

PRELIMINARY DRYWALL INVESTIGATION GUIDANCE



Prepared for

Arnold Layne, Drywall Program Manager
Director, Technology Innovation and Field Services Division
Office of Superfund Remediation and Technology Innovation
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Washington, DC 20004

Prepared by

Raj Singhvi, Drywall Technical Project Manager
Chemist, Environmental Response Team
Technology Innovation and Field Services Division
Office of Superfund Remediation and Technology Innovation
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
Edison, NJ 08837

In conjunction with

Deborah Killeen, QA Officer
Lockheed Martin, Inc/REAC
Edison, NJ 08837

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List of Acronyms

AC	Air Conditioning
ASTM	American Society for Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
COPC	Contaminants of Potential Concern
CPSC	Consumer Product Safety Commission
EPA	Environmental Protection Agency
ERT	Environmental Response Team
FLDOH	Florida Department of Health
g	gram
GC/ECD	Gas Chromatograph/Electron Capture Detector
GC/MS	Gas Chromatograph/Mass Spectrometer
HQ	Headquarters
H ₂ S	Hydrogen Sulfide
H ₂ SO ₄	Sulfuric Acid
LADHH	Louisiana Department of Health and Hospitals
LCD	Liquid Crystal Display
L/min	Liters per minute
mg	milligram
mL	milliliter
mm	millimeter
N	Normal
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NJ	New Jersey
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear Aromatic Hydrocarbons
PC	Personal Computer
PCB	Polychlorinated Biphenyls
ppb	parts per billion
ppm	parts per million
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
SAP	Sampling and Analysis Plan
SO ₂	Sulfur Dioxide
SOP	Standard Operating Procedure
SPM	Single Point Monitor
Sr	Strontium
SVOC	Semivolatile Organic Compounds
TIC	Tentatively Identified Compounds

List of Acronyms (cont'd)

TO	Toxic Organic
TOC	Total Organic Carbon
US	United States
v	volts
VOC	Volatile Organic Compounds
WHO	World Health Organization
XRF	X-ray Fluorescence
°C	degrees Centigrade
%RH	Percent relative humidity

1.0 EXECUTIVE SUMMARY

Occupants of homes built with imported (Chinese) drywall have reported adverse health symptoms and corrosion of indoor metals. The Consumer Product Safety Commission (CPSC) is the lead Federal agency. The United States (US) Environmental Protection Agency Environmental Response Team (EPA/ERT) was requested to conduct indoor air testing by the Agency for Toxic Substances and Disease Registry (ATSDR), the Florida Department of Health (FLDOH), and the Louisiana Department of Health and Hospitals (LADHH).

This document provides guidance for the monitoring and sampling of indoor and ambient air for future testing for the presence of the contaminants of potential concern (COPC). These drywall investigation guidance are based on the work performed on drywall samples and indoor air monitoring/sampling conducted in a total of six houses (four houses with imported drywall and two houses with US manufactured drywall) in Florida and Louisiana. The analytical target compounds and suggested analytical methods are being provided to the CPSC so that Federal and State Agencies will be able to conduct their own drywall investigations. It is not within the scope of this document to provide a generic air sampling plan. Based on recommended methods, the individual entities conducting the drywall investigation will prepare their own Quality Assurance Project Plans (QAPPs) or Sampling and Analysis Plans (SAPs) to meet project or agency goals.

Based on the drywall chemical analysis, and air monitoring and sampling activities conducted during June and July, 2009 in Florida and Louisiana, EPA recommends that the procedures outlined in this document be used to conduct further extensive drywall investigations in potentially impacted states. The investigator may decide during the monitoring and sampling process that there is sufficient information/data to conclude that the home is adversely affected by the installed drywall and more extensive air monitoring for hydrogen sulfide (H₂S) and/or sampling for volatile organic compounds (VOCs), polynuclear aromatic hydrocarbons (PAHs) and aldehydes and ketones may not be necessary.

