate, and report the data collected during the study, including incorporating the following steps:

- Senior level staff at EH&E reviewed and verified the overall study approach, data collection strategy, methodology, appropriateness of all calculations and statistical analysis, and deliverables.

- EH&E developed a database (Microsoft Access), where all field data and laboratory results were stored.

- All (100%) field log entries and calculations were reviewed by independent staff members prior to entry into the study database.

- All (100%) of the data entry into the study database was reviewed and verified by independent, qualified personnel.

- To minimize database entry errors, EH&E requested that, when possible, all laboratory reports be provided in electronic data delivery (EDD) formats, such as Microsoft Excel, so that the data could be imported directly into the central study database.

- After the database was populated, the number and sample identification labels in the database were compared to those on the field log sheets and the analytical laboratory reports (using a program coded in SAS 9.1).
- As discussed above, data summary and analysis was completed using SAS 9.1. All programming codes developed and executed for processing the data were independently reviewed by qualified personnel.
- In the limited instances where data entry or recording errors were identified during the QA/QC review processes described above, the entry was corrected in all relevant locations (back to the original entry). Corrections were noted on all original documentation.
- All of the final results underwent QA/QC review, including completeness and reasonableness checks.

4.10 QUALITY ASSURANCE AND QUALITY CONTROL ANALYSIS

As described above, a number of measures were implemented to ensure the collection of reproducible and accurate data during the study. This section describes the measures used to evaluate the completeness, precision, and accuracy of the data collected during the study. The completeness of the data set was evaluated by analyzing the capture efficiency for each environmental parameter targeted in the study. Accuracy was evaluated by reviewing results of blank samples. Precision was evaluated by examining the strength of the association between paired primary and duplicate samples. Paired duplicates were averaged, and no blank correction was done for purposes of analysis. As discussed below, quantitative analysis of data quality metrics, particularly precision, was limited due to the small sample sizes in the study.

4.10.1 Completeness

The completeness of air sampling data from the study was evaluated by examining the overall data capture efficiency for each sample group and sample type collected in the field (primary samples, duplicate samples, and field blanks and shipping blanks) and submitted for laboratory analysis. Table 4.13 summarizes the data capture efficiency during the study.

Table 4.13 Summary of Data Capture Efficiency for Samples Collected for Laboratory Analysis

Sample Matrix	Analyte Group	Total Samples Collected S	D/R	B	Number of Void Samples	Capture Efficiency (%)
Air	Aldehydes (active)	8	2	4	0	100
	Aldehydes (passive)	8	2	2	0	100
	H_2S (passive)	8	2	2	0	100
	Corrosion coupons	10	2	2	0	100
	Reduced Sulfur	8	2	NA	0	100
	Viable and non-viable fungi	17	6	4	0	100
	Viable fungi	17	6	4	0	100
	VOC (active)	8	2	1	0	100
	VOC (canister)	8	2	1	1 (field blank)	90.9
Surface	Allergen	7	0	1	0	100
	Dust characterization	10	0	NA	0	100
	Metals	6	0	NA	0	100
	Mold growth	13	0	2	0	100
	Pesticides	10	0	0	0	100
	Viable fungi	16	0	2	0	100
Water	Multiple	44	0	10	0	100
Drywall	S_8	20	2	NA	0	100
					Overall data capture efficiency	**99.6**

S primary samples
D/R duplicates and replicates
B field and shipping blanks
H_2S hydrogen sulfide
NA not applicable
VOC volatile organic compound

Overall, data capture efficiency was 99.6%. The field blank from the VOC canister sample group was voided due to loss of pressure during the sampling period. After cleaning at the laboratory, but prior to sampling, the pressure in this evacuated canister was measured at -29.1 pounds per square inch (psig), and the pressure was measured at -8.4 psig upon receipt back at the laboratory after the sampling event, indicating a leak in the sample canister. The pressure decrease was 20.7 psig, well above the acceptable pressure loss of 2.0 psig allowed during the pre-sampling canister cleanliness verification process by the reference EPA method (TO-15). The underlying cause for the pressure drop is unknown. As discussed below, all other precision and accuracy metrics indicated a high level of data quality for the VOC data set. Although not listed in Table 4.13, no data from real-time monitoring results collected in the field (temperature, humidity, CO_2) were excluded from the analysis.

4.10.2 Accuracy

4.10.2.1 Laboratory Measurements

Review of field and shipping blanks analyses were used to assess the accuracy of air, surface, and water sample measurements. For purposes of comparison of the sample data analyzed in this report, the nominal laboratory reporting limit, expressed as quantity per sample and as quantity per unit volume of air sampled, was used as the metric of comparison to determine when results were below detection. The reporting limits presented here are as reported by the respective analytical laboratory.

No blank correction was done in EH&E's analysis of the study data, except any blank corrections performed by the laboratory as part of their standard reporting procedures. All field and media blank results were below detection for all samples (and analytes) analyzed during the study, with the exception of the following very limited instances:

- Silver sulfide (Ag_2S) was detected in both corrosion coupon field blanks (at 160 and 212 A/30days), collected during the study. This represents background rates of Ag_2S formation in homes.

- All analytes were below detection in the drinking water field blank, except four general chemistry parameters. However, each of these parameters was detected at a level slightly above the laboratory reporting limit and at levels well below those detected in the primary drinking water samples from the homes. Further, two detectable parameters (turbidity and specific conductance) are measurements of the physical properties of water, and their detection would be expected in the distilled water field blank. No blank correction for these analytes was performed because of the very low levels detected and because these parameters are indicators of general water characteristics. The four general chemistry parameters detected in the field blank, the laboratory reporting limits, and the levels detected in drinking water from the homes are listed in Table 4.14.

Table 4.14 General Water Chemistry Parameters Detected in Drinking Water Field Blank*				
Parameter	**Units**	**Laboratory Reporting Limit**	**Field Blank**	**Homes (range)**
Sulfate	mg/L	3	4	35 – 36
Nitrate (as nitrogen)	mg/L	0.02	0.06	0.59 – 60
Turbidity	NTU	0.2	0.2	0.60 – 0.80
Specific conductance	umhos/cm	2	27	210 – 220

mg/L milligrams per liter
NTU nephelometric turbidity units
umhos/cm micromhos per centimeter

* All other analytes were below detection in the blank sample (N=76)

EH&E also reviewed the quality assurance procedures implemented by the analytical laboratories to evaluate the accuracy of the laboratory measurements. In accordance with the standard or published methodologies employed for the sampling and analysis, laboratory quality control measures included: blanks, duplicates, standards, and continuing calibration verification. These quality control metrics demonstrated excellent compliance with the accuracy requirements specified in the respective reference methods. EH&E also evaluated the laboratory results to determine if there was potential breakthrough and sample media saturation; no breakthrough or saturation occurred during the study. Finally, the laboratory reports were reviewed to determine if sample handling (e.g., temperature control issues) or holding time exceedances occurred during the study; no issues were noted.

Overall, analytical quality assurance exceptions were noted only in very limited instances; they included the following, and did not warrant data adjustment or exclusion:

- **Active Aldehydes**
  - Matrix interference, which could bias the result high, was indicated for butyraldehyde in three collected samples (out of the 168 laboratory measurements obtained for this group).
  - An exceedance of the upper control criterion for o-Tolualdehyde in continuing calibration verification. This exception affected only one primary sample and two laboratory blanks. However, no corrective action was necessary because the

exception could bias the measurements high, and this compound was below detection in all samples collected from the homes.

- **Active VOCs**
  - 1,4-dioxane was detected in the laboratory blank at a level slightly above the reporting limit (1.9 ng/sample; 1.0 ng/sample reporting limit) and also detected in three of the four samples collected from 144 Groesbeek Street (2.8 – 5.3 ng/sample). The recovery of this compound (63% and 64%) also was slightly below the lower acceptance criteria of 70% in the laboratory control sample and laboratory control sample duplicate, indicating that the reported concentrations either may be biased slightly low (due to the recovery exception) or slightly high (due to the detection in the laboratory blank). No corrective action was taken as a result of these laboratory exceptions because 1,4-dioxane was detected in 144 Groesbeek Street at concentrations ranging from 0.7 to 1.3 $\mu g/m^3$, well below the EPA risk-based concentration (RBC) for residential air (3,800 $\mu g/m^3$, non-cancer).

4.10.2.2 Direct-Read Instruments

The accuracy of the XRF instruments was ensured using several measures. First, the XRF analyzer was calibrated by the manufacturer prior to delivery to EH&E using standard reference materials that include many elements, including strontium. The manufacturer's calibration procedure specifically includes an assessment of the concentration of strontium in the standard reference material and values reported by the analyzer. In addition, internal instrument background checks were run on each instrument before use.

The accuracy of the XRF readings was evaluated in this study by examining repeat XRF strontium readings obtained each day during the laboratory analysis period from a reference material with a known strontium concentration: NIST Standard Reference Material 2702 (SRM 2702), 119.7 ± 3.0 mg/kg Strontium. The XRF strontium readings (N=5, Mean=118.6 mg/kg, range 112 – 123 mg/kg) during laboratory analysis of bulk drywall samples from the study, indicated strong agreement with SRM 2702 and a high degree of accuracy. This is consistent with a recent, extensive study undertaken by

EH&E that demonstrated excellent accuracy of XRF measurements for strontium compared to analysis by ICP-AES (slope = 0.85-0.95, R^2 = 0.96-0.99, $p<0.01$) (EH&E 2010b).

For FTIR, internal calibration programs were run on the instrument each month in accordance with the manufacturer's recommendations.

The accuracy of real-time temperature, relative humidity, and dew point monitors was ensured in accordance with the manufacturer's recommendations (annual calibration against a primary standard). Accuracy of the CO_2 monitors was maintained using a primary calibration procedure, with NIST-traceable zero and span gases, prior to field deployment, where the instrument response was set or calibrated to a primary standard device, zero or span gas, or mercury thermometers and hygrometers. Each day during the field study, the performance of each sensor was measured or verified against these primary standards. This method allows the repeatability (precision) and the instrument accuracy to be recorded.

4.10.3 Precision

Measurement precision for targeted analytes was characterized by analysis of the duplicate samples collected during the field study. Numerous methods have been developed to characterize the precision of environmental measurement systems from duplicate measurements. Estimates of precision attained from the various methods are reported to be a function of the magnitude that the differences between duplicate samples deviate from normality (Hyslop and White 2009). The analysis of precision for the different sample types collected during this study is discussed below. It is important to note that the number of sample and duplicate pairs was very limited for all measurements, except XRF and FTIR readings.

4.10.3.1 Non-biological Samples

Due to the limited number of sample and duplicate pairs (N=2, except XRF and FTIR), the initial evaluation of precision was an evaluation of detection agreement between samples and corresponding duplicates. The detection agreement between samples and duplicate measurements for all samples, except airborne fungi is shown in Table 4.15.

Table 4.15 Summary of Detection Agreement Between Sample and Duplicate Pairs

Sample Matrix	Analyte Group	Number of Pairs	Number of Target Analytes	Detection Agreement
Air	Aldehydes (active)	2	12	100%
Air	Aldehydes (passive)	2	9	100%
Air	Corrosion coupons	2	2	100%
Air	H2S (passive)	2	1	100%
Air	Reduced Sulfur	2	20	100%
Air	VOC (active)	2	53	97.2%
Air	VOC (canister)	2	75	95.3%
Drywall	FTIR	22	1	95.5%
Drywall	S8	2	1	100%
Drywall	XRF	22	1	100%

H_2S hydrogen sulfide
VOC volatile organic compound
FTIR Fourier transform infrared spectroscopy
S_8 orthorhombic sulfur (elemental sulfur)
XRF x-ray fluorescence

As seen in Table 4.15, there was a 100% detection agreement between most sample and duplicate pairs during the study. In addition to detection agreement, the precision of the air sample and coupon measurements, which all had a low sample size (N=2 pairs), was evaluated by calculating the relative percent difference (RPD) between each duplicate pair where both measurements were above the laboratory reporting limit. Average RPDs were calculated for sample groups with multiple analytes. RPDs were calculated as follows, and Table 4.16 summarizes the RPDs from the study:

$$RPD\ (\%) = \frac{Absolute\ Value(Concentration_{sample} - Concentration_{Duplicate})}{(Concentration_{sample} + Concentration_{Duplicate})/2} x100$$

Table 4.16 Summary of Relative Percent Difference (RPD) Calculations Between Sample and Duplicate Pairs*

Sample Matrix	Analyte Group	Average RPD Between Sample/Duplicate Pairs	Number of Analyte Pairs Above Detection
Air	Aldehydes (active)	9.2	12 (50%)
Air	Aldehydes (passive)	40.2	14 (78%)
Air	Corrosion coupons	21.0	2 (50%)
Air	VOC (active)	11.0	35 (33%)
Air	VOC (canister)	7.8	28 (19%)

RPD relative percent difference
VOC volatile organic compound

* Both sample and duplicates were below detection for all reduced sulfur, passive H_2S and S_8 pairs.

In general, the RPDs indicate a high level of precision between paired measurements. The RPDs between duplicate pairs is somewhat lower for passive aldehyde samples than the agreement shown for other groups. It is likely that the low sample size influences the precision estimates for this study. As discussed in Section 5, the aldehyde concentrations detected in the homes were consistent with those seen during the 51-Home Study, during which a high level of precision was demonstrated between sample and duplicate pairs.

4.10.3.2 Airborne Fungal Spore Samples

A high level of precision is not necessarily expected between paired airborne fungal samples because variations between airborne fungal concentrations over time are typically greater than random sampling error (AIHA, 2005). Airborne spore measurements with small sample sizes and low levels of precision, however, can be effective in identifying indoor environments with elevated airborne spore levels (ACGIH, 1999), as was the intent of the current study. Although, a high level of precision was not expected, the variability between paired duplicate measurements was examined by calculating the agreement ratio between the paired sample and replicate viable (culturable) and viable and non-viable airborne spore measurements. These are summarized in Table 4.17 along with the total spore concentrations detected in the paired samples. The agreement ratio was calculated as follows (ACGIH, 1999):

$$Agreement\ Ratio = \frac{2\,W}{(S_{sample} + S_{Duplicate})}$$

Where:

W = Number of fungal types sample and duplicate have in common

S = Total number of fungal types detected in sample or duplicate

Table 4.17 Summary of Agreement Ratios Between Paired Sample and Replicate Pairs for Airborne Fungal Measurements

Home	Location	Agreement Ratio	Total Concentration*	
			Sample	Replicate
Viable and Non-Viable Spores				
144 Groesbeek	Second floor, master bedroom	0.78	1,800	2,700
144 Groesbeek	Outdoors2	0.77	5,000	4,000
144 Groesbeek	Outdoors1	0.78	9,500	5,800
4 Darden	Second floor, master bedroom	0.63	360	330
4 Darden	Outdoors2	0.87	17,300	14,800
4 Darden	Outdoors1	0.89	5,800	4,600
Viable Spores				
144 Groesbeek	Second floor, master bedroom	0.77	300	320
144 Groesbeek	Outdoors2	0.43	410	420
144 Groesbeek	Outdoors1	0.18	580	510
4 Darden	Second floor, master bedroom	0	410	110
4 Darden	Outdoors2	0.50	2,800	2,900
4 Darden	Outdoors1	0.77	1,100	740

* Sum of individual spore concentrations; total concentrations for total viable and non-viable samples are in spores/m^3 and in cfu/m^3 for viable samples.

Agreement ratios approaching or exceeding 0.80 indicate strong agreement between paired measurements (ACGIH, 1999). The viable and non-viable spore measurements indicated a better agreement ratio, compared with the viable spore measurements, possibly related to the lower detected concentrations in the viable measurements. There were no common spore types detected in one sample/replicate pair collected in the 4 Darden Home, but the overall spore concentrations at this location were low. Investigators often evaluate differences in airborne spore sampling results based on order of magnitude variations in spore concentrations between area; as shown in Table 4.17, the paired sample and duplicate total spore measurements were within an order of magnitude for all pairs.

4.10.3.3 XRF and FTIR Measurements

Due to the relatively high number of paired sample and duplicate measurements (N=22 pairs for both), precision for XRF and FTIR laboratory measurements was estimated based upon guidance from the EPA (EPA 2008). In this method, precision is calculated as the root mean square of the scaled relative differences between pairs of duplicate samples (Equation 4.3). The primary estimate of precision derived from this method provides a concentration range within which the actual concentration is expected to occur 68% of the time.

$$Root\ mean\ square = \sqrt{\frac{1}{n}\sum_{i=1}^{n} D_i^2} \times 100\%, \qquad \text{(Equation 4.3)}$$

where

$$D_i = \frac{(C_{i1} - C_{i2})/\sqrt{2}}{(C_{i1} + C_{i2})/2}$$

The estimates of precision for the strontium (by XRF) and carbonate (by FTIR) measurements are shown in Table 4.18 and included all duplicate pairs where both measurements were above the reporting limit. The XRF and FTIR measurements demonstrate a high level of precision.

Table 4.18 Estimate of Measurement Precision for XRF and FTIR Laboratory Measurements

Parameter	Number of Pairs	Precision (%)
Strontium (XRF)	22	1.5
Carbonate (FTIR)	15	7.6

XRF x-ray fluorescence
FTIR Fourier transform infrared spectroscopy

The precision of the FTIR instrument used in testing at EH&E's laboratory also was examined by evaluating the agreement between measurements repeated daily from the same sample of drywall. The repeat reference readings for carbonate, conducted on drywall samples from another study, are presented in Table 4.19 and indicate strong agreement.

Reference Drywall	Number of Measurements	Carbonate (absorbance)		Coefficient of Variation (%)
		Mean	Range	
CH4	5	13.4	12.8 – 13.8	3.2
CPSC14*	5	<1.4	<1.4	0
CPSC19	5	5.2	4.8 – 5.8	4.7
CPSC26	5	9.6	8.8 – 10.4	7.3

Table 4.19 Summary Statistics from Repeat FTIR Readings During Laboratory Analysis

* All measurements were below detection from this reference drywall; the listed reporting limit is 3 times the mean standard deviation from repeat measurements of the other three reference drywall samples.

The precision results for the XRF analyzer used in this study are consistent with results from an extensive study of XRF analyzer performance with regard to quantifying strontium in drywall (EH&E 2010b). In that source marker study, within-instrument precision ranged from 0.4-14% (median = 2%).

In addition to the calibration procedures implemented prior to, and in the field (described above), the precision and reasonableness of real-time monitoring data (temperature, relative humidity, dew point temperature, and CO_2) was evaluated using several measures. For the temperature, relative humidity, and dew point temperature measurements, the coefficient of variation (CV) between the daily average values at each measurement location within the two homes was used as an indicator of agreement (CV=[standard deviation/mean]∗100). Table 4.20 summarizes the mean CVs for the temperature and humidity monitoring data, all of which were less than 10%.

Table 4.20 Coefficient of Variation, Inter-home Temperatures, Relative Humidity and Dew Point Temperature Measurements

Home	CV (%)		
	Temperature	Relative Humidity	Dew Point Temperature
144 Groesbeek	1.6	5.1	1.7
4 Darden	1.1	2.8	1.1

CV coefficient of variation

The precision of air exchange rate measurements was evaluated using linear regression analysis between the two coincident air exchange rate estimates within each home, which were based on CO_2 readings. The CVs for the air exchange rate estimates were 4.9% and 5.0% and indicated excellent agreement between in-home CO_2 relationships.

5.0 RESULTS—PROBLEM DRYWALL ASSESSMENT

5.1 OVERVIEW OF CPSC GUIDANCE

The CPSC and HUD released an updated interim guidance document for identification of homes with corrosion from problem drywall (CPSC/HUD 2010). The identification method, based on extensive testing of problem drywall in homes and in laboratory settings (EH&E 2010a; EH&E 2010b; LBNL 2010), involves two steps: 1) threshold inspection, and 2) corroborating evidence. A summary of the steps and criteria are provided in Table 5.1.

