

5-20-2011

## **Preliminary Assessment: Identification of Chinese Drywall and Exposure to Particulate Matter and Metals during Cutting and Installation of Drywall**

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Preliminary Assessment: Identification of Chinese Drywall and  
Exposure to Particulate Matter and Metals during Cutting and Installation of Drywall

A Thesis

Submitted to the Graduate Faculty of the  
University of New Orleans  
in partial fulfillment of the  
requirements for the degree of

Master of Science  
in  
Environmental Engineering

by

Vandana Karap

B.E Osmania University, 2007

May, 2011

## Dedication

To my late mother who taught me to be independent and is the reason for what I am today. To my father who always had a complete trust and faith in me. To my sisters for their immense support and belief in my dreams, and to my best friends Soujanya and Naveen for being my strength and just being there for me.

*“Hesitating to act because the whole vision might not be achieved, or because others do not yet share it, is an attitude that only hinders progress” – Mohandas Karamchand Gandhi*

## **Acknowledgements**

Thanks to God for being with me and giving me strength to achieve my goals and fulfill my dreams.

I am grateful to Dr. Bhaskar Kura, Dr. Enrique La Motta, and Dr. Patricia Williams for serving on my Graduate Examining Committee.

I owe my gratitude to Dr. Kura for his support, guidance, encouragement, and his patience throughout my master's program, for pushing me towards achieving my goal, for his immense motivation on this project, and for helping me understand new techniques and concepts in the past three years. Dr. La Motta for sharing his knowledge, teaching, and explaining subjects that were new to me. Dr. Williams for her valuable assistance and suggestions on this project.

I would like to acknowledge Mr. Earl Carr and Carr Public Adjusters for providing the samples for this project when there was no source for samples. Mr. Stephen Crawford and Ms. Amy Gagnon for providing the opportunity to study their homes.

I take this opportunity to thank my friends Aashay, Anirudh, Appu, Gomzy, Jaipal, Kaushik, Mon, Murali, Nag Bhai, Naveen, Pinki, and Vamshi for their constant support and encouragement in most difficult and good times during the past three years. For being there for me at all times.

My sincere thanks to my mother, my father, my sisters, Kirthi and Sunny for their backing and motivation through all these years of my life.

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## **Abstract.**

Drywall, a popular building material made of gypsum based plaster sandwiched between two thick sheets of paper is used for building interior walls, is speedier alternative to traditional plaster, decreasing time and labor for construction. Importance of drywall increased with the demand for drywall after nine hurricanes hit Florida in 2004-05 and widespread damage caused in the Gulf Coast after Katrina in 2005. This study has two parts. First part presents an analysis of metals like strontium for the identification of Chinese drywall, and a comparison of strontium concentrations of American drywall and Chinese drywall using XRF (X-Ray Fluorescence) analysis with the Innov-X XRF analyzer. The second part presents an analysis of metal exposure during cutting and installation of drywall using 8stage Cascade impactor. The work space concentration of, different metals is analyzed using XRF analysis and particulate matter within various size ranges, were calculated and their effects are studied.

**Keywords:** Drywall, Chinese Drywall, Identification of Chinese drywall, Strontium, XRF (X-ray Fluorescence) analysis, Innov-X XRF Analyzer, Metal exposure, 8 staged Cascade Impactor, Work space concentration, Metals, Particulate Matter and Effects.

## Introduction

Drywall, a popular building material used for building interior walls, is made of gypsum based plaster sandwiched between two thick sheets of paper. Drywall is the speedier alternative to traditional plaster, decreasing the time and labor for construction. The importance of drywall increased with the increase in the demand of drywall after nine hurricanes hit Florida during 2004-05 and the widespread damage that was caused in the Gulf Coast after Katrina in 2005. Since January 2006, more than 550 million pounds of Chinese drywall were shipped to the United States to build about 60,000 average sized homes. The controversy over Chinese drywall started in 2008 as a result of residents complaining of rotten egg odors in their houses and blackening and corroding of copper wires. Monitored houses showed traces of hydrogen sulfide ( $\text{H}_2\text{S}$ ) and higher levels of strontium concentrations.

This study has two parts. The first part presents an analysis of heavy metals, especially strontium and  $\text{H}_2\text{S}$  monitoring, which can be used in the identification of Chinese drywall in affected homes. Two homes, one with American drywall and one with Chinese drywall, were monitored using the Jerome 631-X  $\text{H}_2\text{S}$  gas analyzer. The home made of Chinese drywall showed traces of  $\text{H}_2\text{S}$  gas, whereas the home with American drywall had no traces of  $\text{H}_2\text{S}$  gas. American and Chinese drywall samples were tested for metals using X-ray fluorescence (XRF) analysis with the Innov-X XRF analyzer. Strontium concentrations in Chinese and American drywall were observed to be in the range of 150 - 220 PPM and 15 - 45 PPM, respectively. Based on the research, strontium can be measured in situ, rapidly and non-destructively, using XRF. Strontium alone may not be the indicator of Chinese drywall, but can be considered as one of the indicators after the prescreening analysis, such as the visual inspection of blackening, corrosion of copper wires and other metals, and health effects of the residents. Orthorhombic sulfur ( $\text{S}_8$ ) can be tested to confirm the analysis and verify the results (EH&E report16512, 2010). This paper also deals with the health effects of the occupants due to exposure to Chinese drywall and metals like strontium.