2.0 INTRODUCTION

Drywall from China was imported to address the shortage of essential construction materials created following record-breaking 2004 and 2005 hurricane seasons and a national demand for new home construction. Based on press report estimates, as many as thousands of houses may have been affected; it is uncertain how many homes have this specific drywall. According to the newspapers, the imported drywall contains reduced sulfur compounds, which are suspected to be the basis for the complaints. It has been reported that as the drywall is exposed to elevated levels of humidity, as well as elevated temperatures, the product may be off-gassing sulfur-based gases that have been associated with the odor, health, and corrosion complaints. Compounds reported to be detected in the suspect drywall include reduced sulfur compounds.

Consumers have reported blackened and corroded metal in their homes, in addition to premature failure of central air conditioning evaporator coils located indoors in the air handling unit and intermittent failure of appliances and/or electronic devices. Visual examination of electrical wiring in suspect homes and the presence of blackened sooty material on electrical wires have been noted by CPSC staff during inspections (CPSC 2009). Tarnishing and pitting of metallic surfaces was also observed in some of the affected homes in Florida and Louisiana.

Various health-related symptoms including cough, bloody and runny noses, headaches, difficulty in breathing and irritated and itchy eyes and skin have been reported by homeowners. These homeowners report that the symptoms lessen or go away when they leave the home and return upon re-entry (CPSC 2009).

The ATSDR contacted the EPA/ERT for analytical assistance with the Chinese-manufactured drywall used in Florida. ATSDR, with concurrence from FLDOH and LADHH, requested that the ERT conduct an elemental analysis of both Chinese and US-manufactured drywall. Two drywall samples collected from two homes in Florida were selected by the FLDOH to be sent to ERT for analysis. Four samples of US-manufactured drywall were purchased from local home improvement stores in Edison, New Jersey (NJ). Five additional drywall samples were then collected and analyzed from two homes in Florida, one home in Louisiana, a warehouse in Virginia and a warehouse in Louisiana to confirm the previous findings. CPSC also requested that ERT conduct elemental analysis and provided fifteen samples of uninstalled drywall from a variety of sources, including imported drywall, domestic calcined drywall, and domestic synthetic drywall collected from warehouses, suppliers, and manufacturers.

The analytical procedures outlined in this guidance are based on the analysis of the drywall samples, air monitoring performed in Florida and Louisiana, air sampling and drywall analysis performed by other organizations for builders, conversations with home owners, and literature searches

2.1 Initial Six Drywall Sample Analysis Reported on May 7, 2009

The two Chinese and four US-manufactured drywall samples were analyzed to determine what compounds may be affecting the homeowners. Prior to analysis, the thin layer of paint was scraped off of the two Chinese drywall samples for metals analysis. The paper was then separated from the drywall gypsum material. The paper portions of the samples were analyzed for metals, formaldehyde and semi-volatile organic compounds (SVOCs). The gypsum portions of the samples were analyzed for metals, SVOCs, VOCs, formaldehyde, elemental sulfur, alkalinity as carbonate and bicarbonate, sulfides, sulfates, water soluble chlorides, pH, total organic carbon (TOC) and Loss of Ignition (LOI). The significant differences between the Chinese-manufactured and US manufactured drywall samples were as follows. The ERT chemical analysis showed the presence of elemental sulfur and strontium in the imported drywall samples. Elemental sulfur was not detected in the US-manufactured samples. Elemental sulfur was present in the Chinese drywall samples at concentrations up to 100 parts per million (ppm)

and strontium at over 2,500 ppm, which is at least twice what was measured in US drywall. In addition to the chemical analysis, it was observed that the gypsum used in the two imported drywall samples are grayish in color and have a characteristic smell of sulfur/burnt match and/or vinegar. At the present time, there are no available US standards for strontium or elemental sulfur levels in drywall.

2.2 Additional Five Drywall Sample Analysis Reported on August 25, 2009

The analysis shows the presence of elemental sulfur and strontium in four out of five imported drywall gypsum portions of the samples ranging from 71.4 ppm to 419 ppm, and from 3,030 ppm to 4,110 ppm, respectively. No elemental sulfur was detected in the fifth gypsum sample collected from the warehouse in New Orleans, but Sr was detected at a concentration of 401 ppm, approximately 10 times less than that found in the other gypsum samples. Elemental sulfur was also detected in the paper portion of the four imported drywall samples ranging from 41.7 ppm to 454 ppm. The presence of elemental sulfur could be attributed to the sulfur leaching out from gypsum or it may have been added in some form during the manufacturing process.