A positive result for Step 1, including both criteria, is a prerequisite to any further consideration. This includes the observation of blackening of the copper in the home and installation of drywall during the relevant time period (2001 – 2008). Once the Step 1 criteria are met, several pieces of corroborating evidence are also necessary to properly identify the home as having problem drywall. Depending upon the date of drywall installation, the number of pieces of required corroborating evidence will vary. For homes built/renovated between 2001 and 2004, at least four of the Step 2 criteria must be met. For homes built/renovated between 2005 and 2008, at least two of the Step 2 criteria must be met.

Table 5.1 Summary of the CPSC/HUD Interim Guidance for Identification of Homes with Corrosion from Problem Drywall, August 27, 2010

Step 1 – Threshold Inspection	a)	Blackening of copper electrical wiring and/or air conditioning evaporator coils.
		-- AND --
	b)	The installation of drywall (for new construction or renovations) between 2001 and 2008.
Step 2 – Corroborating Evidence[a]	a)	Elemental sulfur levels in samples of drywall core found in the home exceeding 10 mg/kg.
	b)	Corrosive conditions in the home, demonstrated by the formation of copper sulfide on copper coupons (test strips of metal) placed in the home for a period of two weeks to 30 days or confirmation of the presence of sulfur in the blackening of the grounding wires and/or air conditioning coils.
	c)	Confirmed markings of Chinese origin for drywall in the home.
	d)	Elevated levels of hydrogen sulfide, carbonyl sulfide, and/or carbon disulfide emitted from samples of drywall from the home when placed in test chambers.
	e)	Corrosion of copper metal to form copper sulfide when copper is placed in test chambers with drywall samples taken from the home.

Table 5.1 Continued
CPSC U.S. Consumer Product Safety Commission HUD U.S. Department of Housing and Urban Development mg/kg milligrams per kilograms [a] For homes built/renovated between 2001 and 2004, at least four of the Step 2 criteria must be met. For homes built/renovated between 2005 and 2008, at least two of the Step 2 criteria must be met.

5.2 EVALUATION OF EVIDENCE OF PROBLEM DRYWALL IN THE FORT BRAGG HOMES

The CPSC/HUD guidance regarding the identification of homes with corrosion from problem drywall provides a useful framework for evaluating the Fort Bragg homes for the presence of problem drywall. This section evaluates each step of the CPSC/HUD guidance in relation to test results from 144 Groesbeek Street and 4 Darden Street. In addition, EH&E evaluated several other relevant factors that, when combined with other test results, are additional aids in the determination of the presence or absence of problem drywall in a home.

5.2.1 Step 1—Threshold Inspection

(a) Blackening of copper electrical wiring and/or air conditioning evaporator coils

There was no evidence of blackened copper electrical wiring in either the 144 Groesbeek Street or 4 Darden Street homes. In-home inspections of copper ground wires in the wall outlets were conducted by a scientist experienced in evaluating problem drywall-related corrosion. In each home, the faceplate of each of the electrical outlets was removed, and a trained scientist evaluated the level of corrosion on a three-point scale where, 1 = no visible corrosion; 2 = moderate visible corrosion; and 3 = significant corrosion (Figure 4.1). The inspections were conducted on a total of 150 ground wires in the two homes (Table 5.2).

Table 5.2 Summary of Visual Corrosion Assessments Scores				
Home	**Total Number of Inspections**	**Significant Corrosion**	**Moderate Visible Corrosion**	**No Visible Corrosion**
144 Groesbeek Street	74	0	0	74
4 Darden Street	76	0	12	64

In 144 Groesbeek Street, all of the ground wires were rated the lowest score (i.e., no visible corrosion). In 4 Darden Street, 84% of the ground wires were rated the lowest score, and 16% were rated as "moderate visible corrosion." Importantly, neither home had any copper ground wires that were rated the highest score (i.e., significant visible corrosion). This is in contrast to the results from the 51-Home Study, which found that every home in that study impacted by problem drywall had at least one ground wire rated the highest score, and in most cases the majority of ground wires were corroded significantly (i.e., heavily blackened) (Figure 5.1).

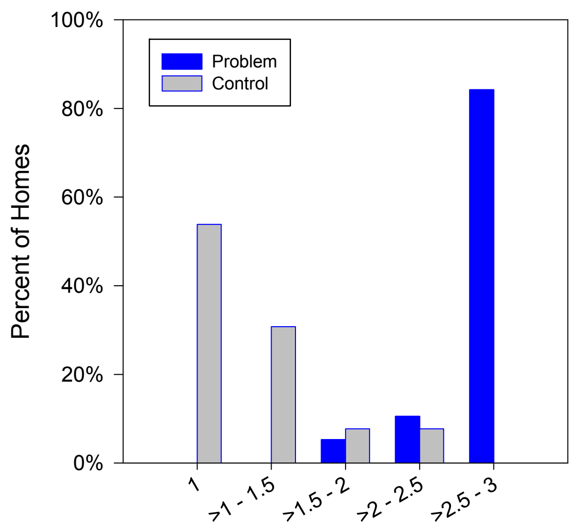

Figure 5.1 Distribution of Mean Ground Wires Corrosion Rating in Homes from the 51-Home Study (Homes with Problem Drywall and Control Homes)

(b) The installation of new drywall (for new construction or renovations) between 2001 and 2008.

Both the 144 Groesbeek Street and 4 Darden Street homes were built in the relevant time period. This information is based on reports from investigations by CPSC field staff. For 144 Groesbeek Street, the CPSC report states: "According to CID, Family 1 moved into the newly constructed home in December 2005 just after it was completed." (CPSC IDI 2010a). For 4 Darden Street, the report states: "The home was built as new construction and was completed in August 2007," and that the drywall distributor reported delivering drywall to the home on June 14, 2007, or June 15, 2007 (CPSC IDI 2010b).

The two Fort Bragg homes in this study fail to satisfy the Step 1 criteria for identification of homes with corrosion from problem drywall due to insufficient evidence of copper corrosion in the homes (Step 1a).

5.2.2 Step 2—Corroborating Evidence

(a) Elemental sulfur levels in samples of drywall core found in the home exceeding 10 mg/kg

Elemental sulfur was not detected in any samples from either Fort Bragg home, and the detection limit for all samples was well below the 10 mg/kg criteria (1 mg/kg = 1 ppm).

S_8 concentrations in drywall samples from each home are presented in Table 5.3 along with comparison data from the 51-Home Study. Ten samples of drywall from each home were analyzed for elemental sulfur, and elemental sulfur was not detected in any of the samples. The method detection limit (5 mg/kg) was less than the criteria level (10 mg/kg). The drywall sample selection criteria for S_8 analysis was designed to increase the likelihood of finding a drywall sample with elemental sulfur. This was done by first selecting drywall samples with the highest strontium content based on XRF testing because strontium and elemental sulfur have been shown to be correlated positively in problem drywall (EH&E 2010b). After selecting samples with elevated strontium, remaining samples were chosen across the distribution of strontium concentrations measured in an effort to select representative pieces of drywall from each home for S_8 analysis.

In addition to the ten drywall samples from each home that were collected and analyzed by EH&E, one former resident of 144 Groesbeek Street provided CPSC with three pieces of drywall collected from the home. Two samples from each drywall piece were analyzed for S_8 for a total of six additional analyses. S_8 was not detected in any of the drywall pieces provided by the former occupant of 144 Groesbeek Street (n=6; all concentrations <5 mg/kg).

Table 5.3 Concentrations (mg/kg) of S_8 in Drywall Samples from the Fort Bragg Homes and Comparison Data from the 51-Home Study

	144 Groesbeek Street		4 Darden Street		*51-Home Study Mean (75th Percentile)**	
Location	**N**	**Mean (Max)**	**N**	**Mean (Max)**	***Problem***	***Control***
Bedroom 1	1	<5.0 (<5.0)	1	<5.0 (<5.0)	*200 (230)*	*4.9 (6.0)*
Bedroom 3	0	NA	1	<5.0 (<5.0)		
Master	1	<5.0 (<5.0)	2	<5.0 (<5.0)		
Living	1	<5.0 (<5.0)	1	<5.0 (<5.0)		
Family Room	2	<5.0 (<5.0)	2	<5.0 (<5.0)		
Kitchen	1	<5.0 (<5.0)	2	<5.0 (<5.0)		
Bath	1	<5.0 (<5.0)	0	NA		
Bath 2	1	<5.0 (<5.0)	0	NA		
Stairs	2	<5.0 (<5.0)	1	<5.0 (<5.0)		

mg/kg milligrams per kilograms
N number
NA not applicable

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

(b) Corrosive conditions in the home, demonstrated by the formation of copper sulfide on copper coupons

Elevated rates of copper sulfide formation were not observed in either Fort Bragg Home.

Copper corrosion classification coupons were deployed in multiple locations of each home for a 14-day period. Previous testing of homes with and without problem drywall identified significantly different rates of copper sulfide formation on classification coupons between problem and non-problem homes (CPSC/HUD 2010). For coupons placed in the air handler air supply stream, elevated rates of copper sulfide formation from homes with problem drywall are defined in this report as those with a corrosion rate greater than 300 angstroms per 30 days. For coupons placed in rooms within a home, elevated rates of copper sulfide formation are defined in this report as those greater than 100 angstroms per 30 days. The results of testing in the two Fort Bragg homes indicate that copper sulfide formation did not exceed those values in either home (Appendix A,

Table A.1). Figure 5.2 depicts the data from the Fort Bragg homes in comparison to results from the 51-Home Study.

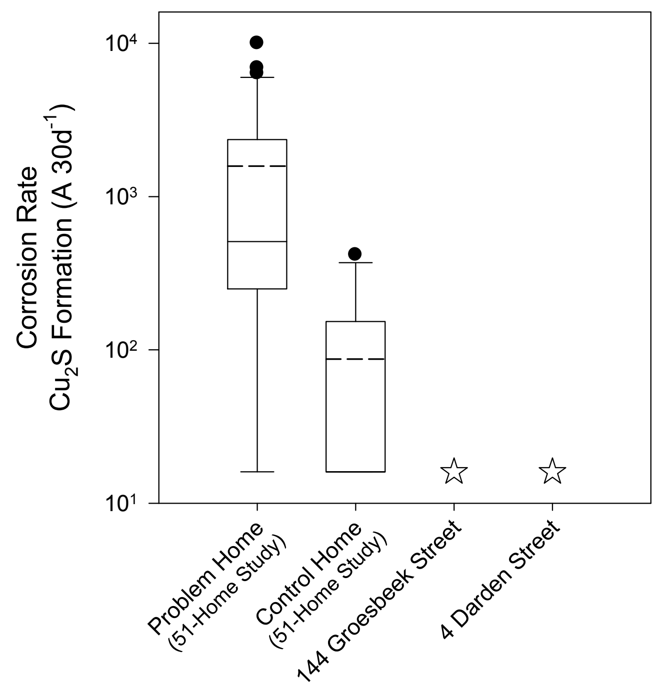

Figure 5.2 Comparison of Cu_2S Formation Rate (A $30d^{-1}$) at AHU Air Supply Register in Homes Impacted and Not Impacted by Problem Drywall from 51-Home Study and Fort Bragg Homes

(c) Confirmed markings of Chinese origin for drywall in the home

Markings of Chinese origin were not observed on the drywall in either Home. Although the presence of non-English character printing on drywall was reported in a previous investigative report for the 4 Darden Street home (CPSC IDI. 2010b), these markings were later confirmed through analysis by a Chinese linguist as not being of Chinese origin.

Multiple exploratory holes were made by EH&E investigators, as well as others, including the CPSC, in each room of both residences. EH&E investigators evaluated each penetration to attempt to determine whether markings specific for origin of manufacture could be identified.

(d) Elevated levels of hydrogen sulfide, carbonyl sulfide, and/or carbon disulfide emitted from samples of drywall from the home when placed in test chambers

This study focused on identifying source characteristics of drywall in the subject homes and characterizing the indoor environment. Laboratory chamber-based testing was not conducted as part of this study.

(e) Corrosion of copper metal to form copper sulfide when copper is placed in test chambers with drywall samples taken from the home.

This study focused on identifying source characteristics of drywall in the subject homes and characterizing the indoor environment. Laboratory chamber-based testing was not conducted as part of this study.

5.2.3 Additional Factors

In addition to the interim guidance for identification of homes with corrosion from problem drywall, EH&E evaluated several other relevant factors that have been found to be useful for aiding in the determination of the presence or absence of problem drywall in a home. The following is a summary of those observations:

(a) Corrosive conditions in the home, demonstrated by the formation of silver sulfide on silver coupons

No elevation in the rates of silver sulfide formation was observed in either of the Fort Bragg homes.

Silver classification coupons were deployed simultaneously with the copper classification coupons in the two Fort Bragg homes. Formation of silver sulfide on the silver coupons previously has been found to be a useful indicator of corrosive conditions in the homes containing problem drywall (EH&E 2010a). For silver coupons deployed in an air handler air supply stream, elevated silver sulfide formation rates are defined in this report as those greater than 1,000 angstroms per 30 days. For silver coupons deployed in rooms in the home, elevated silver sulfide formation rates are defined in this report as those greater than 300 angstroms per 30 days. Results for the two Fort Bragg homes (Appendix A, Table A.1) demonstrate that elevated rates of silver sulfide formation were not observed in either home. The rate of silver sulfide formation was less than outdoor rates and consistent with background rates of silver sulfide formation in homes. Figure 5.3 depicts the data from the Fort Bragg homes in comparison to results from the 51-Home Study.

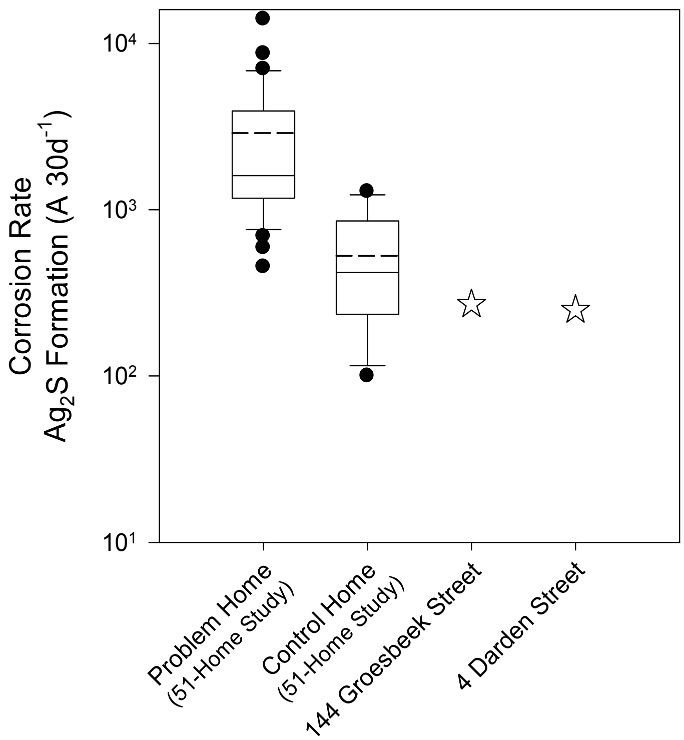

Figure 5.3 Comparison of Ag_2S Formation Rate (A $30d^{-1}$) at AHU Air Supply Register in Homes Impacted and Not Impacted by Problem Drywall from 51-Home Study and Fort Bragg Homes

(b) Presence of Hydrogen Sulfide or other Reduced Sulfur Gases

Neither Hydrogen sulfide nor any other reduced sulfur compound was detected in any sample collected from either 144 Groesbeek Street or 4 Darden Street.

Both in-home and laboratory-based studies have demonstrated that the presence of hydrogen sulfide in the air is associated with problem drywall (EH&E 2010a; EH&E 2010b; LBNL 2010). Two types of air samples were used to collect air in the Fort Bragg homes: discrete samples (short-term) and 14-day integrated samples. Air samples collected using two different methods and obtained from multiple locations in the two Fort Bragg homes contained no detectable levels of hydrogen sulfide (Table 5.4). In addition, measurements for an expanded list of 19 additional reduced sulfur compounds were made on each floor of the homes. None of these compounds were detected in the homes (Table A.2, Appendix A).

Table 5.4 Passive Hydrogen Sulfide Summary (μg/m^3)

Analyte	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
	BR	**LR**	**MB**	**O**	**B**	**LR**	**MB**	**O**	***Problem***	***Control***
Hydrogen Sulfide	<0.60	<0.60	<0.59	<0.63	<0.59	<0.59	<0.59	<0.61	*1.0 (1.3)*	*<0.70 (<0.70)*

μg/m^3 micrograms per cubic meter

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

(c) Presence of Strontium/Carbonate Marker in Drywall Samples

The strontium/carbonate marker was not detected above the criteria levels in any of the drywall samples collected from either 144 Groesbeek Street or 4 Darden Street.

Combined elevated concentrations of strontium (>1,200 mg/kg) and carbonate (>5 absorbance units) may serve as an indicator of the presence of problem drywall ("strontium/carbonate marker") (EH&E 2010a; EH&E 2010b). A total of 78 and 82 core samples were collected from 144 Groesbeek Street and 4 Darden Street, respectively. These samples were analyzed for strontium content by XRF and carbonate content by FTIR. None of the core samples tested in either home had the strontium/carbonate marker of problem drywall present (Table 5.5). In addition, strontium measurements were made on multiple locations of every wall and ceiling in each home, and elevated strontium was not observed in any samples (Table A.3, Appendix A).

Table 5.5 Summary of Bulk Core Samples

	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**			
		Mean (Max)				Mean (Max)			*Problem*		*Control*	
Location	**N**	**Strontium (mg/kg)**	**Carbonate (absorbance)**	**No. Marker**	**N**	**Strontium (mg/kg)**	**Carbonate (absorbance)**	**No. Marker**	***Strontium (mg/kg)***	***Carbonate (absorbance)***	***Strontium (mg/kg)***	***Carbonate (absorbance)***
Bedroom 1	10	980 (1100)	6.5 (15)	0	11	870 (950)	7.6 (12)	0				
Bedroom 2	9	900 (1000)	6.6 (13)	0	11	890 (1100)	7.7 (13)	0				
Bedroom 3	8	960 (1000)	6.7 (9.3)	0	11	880 (940)	7.5 (12)	0				
Master	10	940 (1100)	13 (42)	0	11	880 (980)	6.6 (7.1)	0				
Living	10	470 (1100)	6.9 (25)	0	10	240 (270)	<1.4 (2.0)	0				
Family Room	10	410 (940)	14 (40)	0	12	420 (800)	2.4 (7.0)	0				
Kitchen	11	340 (880)	1.9 (8.0)	0	8	250 (290)	<1.4 (3.5)	0				
Master Bath	5	930 (970)	11 (17)	0	8	870 (1000)	9.2 (20)	0	*2100 (3000)*	*11 (13)*	*520 (630)*	*4.7 (6.0)*
Bath	4	270 (300)	<1.4 (<1.4)	0	4	260 (270)	<1.4 (<1.4)	0				
Bath 2	4	840 (1000)	5.3 (7.5)	0	5	920 (1000)	6.9 (7.3)	0				
Laundry	2	920 (1000)	16 (24)	0	2	840 (850)	9.1 (9.9)	0				
Stairs	6	560 (900)	7.0 (16)	0	4	730 (970)	5.1 (9.7)	0				
Hallway	3	280 (300)	<1.4 (<1.4)	0	4	540 (840)	5.1 (8.1)	0				
Hallway 2	6	510 (940)	7.8 (18)	0	8	830 (950)	11 (31)	0				
Garage	5	320 (410)	4.2 (14)	0	11	450 (880)	3.1 (8.5)	0				
House Totals	103	650 (1100)	7.4 (42)	0	120	660 (1100)	5.5 (31)	0				

N number
Max maximum
mg/kg milligrams per kilogram
No. number

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

5.3 REVIEW OF PREVIOUS TESTING FOR PROBLEM DRYWALL AT FORT BRAGG

On May 3, 2009, an outside consultant contracted by the Fort Bragg Installation Air Program manager took one sample of drywall from the 4 Darden Street residence. This sample was analyzed by EMSL Analytical, Inc. (Westmont, New Jersey) for sulfur-containing VOCs, including carbon disulfide and carbonyl sulfide. The analytical method involved enclosing the drywall sample in a sealed chamber for 24 hours at an elevated temperature (37 °C) and then quantifying VOCs in the headspace of the chamber by GC/MS, according to EPA Method TO-15. Quality assurance testing included one duplicate drywall sample analyzed by the same procedure. Additionally, the laboratory had results from testing of a drywall sample from China (termed the ‘Positive Control Sample’), and results of one reported domestic drywall sample from a local retail store (termed the ‘Negative Control Sample’). Results of the testing from these two samples were used to evaluate the test results from the drywall sample obtained from 4 Darden Street.