The second part of the study presents the “exposure potential” to particulate matter (PM) and heavy metals during the cutting and installation of drywall. Drywall samples were cut using a skill saw and an eight-stage cascade impactor was used for collecting the PM in the plume released during the cutting of the drywall. The mass collected on the filter for each stage of the cascade impactor was used for computing the PM concentration for various particle size ranges. Subsequently, the filters were tested for heavy metals using the Innov-X XRF (X-Ray Fluorescence) analyzer. XRF analysis identified metal concentrations of lead (Pb), iron (Fe), zinc, rubidium (Rb), and strontium (Sr). The workspace concentration and mass fraction of heavy metals like Pb, Fe, Zn, Rb, Sr, and PM within various size ranges were calculated. The health effects due to exposure to these metals are analyzed. The results of this paper give an idea in evaluating the health risks to workers involved in the construction industry.

This report is divided into six chapters. Chapter 1 presents the literature review, such as background and past investigations of the study. Chapter 2 presents descriptions of the instruments used. Chapter 3 presents the methodology followed in the study. Chapter 4, includes the calculated results in tables. Chapter 5 discusses the results and effects of metals and particulate matter. Chapter 6 presents the conclusions from this study.

# Objectives

## General Objective:

The general objective of this thesis is the analysis of heavy metals like strontium for the identification of Chinese drywall and a preliminary assessment of exposure to particulates and heavy metals during the cutting and installation of drywall.

## Specific Objectives:

### *1. Identification of Chinese drywall*

- Prescreen analysis,
- In situ H<sub>2</sub>S monitoring,
- Collection of samples and XRF analysis of samples to identify heavy metals like strontium and its concentration, and a determination of its effects.

### *2. Preliminary assessment of exposure to particulates and heavy metals during cutting and installation of drywall*

- Collection of PM using eight-stage cascade impactor,
- Analysis of work space concentration of PM and heavy metals using XRF analysis,
- Determination of heavy metals found during analysis and its effects.

## **Chapter 1: Literature Review**

### **1.1 Background**

Drywall is a building material that is commonly used to build interior walls. It is usually made of gypsum based plaster sandwiched between two thick sheets of paper and dried in a kiln. General drywall is made of a paper liner wrapped around the inner core made primarily from gypsum plaster. The raw gypsum mined or obtained from flue gas desulfurization must be calcined before use. The plaster is then mixed with fiberglass, plasticizer, a foaming agent, finely ground gypsum crystal as an accelerator, EDTA, starch or other chelate as a retarder, various additives that increase mildew and fire resistance, wax emulsion for lower water absorption, and water. The drywall is then formed by sandwiching the wet gypsum between two sheets of heavy paper or fiberglass mats. When the core sets and is dried in a large drying chamber, then the drywall is ready to be used as a building material. Drywall construction is used for the finished construction of interior walls and ceilings. This became the speedier alternative to traditional plaster, decreasing the time and labor for construction.

Drywall was imported by the United States from foreign countries during 2004 to 2007. The import of drywall increased with increasing demand of drywall during the rebuilding of states after the damage from nine hurricanes in Florida during 2004-05 and the widespread damage that was caused in the Gulf Coast after Katrina in 2005. Since 2006, more than 550 million pounds of drywall were imported from China into the United States, enough to make tens of thousands of houses. Sixty percent of Chinese drywall came into Florida through seven ports. Since January 1, 2008, states have imported at least 1 million pounds of drywall from China. Experts say a general 30 cm x 10 cm board weighs about 90 pounds on average. A total of 100 such boards are used by a typical 2,000-square foot home. Since 2006, the Chinese drywall which entered the United States was used in the construction of 61, 000 homes and more than 36, 000 homes in Florida alone. (Herald Tribune). Homes in more than 37 states, the District of Columbia, and Puerto Rico may contain imported drywall from China. The U.S. Consumer Product Safety Commission (CPSC) has received 3,300 complaints regarding a rotten egg odor, unusual and frequent corrosion of copper wiring, and various health issues like nose bleeds, headaches, and respiratory problems. Most complaints were from the hurricane hit states of Florida and Louisiana, where the Chinese drywall was imported mostly for rebuilding the states after the hurricanes in 2004-2005. (EH&E Report 16512, May 2010)