The additional drywall and paint samples collected from the homes from Florida and Louisiana contained several organic compounds of interest to the EPA/ERT. Liquid paint was collected from the same paint cans used to paint the walls. Analytical results demonstrated the presence of two organic compounds in the three liquid paint samples collected from the two homes in Florida and the one home in Louisiana. The same two organic compounds were found in the painted imported gypsum portion of the drywall samples. The two compounds tentatively identified by the mass spectrometry library search were propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl) propyl ester (CAS # 74367-33-2) at estimated concentrations ranging from 1.78 to 10.6 ppm, and propanoic acid, 2-methyl-, 3-hydroxy-2,4,4-trimethylpentyl ester (CAS # 74367-34-3) at estimated concentrations ranging from 4.04 to 10.7 ppm in the gypsum portion of the drywall. These compounds were also detected in the paper portion of the drywall sample collected from the Louisiana home. These two compounds were at a much higher concentration in the liquid paint (can) samples than that found in the gypsum portion of the drywall (1000-fold higher). The results of the investigation show that these two compounds are most likely components of the paint and not of the gypsum. The presence of these two compounds in the gypsum portion may be attributed to absorption of off gases from these two organic compounds found in the paint.

The headspace screening analysis conducted on drywall (gypsum core) for reduced sulfur compounds shows the presence of hydrogen sulfide, carbonyl sulfide and carbon disulfide in the drywall samples collected from homes in Florida and Louisiana and the warehouse in Virginia. When the drywall was subjected to wet conditions, the H₂S concentration dropped while the carbonyl sulfide and the carbon disulfide concentrations increased. Additional investigations are recommended to confirm these findings.

2.3 Louisiana and Florida Monitoring/Sampling

A total of six homes were selected in Florida and Louisiana for air monitoring/sampling in consultation with FLDOH, LADHH and EPA Headquarters (HQ). A total of four sampling events were performed in each house (two sampling events with the air conditioning [AC] off and two sampling events with the AC on). Concurrent ambient air samples were collected during each event. Real-time continuous monitoring was performed for total VOCs, H₂S, sulfur dioxide (SO₂), sulfuric acid (H₂SO₄), carbon monoxide (CO), carbon dioxide (CO₂), temperature and relative humidity, at two locations in the home (living room and bedroom) and one outside of the home. Air sampling was performed at the same locations and analyzed using appropriate analytical methods for VOCs (EPA Method TO-15 and Modified National Institute for Occupational Safety and Health [NIOSH] 1500, 1501 & 1003), PAHs (Modified NIOSH 5515), inorganic acids (Modified NIOSH 7903), aldehydes/ketones (EPA TO-11A), aliphatic (NIOSH 2010) and aromatic amines (NIOSH 2002) and sulfur-containing compounds such as H₂S, carbonyl sulfide, carbon disulfide, dimethyl sulfide, dimethyl disulfide and mercaptans (American Society for Testing and Materials [ASTM] D5504-08). Air samples were also collected in the wall cavities (i.e., inside a cable outlet, inside an electrical outlet, inside of a closet wall) in these homes and analyzed for VOCs (TO-15) using SUMMA canisters, and for H₂S, carbonyl sulfide, carbon disulfide, dimethylsulfide and dimethyldisulfide using Tedlar[®] bags. During the Louisiana sampling events, samples were also collected for formic and acetic acids (Occupational Safety and Health Administration [OSHA] ID 186SG). The organic acids were added for Louisiana sampling event due to the acetic odor noted during a prior visit. In addition, pesticides/polychlorinated biphenyl (PCB) sampling and analysis using EPA Method TO-10A was performed in Louisiana.