The test results, reported on May 28, 2009, indicate that drywall from 4 Darden Street had detectable levels of carbon disulfide, carbonyl sulfide and total organic sulfide, similar to the “Positive Control” sample. The report concluded that the, “sample is identified as POSITIVE for off-gassing of sulfur compounds associated with odorous drywall.”

This initial testing was conducted at the early stages of public, governmental, academic, and commercial awareness surrounding the problem drywall issue. As such, sufficient testing establishing valid criteria for the identification of problem drywall had yet to be conducted. The comparison data used in the May 28, 2009, report was comprised of only one sample of known problem drywall and one control sample. This was inadequate reference data because it was not fully representative of the population of all problem or non-problem drywall. At this time, there is now a much larger and representative dataset of emission rates (i.e., off-gassing) from drywall with which to compare results against. Lawrence Berkley National Laboratory (LBNL) has conducted extensive off-gassing testing of a broad selection of both problem and non-problem drywall in the period of time following this EMSL Analytical, Inc. laboratory report from 4 Darden Street (LBNL 2010). Results from the LBNL testing demonstrate that while problem drywall has higher emission rates than some sulfur compounds, this is only on average. For some volatile sulfide compounds, such as carbonyl sulfide and carbon disulfide, there is significant overlap in the distribution of sulfur off-gassing from problem and non-problem drywall (Figure 5.4). Although the conclusion that the drywall from 4 Darden Street is “Positive for off-gassing of sulfur compounds” may be correct, the result, in and of itself, is insufficient to indicate that this drywall is problem drywall; positive off-gassing of sulfur compounds is a sensitive, but not specific, marker of problem drywall (i.e., there is the potential for false positives).

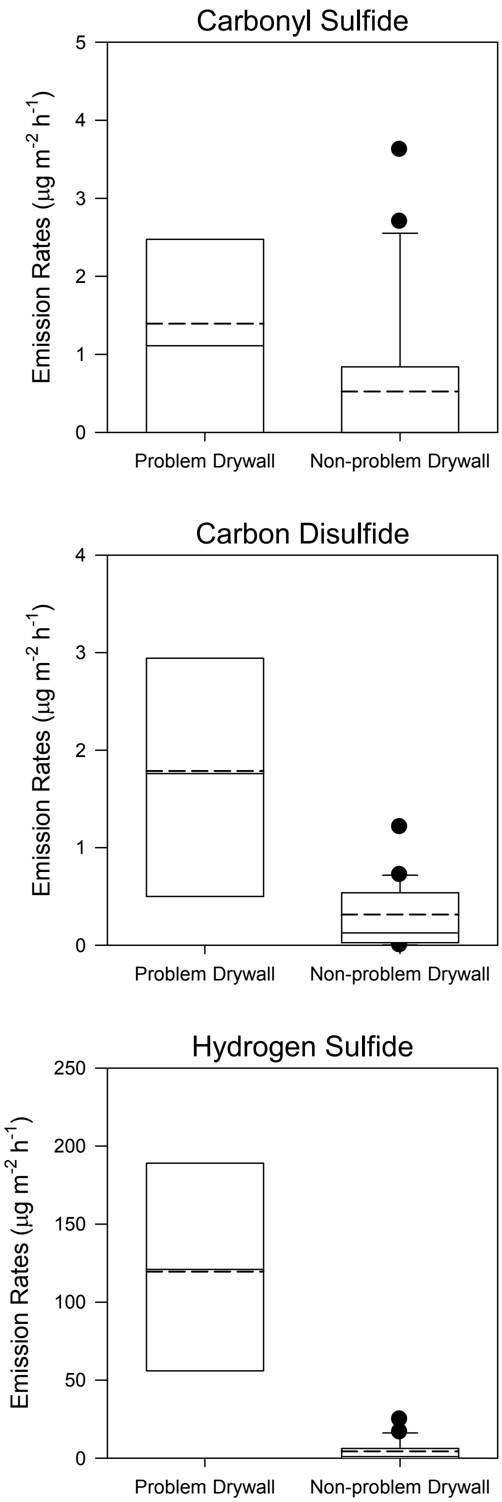

Figure 5.4 Emission Rate Data for Problem and Non-problem Drywall Samples, Defined as Drywall Samples With Elemental Sulfur Marker and Those Without (LBNL 2010)

More comprehensive testing to determine whether the 4 Darden Street drywall was problem drywall was conducted in 2010. Since the initial testing of samples collected on May 3, 2009, the presence of elemental sulfur (S_8) in concentrations greater than 10 mg/kg in drywall has been found to be a sensitive and specific marker of problem drywall. In a report from a U.S. Army contractor dated June 3, 2010, they report that 12 drywall samples collected from multiple rooms at 4 Darden Street were tested for S_8 concentration by EMSL Analytical, Inc., using GC/MS. The tests indicated that S_8 was not detected in any of the drywall samples, and the method limit of detection (2 mg/kg) was well below the guidance level of 10 mg/kg established for problematic drywall. Additional testing conducted by U.S. Army contractors (reported on June 15, 2010), measured strontium concentrations in drywall from 4 Darden Street. None of the samples had levels of strontium above the 1,200 mg/kg criteria (n=12; mean = 580 mg/kg; max = 800 mg/kg).

5.4 CONCLUSIONS REGARDING THE PRESENCE OF PROBLEM DRYWALL

Based on the observations of the field staff and analysis of the results of the in-home sampling and testing, as well as interviews with CID and CPSC field investigators and review of previously collected data, EH&E concludes that 144 Groesbeek Street and 4 Darden Street do not contain problem drywall.

6.0 INDOOR ENVIRONMENTAL ASSESSMENT

6.1 INTRODUCTION AND SURVEY METHODOLOGY

EH&E's assessment was conducted from October 4, 2010, to October 7, 2010, to profile the environmental conditions within the homes and to identify potential sources or conditions that could affect IEQ negatively. EH&E's assessment included visual inspection of each of the subject homes for evidence of moisture intrusion or indoor mold reservoirs, visual inspection of the HVAC systems serving the homes, determination of various building and HVAC performance metrics including indoor temperature and moisture trending, and the measurement of overall air exchange rates within these homes. The findings of this assessment are provided below.

6.2 VISUAL HOME ASSESSMENT

At the time of EH&E's inspection, both the 4 Darden Street and 144 Groesbeek Street homes were vacant and void of furniture and belongings. The HVAC systems serving each home were operational. The interiors of each home were found generally to be clean with minor staining on the carpet from apparent foot traffic or historic localized spill events, consistent with normal residential occupancies. Visual inspection identified no evidence of water damage on floors, walls, or ceiling surfaces in the 4 Darden Street home. Minor evidence of water damage was noted in the 144 Groesbeek Street home, including an area under the window of the second floor bedroom, and the floor of the second floor utility room. For both homes, no evidence of visible mold growth or the presence of mold-like odors was noted in any area inspected. A moisture survey of walls, floors, and ceilings within each home (using a moisture meter and IR camera) did not identify any materials with elevated moisture levels. At the time of inspection, all building materials within the homes were dry.

No odors typical of those commonly associated with problem drywall were noted by EH&E investigators while in the homes. A "wood-like" odor was noted by EH&E investigators within the 144 Groesbeek Street home, and further investigation of this odor identified the existing kitchen cabinetry as the potential odor source. Trash like odor was also noted in the garage of 144 Groesbeek Street, and a similar, although less distinct, odor was noted by EH&E investigators in the garage at 4 Darden Street. In neither home were the odors noted in the garages identified by EH&E investigators within occupied areas of the homes.

6.3 MECHANICAL SYSTEMS

The 144 Groesbeek Street home is heated and cooled through the use of a gas-fired furnace equipped with a direct expansion refrigerant cooling coil, respectively (the unit). This unit is located within a utility room on the second floor. The 4 Darden Street home is equipped with a similar system by design; however, heating is provided by an electric resistance heating element (as opposed to 144 Groesbeek Street, which has a gas fired heat exchanger) located within the housing of the air handling unit. This unit is located within a utility closet at the back end of the garage. Both units are designed and operated as recirculating systems and do not provide outdoor air delivery to the homes.

Both the 144 Groesbeek Street and 4 Darden Street systems provide conditioned air to the first and second floors of the homes through the use of individual thermostatically controlled zone dampers (one serving the first floor and one serving the second floor). For both homes, the thermostat located on the first floor provides master control of the heating or cooling function of the unit. With the master thermostat set to "cooling," the unit fan and cooling coil will cool the space when the room thermostat senses a call for cooling (e.g., room temperature is above the thermostat set point temperature). When the room temperature drops below the thermostat set point temperature, the cooling system will de-energize and the fan will cycle off. Likewise, with the master thermostat set to "heating," the unit fan and gas-fired heat exchanger (or electric resistance element for the 4 Darden Street home) will heat the space when the room thermostat senses a call for heating (e.g., room temperature is below the thermostat set point temperature). When the room temperature reaches or exceeds the thermostat set point temperature, the heating system will de-energize and the fan will cycle off.[6]

Domestic hot water for each of the homes is provided through the use of water heaters located within a utility closet at the back of each of the home's garages. The hot water

[6] Note that the master thermostats in both homes are equipped with a "fan on" setting which enables the fan to operate continuously regardless of whether the heating or cooling demands of the space are satisfied.

heater in the 144 Groesbeek Street home is gas-fired, while the 4 Darden Street home is electric.

6.4 SYSTEM INSPECTION

6.4.1 Visual Survey

A visual inspection of interior and exterior components and surfaces of the HVAC systems was conducted to document general condition in terms of system hygiene. The 144 Groesbeek Street furnace, fan system, and indoor cooling unit appeared original to the home, although EH&E was informed that the outdoor compressor unit was replaced during the summer of 2010. The 4 Darden Street indoor system was not original to the home and reportedly was replaced within the last year. Inspection of the indoor units in both homes found interior surfaces to be clean and free of debris. Interior surfaces of both units showed no evidence of dust or dirt buildup, no signs of apparent mold growth, and no water damage. Air filters, cooling coils, and condensate drain pans appeared clean. In general, visual inspection of both units identified no unusual sources or conditions that could have a negative impact on IEQ.

6.4.2 Operational Assessment

From October 4, 2010, to October 7, 2010, EH&E conducted a review of the heating and cooling functions of the HVAC units serving the homes. This assessment included operating the units in their heating and cooling modes and documenting the function of system components, including heating/cooling function, heating and cooling change-over, and zone damper operation. At the 144 Groesbeek Street home, additional testing was conducted to assess potential back-draft conditions related to the gas-fired furnace (see Section 6.4.3). This testing was not conducted at the 4 Darden Street home because the heat source for this home is electric.

Assessment of the 4 Darden Street HVAC system showed it to operate in a manner consistent with the overall operational intent of systems of similar design. System heating and cooling functions operated appropriately based on manipulation of the thermostat and the zone dampers modulated in accordance with the demand for heating and/or cooling within the respective first or second floor zone.

Although similar findings were documented at the 144 Groesbeek Street home for the heating/cooling function and zone damper operation, EH&E field investigators identified functional problems caused by frost buildup on the indoor cooling coil, which resulted in decreased airflow through the system. On the morning of October 6, 2010, the 144 Groesbeek Street unit was being operated in the cooling mode and continued to operate in this mode into the early afternoon, while temperatures within the home were noted to continue to increase. EH&E investigators' examination of the lack of cooling identified a decrease in airflow from supply diffusers within the home. To assess whether airflow deficiencies were related to zone damper operation, EH&E investigators placed the unit into heating mode to observe zone damper modulation. EH&E noted the gas-fired heat exchanger energized (as appropriate); however, within minutes of operating, a burning odor was noted within the HVAC closet and on the second floor, and the smoke detector on the ceiling of the second floor hallway alarmed. EH&E turned off power to the AC unit immediately.

Following the incident, an inspection of the cooling coil (located directly downstream of the gas-fired heat exchanger) found it to be covered in frost, thus resulting in a restriction of air across the heat exchanger. Based on these observations, EH&E reported to the CPSC that the mechanical systems in the home should be inspected due to the potential fire hazard observed under the above conditions (i.e., period of cooling with frost buildup on coils followed by switching the thermostat to heating). CPSC staff brought this to the attention of Army CID immediately. Further, EH&E recommended that the inspection include diagnosing and correcting the cause of frost buildup on the coils (EH&E understands that the compressor at this home was replaced recently), as well as inspection of the control wiring and logic on the system to ensure that all safeties and wiring are installed in accordance with the manufacturer's specifications.

The cause of the frost buildup on the cooling coil potentially may be related to system cooling cycle deficiencies following the reportedly recent installation of the new outdoor compressor unit. These current performance anomalies cannot be used to assess whether similar anomalies occurred in the past; although, in the absence of documented cases of historical smoke detector trips or odor occurrences, it is unlikely that these anomalies were occurring.

6.4.3 Potential for Flue Gas Back-Drafting

As part of the assessment, EH&E field investigators explored the possibility that the operation of indoor combustion sources within the home were causing a negative impact in IEQ. Of particular interest was the possibility that flue vent effluent may remain in the home due to either insufficient venting of the gas fired appliances or back-drafting of gases within the flue vent. In terms of indoor combustion sources, the 4 Darden Street home is equipped with all electric heating systems (for both domestic hot water and air handling unit heating) and therefore, no combustion sources are present. The 144 Groesbeek Street home, however, is equipped with a gas-fired furnace and a gas-fired domestic hot water system and, as such, potential impact from these sources on IEQ was of interest.

To assess the impact of combustion appliances in the Groesbeek home, EH&E investigators monitored carbon monoxide (CO) levels continuously within the home during periods when the appliances were operating under typical winter heating conditions (windows closed, maintaining indoor heating temperatures of 72 – 74 °F). CO levels were also monitored during periods where back-drafting conditions were induced artificially (indoor space depressurized with doors and windows closed) through the use of a Minneapolis Blower Door equipped with a variable speed fan manufactured by The Energy Conservatory (Minneapolis, Minnesota).

CO levels recorded continuously in the home during the week of October 4, 2010 (while field investigators were at the home) showed no elevations in CO concentration at any of the occupied monitoring locations (family room, bed room); nor was CO detected within the mechanical closet housing the gas fired furnace. These findings were consistent during periods when the home was placed under an artificial negative pressure of 0.12 to 0.20 inches of water. In addition, no CO was detected at any of the monitoring locations during the episode discussed in Section 6.4.2, where frost buildup on the HVAC unit cooling coil resulted in air flow restriction across the coil. Finally, long term monitoring of CO levels within the home from October 7, 2010, through October 21, 2010, did not detect elevations in CO concentration. Overall, the findings from the investigation indicate that combustion sources inside the home are not impacting IEQ negatively, even under conditions that potentially could lead to back-drafting of combustion gases into the home.

6.5 AIR EXCHANGE RATE ASSESSMENT

As part of the investigation, short-term air exchange rates in units of air changes per hour (ACH) were measured in each home and are presented in Table 6.1.

Table 6.1 Summary of Air Exchange Rates in the Fort Bragg Homes

Home	Average Air Changes per Hour	
	First Floor Family Room	Second Floor Master Bedroom
144 Groesbeek Street	0.21	0.39
4 Darden Street	0.33	0.77

The average ventilation rate for 144 Groesbeek Street and 4 Darden Street was 0.30 and 0.55 ACH, respectively. Typical air exchange rates for residential buildings in North America range from a seasonal average of about 0.2 ACH for tightly constructed homes to upwards of 2 ACH for loosely constructed housing (ASHRAE 2005). Additional studies have shown that an ACH of approximately 0.4 to 0.5 is a reasonable estimate of average seasonal air exchange rates for residences (ASHRAE 2005; Ek et al. 1990; Grimsrud et al. 1982; Palmiter and Brown 1989; Parker et al. 1990). This suggests that the Fort Bragg homes are on the lower end of the distribution of typical air exchange rates found in North America, and it may reflect that the homes are of relatively tight construction.

6.6 RESULTS OF AIR MONITORING

6.6.1 Volatile Organic Compounds

Air samples collected in multiple rooms from the 4 Darden Street and 144 Groesbeek Street homes were analyzed for a suite of 75 volatile organic compounds (VOC) (Tables A.4 and A.5). In the 144 Groesbeek Street home, 49 of the 75 VOCs analyzed for in the air samples were not detected. Of the 26 detected, 20 were detected at concentrations less than or similar to the average concentration from those obtained in the 51-home study. Six VOCs were detected in the 144 Groesbeek Street home, which were not detected in the 51-Home Study. The concentrations measured were less than the EPA's

RBC (non-carcinogenic), with the exception of alpha-pinene, which does not have an RBC for non-carcinogenic endpoints. Alpha-pinene is found commonly in the indoor air of residences as well as office buildings. For example, in one study of newly constructed homes, the mean alpha-pinene concentrations in indoor air ranged from 90.8 to 156.6 $\mu g/m^3$ (Hodgson et al., 2000). These values are four to six times higher than the alpha-pinene values measured at 144 Groesbeek Street. Likewise, the EPA and Florida Department of Health 10-Home Study report concentrations of alpha-pinene in indoor air ranging from non-detect to 188.5 $\mu g/m^3$ (EPA/FDOH 2009).

In the 4 Darden Street home, 45 of the 75 VOCs analyzed for in the air samples were not detected. Of the 30 detected, 20 were found at concentrations less than or similar to the average concentration from the 51-Home Study. Ten VOCs were detected in the 4 Darden Street home that were not detected in the 51-Home Study. The concentrations for these VOCs did not exceed the EPA's RBC (non-carcinogenic) for indoor air, with the exception of tetrahydrofuran and dibromochloromethane, which do not have an RBC for non-carcinogenic endpoints. Tetrahydrofuran is present in household adhesives and glues. In a 2003 NYSDOH study of VOCs in homes, tetrahydrofuran was detected in approximately 25 percent of the samples collected. The tetrahydrofuran concentrations measured at 4 Darden Street were lower than the 75th percentile value of the NYSDOH study (NYSDOH 2005). Further, the EPA and Florida Department of Health 10-Home Study reports concentrations of tetrahydrofuran in indoor air ranging from non-detect to 1.8 $\mu g/m^3$ (EPA/FDOH 2009). The results from 4 Darden Street are within the range reported in this EPA/FDOH study. Dibromochloromethane is a common component of chlorinated drinking water, which is the likely source of this compound in the air at 4 Darden Street based on the detection of dibromochloromethane in water samples at the Home (see Section 6.9).

6.6.2 Aldehydes

Air samples taken in multiple rooms of each home were analyzed for a suite of 12 aldehyde compounds. Six of these aldehyde compounds were detected at 144 Groesbeek Street and 4 Darden Street (Table 6.2). All six detected aldehydes were measured at concentrations that were less than the mean aldehyde concentrations measured in homes of the 51-Home Study. For two of the 12 aldehyde compounds analyzed (acetaldehdye and formaldehyde), concentrations were above the EPA's RBC (non-carcinogenic) but were typical of other newly constructed homes.