Consumers from more than 10 states and the District of Columbia have reported concerns related to drywall imported from China. The CPSC is the lead federal agency for this issue. The U.S. Environmental Protection Agency (EPA) is working with the CPSC and the Centers for Disease Control and Prevention - Agency for Toxic Substances and Disease Registry (CDC-ATSDR), in coordination with state and local authorities, to investigate this matter. To gather more information about Chinese drywall, the CDC-ATSDR requested that the EPA conduct an elemental analysis of Chinese drywall and compare it with drywall manufactured in the United States. (Drywall Sampling Analysis, May 2009)

The controversy of Chinese Drywall in 2008 was an important health and safety issue involving the manufacture of drywall in China and imported to the United States. Residents were complaining of the rotten egg odor in their houses. Preliminary tests were conducted on Chinese drywall in the laboratory which identified the emissions of sulfurous gases like carbon disulfide, carbonyl sulfide, and hydrogen sulfide. These emissions caused the rotten egg odor in the homes. The odor increases in the presence of increased humidity and temperature. The monitored houses also have a problem with the corrosion of copper wiring, which is expected to be caused by the drywall. Initially, the cause for the problem was analyzed as the composition of gypsum that was used to manufacture the drywall. The gypsum mines used fly ash, a waste material that is a byproduct of power plants using coal. A test conducted by United Engineering on Chinese drywalls showed the results that it consisted of 5 - 12% of organic material. The results contradicted the theory that Chinese drywall was made of waste from coal fired power plants. Now, it is believed that drywall from China is manufactured from mined gypsum and not from synthetic gypsum made from coal ash. Electron scanning microscopy revealed that mined gypsum contained high levels of strontium. Another belief about Chinese drywall is that it contains bacteria which are degrading iron and sulfur compounds to produce sulfur compounds. Testing has revealed that drywall outer paper and core gypsum releases sulfur compounds. Apart from drywall itself, there are other potential causes, such as the contaminants in the adhesive that binds the paper to drywall. Irrespective of source, preliminary tests of Chinese drywall revealed the presence of strontium sulfide.

The U.S. EPA, the U.S. CPSC, the ATSDR, and the U.S. Department of Housing and Urban Development (HUD) joined hands with the state agencies to determine if the residents with Chinese drywall in their homes face any potential health and safety risks. The state agencies like the Louisiana Department of Health and Hospitals (LA DHH) is currently working with federal partners and other states to evaluate the potential for human health hazards related to corrosion of copper and other metals inside homes because of the presence of Chinese drywall.

## **1.2 Past Investigations**

The controversy over Chinese drywall started in 2008 when the U.S. CPSC received 3,300 complaints regarding corrosion and blackening of indoor metals such as electrical components, central air conditioning system evaporator coils, and various health symptoms, including persistent cough, nose bleeds, difficulty in breathing, and irritated and itchy eyes and skin. Most complaints were from the hurricane hit states of Florida and Louisiana where Chinese drywall was imported mostly for rebuilding after the hurricanes in 2004-2005. When the homes were inspected and tested, Chinese drywall was determined to be the cause for the rotten egg odor and minor ill health effects of the residents. With the increasing number of complaints, federal and state agencies joined hands for research on Chinese drywall and its composition. (USEPA, Drywall Sampling Analysis, July'09).

In response to the number of complaints from residents, a scientific investigation has been coordinated to determine if there is any relation between Chinese drywall and reported complaints from the residents. Investigations were carried out on both Chinese and non-Chinese drywall. Three types of investigations were carried out on both types of drywall. The tests were:

- Elemental and chemical testing,
- Chamber studies, and
- Indoor air sampling.

The results of elemental and chemical analyses of samples tested showed that the Chinese drywall had higher concentrations of strontium (>2,500 PPM) and orthorhombic sulfur (15 - 420 PPM). The preliminary chamber studies showed that Chinese drywall emits total volatile sulfur gases at a higher rate. Indoor air studies did not detect the presence or found very limited and rare indications of sulfur and its compounds such as hydrogen sulfide (lower levels), carbon disulfide (>6 PPBV), and carbonyl sulfide (>8 PPBV) (USEPA, Drywall Sampling Analysis, July'09).

### **1.3 Recent Investigations:**

The CPSC has been investigating homeowner reports of corrosion and adverse health effects associated with Chinese drywall. After receiving approximately 3,300 homeowner reports from 37 states, with the majority of the complaints coming from areas around the Gulf Coast and coastal Virginia, the CPSC initiated a multi-track investigation to examine health and safety concerns potentially associated with Chinese drywall. As part of this investigation, Environmental Health and Engineering, Inc (EH&E) conducted a 51-home study in the summer of 2009 to characterize the relationship between source markers, gas concentrations, building dynamics, and corrosion. The important findings of this study were as follows:

- Those homes from CPSC complaints were found to have elevated rates of corrosion, as measured objectively by metal corrosion and visual inspection. This finding was there when a house's status was determined using an objective source marker of imported drywall (carbonate and strontium measured using FTIR and XRF, respectively).
- The presence of drywall with the carbonate/strontium objective source marker was associated with increased levels of hydrogen sulfide in indoor air of complaint homes.
- Hydrogen sulfide concentrations in the air were associated with higher dew points for complaint homes.
- Hydrogen sulfide and formaldehyde concentrations in indoor air were associated with elevated corrosion rates.
- Objective source markers of imported drywall in CPSC complaint homes can be quantified using the portable Fourier transformed infrared spectroscopy (FTIR) and XRF analyzers.
- Air exchange rates in the study homes were all on the low-end of typical air exchange rates in homes. These low air exchange rates may play an important role in the effect of gases and indoor environmental conditions on corrosion and possible exposure to indoor contaminants.

- Additional source investigations by agencies identified orthorhombic sulfur ( $S_8$ ) as an important marker of not only Chinese drywall, but problematic drywall associated with corrosion, emission of reduced sulfur gases, and possessing a distinctly bad odor.
- Strontium and  $S_8$  concentrations were found both in chamber studies and in-home studies. A stronger association was found for  $Ag_2S$  corrosion than for  $Cu_2S$  corrosion due to the mass increase rates. Silver was found to have a faster magnitude of mass increase rate than copper, showing a mass response within several minutes after  $H_2S$  was introduced.
- In chamber studies, corrosion was associated with sulfur concentrations, and strontium alone was found to be a poor predictor. But, for in-home studies, strontium was strongly associated with problem homes and corrosion. This inconsistency may be due to the selection of the drywall, as the drywall samples were selected on a different basis. However, in samples from the home, concentrations of strontium and  $S_8$  are highly correlated.
- As a result, both strontium and  $S_8$  concentrations are markers of problematic drywall. If the concentrations of strontium and  $S_8$  are greater than 1,200 ppm and 10 ppm, respectively, the drywall is considered to be Chinese drywall.
- Strontium alone is not a specific marker of problematic drywall, as even the non-problematic drywall sometimes contains high levels of strontium concentrations.
- Analysis of strontium can be reliably measured using XRF.
- $S_8$  is a sensitive marker of problematic drywall, as it is associated with  $H_2S$  emissions in homes, and  $S_8$  concentrations were not detected in non-complaint homes. Hence,  $S_8$  concentrations can be considered as confirmative analysis.
- After the prescreening criteria, if the complaint homes had high levels of strontium (greater than 1,200 ppm), then the drywall was tested for  $S_8$  concentrations for confirmative analysis, and if this was greater than 10 ppm, then the wall was confirmed as problematic drywall (EH&E Report 16512, 2010).

Depending on past research, the first part of the study deals with the analysis of heavy metals like strontium in the composition of Chinese drywall and the comparison of concentrations of strontium in both American and Chinese-made drywall. The prescreen analysis of the affected homes and problems faced by the residents.

In this study, the heavy metals and their concentrations are analyzed with XRF analysis. Due to a limited number of samples and unavailability of methods to test orthorhombic sulfur at the local laboratories, the analysis of orthorhombic sulfur is not included in this study.



#### 1.4 Exposure to dust produced during cutting and installation of drywall as particulate matter

Construction workers who are involved in the cutting and installation of drywall are often exposed to high concentrations of dust produced during these processes. The drywall is usually made of gypsum or calcium sulfate dihydrate, cellulose, starch, crystalline silica, propriety additives, fibrous glass, or synthetic (continuous filament). The dust produced during the cutting and installation of drywall usually contains particulate matter of gypsum, respirable silica, and small amounts of metals. Exposure to these particulate matters is associated with varying degrees of eye, nose, throat, and upper respiratory tract irritation. Inhalation of dust during drywall cutting and installation may cause persistent throat and airway irritation, coughing, phlegm production, and breathing difficulties similar to asthma. Smokers or workers with sinus or respiratory conditions may risk even worse health problems. Prolonged and repeated exposure to airborne free respirable crystalline silica can result in lung disease (i.e., silicosis) and/or lung cancer. The development of silicosis may increase the risk of additional health effects. The risk of developing silicosis is dependent upon exposure intensity and duration.