2.4 Louisiana and Florida Monitoring/Sampling Results

The real-time monitoring results for the houses in Florida showed the presence of H₂S in indoor and in outdoor air. While the water sprinklers were on, a strong odor of rotten eggs was noted outside of the house due to the presence of H₂S; however, the odor of H₂S inside the house was not as strong. There was a definite noxious odor in the test houses that is probably due to a combination of several organic/inorganic compounds.

Air samples were analyzed for reduced sulfur compounds collected in all six units in Florida and Louisiana with a detection limit of 5.0 parts per billion (ppb). The results show the absence of reduced sulfur gases in units 100, 101, 102, 200, 201 and 202, except during the Night 2 sampling event when carbonyl sulfide ranged from ND to 8.8 ppb and carbon disulfide ranged from ND to 6.3ppb. It should be noted that the sprinkler system came on during this sampling event.

Water was collected indoors and outdoors using dehumidifiers in the selected houses. In Florida, the indoor copper concentrations were 39 to 51 times higher than that found outdoors. In Louisiana, the copper concentrations were 6 to 23 times higher indoors than outdoors. The data demonstrate that there appears to be an acidic vapor (organic/inorganic) presence in the house

possibly causing erosion of copper coils in dehumidifiers. It should be noted that the copper concentrations found in the condensates collected in the control homes were not the lowest detected, suggesting that there may be other factors influencing the results besides the type of drywall present in the homes.

The air sampling results show the presence of formaldehyde in four test houses and also in two background houses in Florida and Louisiana at levels equal to or greater than 100 ppb. The formaldehyde levels in one test house in Louisiana were measured at 400 ppb. The World Health Organization (WHO) guideline for formaldehyde is 100 $\mu\text{g}/\text{m}^3$ or 81.4 parts per billion by volume (ppbv) as a 30-minute average. Predominant sources of formaldehyde and other aldehydes can be found in building materials, carpets, draperies and subfloors, and in wood fillers and some types of adhesives. Further investigations are necessary to determine the sources of formaldehyde in the test houses and background houses.

The two organic compounds found in the three paint samples collected from homes in Florida and Louisiana were also detected in condensate (water from dehumidifiers) and in indoor air. These compounds were tentatively identified by the mass spectrometry library search as propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl) propyl ester (CAS # 74367-33-2) and propanoic acid, 2-methyl-, 3-hydroxy-2,4,4-trimethylpentyl ester (CAS # 74367-34-3) and were detected at higher concentrations in the test houses than in the background houses. These two compounds are commonly found in indoor air.

Isomers of pinene were detected in the test houses and in the background houses. The presence of pinene isomers may be attributed to wood flooring and other compressed wood material.

Low levels of target compound VOCs were detected in indoor air samples collected from all six houses; the target VOC compounds detected are ones generally found in indoor air. Acetic acid and formic acid were detected at low concentrations in three houses in Louisiana (test house and background houses). Sampling and analysis of acetic acid and formic acid was added due to the presence of an acetic acid-like odor detected in one of the test houses in Louisiana during a pre-screening visit.

Based on the drywall chemical analysis, and air monitoring/air sampling results conducted during the months of June and July in Florida and Louisiana, EPA recommends the following procedures for investigating drywall complaints: 1) Real time monitoring for hydrogen sulfide; 2) Sampling of drywall for elemental sulfur and strontium; and 3) Air sampling for VOCs, PAHs and aldehydes and ketones. Although target VOCs and PAHs were not found, tentatively identified compounds (TICs) for both parameters were noted during the mass spectral library search and may be a potential indicator of imported drywall. A data analysis of these non-target compounds is currently in progress. Based on the results of the analysis, EPA may decide to modify/delete some of the parameters recommended in this guidance. The Federal and/or State investigators may also at any time during the process decide that there is sufficient information to conclude a problem exists with the drywall and extensive air monitoring and/or

sampling may not be performed. The recommended drywall investigation guidance is provided in Figure 1.

3.0 RECOMMENDATIONS FOR FUTURE DRYWALL ASSESSMENTS

3.1 Strategy for Selecting Units

The FLDOH published a case definition on March 31, 2009 for premature copper corrosion possibly associated with imported drywall. To meet the current case definition, homes constructed from 2004 to present must meet two or more of the conditions specified below and those homes built prior to 2004 must meet three of the following conditions.