Table 6.2 Aldehyde Concentrations (μg/m^3) in Fort Bragg Homes and Comparison Data from the 51-Home Study

Analyte	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
	BR	**LR**	**MB**	**O**	**BR**	**LR**	**MB**	**O**	***Problem***	***Control***
2,5-Dimethylbenzaldehyde	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*<2.2 (<2.2)*	*<2.2 (<2.2)*
Acetaldehyde	5.8	5.6	5.1	1.7	12	13	12	1.7	*36 (48)*	*33 (46)*
Benzaldehyde	2.2	2.1	1.9	<1.0	4.9	3.9	4.8	<1.0	*7.9 (9.9)*	*7.5 (9.6)*
Butyraldehyde	2.1	1.7	1.6	<1.0	2.2	2.2	2.2	<1.0	*4.7 (5.8)*	*5.1 (6.4)*
Crotonaldehyde, Total	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*<2.4 (<2.4)*	*<2.4 (<2.4)*
Formaldehyde	31	30	25	4.0	45	49	44	3.7	*84 (100)*	*66 (79)*
Isovaleraldehyde	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*1.5 (2.0)*	*1.5 (2.3)*
Propionaldehyde	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*4.5 (5.2)*	*4.6 (5.5)*
Valeraldehyde	1.9	1.9	1.1	<1.0	6.4	6.8	6.6	<1.0	*11 (15)*	*10 (14)*
m,p-Tolualdehyde	<2.0	<2.1	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	*<2.9 (<2.9)*	*<2.9 (<2.9)*
n-Hexaldehyde	5.5	5.2	4.0	<1.0	20	21	21	<1.0	*45 (56)*	*42 (60)*
o-Tolualdehyde	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	*<1.4 (<1.4)*	*<1.4 (<1.4)*

BR bedroom
LR living room
MB master bedroom
O outdoor

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Concentrations of formaldehyde in the indoor air of both homes were similar to levels of formaldehyde measured in newly constructed homes (median 47 μg/m^3) (Hodgson et al. 2000). (Variation in concentrations of aldehydes in indoor air may be a function of age of construction, materials used in their construction, and related factors such as air exchange rate.) These formaldehyde levels are somewhat higher than concentrations reported for homes in various areas of the United States that were not newly constructed. For example, the average concentrations of formaldehyde were 29 μg/m^3 (144 Groesbeek Street) and 46 μg/m^3 (4 Darden Street), while mean values reported in studies of homes in large cities like New York City, Houston, Elizabeth, New Jersey, and Los Angeles ranged from 18 to 22 μg/m^3 (NUATRC 2000; Weisel et al. 2004).

6.7 DUST

6.7.1 Characterization

Cellulose fibers, skin, and starch grains were detected in samples from both homes and are common components of indoor dust and are found in areas where people live or work. Overall, the dust characterization of both homes is consistent with typical residential dust. Detailed results of the dust characterization are reported in the Appendix, Table A.6.

The main component detected in seven of the 10 submitted dust samples was highly birefringent mineral grains. These grains were seen individually and clustered in larger aggregates. Examination of these particles by SEM, using EDX, showed them to consist mainly of calcium. Some of these aggregates contained calcium with sulfur or silicon, which would be consistent with gypsum or cement. Calcium carbonate was also found, some with titanium dioxide, which may be associated with paint. The large number of mineral grains consisting of calcium in the dust samples can be attributed to the large number of drywall samples taken in the home over several months, by multiple investigators, which generated drywall debris.

Biological material detected in the dust was not unusual and consisted of skin, starch, insect parts, and plant pieces. Detection of biological material of outdoor origin in some samples, such as trichome, pollen, and insect pieces indicate an outdoor air source, such as penetration through an open window or door, at some time in the past.

Cotton and paper cellulose fibers were also detected as well as a few synthetic fibers. Glass fibers were seen in trace amounts in six of the samples (three samples from 144 Groesbeek Street and three from 4 Darden Street). Glass fibers in samples collected in the HVAC return duct with internal fiberglass insulation were estimated at 5 percent and 10 percent in 4 Darden Street and 144 Groesbeek Street, respectively. The larger amounts of glass fibers detected in two of the 10 samples, both collected from the HVAC system return duct, is not unusual because the duct itself is lined with fiberglass insulation. The remaining eight samples, collected in the living areas, contained zero to trace amounts of glass fibers and indicate that the internal lining of the ductwork does not appear to impact the occupied areas of the homes.

Opaque material, consistent with metal or paint particles, was confirmed by the SEM in four samples, two from 144 Groesbeek Street and two from 4 Darden Street. A sample collected in the master bedroom at 4 Darden Street was the only sample that contained clear, rounded particles that appeared to be polymeric by EDX. Additional analysis of these samples by FTIR indicate that the material appears to be an unsaturated, largely aliphatic ether polymer, possibly representing a filler or packaging material.

6.7.2 Metals

Concentrations of metals found in dust at the Fort Bragg homes are reported in Tables A.7 and A.8. Evaluation of metals in surface dust collected at both homes was conducted by comparison with screening level guidelines for surface dust developed by the EPA (EPA 2003). Screening level values are available for 16 of the 20 metals identified in the dust samples; metal concentrations in surface dust from both homes were well below the screening level criteria for all 16 of these metals. Health-based benchmarks for two of the metals (calcium and magnesium) were not developed by the EPA because they are classified as essential nutrients and possess relatively low oral toxicity. Therefore, quantitative toxicity criteria required to develop health-based benchmarks for these essential nutrients have not been established. The final two metals that were not included by the EPA, tin and titanium, have comparison background values published in a limited number of published research papers (RIVM Report 609021064). The mean values for tin and titanium were lower in the homes than the values published in the literature (tin: 22 mg/kg v. 17 mg/kg [Groesbeek] and 2.2 mg/kg [Darden]; titanium: 2,800 mg/kg v. 28 mg/kg [Groesbeek] and 88 mg/kg [Darden]).

6.7.3 Allergens

Results of the allergen testing included cat allergen (Fel d 1), cockroach allergen (Bla g 1), dog allergen (Can f 1), and two dust mite allergens (Der f 1; Der p 1) and are reported in Table 6.3. Significant concentrations of dog allergen (Can f 1) and a low level of dust mite allergen (Der f 1) were found in the master bedroom at 4 Darden Street. In addition, a low to significant concentration of dust mite allergen (Der f 1) were measured in the northwest corner of bedroom 1. No other allergens were detected in the 4 Darden Street home. At 144 Groesbeek Street, only low (trace) amounts of cat allergen (Fel d 1) were identified in the return air duct.

The guidelines used for interpretation of the allergen results have been developed by EMLab P&K laboratories and are compiled from a review of the available scientific literature. As stated in the evaluation guidelines, an individual's susceptibility to allergic symptoms depends not only on the level of allergens present in the environment, but also on the individual's response to allergens and previous exposure history. Guidance levels have been adopted from the *Field Guide for the Determination of Biological Contaminants in Environmental Samples* (AIHA 2005) (Table 6.4).

Table 6.3 Results of Analyses for Selected Allergens in Dust Samples Obtained at 144 Groesbeek Street and 4 Darden Street, Fort Bragg, North Carolina, October 5 and 6, 2010

Location	Dust Mite Allergen Der p 1 (μg/g)	Dust Mite Allergen Der f 1 (μg/g)	Cat Allergen Fel d 1 (μg/g)	Dog Allergen Can f 1 (μg/g)	Cockroach Allergen Bla g 1 (U/g)
144 Groesbeek Street					
First floor, family room carpet, southeast corner	<0.39 Low	<0.39 Low	<0.16 Low	<1.6 Low	<0.39 Low
Second floor, HVAC return grill	<0.001 NA	<0.001 NA	0.009 ± 0.001 NA	<0.001 NA	<0.03 NA
Second floor, bedroom 1 floor, north wall	<0.39 Low	<0.39 Low	<0.16 Low	<0.39 Low	<1.6 Low
Second floor, master bedroom floor	<0.39 Low	<0.39 Low	<0.16 Low	<0.39 Low	<1.6 Low
4 Darden Street					
First floor, family room, south wall	<0.39 Low	<0.39 Low	<0.16 Low	<0.39 Low	<1.6 Low
Master bedroom, northwest corner	<0.39 Low	0.46 ± 0.13 Low	<0.16 Low	4.35 ± 0.92 Significant	<1.6 Low
Second floor, bedroom 1, northwest corner	<0.39 Low	1.94 ± 0.54 Low / Significant	<0.16 Low	<0.39 Low	<1.6 Low
Field blank	0.01 NA	0.01 NA	<0.003 NA	0.01 NA	<0.03 NA

μg/g micrograms per gram
U/g units per gram
NA Not applicable

Samples analyzed by EMLab P&K, Phoenix, Arizona
Method: Dust, allergen – enzyme-linked immunosorbent assay (ELISA) full list

Table 6.4 Allergen Levels Associated with an Increased Risk of Sensitization Among Atopic Individuals

Allergen	Level Associated with Sensitization Among Atopics	2005 AIHA Reference
Dust Mite Allergen Der p 1 (μg/g)	2 μg of allergen per gram of dust	Platts-Mills et al. 1997
Dust Mite Allergen Der f 1 (μg/g)	2 μg of allergen per gram of dust	Platts-Mills, et al. 1997.
Cat Allergen Fel d 1 (μg/g)	0.5 – 2 μg of allergen per gram of dust	Platts-Mills et al. 1997. Gelber et al. 1993.
Dog Allergen Can f 1 (μg/g)	1 – 2 μg of allergen per gram of dust	Ingram et al. 1995.
Cockroach Allergen Bla g 1 (U/g)	1 unit of allergen per gram of dust	Eggleston et al. 1998.

μg/g micrograms per gram
U/g units per gram

Source: AIHA. 2005. *Field Guide for the Determination of Biological Contaminants in Environmental Samples.* Second Edition. Hung LL, Miller JD, Dilllon HK, eds. Fairfax, VA: American Industrial Hygiene Association.

Refer to Section 7 of this report for full references.

The interpretive guidelines state that allergen levels classified as “low” are not considered to increase risk of sensitization or symptoms. Levels classified as “significant” may increase the risk of sensitization; and levels in the “high” range are reported to increase the risk of allergic symptoms in sensitized people. Based on the sampling results, allergen levels measure at 144 Groesbeek Street are not considered to be present in a range that will increase the risk of sensitization or symptoms. Allergen levels in the two bedrooms at 4 Darden Street may increase the risk of sensitization to dust allergies. Guidelines reviewed state that sufficient evidence is not available yet to establish threshold risk levels for dog allergens.

6.7.4 Pesticides

6.7.4.1 Summary of Results

The analysis for pesticides in dust samples included a comprehensive list of analytes in four broad pesticide classes—organochlorine pesticides, triazine pesticides, organophosphate pesticides, and pyrethroid pesticides. The majority of pesticides were not detected in the dust samples from 144 Groesbeek Street and 4 Darden Street.

Results for pesticides that were detected in at least one sample are reported in Table 6.5 and discussed below; complete results for all pesticides are reported in the Appendix, Tables A.9 and A.10.

6.7.4.2 Pesticides Detected in Dust at Fort Bragg

Pesticides detected in at least one of the two Fort Bragg homes are reported in Table 6.5 along with concentrations from the peer-reviewed literature for comparison. The EPA's Risk-Based Concentrations (RBC) for residential soil, while not directly applicable, are also presented for a point of comparison (EPA does not publish RBCs for residential dust).

The pesticide concentrations in the two homes are all well below the EPA's risk-based screening levels for residential soil. In addition, the maximum concentration found at each home was less than the median concentrations reported in the scientific literature, where available, with the exception of chlordane and two pyrethroids (permethrin and cypermethrin), which are discussed below.

6.7.4.3 Chlordane

Chlordane is a pesticide that was used in homes for termite control and in agriculture in the United States from the 1950s until the 1980s (CDC 2009). Although all uses of chlordane were banned by the EPA in 1988, chlordane is still detected in many environments, throughout the United States, due to its widespread use until implementation of the ban and its persistence in the environment (EPA 2010; CDC 2009). This is also true for other organochlorine pesticides, such as DDT, which were banned in the United States several decades ago but are still commonly found in dust in homes (DDT was detected at very low concentrations in the Fort Bragg homes, well below median concentrations found in U.S. homes, and is therefore not discussed further in this report). As a result of historical uses of chlordane and its persistence, chlordane is commonly found in residential dust; in the Children's Total Exposure to Persistent Pesticides and Other Persistent Organic Pollutants study, chlordane was detected in 95% of the 121 study homes (Morgan et al. 2004). In a large study conducted across four U.S. cities, chlordane was detected in approximately 40% of house dust samples (Colt et al. 2004).

The maximum chlordane concentrations in 144 Groesbeek Street and 4 Darden Street were higher than the median concentrations reported in three relevant studies of pesticide concentrations in homes but well below the 90th and 95th percentiles values for those studies (Note: For chlordane, comparison data were available for the gamma- and alpha-isomers.) (Table 6.5; Morgan et al. 2004; Colt et al. 2004; Rudel et al. 2003). Therefore, the chlordane concentrations measured at the Fort Bragg homes are within the concentrations often found in U.S. residences and are not atypical.

6.7.4.4 Permethrin and Cypermethrin

Permethrin and cypermethrin are part of the pyrethroid class of pesticides that are derived from naturally occurring insecticides found in chrysanthemum flowers (CDC 2009). Currently, they are used in a wide range of applications, including: indoor and outdoor residential spaces, pets, clothing, buildings, modes of transportation, food/feed crops, public health mosquito abatement programs, livestock and livestock housing, and skin lotions and shampoos as medical treatments for lice and scabies (EPA 2009; EPA 2008; CDC 2009). As a result of their widespread use, pyrethroids are commonly found in homes, with many studies detecting permethrin in 100% of the dust samples analyzed (Julien et al. 2008; Starr et al. 2008; Leng et al. 2005) and cypermethrin detected in up to 60% of dust samples (Julien et al. 2008). Additional evidence of pyrethroid ubiquity comes from a nationally representative biomonitoring study (National Health and Nutrition Examination Survey [NHANES]), which detected pyrethroid metabolites in urine of 70% of the U.S. population indicating widespread exposure to pyrethroids (Barr et al. 2010).

The total permethrin concentration in the dust sample from the return air duct at 4 Darden Street was 1,130 nanograms per gram (ng/g) and is consistent with, or slightly higher than, median concentrations measured in residential dust (Table 6.5) (Note: permethrin concentrations are reported two ways in the literature: cis- and trans-permethrin isomers reported individually, or 'total permethrin' which includes both cis- and trans- isomers). The cypermethrin concentration at 4 Darden Street (120 ng/g) was generally lower than median concentrations reported in the literature (Julien et al. 2008; Leng et al. 2005; Starr et al. 2008).

The total permethrin and cypermethrin concentrations in dust from the return air duct at the 144 Groesbeek Street home (86,000 ng/g and 1,450 ng/g, respectively) were on the high end (i.e., generally greater than the 90^{th} percentile) of the distribution of values reported in the literature for U.S. homes. For example, in the Children's Total Exposure to Persistent Pesticides and Other Persistent Organic Pollutants study, permethrin was detected in 100% of homes where children resided with median cis- and trans-permethrin concentrations in floor dust of 804 ng/g and 629 ng/g, respectively (95^{th} percentile: 21,100 ng/g and 19,400 ng/g; maximum: 311,000 ng/g and 322,000 ng/g). For cypermethrin, the 95^{th} percentile concentration measured in the same study (1,571 ng/g) was similar to the concentration measured at 144 Groesbeek Street (1,450 ng/g). Similarly, in a large study conducted in four U.S. cities (513 homes), permethrin was detected in more than 70% of the homes, with the geometric mean concentration for cis- and trans-permethrin reported as 337 ng/g and 517 ng/g, respectively (Colt et al. 2004). The authors did not report the maximum concentrations detected; however, the 95^{th} percentile could be calculated from their summary data and was determined to be 58,700 ng/g and 151,000 ng/g, respectively, which although higher, is consistent with the concentration found at 144 Groesbeek Street. In a study of 119 homes, cis- and trans-permethrin were detected in 50% of the homes with a median concentration of <300 ng/g and 387 ng/g (90^{th} percentile: 7,040 ng/g and 16,500 ng/g; maximum: 61,900 ng/g and 98,000 ng/g). For cypermethrin, the 90^{th} percentile concentration was reported as <1,000 ng/g (maximum: 172,000 ng/g).

The concentrations of permethrin and cypermethrin in dust from the air duct of 144 Groesbeek Street are above the median concentrations reported in the literature and are similar to concentrations at the 95^{th} percentile of reported values. The pesticide analysis of dust was intended to screen for a wide range of compounds, and the results for pyrethroids presented in this report reflect concentrations measured in one sample from each home. The dust samples from 4 Darden Street and 144 Groesbeek Street were obtained from the surface of the heating, ventilating, and air conditioning system return air duct and return air grill, respectively. These sample locations were selected to provide a sample that would reflect an integration of dust from various areas in the home that would serve as a first-pass screening tool and not to reflect exposure concentrations in the home. The concentrations measured in the ducts may be higher than room concentrations due to differential cleaning practices, composition of the dust, and the impact of various degradation processes. As a result, EH&E recommends analyzing additional dust samples collected from other locations at 144 Groesbeek Street for pesticides to further characterize exposure conditions in this home.

Table 6.5 Comparison of Maximum Concentrations (ng/g) of Detected Pesticides in Dust from Fort Bragg Homes and Results from the Peer-Reviewed Literature

Analyte	Notes	Fort Bragg		Morgan et al.				Colt et al.			Rudel et al.				Miscellaneous Studies					EPA Region II
		Maximum Concentration		n=121				n=513			n=119									Non-carcinogenic SL
		144 Groesbeek Street	4 Darden Street	Percent Detect	Median	95th Percentile	Maximum	Percent Detect	Geometric Mean	95th Percentile	Percent Detect	Median	90th Percentile	Maximum	Percent Detect	Median	Percentile	Maximum	Ref	Soil
Hexachlorobenzene		0.85[a]	0.68																	49,000
HCH, alpha	Lindane	0.35[a]	0.04	14%	<MDL	51.2	*				2%	<400	<400	1,040						490,000
HCH, gamma		5.94[a]	6.59																	21,000
Heptachlor		6.94[a]	12.2	41%	<MDL	552	1,610				3%	<200	<200	549						31,000
Aldrin		0.24	0.26[a]	16%	<MDL	35.4	276				0%	<400	<400	<400						1,800
Chlordane, gamma (trans)	Chlordane	53.8	24.4	97%	30.6	649	1,980	48%	19	853	41%	<300	926	10,600						35,000
Chlordane, alpha (cis)		44.9	13.9	95%	22	401	2,010	38%	11	687	39%	<300	864	9,970						
Nonachlor, trans-		22.7	8.35																	
Nonachlor, cis-		2.36[a]	1.26																	
2,4'-DDD	DDD	<1.42	0.17																	
4,4'-DDD		<1.61	0.40								9%	<200	<200	718						
4,4'-DDE		6.18[a]	1.54	40%	<MDL	53	203	46%	18	233	13%	<200	156	738						36,000
2,4'-DDT	DDT	2.68[a]	0.90																	
4,4'-DDT		6.95[a]	2.18	39%	<MDL	208	4,080	70%	72	3,042	65%	279	3,190	9,610						36,000
Mirex		0.09[a]	<0.04																	12,000
Heptachlor-Epoxide		0.36	0.74																	790
Dieldrin		3.38	2.39	43%	<MDL	158	473				12%	<400	236	4,890						
Simazine		7.98	12.8								0%	<200	<200	<200						310,000
Methamidophos		<4.82	1.72																	3,100
Diazinon		<3.96	0.61	96%	17.5	388	11,000	39%	25	2,025	14%	<200	224	51,000	94%	50	200	4,400	b	
Chlorpyriphos.		10.4	11.0	100%	135	1,180	15,100	68%	113	6,875	18%	<200	1,870	228,000	89%	60	200	3,000	b	180,000
Total-Permethrins	cis-permethrin	85,900	1,130	100%	804	21,100	311,000	72%	337	58,700	45%	<300	7,040	61,900	100%	920	1,130	13,100	b	3,100,000
	trans-permethrin			100%	629	19,400	322,000	74%	517	151,000	53%	387	16,500	98,000						
Total-Cypermethrins		1,450	120								5%	<1,000	<1,000	172,000	60%	300	800	5,200	b	610,000
															17%	<500	3,000	NA	c	
															34%	<27	1,571	6,492	d	

ng/g nanograms per gram
SL screening level
MDL method detection limit
NA not applicable

* Reported as '000'; apparent typographical error in the original report.

a Concentration less than the lowest calibration limit
b Julien et al., 2008; n=35; median, 75th percentile and maximum
c Leng et al., 2005; n=18; median, 95th percentile
d Starr et al, 2008; n=85; median, 95th percentile and maximum

Sources:

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6.8 FUNGI

Complete results of the surface and airborne fungi testing are presented in the Appendix (Tables A.11, A.12, A.13 and A.14), and a brief summary of the findings is presented in Table 6.5. For airborne fungi, results for viable and nonviable fungi reflect the total numbers of spores present, and not just those that are viable and may proliferate in indoor environments. This is an important consideration because fungal spores can produce allergic reactions in individuals who are sensitive to them whether or not they are viable. In general, fungi concentrations in the two homes are unremarkable and typical of those found in indoor environments without known indoor mold sources. Surface fungi testing indicated "normal trapping" for all samples collected.[7] Airborne fungi generally were low and consistent with outdoors. Several spore types detected at low levels indoors that were not outdoors in the 144 Groesbeek Street home may be suggestive of the cleanliness of the house during the time of sampling. Similar results for the two homes were observed for airborne viable fungi.