The occupational exposure limits for dust determined by OSHA is 15 mg/m<sup>3</sup> (total), 5 mg/m<sup>3</sup> (respirable), and the threshold limit value (TLV) for dust is 10 mg/m<sup>3</sup>. **Table 1**, below, presents the exposure limits by OSHA and ACGIH for the drywall board dust components

**Table 1: Exposure Limits for Dust from Drywall Composition**

<b>Table 1: Exposure limits for Dust from Drywall Composition</b>			
<b>Components</b>	<b>Weight %</b>	<b>OSHA PEL (mg/m<sup>3</sup>)</b>	<b>ACGIH TLV (mg/m<sup>3</sup>)</b>
<i>Gypsum or Calcium Sulfate Dihydrate</i>	>80	15 <sup>(T)</sup> / 5 <sup>(R)</sup>	10
<i>Cellulose (Paper Fiber)</i>	<15	15 <sup>(T)</sup> / 5 <sup>(R)</sup>	10
<i>Starch</i>	<5	15 <sup>(T)</sup> / 5 <sup>(R)</sup>	10
<i>Propriety Additives</i>	<1	NE	NE
<i>Fibrous Glass or Synthetic Continuous Filament</i>	<1	15 <sup>(T)</sup> / 5 <sup>(R)</sup>	1 f/cc <sup>(R)</sup>
<i>Crystalline Silica</i>	<5	0.1	0.025
(T)—Total; (R)—Respirable; (NE)—Not Established; f/cc-fiber per cubic centimeter			
*ACGIH: 1 fiber/cubic centimeter air for fibers longer than 5 micrometers and thinner than 3 micrometers. Continuous filaments that are chopped, crushed, or severely mechanically processed during manufacture or use may contain very small amounts of respirable particulates [PEL = 5 mg/m <sup>3</sup> (R)].			

Source: USG and NG Material Safety of Drywall Boards and Sheetrock Panels

Total inhalable dust is the fraction of airborne material that enters the nose and mouth during breathing and is, therefore, available for deposition in the respiratory tract. Respirable dust approximates to the fraction which penetrates to the gas exchange region of the lung. The concentration of respirable dust shall be determined from the fraction passing a size selector with an efficiency that will allow:

- 100% of particles of 1 mm aerodynamic diameter,
- 50% of particles of 5 mm aerodynamic diameter,
- 20% of particles of 6 mm aerodynamic diameter,
- 0% of particles of 7 mm aerodynamic diameter and larger to pass through the size selector. (Annexure1, 2003)

Work activities such as cutting and installation produce a substantial amount of fine airborne particulate matter. Particles, also known as particulates or particulate matter, are aggregate assemblages of matter in liquid or solid state that are small enough to remain suspended in a gaseous medium. The size range for particulates is from 10 nanometers to 100 micrometers in aerodynamic diameter. Particles with aerodynamic diameters greater than 100 micrometers have not been thoroughly studied, although recent publications indicate they may have health implications in the nasopharyngeal region (Vincent, 1999). The aerodynamic diameter, which is the diameter of a sphere of unit density and equivalent mass to the particle in question, is an important determinant in the regional deposition of particles in the human respiratory tract.

Particles are divided into three size classes, based on their depositional trends: inhalable, thoracic, and respirable.

- Inhalable particulate matter is that fraction of particles, defined in terms of the probability as a function of particle aerodynamic diameter, which are aspirated through the nose and mouth during breathing.
- Thoracic particulate matter is that fraction of inhalable particles that, in terms of a probability function, will deposit into the regions of the respiratory tract below the larynx.
- Respirable particulate matter is that fraction of inhalable particles that, again defined by a probability function, will pass into the alveolar, or gas-exchange, region of the lung. (E. Young, August 2007).

The American Conference of Government Industrial Hygienists (ACGIH) defines the classes according to several probability functions. These functions are based on the collection efficiencies of air sampling devices that model aspiration efficiency of the human respiratory system. Each size class is referred to by its median cut point, or the particle size for which there is a 50% probability of capture/inspiration. For example:

- The thoracic class is said to have a cut point of 10  $\mu\text{m}$ . There is a 50% chance that particles with an aerodynamic diameter of 10  $\mu\text{m}$  will be inspired into the human head and reach the regions of the respiratory system below the larynx (or captured by the air sampling device that models this respiratory function).
- The respirable class has a cut point of 4.0  $\mu\text{m}$ , meaning that there is a 50% chance that particles of this size will be inspired and will reach the alveolar region of the lung (ACGIH, 2005).

The fate of inspired particles depends upon deposition and solubility. Particle deposition is dependent on flow rate, particle diameter, particle concentration, and air flow patterns in the respiratory tract. The three principal mechanisms of deposition are inertial impaction, gravitational sedimentation, and radial diffusion. Deposition of particles larger than 10  $\mu\text{m}$  will occur in the nasopharyngeal regions via impaction. Thoracic particles, less than 10  $\mu\text{m}$ , will reach regions beyond the larynx, and will deposit on the mucociliary elevator for removal. Respirable particles, less than 4  $\mu\text{m}$  in diameter, will reach the alveolar regions for deposition. Fine particles, from 0.1 to 2.5  $\mu\text{m}$ , will remain entrained in the air stream and fail to deposit in the respiratory tract. Ultrafine particles, less than 0.1  $\mu\text{m}$ , have been demonstrated to deposit via diffusion throughout the respiratory tract (E. Young, August 2007).