1. Presence of sulfur-like or unusual odors
2. Confirmed presence of imported drywall in the homes
3. Observed copper corrosion (black sooty coating) of un-insulated copper wire leading to the air handling unit in the garage or mechanical closet of the home
4. Documented failure of the air conditioner coil (located inside of the air handling unit)
5. Confirmation by an outside expert or professional for the presence of premature copper corrosion on un-insulated copper wires and/or air conditioner evaporator coils.

3.2 Visual Drywall Inspection

The Federal or State entities will obtain signed access agreements to each of the homes selected. The eligible residential units should be characterized using checklists or survey guidance for information such as age of construction (or rebuild, remodel), square footage, number of rooms, replacement history of appliances, air conditioning units, electronics, etc.

The house should be inspected to ascertain whether it contains imported drywall or domestic drywall by first inspecting the back of drywall for any markings at various locations in the home based on judgment of the investigator. A small hole should be drilled at a few locations to facilitate the collection of the gypsum portion of the drywall for further observation and chemical analysis as discussed in section 4.6.

3.3 Drywall Sampling

Upon inspecting the home, if the investigator determines that the house meets the case definition listed in Section 3.1, five drywall samples (approximately 10 g of gypsum core-) should be collected into 40-milliliter (mL) VOC vials from the subject home and examined visually for color and odor. Use professional judgment to pick two of the drywall (gypsum core) samples collected and analyze for elemental sulfur (to determine if the concentration is >15 ppm) and strontium (to determine if the concentration is >2300 ppm), which are indicators of imported drywall found in most of the samples analyzed thus far.

3.4 Air Monitoring and Sampling

Sufficient data should be obtained with real-time instruments during the initial entry to screen the home for the H₂S. If an investigator determines that air sampling is necessary in homes with noxious odors and metal corrosion, air sampling should be conducted at two locations in the house and at one outdoor ambient air location for a minimum of 24 hours consisting of two sampling events each of at least 8-12 hour duration, one event with the AC off. Typically locations should be chosen based on use of areas within a home and rooms in which potentially sensitive receptors (i.e., children, the elderly, and people with existing respiratory conditions) sleep, play or spend most of their time. Sampling should typically be conducted at breathing height approximately 3 to 4 feet for children's rooms or 4-5 feet for the general population. If homes are located within close proximity of each other, it may be feasible to select one ambient air location for both residences.

4.0 AIR MONITORING AND DRYWALL INVESTIGATION INSTRUMENTS

4.1 Hydrogen Sulfide Instruments

Continuous air monitoring for H₂S, temperature and humidity in the home and outside of the home should be conducted using calibrated air monitoring instruments specific for these parameters. There are several types of air monitoring instruments on the market that can be used. The selection of the air monitoring instrument should be based on availability, detection limit required, and ease of use. Detailed descriptions for several types of H₂S monitoring instruments are discussed below. It should be noted that the following instruments represent a small fraction of those available. The mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

The Single Point Monitor (SPM) or tapemeter (e.g., Zellweger Analytics) employs a specially treated cloth tape reel called a "Chemcassette" and an electronic key called a "Chemkey" for the monitoring of H₂S. The Chemkey stores setup information and other functional information (i.e. flow rate, alarm levels and compound concentration times) needed for accurate detection of target gases. The Chemcassette is a medium onto which a known quantity of ambient air is concentrated. The use of the Chemcassette as a concentration media allows the instrument to see a variety of compounds in some cases down to the low ppb range. When the tapemeter is monitoring, the tape from the Chemcassette is drawn into the "read head" where it is exposed to a predetermined amount of ambient air. If the target gas is present the tape responds with a color change in proportion to the concentration of the target gas present. The tapemeter reads this color change and through the Chemkey converts the observed color change into the concentration which is sent to the SPM's LED display. The range and detection limits of the SPM are determined by the pre-programmed Chemkey specific for an analyte or a group of analytes.