Table 6.6 Summary of Results of Surface and Airborne Fungi Testing

Parameter	144 Groesbeek Street	4 Darden Street
Surface fungi	All results "normal trapping"	All results "normal trapping"
Airborne viable + nonviable fungi	• Consistent with outdoors • A number of different spore types detected at low levels indoors that were not outdoors • May be suggestive of house condition/cleanliness/dust loading	• Nothing remarkable compared to outdoors • Indoor concentrations were low
Airborne viable fungi	• Generally low • Mix of common outdoor spore types indoors at concentrations similar to or less than outdoors • Some common outdoor spore types detected at low levels indoors but not outdoors	• Generally low • Mix of common outdoor spore types indoors at concentrations similar to or less than outdoors • Some common outdoor spore types detected at low levels indoors but not outdoors

[7] Because mold spores of many types are virtually ubiquitous in the indoor and outdoor air, those surfaces with only a few spores of several types, with no indication of active growth, are designated as "normal trapping."

6.9 WATER

Water samples collected from each home were tested for a comprehensive list of chemicals and markers of water quality (Table A.15). There were no contaminants found at levels of concern in the water of either home. The results were evaluated against the EPA's "maximum contaminant level" (MCL), the mandatory water quality standards for drinking water contaminants as determined under the National Primary Drinking Water Regulations. The contaminant concentrations in the Fort Bragg home were all less than the EPA's MCLs, for all contaminants with a published MCL. The EPA also publishes a "secondary maximum contaminant level" (SMCL). SMCLs are not mandatory, not enforced, and are "established only as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color and odor." For contaminants with a published SMCL, the concentration in the Fort Bragg homes was less than the published SMCLs, except for total manganese in the 144 Groesbeek Street home (Test results = 0.06 mg/L; SMCL = 0.05 mg/L). For the majority of other potential contaminants, the concentrations in the water were less than the detection limit of the analytical method. The EPA does not publish MCLs or SMCLs for nutrients and minerals, including calcium, magnesium, and sodium. According to the EPA, sodium levels in drinking water from most public water systems are unlikely to be a significant contributor to adverse health effects. And, according to the World Health Organization, there does not appear to be any convincing evidence that hard water (calcium and magnesium) causes any adverse health effects in humans (WHO 2003).

6.10 CONCLUSIONS REGARDING INDOOR ENVIRONMENTAL QUALITY

The indoor environmental and building systems investigation did not identify any issues or contaminants of concern in the air, dust, or water of either home at levels that would potentially pose a health concern to residents of the homes. One dust sample collected at 144 Groesbeek Street that was screened for pesticide content was observed to have concentrations of permethrin and cypermethrin in dust from the air duct, which were above the median concentrations reported in the literature and are similar to concentrations at the 95^{th} percentile of reported values. Although the concentrations measured in this sample are not considered hazardous EH&E recommends analyzing additional dust samples collected from other locations at 144 Groesbeek Street for pesticides in order to further characterize the range of potential exposure conditions in this home.

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APPENDIX A

SUMMARY DATA TABLES

APPENDIX A—SUMMARY TABLES

Table A.1 Summary of Corrosion Rates Measured by Corrosion Classification Coupons

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
Copper sulfide	A/30d	<32	<32	<32	<32	<32	<32	<32	<32	*340 (510)*	*<32 (<32)*
Silver sulfide	A/30d	160	260	290	320	200	260	260	440	*970 (1100)*	*200 (250)*
AHU Air Register											
Copper sulfide	A/30d	<32				<32				*1600 (2300)*	*87 (120)*
Silver sulfide	A/30d	270				250				*2900 (3300)*	*530 (740)*

A/30d angstrom per 30 days
AHU air handling unit

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Table A.2 Summary of Reduced Sulfur Concentrations in Air

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
2,5-Dimethylthiophene	$\mu g/m^3$	<23	<23	<23	<23	<23	<23	<23	<23	*<23 (<23)*	*<23 (<23)*
2-Ethylthiophene	$\mu g/m^3$	<23	<23	<23	<23	<23	<23	<23	<23	*<23 (<23)*	*<23 (<23)*
3-Methylthiophene	$\mu g/m^3$	<20	<20	<20	<20	<20	<20	<20	<20	*<20 (<20)*	*<20 (<20)*
Carbon disulfide	$\mu g/m^3$	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	<7.8	*<7.8 (<7.8)*	*<7.8 (<7.8)*
Carbonyl sulfide	$\mu g/m^3$	<12	<12	<12	<12	<12	<12	<12	<12	*<12 (<12)*	*<12 (<12)*
Diethyl disulfide	$\mu g/m^3$	<12	<12	<12	<12	<12	<12	<12	<12	*<12 (<12)*	*<12 (<12)*
Diethyl sulfide	$\mu g/m^3$	<18	<18	<18	<18	<18	<18	<18	<18	*<18 (<18)*	*<18 (<18)*
Dimethyl disulfide	$\mu g/m^3$	<9.6	<9.6	<9.6	<9.6	<9.6	<9.6	<9.6	<9.6	*<9.6 (<9.6)*	*<9.6 (<9.6)*
Dimethyl sulfide	$\mu g/m^3$	<13	<13	<13	<13	<13	<13	<13	<13	*<13 (<13)*	*<13 (<13)*
Ethyl mercaptan	$\mu g/m^3$	<13	<13	<13	<13	<13	<13	<13	<13	*<13 (<13)*	*<13 (<13)*
Ethyl methyl sulfide	$\mu g/m^3$	<16	<16	<16	<16	<16	<16	<16	<16	*<16 (<16)*	*<16 (<16)*
Hydrogen sulfide	$\mu g/m^3$	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	<7.0	*<7.0 (<7.0)*	*<7.0 (<7.0)*
Isobutyl mercaptan	$\mu g/m^3$	<18	<18	<18	<18	<18	<18	<18	<18	*<18 (<18)*	*<18 (<18)*
Isopropyl mercaptan	$\mu g/m^3$	<16	<16	<16	<16	<16	<16	<16	<16	*<16 (<16)*	*<16 (<16)*
Methyl mercaptan	$\mu g/m^3$	<9.8	<9.8	<9.8	<9.8	<9.8	<9.8	<9.8	<9.8	*<9.8 (<9.8)*	*<9.8 (<9.8)*
Tetrahydrothiophene	$\mu g/m^3$	<18	<18	<18	<18	<18	<18	<18	<18	*<18 (<18)*	*<18 (<18)*
Thiophene	$\mu g/m^3$	<17	<17	<17	<17	<17	<17	<17	<17	*<17 (<17)*	*<17 (<17)*
n-Butyl mercaptan	$\mu g/m^3$	<18	<18	<18	<18	<18	<18	<18	<18	*<18 (<18)*	*<18 (<18)*
n-Propyl mercaptan	$\mu g/m^3$	<16	<16	<16	<16	<16	<16	<16	<16	*<16 (<16)*	*<16 (<16)*
tert-Butyl mercaptan	$\mu g/m^3$	<18	<18	<18	<18	<18	<18	<18	<18	*<18 (<18)*	*<18 (<18)*

$\mu g/m^3$ micrograms per cubic meter

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Table A.3 Summary of Strontium Concentrations (mg/kg) Measured by XRF on Walls in Homes[1]

Location	144 Groesbeek Street		4 Darden Street		*51-Home Study Mean (75th Percentile)**	
	N	Mean (Max)	N	Mean (Max)	*Problem*	*Control*
Bedroom 1	54	500 (620)	66	490 (680)	*807 (1200)*	*368 (410)*
Bedroom 2	77	520 (610)	65	470 (560)		
Bedroom 3	16	540 (590)	49	500 (580)		
Master	36	530 (600)	55	490 (600)		
Living	53	280 (580)	35	180 (360)		
Family room	41	210 (550)	79	230 (530)		
Kitchen	45	290 (590)	28	290 (560)		
Master bath	47	520 (630)	49	500 (630)		
Bath	19	200 (310)	32	280 (540)		
Bath 2	15	440 (620)	18	510 (570)		
Laundry	14	560 (620)	14	500 (550)		
Stairs	35	380 (550)	44	400 (500)		
Hallway	33	170 (320)	24	210 (440)		
Hallway 2	36	390 (650)	44	480 (620)		
Garage	47	240 (590)	43	260 (520)		
Ceiling	68	500 (620)	75	460 (680)		

XRF
N number
Max maximum

1 In-home measurements were made on the wall surface and include any surface coatings that were present (e.g., paint).

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Table A.4 Summary of Volatile Organic Compound Concentrations ($\mu g/m^3$) by Summa Canister Method

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
1,1,1-Trichloroethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1,2,2-Tetrachloroethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1,2-Trichloroethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1,2-Trichlorotrifluoroethane	$\mu g/m^3$	0.53	0.53	0.51	0.51	0.49	0.50	0.50	0.48	*<0.62 (0.64)*	*<0.62 (0.73)*
1,1-Dichloroethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1-Dichloroethene	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2,4-Trichlorobenzene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
1,2,4-Trimethylbenzene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*6.4 (7.7)*	*8.3 (12)*
1,2-Dibromo-3-chloropropane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
1,2-Dibromoethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2-Dichloro-1,1,2,2-tetrafluoroethane (CFC 114)	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
1,2-Dichlorobenzene	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2-Dichloroethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*2.9 (3.0)*	*2.3 (5.0)*
1,2-Dichloropropane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	0.57	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,3,5-Trimethylbenzene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (3.2)*
1,3-Butadiene	$\mu g/m^3$	<0.26	<0.24	<0.33	<0.27	<0.32	<0.29	<0.24	<0.25	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,3-Dichlorobenzene	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,4-Dichlorobenzene	$\mu g/m^3$	0.22	0.23	0.22	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,4-Dioxane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
2-Butanone (MEK)	$\mu g/m^3$	<6.5	<6.1	<8.3	<6.7	<8.0	13	<6.1	<6.3	*8.0 (10)*	*12 (15)*
2-Hexanone	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	0.83	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
2-Propanol (isopropyl alcohol)	$\mu g/m^3$	2.0	1.3	2.5	<1.3	3.2	26	3.6	<1.3	*56 (50)*	*45 (69)*
3-Chloro-1-propene (allyl chloride)	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
4-Ethyltoluene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (3.6)*
4-Methyl-2-pentanone	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Acetone	$\mu g/m^3$	23	23	26	<6.7	43	49	48	11	*110 (150)*	*100 (140)*
Acetonitrile	$\mu g/m^3$	220	6.2	200	1.0	300	230	9.6	1.1	*140 (250)*	*100 (100)*
Acrolein	$\mu g/m^3$	<2.6	<2.4	<3.3	<2.7	<3.2	<2.9	2.9	<2.5	*6.1 (7.5)*	*5.1 (6.5)*
Acrylonitrile	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Benzene	$\mu g/m^3$	0.37	0.41	0.40	0.24	0.47	0.98	0.51	0.23	*5.1 (7.0)*	*7.6 (12)*
Benzyl chloride	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Bromodichloromethane	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Bromoform	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*

Table A.4 Continued

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
Bromomethane	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Carbon disulfide	μg/m^3	<6.5	<6.1	<8.3	<6.7	<8.0	<7.2	<6.1	<6.3	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Carbon tetrachloride	μg/m^3	0.23	0.24	0.22	0.23	<0.16	<0.14	0.22	0.23	*0.64 (0.73)*	*<0.62 (0.62)*
Chlorobenzene	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Chloroethane	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Chloroform	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	0.90	<0.12	<0.13	*1.9 (1.6)*	*1.6 (2.2)*
Chloromethane	μg/m^3	<0.26	<0.24	<0.33	0.34	<0.32	<0.29	<0.24	0.35	*1.3 (0.98)*	*<0.62 (0.85)*
Cumene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Cyclohexane	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	4.0	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Dibromochloromethane	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Dichlorodifluoromethane (CFC 12)	μg/m^3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	*3.3 (<3.1)*	*<3.1 (<3.1)*
Ethanol	μg/m^3	15	12	16	7.3	20	74	22	<6.3	*1100 (1400)*	*490 (670)*
Ethyl acetate	μg/m^3	4.8	1.9	5.5	7.7	3.7	22	3.5	0.80	*10 (7.5)*	*9.0 (13)*
Ethylbenzene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*5.9 (7.7)*	*6.9 (8.3)*
Hexachlorobutadiene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Methyl Methacrylate	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<6.2 (<6.2)*	*<6.2 (<6.2)*
Methyl tert-Butyl ether	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Methylene chloride	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Naphthalene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*3.5 (<3.1)*
Propene	μg/m^3	1.5	1.2	1.7	0.72	2.5	11	2.5	<0.63	*12 (13)*	*12 (20)*
Styrene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*3.8 (4.9)*	*<3.1 (3.2)*
Tetrachloroethene	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	0.48	<0.12	0.25	*0.82 (0.68)*	*8.0 (2.2)*
Tetrahydrofuran (THF)	μg/m^3	<0.65	<0.61	<0.83	<0.67	0.83	0.93	0.77	<0.63	*<3.1 (<3.1)*	*7.7 (<3.1)*
Toluene	μg/m^3	1.4	1.3	2.0	0.95	1.9	14	2.1	<0.63	*30 (43)*	*36 (41)*
Trichloroethene	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*0.62 (<0.62)*	*<0.62 (0.79)*
Trichlorofluoromethane	μg/m^3	1.1	1.2	1.1	1.1	1.4	1.5	1.5	1.1	*1.4 (1.5)*	*1.2 (1.5)*
Vinyl acetate	μg/m^3	<6.5	<6.1	<8.3	<6.7	<8.0	<7.2	<6.1	<6.3	*<31 (<31)*	*<31 (<31)*
Vinyl chloride	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
alpha-Pinene	μg/m^3	23	25	21	<0.67	64	61	72	0.87	*97 (130)*	*71 (100)*
cis-1,2-Dichloroethene	μg/m^3	<0.13	<0.12	<0.17	<0.13	<0.16	<0.14	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
cis-1,3-Dichloropropene	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
d-Limonene	μg/m^3	2.3	2.3	2.3	<0.67	5.0	5.5	5.5	<0.63	*25 (37)*	*21 (35)*
m,p-Xylenes	μg/m^3	<0.65	<0.61	<0.83	<0.67	<0.80	0.98	<0.61	<0.63	*18 (23)*	*23 (28)*
n-Butyl acetate	μg/m^3	<0.65	<0.61	0.84	<0.67	<0.80	<0.72	<0.61	<0.63	*5.2 (5.0)*	*3.4 (5.0)*

Table A.4 Continued

Analyte	Units	144 Groesbeek Street				4 Darden Street				51-Home Study Mean (75th Percentile)*	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
n-Heptane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*3.9 (4.5)*	*6.1 (8.8)*
n-Hexane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	1.6	<0.61	<0.63	*8.3 (11)*	*15 (17)*
n-Nonane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (3.5)*
n-Octane	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*3.5 (4.5)*
n-Propylbenzene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
o-Xylene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*6.7 (8.5)*	*7.5 (9.6)*
trans-1,2-Dichloroethene	$\mu g/m^3$	<0.13	<0.12	<0.17	<0.13	<0.16	1.7	<0.12	<0.13	*<0.62 (<0.62)*	*<0.62 (<0.62)*
trans-1,3-Dichloropropene	$\mu g/m^3$	<0.65	<0.61	<0.83	<0.67	<0.80	<0.72	<0.61	<0.63	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Tentatively Identified Compound											
1-Butanol	$\mu g/m^3$							3.5		*NA*	
1-Chloro-1,1-difluoroethane	$\mu g/m^3$	12	16	14		86	88	95			
1-Pentanol	$\mu g/m^3$							3.5			
3,4-Dichlorobenzotrifluoride	$\mu g/m^3$			3.2							
3-Carene	$\mu g/m^3$		3.5			4.0	4.1	4.5			
Acetaldehyde	$\mu g/m^3$			3.3			3.7	4.4			
Benzaldehyde	$\mu g/m^3$	9.0	3.4	3.4		10		3.8	3.4		
Cyclopentane + trimethylsilanol	$\mu g/m^3$						4.4				
Hexamethylcyclotrisiloxane	$\mu g/m^3$						6.9				
Isobutane	$\mu g/m^3$						5.1				
Isoprene	$\mu g/m^3$	6.2	4.3	6.4							
Trimethylsilanol	$\mu g/m^3$	7.0									
Unidentified Siloxane A	$\mu g/m^3$	88	150	85		29	10	12			
Unidentified Siloxane B	$\mu g/m^3$				4.3		3.9				
beta-Pinene	$\mu g/m^3$		5.5			7.0	7.0	7.9			
n-Butane	$\mu g/m^3$		3.2								
n-Dodecane	$\mu g/m^3$							3.2			
n-Hexanal	$\mu g/m^3$	4.6	4.8	4.9		15	14	17			
n-Octanal	$\mu g/m^3$						3.6	3.6			
n-Pentanal	$\mu g/m^3$					4.5	4.6	5.1			
n-Pentane	$\mu g/m^3$						15				
n-Tetradecane	$\mu g/m^3$							5.0			
n-Tridecane	$\mu g/m^3$					9.0	6.4	11			

Table A.4 Continued

μg/m³ micrograms per cubic meter
NA not available

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Table A.5 Summary of Volatile Organic Compound Concentrations (μg/m³) by Sorbent Tube Method

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
1,1,1-Trichloroethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1,2,2-Tetrachloroethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1,2-Trichloroethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1-Dichloroethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,1-Dichloroethene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2,4-Trichlorobenzene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
1,2,4-Trimethylbenzene	μg/m³	0.43	0.44	0.43	0.13	0.20	0.19	0.21	<0.12	*6.4 (7.7)*	*8.3 (12)*
1,2-Dibromo-3-chloropropane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
1,2-Dibromoethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2-Dichlorobenzene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,2-Dichloroethane	μg/m³	<0.12	<0.12	<0.12	<0.13	0.14	0.13	0.15	<0.12	*2.9 (3.0)*	*2.3 (5.0)*
1,2-Dichloropropane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,3,5-Trimethylbenzene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (3.2)*
1,3-Dichlorobenzene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,4-Dichlorobenzene	μg/m³	0.33	0.29	0.30	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
1,4-Dioxane	μg/m³	0.70	<0.25	1.3	0.71	<0.25	<0.25	<0.25	<0.25	*<3.1 (<3.1)*	*<3.1 (<3.1)*
2,2,4-Trimethylpentane (isooctane)	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*NA*	*NA*
2-Butanone (MEK)	μg/m³	1.0	0.99	1.1	0.52	1.6	1.4	1.6	0.49	*8.0 (10)*	*12 (15)*
2-Hexanone	μg/m³	0.32	0.26	0.33	<0.13	0.58	0.70	0.79	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
2-Propanol (isopropyl alcohol)	μg/m³	0.55	7.8	0.63	<0.50	1.4	1.3	1.4	<0.49	*56 (50)*	*45 (69)*
4-Methyl-2-pentanone	μg/m³	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Acetone	μg/m³	7.9	6.4	6.9	3.2	13	11	12	3.3	*110 (150)*	*100 (140)*