### **1.5 Particulate Matter (PM)**

Particulate is the term employed to define airborne solid and liquid elements as the addition of several molecules. Generally, airborne molecules have a diameter of about 0.0002  $\mu\text{m}$ , while particulates could range from 0.001  $\mu\text{m}$  to up to 500  $\mu\text{m}$  in size. Due to the large range in particulate size, the study of their behavior, their effects on the human body, and the effect of these pollutants in the environment have been distributed into different categories depending on the aerodynamic size of the particle. The aerodynamic size of a particle is an approximation used to simplify its size description because it will be impossible to describe the volume of a group of particles with only one value if they are not perfect spheres. In practice, airborne particles rarely have a spherical shape. Actually, most particulates have a very complex and bizarre structure. However, when one states that the particulate size of a pollutant is 3.4  $\mu\text{m}$ , it does not mean that the particles have a diameter of 3.4  $\mu\text{m}$ . It actually means that the one particle of that dust accelerates in a free fall at the same rate of a drop of pure water (density = 1 kg/L) with a diameter of 3.4  $\mu\text{m}$  (Federico, 2008).

For environmental, regulatory, and toxicological study purposes, fine particles are those with an aerodynamic diameter equivalent or smaller than 2.5  $\mu\text{m}$ . This group of pollutants is known as  $\text{PM}_{2.5}$  and is mainly generated during the combustion of liquid hydrocarbons, coal, and wood. On the other hand, coarse particles are those with an aerodynamic diameter between 2.5 and 10  $\mu\text{m}$ . These particles are related to  $\text{PM}_{10}$  because  $\text{PM}_{10}$  includes all the particles with a diameter equal to or smaller than 10  $\mu\text{m}$ .  $\text{PM}_{10}$  refers to the group made by coarse and fine particles together. Common sources of coarse particles include windblown dust, abrasion or fragmentation of solid materials, solid products of incomplete combustion, sea spray, and aerosols (Kavouras, March 2001). In addition to  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ , there is another group of particulate pollutants with an aerodynamic diameter equal to or smaller than 40  $\mu\text{m}$  which are termed as Total Suspended Particles (TSP). However, several studies have shown that the smaller particles cause more severe effects on the environment and human body, which has shifted the focus of attention away from TSP (Cooper, 2002).

The size and composition of particulate matter determines the density and aerodynamics of the particles, and, once they are released, define the dispersion pattern of these pollutants. Similarly, size and composition of the particles suspended in the air greatly affect the way these pollutants affect the human body once a population is exposed to polluted air. The major exposure route for PM in ambient air is through the respiratory system. Therefore, the study of PM health effects has been centered on the way these pollutants invade the respiratory tracts. Coarse particles are commonly called inhalable particles because their size and density will allow them to travel through the respiratory system aggravating several respiratory afflictions like asthma. However, coarse particles might be caught by the ciliated stratified epithelium cells lining the inner wall of the trachea, bronchi, and other respiratory airways. On the other hand, it has been demonstrated that fine particles might travel through the deepest passages of the respiratory system to the pulmonary alveoli blocking them, or, even worse, passing to the blood stream; this is one of the reasons for the commonly observed link between exposure to fine PM and heart and circulatory system afflictions (Klaassen, et al., 2003).

## **1.6 Heavy Metals**

Metals and heavy metals are generally solid substances at ambient temperature that cannot be synthesized or broken down by any biological process. Metals are released into the environment as PM by fragmentation of bigger pieces during various processes and can surprisingly travel large distances as airborne particles before settling down to the ground. Metals and heavy metals are produced into ambient air through different processes such as the industrial process, construction activity and industry, cigarette smoking, medicinal compounds, auto emissions, etc. Heavy metals are also released into the atmosphere in small traces in the exhaust of combustion processes. Combustion gases can travel even farther distances than industrial dusts due to the buoyancy effect generated as a consequence of their high temperature with respect to the surrounding environment (Kavouras, March 2001).

Some heavy metals include mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb). These heavy metals occur mainly from the earth's crust. They cannot be degraded or destroyed. To a small extent, they enter our bodies via food, drinking water, and air. Some metals like iron, magnesium, and zinc are required in very small amounts by the human body for its normal physiological activities, but will cause a wide range of adverse effects in excess concentrations. Additionally, other elements like lead, mercury, and plutonium (heavy metals) are clearly identified as detriments to human health at any concentration level. These heavy metals exhibit negative inotropic (decrease in the strength of muscular contraction) and dromotropic (impairing of electrical impulses conduction in the heart) effects that can seriously alter normal cardiovascular activities. The cardiotoxic characteristics of heavy metals are suspected to be related to their ability to form complexes with intracellular macromolecules and to their ability to antagonize the calcium mediated metabolic activated and storage mechanism (Federico, 2008)

Metals and heavy metals can be present in the PM suspended in the ambient air of urban areas. Metals can be absorbed in the human body through the respiratory system. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