Hydrogen sulfide monitors (e.g., Arizona Instruments Jerome 631-X) operate on the principle that electric resistivity increases across a gold film as a function of H₂S concentration. The monitors provide rapid and relatively low detection limits for H₂S in air. While the units have similar cross-interferents, internal filters are used to minimize them. An external data logger allows for data acquisition during surveys or unattended sampling without a computer. Data may be downloaded after the monitoring event.

The following table compares the range or detection limits for the previously discussed H₂S monitoring instruments.

Monitoring Parameter	Instrument	Range or Detection Limit
H ₂ S	Zellweger SPM	2 - 90 ppb (low range) 53 – 1500 ppb (MVIP range)
H ₂ S	Jerome 631X	3 – 99 ppb (low range) 3 ppb detection limit @ 30 second response time

Based on the data obtained from real-time air monitoring in Florida and Louisiana, H₂S appears to be the major target compound of concern; therefore, real-time monitoring options for VOCs, SO₂ and H₂SO₄ are not included in this guidance.

4.2 Temperature and Humidity Monitoring

For temperature and humidity monitoring, a digital humidity temperature meter (e.g., Omegaette HH314) is applicable for measurements obtained in a zero to 50 degrees Celsius (°C) environment with a maximum relative humidity (RH) of 90%. Temperature is measured using either a semiconductor sensor or a K-type thermocouple, and % RH using a polymer capacitive. Results are digitally displayed on the liquid crystal display (LCD) screen. The instrument can be operated with either a 9-Volt (v) battery or a 9-v alternate current adapter. Data are stored in the internal memory (up to 16300 readings). A RS-232 interface provides bi-directional communication with a personal computer (PC). The information is not critical to evaluate potential drywall impacts; however, it is good practice to conduct these secondary measurements as part of any drywall investigation.

Pocket PC running appropriate application software (e.g., GrayWolf IQ410) provides indoor air quality measurements. The percent RH is measured by absorption or desorption of moisture by a thin polymeric film. As the relative humidity changes so does the dielectric property of the film changes and the capacitance of the sensor. Relative humidity can be measured from 0 to 100%. For temperature, resistance over a platinum element is measured. Platinum sensors are highly accurate over a wide temperature range (-10 to 70°C).

4.3 XRF Screening

XRF screening may be used for strontium analysis in the field as an indicator for imported drywall to determine if the concentration exceeds 2300 ppm. Samples may be analyzed in-situ with an XRF instrument such as a NITON XLt792YW with proper X-ray tube/filter selection, application setup, measurement conditions, and instrument calibration. An Innov-X 4100SL XRF unit may also be used which is a hand-held, battery operated energy dispersive X-ray fluorescence analyzer used in the detection and quantification of elements. Miniaturized X-ray tube technology is used by the Innov-X System XRF instrument for the production of primary X-rays.

A gypsum core sample is positioned in front of the X-ray tube/detector window and sample measurement is initiated. This exposes the sample to filtered primary radiation. Fluorescent and backscattered X-rays from the sample enter through the detector window and are counted by the high-performance, solid-state detector. Elemental concentrations are computed based on ratios of analyte X-ray intensity to backscatter. The raw ratios are corrected for spectral overlap and inter-element effects.

5.0 AIR SAMPLING METHODS

5.1 Volatile Organic Compound Sampling

VOC sampling should be conducted to determine the types of non-target compounds that may help gain insight into the potential sources of VOCs that may be responsible for the odor complaints. Ambient air sampling should be conducted following the modified NIOSH Method 1500, *Hydrocarbons, BP 36-126 EC*, Method 1501, *Hydrocarbons, Aromatic* and Method 1003, *Hydrocarbons, Halogenated*. The sampling train consists of a 600-milligram (mg) charcoal solid sorbent tube connected to a low flow personal sampling pump. The sampling pump should be calibrated to collect approximately 1.0 liter per minute (L/min) of air through the sorbent tube for 8-12 hours for a total of 480- 720 L. Modifications to the NIOSH sampling methods include the use of a 600-mg sorbent tube instead of a 150 mg tube and a flow rate of 1.0 L/min instead of the 0.2 L/min listed in the NIOSH methods.