Table A.5 Continued

Analyte	Units	144 Groesbeek Street				4 Darden Street				51-Home Study Mean (75th Percentile)*	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
Benzene	μg/m³	<1.2	<1.2	<1.2	<1.3	<1.3	<1.2	<1.2	<1.2	*5.1 (7.0)*	*7.6 (12)*
Bromodichloromethane	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	0.13	0.13	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Bromoform	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Carbon disulfide	μg/m³	<0.50	<0.50	3.5	<0.50	<0.50	0.65	<0.50	<0.49	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Carbon tetrachloride	μg/m³	0.31	0.32	0.32	0.33	0.35	0.33	0.33	0.31	*0.64 (0.73)*	*<0.62 (0.62)*
Chlorobenzene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Chloroform	μg/m³	<0.12	<0.12	<0.12	<0.13	0.13	<0.12	0.15	<0.12	*1.9 (1.6)*	*1.6 (2.2)*
Cumene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Cyclohexane	μg/m³	<0.12	0.14	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Dibromochloromethane	μg/m³	<0.12	<0.12	<0.12	<0.13	0.14	0.17	0.16	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Ethylbenzene	μg/m³	0.24	0.23	0.23	<0.13	0.20	0.19	0.20	<0.12	*5.9 (7.7)*	*6.9 (8.3)*
Hexachlorobutadiene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Methyl tert-Butyl ether	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
Methylene chloride	μg/m³	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.49	*<3.1 (<3.1)*	*<3.1 (<3.1)*
Naphthalene	μg/m³	0.24	0.20	0.21	<0.13	0.19	0.19	0.19	<0.12	*<3.1 (<3.1)*	*3.5 (<3.1)*
Styrene	μg/m³	0.46	0.47	0.49	<0.25	0.40	0.44	0.47	<0.25	*3.8 (4.9)*	*<3.1 (3.2)*
Tetrachloroethene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*0.82 (0.68)*	*8.0 (2.2)*
Tetrahydrofuran (THF)	μg/m³	<0.25	<0.25	<0.25	<0.25	0.31	0.33	0.33	<0.25	*<3.1 (<3.1)*	*7.7 (<3.1)*
Toluene	μg/m³	1.5	2.3	1.5	0.57	1.9	1.8	1.9	0.41	*30 (43)*	*36 (41)*
Trichloroethene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*0.62 (<0.62)*	*<0.62 (0.79)*
Trichlorofluoromethane	μg/m³	0.32	0.27	0.31	0.31	0.38	0.38	0.39	0.21	*1.4 (1.5)*	*1.2 (1.5)*
Trichlorotrifluoroethane	μg/m³	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.49	*NA*	*NA*
cis-1,2-Dichloroethene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
cis-1,3-Dichloropropene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*
m,p-Xylenes	μg/m³	0.70	0.67	0.68	0.31	0.53	0.54	0.54	<0.25	*18 (23)*	*23 (28)*
n-Heptane	μg/m³	0.27	0.28	0.27	0.16	0.36	0.31	0.33	0.14	*3.9 (4.5)*	*6.1 (8.8)*
n-Hexane	μg/m³	0.37	0.42	0.38	0.22	0.49	0.45	0.48	0.22	*8.3 (11)*	*15 (17)*
n-Octane	μg/m³	0.26	<0.12	<0.12	<0.13	0.47	0.27	0.32	<0.12	*<3.1 (<3.1)*	*3.5 (4.5)*
o-Xylene	μg/m³	0.26	0.27	0.24	<0.13	0.19	0.20	0.20	<0.12	*6.7 (8.5)*	*7.5 (9.6)*
trans-1,2-Dichloroethene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<0.62 (<0.62)*	*<0.62 (<0.62)*
trans-1,3-Dichloropropene	μg/m³	<0.12	<0.12	<0.12	<0.13	<0.13	<0.12	<0.12	<0.12	*<3.1 (<3.1)*	*<3.1 (<3.1)*

Table A.5 Continued

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
Tentatively Identified Compounds											
1-Decene	µg/m³	1.8		2.1		3.2		1.1		*NA*	
1-Dodecene	µg/m³		1.6								
1-Octanol	µg/m³	1.4		1.4		2.0	1.8	1.8			
1-Octanol + acetophenone	µg/m³		1.6								
1-Pentanol	µg/m³	1.6	1.6	1.6		3.5	3.4	3.6			
2,6-Dimethyl-7-octene-2-ol	µg/m³		1.2								
2-Ethyl-1-hexanol	µg/m³				0.70				2.9		
2-Ethylhexanoic acid	µg/m³							0.96			
2-Phenoxyethyl isobutyrate	µg/m³			1.7							
2-Phenoxyethyl isobutyrate + pentadec	µg/m³		1.4								
3-Carene	µg/m³	2.3	2.3	2.2		2.6	2.5	2.5			
3-Methyleneheptane	µg/m³								0.69		
4-Methyl-1-hexanol	µg/m³	1.3	1.8	1.4							
5-Methyl-1-hexanol	µg/m³	1.8	2.2	1.8							
Acetaldehyde	µg/m³			1.8	1.2				0.54		
Acetic acid	µg/m³	16	15	18	4.0	1.9	1.8	1.8	3.8		
Acetophenone	µg/m³				0.55				1.5		
Benzoic acid	µg/m³				1.4		1.1		3.4		
C12H24 compound	µg/m³						1.5	0.98			
Camphene	µg/m³					1.4		1.3			
Diethylene glycol	µg/m³	1.1									
Dimethyl silanediol	µg/m³				0.65				0.52		
Formic acid	µg/m³				0.43				0.47		
Furfural	µg/m³		1.2	1.2		1.2		1.1			
Hexamethylcyclotrisiloxane	µg/m³		4.8	5.2	3.4	2.1	2.6		2.4		
Hexanoic acid	µg/m³	2.5	2.9	2.3		2.6	2.3	2.2			
Octamethylcyclotetrasiloxane	µg/m³				1.3						
Phenol	µg/m³		3.2		1.2						
Phenol + 1-Heptanol	µg/m³	2.9	2.9	3.1		3.0	2.9	2.9			
Phenylmaleic anhydride	µg/m³								0.39		
Phthalic anhydride	µg/m³								0.47		
Propylene glycol	µg/m³						1.1	1.1			

Table A.5 Continued

Analyte	Units	144 Groesbeek Street				4 Darden Street				*51-Home Study Mean (75th Percentile)**	
		Bedroom	Living Room	Master Bedroom	Outdoor	Bedroom	Living Room	Master Bedroom	Outdoor	*Problem*	*Control*
Tentatively Identified Compounds											
Texanol isomer A	$\mu g/m^3$	8.6	7.4	8.5		11	10	11		*NA*	
Texanol isomer B	$\mu g/m^3$	12	9.7	11	0.43	13	13	13	0.42		
Unidentified compound A	$\mu g/m^3$				1.0						
Unidentified compound B	$\mu g/m^3$				0.48						
Unidentified compound C	$\mu g/m^3$								0.37		
Unidentified compound D	$\mu g/m^3$								1.0		
Unidentified compound E	$\mu g/m^3$							0.98			
Unidentified siloxane C	$\mu g/m^3$	3.2						3.1			
Unidentified siloxane D	$\mu g/m^3$	91	89	92	1.0	30	29	27	0.44		
alpha,alpha-Dihydroxyacetophenone	$\mu g/m^3$								0.64		
n-Decanal	$\mu g/m^3$	2.0	3.1	1.7	1.8	3.4	1.8	2.3	4.1		
n-Heptanal	$\mu g/m^3$					1.5	1.5	1.5			
n-Hexanal	$\mu g/m^3$	3.7	3.3	3.8							
n-Nonanal	$\mu g/m^3$	6.2	5.9	5.8	1.7	7.1	6.6	6.9	2.8		
n-Octanal	$\mu g/m^3$	3.4	3.2	3.6		4.3	4.3	4.6	1.6		
n-Pentadecane	$\mu g/m^3$		2.3		0.65	1.6	1.3	1.4			
n-Pentadecane + 2-Phenoxyethyl isobut	$\mu g/m^3$	2.3									
n-Pentanal	$\mu g/m^3$							1.1			
n-Tetradecane	$\mu g/m^3$	1.4	1.4		0.65	10	11	9.9	0.42		
n-Tridecane	$\mu g/m^3$					12	13	12			

$\mu g/m^3$ micrograms per cubic meter
NA not available

* Environmental Health & Engineering, Inc., *Final Report on an Indoor Environmental Quality Assessment of Residences Containing Chinese Drywall*, January 28, 2010.

Table A.6 Results of Sampling for Dust Characterization

Location	Dust Category	%	Specific Particle Types Identified
144 Groesbeek Street			
First floor, HVAC return grill	Biologicals	40	Organic debris, Hair, Skin, Spores, Plant, Trichome, Pollen
	Cellulose	35	Cotton, Paper
	Opaques	15	Ambiguous
	Minerals	10	
	Glass fiber	Trace	
First floor, family room carpet	Minerals	65	
	Opaques	15	Ambiguous, Paint, Rust/Metallic
	Biologicals	10	Organic debris, Insect pieces, Skin
	Cellulose	10	Cotton, Paper
	Glass fiber	Trace	
Second floor, HVAC return duct	Cellulose	40	Cotton, Paper
	Opaques	30	Ambiguous, Paint
	Biologicals	15	Organic debris
	Glass fiber	10	
	Minerals	5	
Second floor, bedroom 1 floor	Minerals	60	
	Opaques	20	Ambiguous, Paint
	Cellulose	15	Cotton, Paper
	Synthetic fibers	5	
	Glass Fiber	Trace	
Second floor, master bedroom floor	Minerals	35	
	Biologicals	25	Organic debris, Insect parts, Starch
	Cellulose	20	Cotton, Paper
	Opaques	20	Ambiguous, Paint
4 Darden Street			
First floor, HVAC return duct	Minerals	65	
	Opaques	15	Ambiguous, Paint, Metal
	Cellulose	15	Cotton, Paper
	Glass fiber	5	
	Biologicals	Trace	Pollen, Skin, Starch
First floor, family room carpet/carpet pad	Minerals	80	
	Opaques	10	Ambiguous, Paint, Metal
	Cellulose	10	Cotton, Paper
Second floor, HVAC return duct	Minerals	65	
	Opaques	20	Ambiguous, Paint, Rust
	Cellulose	15	Cotton, Paper
	Glass Fiber	Trace	
Second floor, master bedroom carpet	Cellulose	50	Cotton, Paper
	Biologicals	35	Organic debris, Starch, Hair, Insect, Trichome, Skin
	Minerals	10	
	Opaques	5	Ambiguous
	Glass fibers	Trace	
Second floor, bedroom 1 carpet pad	Minerals	60	
	Opaques	25	Ambiguous, Paint, Plastic
	Cellulose	15	Cotton, Paper
	Biologicals	Trace	Starch
	Glass fiber	Trace	

Samples analyzed by MicroVision Laboratories, Inc., Chelmsford, Massachusetts.

Table A.7 Summary of Metal Concentrations (mg/kg) Referenced to U.S. Environmental Protection Agency Risk-based Concentration

Analyte	Units	144 Groesbeek Street			4 Darden Street			
		Bedroom	Master Bedroom	HVAC Return Grill	Bedroom	Stairs	HVAC Return Grill	*EPA Region 3 RBCs Criteria*
Aluminum	mg/kg	3,500	3,200	3,000	3,400	2,100	650	*77,000*
Antimony	mg/kg	0.65	0.93	0.92	0.95	3.4	0.18	*31*
Arsenic	mg/kg	2.0	1.5	6.2	4.3	2.8	1.1	*22*
Beryllium	mg/kg	0.14	0.13	0.17	0.13	0.09	0.06	*160*
Cadmium	mg/kg	0.10	20	1.6	1.3	0.64	0.18	*70*
Calcium	mg/kg	140,000	100,000	13,000	33,000	29,000	58,000	*–*
Chromium	mg/kg	3.7	5.6	35	21	11	3.1	*230**
Cobalt	mg/kg	0.65	0.73	1.1	2.6	0.95	0.45	*23*
Copper	mg/kg	5.1	85	95	93	43	9.0	*3,100*
Iron	mg/kg	1,400	1,500	2,500	4,700	1,200	940	*55,000*
Lead	mg/kg	0.15	2.2	17	19	11	0.32	*400*
Magnesium	mg/kg	8,300	5,900	1,300	2,400	1,400	1,200	*–*
Manganese	mg/kg	49	39	55	62	34	14	*1,800*
Nickel	mg/kg	7.0	4.2	35	53	13	2.4	*1,500***
Selenium	mg/kg	0.65	0.93	0.92	0.95	0.95	0.18	*390*
Thallium	mg/kg	0.30	0.42	0.42	0.43	0.43	0.08	*–*
Tin	mg/kg	0.98	4.7	17	1.2	2.2	1.5	*47,000*
Titanium	mg/kg	21	17	28	88	34	11	*–*
Vanadium	mg/kg	3.5	3.7	6.8	4.5	1.9	1.4	*390*
Zinc	mg/kg	56	110	450	470	260	74	*23,000*

mg/kg milligrams per kilogram
EPA U.S. Environmental Protection Agency
RBC risk-based concentration
HVAC heating, ventilating, and air-conditioning
– EPA Region 3 RBCs Criteria not available

* Chromium (VI)
** Nickel soluble salts

Table A.8 Summary of Metal Concentrations (µg/m²) Referenced to U.S. Environmental Protection Agency World Trade Center

Analyte	Units	144 Groesbeek Street			4 Darden Street			*EPA WTC Criteria*
		Bedroom	Master Bedroom	HVAC Return Grill	Bedroom	Stairs	HVAC Return Grill	
Aluminum	µg/m²	31,000	1,900	15,000	2,000	1,200	7,800	*1570,000*
Antimony	µg/m²	5.9	0.55	4.4	0.55	2.0	2.1	*627*
Arsenic	µg/m²	18	0.87	30	2.5	1.6	13	*387*
Beryllium	µg/m²	1.3	0.08	0.80	0.08	0.05	0.78	*3,140*
Cadmium	µg/m²	0.94	12	7.5	0.74	0.37	2.2	*1,560*
Calcium	µg/m²	1,300,000	59,000	65,000	19,000	17,000	700,000	*–*
Chromium	µg/m²	33	3.3	170	12	6.3	38	*4,700*
Cobalt	µg/m²	5.9	0.43	5.4	1.5	0.55	5.4	*31,140*
Copper	µg/m²	46	50	460	54	25	110	*62,716*
Iron	µg/m²	13,000	850	12,000	2,700	700	11,000	*941,000*
Lead	µg/m²	1.4	1.3	81	11	6.6	3.8	*269*
Magnesium	µg/m²	75,000	3,500	6,100	1,400	820	15,000	*–*
Manganese	µg/m²	440	23	270	36	20	160	*31,400*
Nickel	µg/m²	64	2.5	170	31	7.3	29	*31,400*
Selenium	µg/m²	5.9	0.55	4.4	0.55	0.55	2.1	*7,840*
Thallium	µg/m²	2.7	0.25	2.0	0.25	0.25	0.97	*110*
Tin	µg/m²	8.8	2.8	81	0.72	1.3	19	*–*
Titanium	µg/m²	190	9.9	140	51	20	140	*–*
Vanadium	µg/m²	31	2.2	33	2.6	1.1	16	*10,100*
Zinc	µg/m²	510	62	2,200	270	150	890	*470,000*

µg/m² micrograms per square meter
EPA U.S. Environmental Protection Agency
WTC World Trade Center
HVAC heating, ventilating, and air-conditioning
– EPA WTC Criteria not available

Table A.9 Results of Analyses for Selected Organochlorine Pesticides in Dust Samples Obtained at 144 Groesbeek Street and 4 Darden Street, Fort Bragg, North Carolina, October 5 and 6, 2010

	144 Groesbeek Street				**4 Darden Street**			
	HVAC Return Grill, First Floor ID 117987	**Family Room Carpet** ID 117995	**Master Bedroom Carpet** ID 118009	**HVAC Return Duct, Second Floor** ID 118004	**Bedroom 1 Carpet Pad** ID 118272	**Family Room Carpet** ID 118263	**HVAC Return Duct, Second Floor** ID 118267	**Master Bedroom Carpet** ID 118270
Analyte	**ng/g**							
Hexachlorobenzene	B J 0.66	B J 0.11	B J 0.27	B J 0.85	B J 0.29	B J 0.12	B J 0.12	B J 0.08
HCH, alpha	< 0.12	< 0.04	< 0.05	J 0.35	< 0.08	< 0.06	< 0.04	< 0.04
HCH, beta	< 0.22	< 0.11	< 0.17	< 0.88	< 0.19	< 0.11	< 0.07	< 0.09
HCH, gamma	J 1.67	K J 0.14	J 0.27	J 5.94	J 0.78	6.59	J 0.29	J 0.48
Heptachlor	J 2.75	J 0.31	J 1.17	J 6.94	7.41	3.66	2.00	3.31
Aldrin	K J 0.334	< 0.06	< 0.05	K J 0.29	J 0.16	J 0.26	< 0.04	< 0.06
Chlordane, oxy-	< 0.21	< 0.21	< 0.14	< 0.58	< 0.21	< 0.11	< 0.12	< 0.17
Chlordane, gamma (trans)	31.33	J 0.81	J 2.11	53.8	4.34	4.42	4.55	5.95
Chlordane, alpha (cis)	24.2	J 0.68	J 1.35	44.9	J 2.44	J 2.80	J 2.82	J 3.50
Nonachlor, trans-	11.7	J 0.32	J 0.50	22.7	J 1.03	J 1.50	J 1.40	J 1.84
Nonachlor, cis-	J 2.36	< 0.12	J 0.15	< 12.8	< 0.41	< 0.29	J 0.41	< 0.38
2,4'-DDD	< 0.51	< 0.06	< 0.07	< 1.42	J 0.17	< 0.06	< 0.07	< 0.09
4,4'-DDD	< 0.58	< 0.07	< 0.08	< 1.61	J 0.40	< 0.07	< 0.07	< 0.10
2,4'-DDE	J 0.53	< 0.05	< 0.06	J 0.71	< 0.07	< 0.04	< 0.06	< 0.06
4,4'-DDE	4.50	J 0.29	J 0.23	J 6.18	J 0.42	J 0.38	J 0.284	J 0.35
2,4'-DDT	J 1.45	< 0.08	< 0.08	J 2.68	K J 0.35	J 0.17	J 0.216	J 0.34
4,4'-DDT	J 2.94	J 0.36	J 0.13	J 6.95	J 0.82	J 0.34	J 0.484	J 0.92
Mirex	J 0.09	< 0.04	< 0.05	< 1.33	< 0.04	< 0.04	< 0.04	< 0.04

HVAC heating, ventilating, and air-conditioning
ng/g nanogram per gram
B analyte found in sample and the associated blank
J concentration less than LMCL
K peak detected, but did not meet quantification criteria, result reported represents the estimated maximum possible concentration

Table A.10 Results of Analyses for Organochlorine, Triazine, Organophosphate and Pyrethroid Pesticides in Dust Samples Obtained at 144 Groesbeek Street and 4 Darden Street, Fort Bragg, North Carolina, October 5 and 6, 2010