During the cutting and installation of drywall, workers are usually exposed to concentrations of dust. This dust produced during the cutting of drywall may contain traces of heavy metals. It is important to understand the exposure levels of workers to this type of airborne metal. The workers will be exposed to these contaminants on a regular basis and usually they inhale this dust. Though the metals may not be harmful or affect the workers instantly, exposure to them over a prolonged period of time is always harmful. Not all metals have been assigned with occupational exposure levels, but the lack of such limits does not mean that the metals are not harmful. Lead with work space exposure limits of OSHA/PEL-  $0.05\text{mg}/\text{m}^3$ , ACGIH/TLV- $0.15\text{mg}/\text{m}^3$  and molybdenum with work space exposure limits of OSHA/PEL- $15\text{mg}/\text{m}^3$  ACGIH/TLV- $10\text{mg}/\text{m}^3$  are some of the metals which are studied in the second part of this study, but metals like zinc, iron, rubidium, and strontium which were also found in the metal analysis of drywall dust have no work space exposure limits established by OSHA or ACGIH., though all the metals have potential health effects on being inhaled. On inhalation, apart from Pb and Mo, other metals like Zn, Fe, Ru, and Sr may cause irritation in the upper respiratory region, nose, skin, and eyes.

The second part of this study presents the preliminary assessment of exposure to PM and metals during the cutting and installation of drywall. Particulate matter is collected using an eight-staged cascade impactor, the collected sample filters are analyzed for metals using XRF analysis. The work space concentration for PM and metals are calculated. The health effects due to the exposure to metals is presented

## Chapter 2: Instruments Used

Four important instruments were used for this study:

1. Jerome 631-X H<sub>2</sub>S Analyzer,
2. Innov-X Handheld XRF Analyzer,
3. Eight-Staged Ambient Cascade Impactor,
4. Skil Table Cutting Saw.

### 2.1 Jerome 631-X H<sub>2</sub>S Analyzer

The Jerome 631-X Hydrogen Sulfide Analyzer is an ambient air analyzer with a range of 0.003 ppm to 50 ppm (parts per million). The 631-X is designed to be easy to operate for quick and accurate analysis of hydrogen sulfide vapor levels (see Figure 1).

#### *Features*

- Accurate analysis of hydrogen sulfide in seconds,
- Wide detection range allows multiple applications,
- Survey mode for rapid source detection of hydrogen sulfide concentrations,
- Rechargeable internal battery pack for portability,
- Automatic backlight for LCD during low light conditions,
- Microprocessor ensures a linear response throughout the entire range of the sensor,
- Inherently stable gold film sensor. (Jerome 631-X manual, Jan 2011)

#### *Applications*

- Ambient air analysis,
- Odor nuisance monitoring,
- Regulatory compliance,
- Control room corrosion monitoring,
- Quality control,
- Scrubber efficiency testing,
- Accuracy check for other hydrogen sulfide monitors and control systems,
- Hydrogen sulfide source detection,
- Leak detection,
- Portable hydrogen sulfide detection. (Jerome 631-X manual, Jan 2011)

**Figure 1: Jerome 631-X H<sub>2</sub>S Analyzer**



Source: Figure 1 from Jerome 631-X H<sub>2</sub>S analyzer user manual

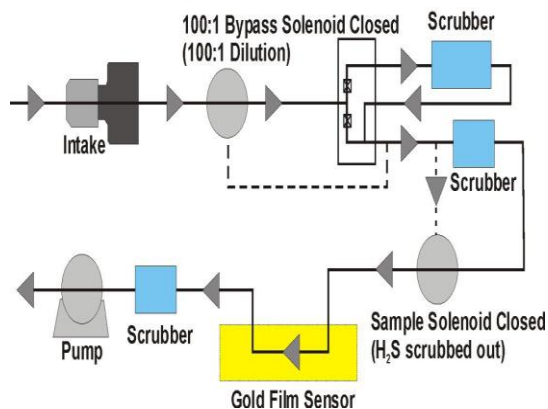
### ***Operation Principle***

A thin gold film in the presence of hydrogen sulfide undergoes an increase in electrical resistance proportional to the mass of hydrogen sulfide in the sample. When the SAMPLE button is pressed, an internal pump pulls ambient air over the gold film sensor for a precise period. The sensor absorbs the hydrogen sulfide. The instrument determines the amount absorbed and displays the measured concentration of hydrogen sulfide in ppm. During normal sampling, the ambient air sample is diluted in the flow system at a ratio of 100:1. When sampling in Range 0, (where low levels of hydrogen sulfide are expected), undiluted air samples are drawn across the gold film sensor. (See Figures 2 and 3 for initial pump and sample flow diagrams.)