5.2 Polynuclear Aromatic Hydrocarbon Sampling

PAH sampling is being conducted to determine the types of non-target compounds that may help gain insight into the potential sources of organic compounds that may be responsible for the odor complaints. In addition to that PAH sampling was retained in this guidance to identify TICs specifically propanoic acid, 2-methyl-, 2,2-dimethyl-1-(2-hydroxy-1-methylethyl) propyl ester (CAS # 74367-33-2) and propanoic acid, 2-methyl-, 3-hydroxy-2,4,4-trimethylpentyl ester (CAS # 74367-34-3). Ambient air sampling for PAHs should be conducted following modified NIOSH Method 5515, *Polynuclear Aromatic Hydrocarbons*. The sampling train consists of a 600-mg washed XAD-2 sorbent tube and 37-millimeter (mm) Teflon® (PTFE) filter connected to a personal sampling pump (SKC). The sampling pumps should be calibrated

to collect approximately 1.0 L/min of air through the sorbent tube and filter for approximately 8-12 hours for a total of 480 to 720 L. Modifications include the use of a 600-mg XAD tube instead of the 150-mg tube and a lower flow rate of 1.0 L/min as opposed to the 2.0 L/min listed in the method.

5.3 Aldehyde/Ketone Sampling

Ambient and indoor air sampling for aldehydes/ketones should be conducted using EPA Method TO-11A, *Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Pressure Liquid Chromatography (HPLC)*. The sampling train consists of a 150/300 mg silica gel tube treated with 2,4-dinitrophenylhydrazine (DNPH) connected to a personal sampling pump. Although EPA Method TO-11A recommends a flow rate of 1.0 L/min through one cartridge, the sampling pump should be calibrated to collect approximately 0.25 L/min of air through the tube for approximately 4 hours or 0.5 L/min for 2 hours for a total of 60 L to minimize breakthrough, which was noted during the Florida and Louisiana sampling events. Multiple pumps set on various time delays may be used to encompass the whole 8-12 hour sampling period.

5.4 Condensate Water Collection

One dehumidifier should be placed inside the house and one outdoors. Ten mL of 1.0 Normal (N) sodium hydroxide is added to the tray in each dehumidifier. The condensate water is collected and analyzed for copper and SVOCs. The copper results from the water collected indoors and the water collected outdoors should be compared. If the concentration of copper is higher in the indoor condensate, acid vapors are present and copper is leaching from the dehumidifier copper coils. At this time, sufficient data have not been collected to determine the useful life of each dehumidifier. The investigator must closely monitor the condition of dehumidifier and decide when to replace the dehumidifier. At this time, it is recommended that the dehumidifier be replaced after use at three houses, if a visual inspection indicates that there is a drastic change in the coloration of the copper coils, or analytical results obtained from both the test and control houses are questionable.

6.0 ANALYTICAL METHODS

The analytical methods were modified to accommodate these sample matrices as standard methods were not available in the area of sample digestion/preparation procedures. The ERT/REAC standard operating procedures (SOPs) cited in this guidance may be found at http://www.epaossc.org/site/site_profile.aspx?site_id=2107. Any modifications to these methods are discussed in Section 6.0, Analytical Methods.

6.1 Drywall Analytical Methods

The ERT/REAC Laboratory has developed a screening analytical method (draft REAC SOP #1744, *Field Analysis of Sulfur in Drywall by GC/ECD*) to determine elemental sulfur concentrations. The screening method is very fast and effective and has a reporting limit (RL) of approximately 150 parts per billion (ppb). Strontium can be analyzed using REAC SOP #1811, *Determination of Metals by Inductively Coupled Plasma (ICP) Methods* or EPA Method 6010B. Microwave digestion was used for the preparation of drywall samples for subsequent metals analysis. EPA Method 3051A, *Microwave Assisted Acid Digestion of Sediments, Sludges, Soils, and Oils* can be found at <http://www.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/3051a.pdf>

6.2 Air Analytical Methods

The following methods should be used to analyze ambient and indoor air samples. It should be noted that the NIOSH methods for VOCs and PAHs have been modified to incorporate the use of a Gas Chromatograph/Mass Spectrometer (GC/MS) to execute a library search for non-target compounds present in method blanks and samples for the purpose of tentative identification. In this case, the National Institute of Standards and Technology (NIST) Mass Spectral Library (or equivalent) should be used for identification search.