Pesticide Group	Analyte	Units	144 Groesbeek Street HVAC Return Grill, Second Floor ID 117999	4 Darden Street HVAC Return Duct, First Floor ID 118261	Laboratory Blank
Organochlorine pesticides	Tecnazene	ng/g	< 0.30	< 0.10	< 0.10
	HCB	ng/g	B 0.42	B 0.68	B 0.02
	Quintozene	ng/g	< 0.30	< 0.01	< 0.10
	Heptachlor	ng/g	1.68	12.2	< 0.02
	alpha-HCH	ng/g	< 0.08	0.04	< 0.03
	gamma-HCH	ng/g	1.17	1.64	< 0.04
	beta-HCH	ng/g	< 0.14	K 0.07	< 0.04
	delta-HCH	ng/g	< 0.13	< 0.06	< 0.03
	Chlorothalonil	ng/g	0.31	0.70	< 0.10
	Aldrin	ng/g	0.24	0.08	< 0.03
	Dacthal	ng/g	< 0.30	< 0.10	< 0.10
	Octachlorostyrene	ng/g	< 0.14	< 0.07	< 0.08
	Oxychlordane	ng/g	< 0.34	< 0.13	< 0.05
	Heptachlor-epoxide	ng/g	B 0.36	B 0.74	K B 0.05
	t-Chlordane	ng/g	16.10	24.4	< 0.06
	c-Chlordane	ng/g	12.4	13.9	< 0.06
	t-Nonachlor	ng/g	6.41	8.35	< 0.06
	c-Nonachlor	ng/g	0.95	1.26	< 0.03
	alpha-Endosulphan	ng/g	K B 4.33	K B 1.77	K B 1.26
	beta-Endosulphan	ng/g	K B 4.05	K B 2.31	K B 0.64
	Dieldrin	ng/g	B 3.38	B 2.39	K B 0.03
	o,p-DDD	ng/g	< 0.13	0.11	< 0.06
	p,p-DDD	ng/g	< 0.33	0.30	< 0.05
	o,p-DDE	ng/g	< 0.30	< 0.11	< 0.16
	p,p-DDE	ng/g	2.76	1.54	< 0.21
	o,p-DDT	ng/g	0.92	0.90	< 0.08
	p,p-DDT	ng/g	1.79	2.18	< 0.07
	Captan	ng/g	< 49.5	< 3.84	< 1.01
	Perthane	ng/g	< 45.9	< 21.4	< 0.34
	Endrin	ng/g	< 0.46	< 0.11	K B 0.06
	Endosulphan-sulphate	ng/g	K 4.47	K 1.50	< 0.07
	Mirex	ng/g	< 0.22	< 0.10	< 0.01
	Methoxychlor	ng/g	< 7.19	< 5.06	< 0.05
	Endrin-ketone	ng/g	< 0.79	< 0.31	< 0.081
Triazine pesticides	Desethylatrazine	ng/g	< 0.33	< 0.10	< 0.10
	Simazine	ng/g	K 7.98	12.8	< 0.18
	Atrazine	ng/g	< 6.25	< 1.94	< 0.41
	Metribuzin	ng/g	< 3.68	< 1.25	< 0.17
	Cyanazine	ng/g	< 8.50	< 2.48	< 0.67
Organo-phosphate pesticides	Methamidophos	ng/g	< 4.82	1.72	< 0.71
	Terbufos	ng/g	< 0.42	< 0.20	< 0.10
	Diazinon	ng/g	< 3.96	0.61	< 1.56
	Disulfoton	ng/g	< 2.76	< 0.83	< 0.49
	Fonofos	ng/g	< 0.33	< 0.15	< 0.48
	Dimethoate	ng/g	< 39.9	< 8.19	< 11.0
	Chlorpyriphos-methyl	ng/g	< 0.30	< 0.10	< 0.10
	Parathion-methyl	ng/g	< 10.1	< 4.65	< 2.55
	Pirimiphos-methyl	ng/g	< 0.30	< 0.12	< 0.10
	Chlorpyriphos	ng/g	10.4	11.0	< 0.10

Table A.10 Continued

Pesticide Group	Analyte	Units	**144 Groesbeek Street HVAC Return Grill, Second Floor** ID 117999	**4 Darden Street HVAC Return Duct, First Floor** ID 118261	Laboratory Blank
Organo-phosphate pesticides (continued)	Fenitrothion	ng/g	< 1.05	< 0.31	< 0.18
	Malathion	ng/g	< 2.82	< 0.94	< 0.99
	Parathion-ethyl	ng/g	< 1.69	< 0.488	< 0.18
	Disulfoton-sulfone	ng/g	< 1.26	K 0.787	< 0.10
	Ethion	ng/g	< 0.93	< 0.35	< 0.16
	Phosmet	ng/g	< 9.81	< 4.64	< 0.10
	Azinphos-methyl	ng/g	< 28.7	< 15.4	< 0.34
Pyrethroid pesticides	Total permethrins	ng/g	B D 85,900	B 1,130	B 0.24
	Total cypermethrins	ng/g	D 1,450	120	< 0.56

HVAC heating, ventilating, and air-conditioning
ng/g nanograms per gram
B analyte found in sample and the associated blank
K peak detected, but did not meet quantification criteria, result reported represents the estimated maximum possible concentration
D dilution data

Table A.11 Results of Air Sampling for Fungal Spores

Location	Fungal Type	Raw Spore Count	% Read	Number of Spores/m^{3*}
144 Groesbeek Street				
First floor, family room	*Alternaria*	7	100	93
	Ascospores	1	25	53
	Basidiospores	27	25	1,400
	Bipolaris/Drechslera group	8	100	110
	Cladosporium	1	25	53
	Curvularia	23	100	310
	Epicoccum	2	100	27
	Nigrospora	6	100	80
	Pithomyces	5	100	67
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	11	100	150
				Total 2,400
Outdoors	Ascospores	4	25	210
	Basidiospores	130	25	6,900
	Bipolaris/Drechslera group	1	100	13
	Cladosporium	40	25	2,100
	Curvularia	1	100	13
	Epicoccum	1	100	13
	Ganoderma	3	25	160
	Smuts, *Periconia*, myxomycetes	3	100	40
				Total 9,500
Outdoors (replicate)	*Alternaria*	2	100	27
	Ascospores	2	25	110
	Basidiospores	80	25	4,300
	Bipolaris/Drechslera group	1	100	13
	Cercospora	2	100	27
	Cladosporium	10/53	25/100	1,200
	Curvularia	2	100	27
	Ganoderma	1	25	53
	Nigrospora	3	100	40
	Smuts, *Periconia*, myxomycetes	1	100	13
				Total 5,800
First floor, kitchen	*Alternaria*	2	100	27
	Basidiospores	41	25	2,200
	Bipolaris/Drechslera group	4	100	53
	Cladosporium	7	25	370
	Curvularia	5	100	67
	Epicoccum	1	100	13
	Nigrospora	1	100	13
	Penicillium/Aspergillus types	2	25	110
	Smuts, *Periconia*, myxomycetes	1	100	13
	Spegazzinia	1	100	13
	Tetraploa	1	100	13
				Total 2,900
First floor, living room	*Alternaria*	4	100	53
	Ascospores	1	25	53
	Basidiospores	22	25	1,200
	Bipolaris/Drechslera group	5	100	67
	Curvularia	11	100	150
	Nigrospora	10	100	130
	Pithomyces	1	100	13
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	4	100	53
	Tetraploa	1	100	13
				Total 1,700

Table A.11 Continued

Location	Fungal Type	Raw Spore Count	% Read	Number of Spores/m³*
144 Groesbeek Street (continued)				
Field blank	None observed	ND	–	NA
Second floor, master bedroom	*Alternaria*	4	100	53
	Ascospores	3	25	160
	Basidiospores	22	25	1,200
	Bipolaris/Drechslera group	1	100	13
	Cladosporium	4	25	210
	Curvularia	5	100	67
	Epicoccum	1	100	13
	Nigrospora	3	100	40
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	4	100	53
				Total 1,800
Second floor, master bedroom (replicate)	*Alternaria*	5	100	67
	Basidiospores	38	25	2,000
	Cladosporium	8	25	430
	Curvularia	7	100	93
	Epicoccum	2	100	27
	Nigrospora	2	100	27
	Pithomyces	2	100	27
	Smuts, *Periconia*, myxomycetes	4	100	53
				Total 2,700
Second floor, bedroom 3	*Alternaria*	7	100	93
	Ascospores	2	25	110
	Basidiospores	24	25	1,300
	Bipolaris/Drechslera group	3	100	40
	Chaetomium	2	100	27
	Cladosporium	3	25	160
	Curvularia	7	100	93
	Epicoccum	1	100	13
	Nigrospora	2	100	27
	Pithomyces	2	100	27
	Smuts, *Periconia*, myxomycetes	5	100	67
				Total 1,900
Second floor, bedroom 1	*Alternaria*	9	100	120
	Ascospores	3	25	160
	Basidiospores	44	25	2,300
	Bipolaris/Drechslera group	4	100	53
	Cercospora	1	100	13
	Cladosporium	9	25	480
	Curvularia	12	100	160
	Epicoccum	1	100	13
	Nigrospora	1	100	13
	Pithomyces	4	100	53
	Smuts, *Periconia*, myxomycetes	4	100	53
				Total 3,500
Second floor, bedroom 2	*Alternaria*	4	100	53
	Ascospores	2	25	110
	Basidiospores	28	25	1,500
	Cercospora	2	100	27
	Cladosporium	3	25	160
	Curvularia	8	100	110
	Epicoccum	1	100	13
	Nigrospora	2	100	27
	Smuts, *Periconia*, myxomycetes	1	100	13
	Torula	8	100	110
				Total 2,100

Table A.11 Continued

Location	Fungal Type	Raw Spore Count	% Read	Number of Spores/m[3*]
144 Groesbeek Street (continued)				
Outdoors	Ascospores	9	25	480
	Basidiospores	62	25	3,300
	Bipolaris/Drechslera group	2	100	27
	Cercospora	1	100	13
	Cladosporium	21	25	1,100
	Curvularia	2	100	27
	Smuts, *Periconia*, myxomycetes	2	100	27
				Total 5,000
Outdoors (replicate)	*Alternaria*	3	100	40
	Ascospores	4	25	210
	Basidiospores	59	25	3,100
	Cladosporium	10	25	530
	Curvularia	2	100	27
	Smuts, *Periconia*, myxomycetes	2	100	27
				Total 4,000
Media blank	None observed	ND	–	NA
4 Darden Street				
Outdoors	*Alternaria*	3	100	40
	Ascospores	11	25	590
	Basidiospores	63	25	3,400
	Bipolaris/Drechslera group	4	100	53
	Cercospora	1	100	13
	Cladosporium	29	25	1,500
	Curvularia	2	100	27
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	12	100	160
				Total 5,800
Outdoor (replicate)	*Alternaria*	4	100	53
	Ascospores	4	25	210
	Basidiospores	53	25	2,800
	Bipolaris/Drechslera group	2	100	27
	Cladosporium	25	25	1,300
	Curvularia	1	100	13
	Epicoccum	2	100	27
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	7	100	93
				Total 4,600
Field blank	None observed	ND	–	NA
Media blank	None observed	ND	–	NA
First floor, family room	*Alternaria*	1	100	13
	Basidiospores	4	25	210
	Bipolaris/Drechslera group	1	100	13
	Cladosporium	2	25	110
	Curvularia	3	100	40
	Epicoccum	1	100	13
	Smuts, *Periconia*, myxomycetes	2	100	27
	Tetraploa	1	100	13
				Total 440
First floor, living room	Basidiospores	3	25	160
	Bipolaris/Drechslera group	4	100	53
	Cladosporium	1	25	53
	Curvularia	2	100	27
	Epicoccum	1	100	13
	Nigrospora	1	100	13
	Pithomyces	1	100	13
	Smuts, *Periconia*, myxomycetes	1	100	13
				Total 350

Table A.11 Continued

Location	Fungal Type	Raw Spore Count	% Read	Number of Spores/m^{3*}
4 Darden Street (continued)				
Second floor, master bedroom	*Alternaria*	1	100	13
	Basidiospores	2	25	110
	Bipolaris/Drechslera group	6	100	80
	Cladosporium	1	25	53
	Curvularia	3	100	40
	Epicoccum	1	100	13
	Pithomyces	2	100	27
	Smuts, *Periconia*, myxomycetes	1	100	13
	Spegazzinia	1	100	13
				Total 360
Second floor, master bedroom (replicate)	Basidiospores	4	25	210
	Bipolaris/Drechslera group	2	100	27
	Curvularia	3	100	40
	Epicoccum	1	100	13
	Nigrospora	1	100	13
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	1	100	13
				Total 330
Second floor, bedroom 3	Ascospores	1	25	53
	Basidiospores	4	25	210
	Curvularia	2	100	27
	Nigrospora	1	100	13
	Smuts, *Periconia*, myxomycetes	1	100	13
				Total 320
Second floor, bedroom 1	Ascospores	1	25	53
	Basidiospores	4	25	210
	Bipolaris/Drechslera group	1	100	13
	Cladosporium	2	25	110
	Curvularia	1	100	13
	Smuts, *Periconia*, myxomycetes	3	100	40
				Total 440
Second floor, bedroom 2	Basidiospores	2	25	110
	Cladosporium	1	25	53
	Curvularia	2	100	27
	Smuts, *Periconia*, myxomycetes	2	100	27
				Total 210
Outdoors	*Alternaria*	10	100	130
	Ascospores	5	25	270
	Basidiospores	55	25	2,900
	Bipolaris/Drechslera group	32	25	1,700
	Cladosporium	87	12	9,700
	Curvularia	18	25	960
	Epicoccum	3	100	40
	Nigrospora	4	100	53
	Pithomyces	29	25	1,500
	Rusts	1	100	13
				Total 17,000

Table A.11 Continued

Location	Fungal Type	Raw Spore Count	% Read	Number of Spores/m^{3*}
4 Darden Street (continued)				
Outdoors (replicate)	*Alternaria*	6	100	80
	Ascospores	5	25	270
	Basidiospores	46	25	2,500
	Bipolaris/Drechslera group	30	25	1,600
	Cladosporium	73	12	8,100
	Curvularia	20	25	1,100
	Epicoccum	4	100	53
	Nigrospora	2	100	27
	Other colorless	1	25	53
	Pithomyces	18	25	960
	Rusts	1	100	13
	Smuts, *Periconia*, myxomycetes	5	100	67
	Spegazzinia	1	100	13
				Total 15,000

spores/m^3 spores per cubic meter
NA not applicable
ND none detected

* Total spore concentrations reported by the laboratory are rounded to two significant digits.

At 100 percent read, total counts of 13 spores/m^3 indicated that, based on the volume of air sampled, only one spore was present.

Samples analyzed by EMLab P&K, Fairfax, Virginia.
Method: Air-O-Cell, spore trap analysis

Table A.12 Results of Surface Sampling for Fungal Spores

Location	Fungal Type	Colony Counts	Percent	cfu/square inch
144 Groesbeek Street				
First floor, HVAC return duct	*Cladosporium cladosporioids*	200	4	200
	Curvularia lunata	400	7	400
	Eurotium herbariorum	200	4	200
	Non-sporulating fungi	200	4	200
	Penicillium citrinum	400	7	400
	Penicillium decumbens	4,200	75	4,200
				Total 5,600
First floor, HVAC return duct	*Curvularia lunata*	80	80	80
	Pithomyces chartarum	20	20	20
				Total 100
First floor, internal duct surface	*Acremonium strictum*	48,000	64	48,000
	Aureobasidium pullulans	1,000	1	1,000
	Penicillium citrinum	13,000	17	13,000
	Pithomyces chartarum	2,000	3	2,000
	Yeasts	11,000	15	11,000
				Total 75,000
Second floor, HVAC return duct	*Aspergillus sydowii*	200	44	200
	Aureobasidium pullulans	10	2	10
	Cladosporium cladosporioids	10	2	10
	Curvularia lunata	200	44	200
	Non-sporulating fungi	20	4	20
	Penicillium citrinum	10	2	10
				Total 450
Second floor, return duct	*Curvularia lunata*	20	10	20
	Penicillium decumbens	180	90	180
				Total 200
4 Darden Street				
First floor, return grill	*Chaetomium globosum*	30	14	30
	Cladosporium cladosporioids	30	14	30
	Curvularia lunata	20	10	20
	Penicillium chrysogenum	70	33	70
	Pithomyces chartarum	60	29	60
				Total 210
First floor, return grill	*Alternaria alternata*	100	1	100
	Cladosporium cladosporioids	700	4	700
	Curvularia lunata	300	2	300
	Epicoccum nigrum	500	3	500
	Penicillium chrysogenum	700	4	700
	Pithomyces chartarum	300	2	300
	Rhodotorula mucilaginosa	12,000	73	12,000
	Yeasts	1,900	12	1,900
				Total 17,000
First floor, return grill	*Aureobasidium pullulans*	240,000	80	240,000
	Curvularia lunata	10,000	3	10,000
	Penicillium chrysogenum	10,000	3	10,000
	Rhodotorula mucilaginosa	20,000	7	20,000
	Yeasts	20,000	7	20,000
				Total 300,000

Table A.12 Continued

Location	Fungal Type	Colony Counts	Percent	cfu/square inch
4 Darden Street (continued)				
First floor, return duct	*Aureobasidium pullulans* *Chaetomium globosum* *Epicoccum nigrum* *Penicillium* species *Rhodotorula mucilaginosa* *Sodaria fimicola* Yeasts	3,000 300 200 200 60,000 100 3,000	4 <1 <1 <1 90 <1 4	3,000 300 200 200 60,000 100 3,000 Total 67,000
First floor, return duct	*Aureobasidium pullulans* *Cladosporium cladosporioides* *Curvularia lunata* *Rhodotorula mucilaginosa* Yeasts	1,000 100 100 1,300 900	29 3 3 38 26	1,000 100 100 1,300 900 Total 3,400
Field blank	None observed	ND	—	<10 Total <10
Media blank	None observed	ND	—	<10 Total <10
Second floor, return grill	*Cladosporium cladosporioides* *Curvularia lunata* *Fusarium solani* *Rhodotorula mucilaginosa* Yeasts	100 200 500 2,600 14,000	1 1 3 15 80	100 200 500 2,600 14,000 Total 17,000
Second floor, return grill	*Cladosporium cladosporioides* *Curvularia lunata* *Penicillium chrysogenum* *Rhodotorula mucilaginosa* *Yeasts*	3,000 2,000 43,000 30,000 50,000	2 2 34 23 39	3,000 2,000 43,000 30,000 50,000 Total 130,000
Second floor, return grill, bottom frame	Non-sporulating fungi *Penicillium minioluteum*	10 10	50 50	10 10 Total 20
Second floor, return grill, side	*Cladosporium cladosporioides* Non-sporulating fungi Yeasts	40 10 920	4 1 95	40 10 920 Total 970
Second floor, return duct	*Curvularia lunata* Non-sporulating fungi *Penicillium chrysogenum* *Pithomyces chartarum*	30 20 30 30	27 18 27 27	30 20 30 30 Total 110
Second floor, return duct	*Alternaria alternaria* *Cladosporium cladosporioides* Non-sporulating fungi Yeasts	100 200 100 4,300	2 4 2 91	100 200 100 4,300 Total 4,700

Table A.12 Continued

cfu colony forming units
NA not applicable
ND none detected

* Total colony forming units reported by the laboratory are rounded to two significant digits.

When detected, the minimum detection and reporting limit is a colony count of 1 at the lowest dilution plated.