Parameter	Method	Matrix
VOCs (Sorbent Tubes)	SOP #1816, <i>Indoor Air Analysis of Volatile Organic Compounds by Gas Chromatography/Mass Spectrometry</i> (Including up to 30 TICs)	Air
PAHs (Sorbent Tubes)	SOP #1817, <i>Analysis of Polynuclear Aromatic Hydrocarbons (PAHs) in Air by GC/MS</i> (Including up to 30 TICs)	Air
Aldehydes/Ketones	EPA Method TO-11A, <i>Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Pressure Liquid Chromatography (HPLC)</i>	Air

TICs = Tentatively Identified Compounds

6.3 Water Condensate Analytical Methods

The following methods should be used to analyze the water condensate samples collected from the dehumidifier trays:

Parameter	Method	Matrix
Metals, i.e., Copper	REAC SOP #1811, <i>Determination of Metals by Inductively Coupled Plasma (ICP) Methods</i> or EPA Method 6010B	Water
SVOCs	REAC SOP #1804, <i>Routine Analysis of Semivolatiles in Water by GC/MS</i> or EPA Method 8270C (Including up to 30 TICs)	Water

TICs = Tentatively Identified Compounds

7.0 MAINTENANCE, CALIBRATION AND TESTING

Equipment used for sampling and monitoring should be inspected, cleaned and tested. Equipment used for the generation, measurement and assessment of data should also be adequately tested, calibrated and/or standardized. Sampling pumps should be calibrated on a routine basis and prior to use. A rotameter can be used provided it has been calibrated with a primary calibrator. Sampling pumps should be calibrated prior to coming on-site in order to expedite on-site calibration. However, calibration must be verified on-site prior to use. The frequency for calibration and testing should be based on the manufacturers' recommendations and be included in the project-specific QAPP or SAP.

8.0 QUALITY ASSURANCE/QUALITY CONTROL CONSIDERATIONS

Quality Assurance/Quality Control (QA/QC) samples provide information on the variability and usability of environmental sample results. QA/QC samples should be collected to detect error. QA/QC samples are submitted with the field samples for analysis to aid in identifying the origin of analytical discrepancies; then a determination can be made as to how the analytical results should be used. Collocated samples, background samples, field blanks, and lot blanks are the most commonly collected QA/QC field samples. QA/QC results may suggest the need for modifying sample collection, preparation, handling, or analytical procedures if the resultant data do not meet site-specific QA or data quality objectives. Official custody of samples must be maintained from the time of collection to final deposition. In the case of litigation, the chain of custody (COC) record would be evaluated to ensure that sample integrity was maintained from the time of sample collection to completion of analysis.

9.0 INVESTIGATION REPORT

An investigation report should be prepared based on the findings at each home. The results of the investigation should be provided to appropriate agency/department for health-related decisions and for dissemination to the homeowners.

10.0 REFERENCES

Consumer Product Safety Commission. 2009. <http://www.cpsc.gov/info/drywall/where.html>

Florida Department of Health. 2009. <http://www.doh.state.fl.us/environment/community/indoor-air/casedefinition.html>

Hodgson, A.T. et al, 2000. Volatile Organic Compound Concentrations and Emission Rates in New Manufactured and Site-Built Homes, *Indoor Air*, 10: p. 178-192.

Hodgson, A.T. et al, 2002. Sources of formaldehyde, other aldehydes and terpenes in a new manufactured house, *Indoor Air*, 12: p.235-242.

Park, J.S. and Ikeda, K, 2006. Variations of formaldehyde and VOC levels during 3 years in new and older homes, *Indoor Air*, 16: p. 129-135.

U.S. EPA, 2007. Microwave Assisted Digestion of Sediments, Sludges, Soils and Oils, Method 3051A. <http://www.epa.gov/epawaste/hazard/testmethods/sw846/pdfs/3051a.pdf>

FIGURE-1