Samples analyzed by EMLab P&K, Fairfax, Virginia.
Method: Swab, culturable fungi

Table A.13 Sampling Results for Viable Fungal Spores in Air Samples Collected

Location	Fungal Type	Raw Count		cfu/m³
144 Groesbeek Street				
First floor, family room	*Alternaria alternata*	2		14
	Aureobasidium pullulans	1		7
	Basidiomycetes	2		14
	Cladosporium cladosporioides	81		640
	Epicoccum nigrum	2		14
	Trichoderma harzianum	1		7
			Total	700
Outdoors	*Alternaria alternata*	2		14
	Cladosporium cladosporioides	77		610
	Epicoccum nigrum	2		14
	Penicillium brevicompactum	1		7
			Total	640
Outdoors (replicate)	*Arthrinium phaeospermum*	1		7
	Aspergillus niger	1		7
	Basidiomycetes	2		14
	Cladosporium cladosporioides	64		490
	Curvularia lunata	1		7
	Penicillium oxalicum	2		14
	Penicillium sclerotiorum	1		7
			Total	550
First floor, kitchen	*Alternaria alternata*	2		14
	Aspergillus versicolor	1		7
	Basidiomycetes	2		14
	Cladosporium cladosporioides	49		370
	Curvularia lunata	2		14
	Epicoccum nigrum	2		14
	Fusarium solani	2		14
	Penicillium oxalicum	1		7
	Penicillium sclerotiorum	1		7
			Total	460

Table A.13 Continued			
Location	**Fungal Type**	**Raw Count**	**cfu/m³**
144 Groesbeek Street (continued)			
First floor, living room	*Alternaria alternata*	2	14
	Arthrinium phaeospermum	1	7
	Cladosporium cladosporioides	35	260
	Curvularia lunata	2	14
	Epicoccum nigrum	1	7
	Penicillium crustosum	1	7
			Total 310
Field blank	None observed	ND	NA
Second floor, master bedroom	*Alternaria alternata*	1	7
	Cladosporium cladosporioides	34	250
	Curvularia lunata	2	14
	Epicoccum nigrum	1	7
	Nigrospora sphaerica	1	7
	Penicillium oxalicum	1	7
	Pithomyces chartarum	3	21
			Total 320
Second floor, master bedroom (replicate)	*Alternaria alternata*	1	7
	Cladosporium cladosporioides	36	270
	Curvularia lunata	5	35
	Nigrospora sphaerica	1	7
	Penicillium oxalicum	1	7
	Penicillium sclerotiorum	1	7
			Total 330
Second floor, bedroom 3	*Alternaria alternata*	1	7
	Cladosporium cladosporioides	37	280
	Curvularia lunata	5	35
	Nigrospora sphaerica	2	14
	Penicillium glabrum	1	7
	Penicillium oxalicum	1	7
	Phoma herbarum	1	7
	Pithomyces chartarum	4	28
			Total 380
Second floor, bedroom 1	*Alternaria alternata*	2	14
	Basidiomycetes	2	14
	Choanephora cucurbitarum	1	7
	Cladosporium cladosporioides	21	160
	Curvularia lunata	2	14
	Nigrospora sphaerica	1	7
	Penicillium oxalicum	1	7
	Penicillium sclerotiorum	2	14
	Penicillium species	1	7
	Pithomyces chartarum	2	14
			Total 250

Table A.13 Continued

Location	Fungal Type	Raw Count	cfu/m^3
144 Groesbeek Street (continued)			
Second floor, bedroom 2	*Alternaria alternata*	2	14
	Aspergillus versicolor	1	7
	Cladosporium cladosporioides	26	190
	Curvularia lunata	5	35
	Fusarium solani	1	7
	Penicillium minioluteum	1	7
	Penicillium oxalicum	2	14
	Penicillium species	1	7
			Total 280
Outdoors	*Alternaria alternata*	1	7
	Cladosporium cladosporioides	49	370
	Curvularia lunata	3	21
	Nigrospora sphaerica	1	7
	Penicillium glabrum	2	14
	Penicillium oxalicum	2	14
			Total 430
Outdoors (replicate)	*Aspergillus ochraceus*	1	7
	Basidiomycetes	2	14
	Cladosporium cladosporioides	50	370
	Curvularia lunata	1	7
	Epicoccum nigrum	1	7
	Penicillium glabrum	1	7
	Penicillium minioluteum	1	7
	Penicillium sclerotiorum	2	14
			Total 440
Media blank	None observed	ND	NA
4 Darden Street			
Outdoors	*Aureobasidium pullulans*	1	7
	Cladosporium cladosporioides	136	1,200
	Curvularia lunata	2	14
	Epicoccum nigrum	5	35
	Penicillium chrysogenum	2	14
	Penicillium oxalicum	1	7
	Penicillium sclerotiorum	2	14
			Total 1,300
Outdoors (replicate)	*Aspergillus versicolor*	1	7
	Cladosporium cladosporioides	88	700
	Epicoccum nigrum	6	42
	Penicillium chrysogenum	4	28
	Penicillium oxalicum	2	14
	Penicillium sclerotiorum	4	28
			Total 820
Field blank	None observed	ND	NA
Media blank	None observed	ND	NA

Table A.13 Continued

Location	Fungal Type	Raw Count		cfu/m^3
4 Darden Street (continued)				
First floor, family room	*Basidiomycetes*	2		14
	Cladosporium cladosporioides	73		570
	Curvularia lunata	2		14
	Epicoccum nigrum	2		14
	Nigrospora sphaerica	1		7
	Penicillium decumbens	1		7
	Penicillium oxalicum	1		7
	Pithomyces chartarum	3		21
			Total	660
First floor, living room	*Alternaria alternata*	3		21
	Arthrinium phaeospermum	2		14
	Basidiomycetes	2		14
	Cladosporium cladosporioides	43		320
	Curvularia lunata	2		14
	Nigrospora sphaerica	1		7
	Penicillium chrysogenum	1		7
	Penicillium decumbens	1		7
	Penicillium oxalicum	1		7
	Pithomyces chartarum	5		35
			Total	450
Second floor, master bedroom	*Cladosporium cladosporioides*	46		350
	Curvularia lunata	3		21
	Penicillium decumbens	1		7
	Penicillium oxalicum	1		7
	Pithomyces chartarum	7		49
			Total	430
Second floor, master bedroom	*Basidiomycetes*	2		14
	Epicoccum nigrum	10		71
	Non-sporulating fungi	2		14
	Penicillium solitum	1		7
			Total	110
Second floor, bedroom 3	*Alternaria alternata*	2		14
	Aphanocladium aranearum	1		7
	Aureobasidium pullulans	1		7
	Cladosporium cladosporioides	26		190
	Curvularia lunata	8		57
	Nigrospora sphaerica	1		7
	Penicillium chrysogenum	1		7
	Penicillium glabrum	1		7
	Penicillium oxalicum	1		7
			Total	300
Second floor, bedroom 1	*Cladosporium cladosporioides*	27		200
	Curvularia lunata	2		14
	Epicoccum nigrum	1		7
	Nigrospora sphaerica	1		7
	Penicillium decumbens	1		7
	Pithomyces chartarum	5		35
			Total	270

Table A.13 Continued

Location	Fungal Type	Raw Count	cfu/m³
4 Darden Street (continued)			
Second floor, bedroom 2	*Basidiomycetes*	2	14
	Cladosporium cladosporioides	18	130
	Curvularia lunata	2	14
	Epicoccum nigrum	1	7
	Nigrospora sphaerica	1	7
	Non-sporulating fungi	1	7
	Penicillium decumbens	1	7
	Pithomyces chartarum	2	14
			Total 200
Outdoors	*Basidiomycetes*	2	14
	Cladosporium cladosporioides	380	8,500
	Epicoccum nigrum	5	35
	Fusarium species	2	14
	Non-sporulating fungi	2	14
	Penicillium chrysogenum	1	7
	Penicillium oxalicum	1	7
	Penicillium species	1	7
			Total 8,600
Outdoors (replicate)	*Alternaria alternata*	2	14
	Cladosporium cladosporioides	400	>19,000
	Epicoccum nigrum	6	42
	Penicillium oxalicum	2	14
			Total >19,000

cfu/m³ colony forming units per cubic meter

Samples collected with an Andersen N-6 Impactor onto malt extract agar and incubated at 37 degrees Celsius to isolate thermophilic fungal species.
Samples analyzed by Environmental Microbiology Laboratory, Inc., Fairfax, Virginia;

Sampling Method: Andersen volumetric air sampler.

Table A.14 Results of Direct Microscopic Examination for Mold in Surface Samples Collected

Description	Misc. Spores Present[1]	Molds with Mycelial and/or Sporulating Structures[2]	Impression
144 Groesbeek Street			
First floor, HVAC return duct	Variety	None	Normal trapping
First floor, HVAC return duct	Variety	None	Normal trapping
First floor, internal duct surface	Variety	None	Normal trapping
Second floor, HVAC return duct	Variety	None	Normal trapping
Second floor, HVAC return duct	Variety	None	Normal trapping
4 Darden Street			
First floor, return grill	Variety	None	Normal trapping
First floor, return grill	Variety	None	Normal trapping
First floor, return duct	Variety	None	Normal trapping
First floor, return duct	Variety	None	Normal trapping
Blank	None	None	No mold spores detected
Blank	None	None	No mold spores detected
Second floor, return grill	Variety	None	Normal trapping
Second floor, return grill	Variety	None	Normal trapping
Second floor return duct, bottom	Variety	None	Normal trapping
Second floor, return duct, side	Variety	None	Normal trapping

[1] Indicative of typical conditions, i.e., seen on surfaces everywhere. Includes basidiospores (mushroom spores), myxomycetes, plant pathogens such as ascospores, rusts, and smuts, and a mix of saprophytic genera with no particular spore type predominating. Distribution of spore types seen mirrors that usually seen outdoors.

[2] Quantities of molds seen growing are graded 1+ to 4+, with 4+ denoting the highest numbers.

Samples analyzed by Environmental Microbiology Laboratory, Fairfax, Virginia.

Table A.15 Results of Water Samples Collected in Fort Bragg Homes

Analyte Group	Analyte	Units	144 Groesbeek Street	4 Darden Street	*EPA Guidance*		
					MCL	*SMCL*	*Region 3 RBC (non-cancer)*
Metals	Calcium, Total	mg/L	12	12			
	Copper, Total	mg/L	0.07	<0.03	*1.3*	*1*	*1.5*
	Iron, Total	mg/L	<0.10	<0.10		*0.3*	*26*
	Magnesium, Total	mg/L	2.8	2.8			
	Manganese, Total	mg/L	0.06	<0.05		*0.05*	*0.88*
	Potassium, Total	mg/L	4.0	5.0			
	Sodium, Total	mg/L	26	21			
	Lead, Total	mg/L	0.005	0.002	*0.015*		
Volatile organic compounds	1,1,1,2-Tetrachloroethane	mg/L	<0.0005	<0.0005			*1.1*
	1,1,1-Trichloroethane	mg/L	<0.0005	<0.0005	*0.2*		*9.1*
	1,1,2,2-Tetrachloroethane	mg/L	<0.0005	<0.0005			*0.73*
	1,1,2-Trichloroethane	mg/L	<0.0005	<0.0005	*0.005*		*0.15*
	1,1-Dichloroethane	mg/L	<0.0005	<0.0005			*7.3*
	1,1-Dichloroethene	mg/L	<0.0005	<0.0005	*0.007*		*0.34*
	1,1-Dichloropropene	mg/L	<0.0005	<0.0005			
	1,2,3-Trichlorobenzene	mg/L	<0.0005	<0.0005			*0.029*
	1,2,3-Trichloropropane	mg/L	<0.0005	<0.0005			*0.00062*
	1,2,4-Trichlorobenzene	mg/L	<0.0005	<0.0005	*0.07*		*0.0041*
	1,2,4-Trimethylbenzene	mg/L	<0.0005	<0.0005			*0.015*
	1,2-Dichlorobenzene	mg/L	<0.0005	<0.0005	*0.6*		*0.37*
	1,2-Dichloroethane	mg/L	<0.0005	<0.0005	*0.005*		*0.64*
	1,2-Dichloropropane	mg/L	<0.0005	<0.0005	*0.005*		*0.0083*
	1,3,5-Trimethylbenzene	mg/L	<0.0005	<0.0005			*0.37*
	1,3-Dichlorobenzene	mg/L	<0.0005	<0.0005			
	1,3-Dichloropropane	mg/L	<0.0005	<0.0005			*0.73*
	1,4-Dichlorobenzene	mg/L	<0.0005	<0.0005	*0.75*		*1.0*
	2,2-Dichloropropane	mg/L	<0.0005	<0.0005			
	2-Chlorotoluene	mg/L	<0.0005	<0.0005			*0.73*
	4-Chlorotoluene	mg/L	<0.0005	<0.0005			*2.6*
	4-Isopropyltoluene	mg/L	<0.0005	<0.0005			
	Benzene	mg/L	<0.0005	<0.0005	*0.005*		*0.044*
	Bromobenzene	mg/L	<0.0005	<0.0005			*0.088*
	Bromochloromethane	mg/L	<0.0005	<0.0005			
	Bromodichloromethane	mg/L	0.02	0.01	*0.08***		*0.73*
	Bromoform	mg/L	0.005	0.008	*0.08***		*0.73*
	Bromomethane	mg/L	<0.0005	<0.0005			*0.0087*
	Carbon tetrachloride	mg/L	<0.0005	<0.0005	*0.005*		*0.086*
	Chlorobenzene	mg/L	<0.0005	<0.0005	*0.1*		*0.091*
	Chloroethane	mg/L	<0.0005	<0.0005			*21*
	Chloroform	mg/L	0.02	0.005	*0.08***		*0.13*
	Chloromethane	mg/L	<0.0005	<0.0005			*0.19*
	Dibromochloromethane	mg/L	0.02	0.02	*0.08***		*0.73*
	Dibromomethane	mg/L	<0.0005	<0.0005			*0.0082*
	Dichlorodifluoromethane	mg/L	<0.0005	<0.0005			*0.39*
	Ethylbenzene	mg/L	<0.0005	<0.0005	*0.7*		*1.3*
	Hexachlorobutadiene	mg/L	<0.0005	<0.0005			*0.037*
	Isopropylbenzene	mg/L	<0.0005	<0.0005			*0.68*
	Methyl tert-butyl ether (MTBE)	mg/L	<0.0005	<0.0005			*6.3*
	Methylene chloride	mg/L	<0.0005	<0.0005			*1.1*
	Naphthalene	mg/L	<0.0005	<0.0005			*0.0062*

Table A.15 Continued

Analyte Group	Analyte	Units	144 Groesbeek Street	4 Darden Street	*EPA Guidance* *MCL*	*SMCL*	*Region 3 RBC (non-cancer)*
Volatile organic compounds (continued)	Styrene	mg/L	<0.0005	<0.0005	*0.1*		*1.6*
	Tetrachloroethene	mg/L	<0.0005	<0.0005	*0.005*		*0.22*
	Toluene	mg/L	<0.0005	<0.0005	*1*		*2.3*
	Trichloroethene	mg/L	<0.0005	<0.0005	*0.005*		
	Trichlorofluoromethane	mg/L	<0.0005	<0.0005			*1.3*
	Vinyl Chloride	mg/L	<0.0005	<0.0005	*0.002*		*0.072*
	cis-1,2-Dichloroethene	mg/L	<0.0005	<0.0005	*0.07*		*0.073*
	cis-1,3-Dichloropropene	mg/L	<0.0005	<0.0005			
	meta-Xylene and para-Xylene	mg/L	<0.0005	<0.0005			*1.2*
	n-Butylbenzene	mg/L	<0.0005	<0.0005			
	n-Propylbenzene	mg/L	<0.0005	<0.0005			*1.3*
	ortho-Xylene	mg/L	<0.0005	<0.0005			*1.2*
	sec-Butylbenzene	mg/L	<0.0005	<0.0005			
	tert-Butylbenzene	mg/L	<0.0005	<0.0005			
	trans-1,2-Dichloroethene	mg/L	<0.0005	<0.0005	*0.1*		
	trans-1,3-Dichloropropene	mg/L	<0.0005	<0.0005			
Pesticide/ Herbicide/ Insecticide	1,2-Dibromo-3-chloropropane (DBCP)	mg/L	<0.00002	<0.00002	*0.0002*		*0.00039*
	Ethylene Dibromide (EDB)	mg/L	<0.00002	<0.00002	*0.00005*		*0.018*
	Toxaphene	mg/L	<0.001	<0.001	*0.003*		
	2,4,5-TP (Silvex)	mg/L	<0.0003	<0.0003	*0.05*		*0.29*
	2,4-D	mg/L	<0.001	<0.001	*0.07*		*0.37*
	Dalapon	mg/L	<0.001	<0.001	*0.2*		*1.1*
	Diacamba	mg/L	<0.0002	<0.0002			
	Dinoseb	mg/L	<0.0005	<0.0005	*0.007*		*0.037*
	Pentachlorophenol	mg/L	<0.0001	<0.0001	*0.001*		*0.18*
	Picloram	mg/L	<0.001	<0.001	*0.5*		*2.6*
	3-Hydroxycarbofuran	mg/L	<0.001	<0.001			
	Aldicarb	mg/L	<0.001	<0.001			*0.037*
	Aldicarb Sulfone	mg/L	<0.001	<0.001			*0.037*
	Aldicarb Sulfoxide	mg/L	<0.001	<0.001			
	Carbaryl	mg/L	<0.001	<0.001			*3.7*
	Carbofuran	mg/L	<0.0009	<0.0009	*0.04*		*0.18*
	Methiocarb	mg/L	<0.001	<0.001			
	Methomyl	mg/L	<0.001	<0.001			*0.91*
	Oxamyl (Vydate)	mg/L	<0.001	<0.001	*0.2*		*0.91*
	Propoxur (Baygon)	mg/L	<0.001	<0.001			
PCBs	Aroclor 1016	mg/L	<0.0002	<0.0002	*0.0005*		*0.0026*
	Aroclor 1221	mg/L	<0.0002	<0.0002	*0.0005*		
	Aroclor 1232	mg/L	<0.0002	<0.0002	*0.0005*		
	Aroclor 1242	mg/L	<0.0002	<0.0002	*0.0005*		
	Aroclor 1248	mg/L	<0.0002	<0.0002	*0.0005*		
	Aroclor 1254	mg/L	<0.0002	<0.0002	*0.0005*		*0.00073*
	Aroclor 1260	mg/L	<0.0002	<0.0002	*0.0005*		

Table A.15 Continued							
Analyte Group	**Analyte**	**Units**	**144 Groesbeek Street**	**4 Darden Street**	***EPA Guidance*** ***MCL***	***SMCL***	***Region 3 RBC (non-cancer)***
Organic compounds	Alachlor	mg/L	<0.0001	<0.0001	*0.002*		*0.37*
	Aldrin	mg/L	<0.0001	<0.0001			*0.0011*
	Atrazine	mg/L	<0.0001	<0.0001	*0.003*		*1.3*
	Benzo(a)pyrene	mg/L	<0.0001	<0.0001	*0.0002*		
	Butachlor	mg/L	<0.0001	<0.0001			
	Chlordane	mg/L	<0.0002	<0.0002	*0.002*		*0.018*
	Di(2-ethylhexyl)adipate	mg/L	<0.0006	<0.0006	*0.4*		*22*
	Di(2-ethylhexyl)phthalate	mg/L	<0.003	<0.003	*0.006*		*0.73*
	Dieldrin	mg/L	<0.00004	<0.00004			*0.0018*
	Endrin	mg/L	<0.0001	<0.0001	*0.002*		*0.011*
	Heptachlor	mg/L	<0.00004	<0.00004	*0.0004*		*0.018*
	Heptachlor Epoxide	mg/L	<0.00006	<0.00006	*0.0002*		*0.00047*
	Hexachlorobenzene	mg/L	<0.0001	<0.0001	*0.001*		*0.029*
	Hexachlorocyclopentadiene	mg/L	<0.0001	<0.0001	*0.05*		*0.22*
	Lindane	mg/L	<0.00007	<0.00007	*0.0002*		*0.011*
	Methoxychlor	mg/L	<0.0001	<0.0001	*0.04*		*0.18*
	Metolachlor	mg/L	<0.0001	<0.0001			*5.5*
	Metribuzin	mg/L	<0.0001	<0.0001			*0.91*
	Propachlor	mg/L	<0.0001	<0.0001			*0.47*
	Simazine	mg/L	<0.0001	<0.0001	*0.004*		*0.18*
General chemistry	Total Hardness	mg/L	42	42			
	Chloride	mg/L	18	20		*250*	
	Sulfate	mg/L	35	36		*250*	
	Nitrate (as Nitrogen)	mg/L	0.59	0.60	*10*		*58*
	Nitrite (as Nitrogen)	mg/L	<0.02	<0.02	*1*		*3.7*
	Ammonia (as Nitrogen)	mg/L	<0.20	<0.20			
	Turbidity	N.T.U.	0.80	0.60	*1.0****		
	Specific Conductance	umhos/ cm	210	220			
	Sulfide	mg/L	<0.05	<0.05			
Perchlorate	Perchlorate	mg/L	<0.0003	<0.0003			*0.026*
Coliform bacteria	Coliform, Total	Colonies/ 1	absent	absent	*5.0%*		

MCL Maximum Contaminant Level
SMCL Secondary Maximum Contaminant Level
EPA U.S. Environmental Protection Agency
mg/L milligrams per liter
PCBs polychlorinated biphenyls

* Sample collected at Kitchen spigot and outdoor spigot. Sample results for both samples.
** The sum of all four trihalomethanes as an annual average
*** For systems that use direct or conventional filtration, at no time can turbidity go higher that 1.0 N.T.U. (nephelolometric turbidity unit)