The instrument's microprocessor automatically re-zeroes the digital meter at the start of each sample cycle and freezes the meter reading until the next sample cycle is activated, thus eliminating drift between samples. During the sample mode cycle, bars on the LCD represent the percentage of sensor saturation. Depending on the concentrations, 50 to 500 samples may be taken before the sensor reaches saturation. At that point, a 10-minute heat cycle must be initiated to remove the accumulated hydrogen sulfide from the sensor. During the sensor regeneration cycle, both solenoids are closed to cause air to pass through a scrubber filter and provide clean air for the regeneration process. The flow system's final scrubber filter prevents contamination of the environment. The heat generated during the regeneration may cause some low level thermal drift. To ensure maximum sample accuracy, the operator must wait 30 minutes after regeneration before zeroing and using the instrument. Figure 2 and Figure 3 below shows the flow diagram of H<sub>2</sub>S analyzer during the initial pump stage and during the sampling stages respectively. (Jerome 631-X manual, Jan 2011).

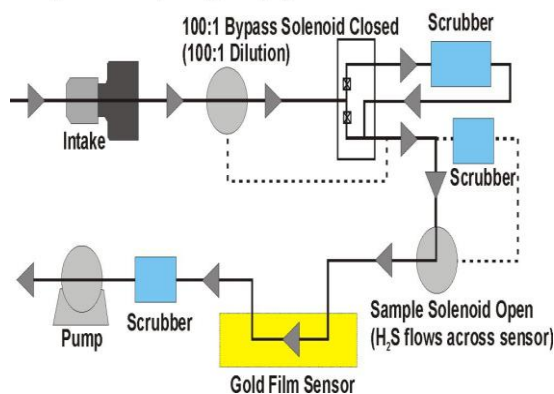
**Figure 2: Initial Pump Flow Diagram**

Initial Pump, Ranges 1, 2, and 3



**Figure 3: Sample Flow Diagram**

Sample Period, Ranges 1, 2, and 3



Source: Figures 2 and 3 from Jerome 631-X H<sub>2</sub>S analyzer user manual

### ***Operation with Zero Filter***

The zero air filter removes mercury vapor, mercaptans, and hydrogen sulfide from the air sample. Readings with the filter installed should be near zero. Because air that is cooler than the instrument will cause low readings and warmer air will cause higher readings, the zero air filter should be used to equilibrate the unit to ambient air temperature. Continuous sampling with clean air will not cause saturation of the gold film sensor, but will equalize temperatures faster to allow accurate analysis to begin sooner. For accurate results, the instrument must be at the same temperature as the environment before testing. The zero air filter can also be used to identify contamination within the instrument. If the readings do not reduce to near zero with the filter installed, contamination should be suspected. If the readings do drop to near zero with the filter installed, but elevate with the filter removed, the presence of hydrogen sulfide at the sampled location is confirmed. (Jerome 631-X manual, Jan 2011)

## **2.2 Innov-X XRF Analyzer:**

Innov-X XRF Alpha series analyzers offer an easy to use piece of equipment for non-destructive assays able to identify metals and heavy metals in solid samples, such as soil, solid surfaces, or filters. XRF spectrometry is used to identify the atomic elements present in a sample without destruction of the material. An element is identified by its characteristic X-ray wavelength emission ( $\lambda$ ), while the amount of this specific element is determined by quantifying the intensity of the X-ray emission. (Innov-X XRF Manual, Alpha Series)



## ***Principles of Operation of the XRF Analyzer***

Every element of the periodic table can be identified by the number of protons in its nucleus. In stable state, the number of protons is equal to the total number of electrons located on the different orbits around the nucleus. Energy Dispersion X-Ray Fluorescence (ED-XRF) utilizes the electrons in the three first orbits of an atom because of their low energy level: these orbits are K, L, and M. The K orbit is closest to the nucleus (lower energy level) and M is the third orbit from the nucleus (higher energy level than L and K). In ED-XRF, high energy photons emitted from an X-ray source strike the sample material, displacing the electrons in the orbits with low energy levels. At this point, the atom becomes an ion (unstable), and electrons from orbits of higher energy levels move downward to fill out the empty space in the low orbits, traveling from the outermost orbits to those small, innermost orbits close to the nucleus. When an electron moves from an outer orbit to an inner orbit, it emits a type of energy known as secondary X-ray photon, also known as fluorescent energy, which is characteristic of each specific element. This energy is inversely proportional to the wavelength and is related through the following formula:

$$E=hc/\lambda$$

where: h is Planck's constant, c is the speed of light, and  $\lambda$  is the wavelength of the emitted photon. The energy (E) of the emitted fluorescent photon is determined by the difference in energy between the initial and final orbit of the individual transition. Additionally, the intensity of the fluorescent emission is measured to determine the quantity of the newly identified element. (Innov-X XRF Manual, Alpha Series)

### ***Description:***

The Innov-X X-Ray Fluorescence spectrometer works on X-rays. Metals are detected by the emitted X-rays from the lens, then quickly and easily quantifies the elements over a wide dynamic concentration range. It is accurate and quicker than many other elemental analyses. It can be also used as a handheld device (portable). It is ideally suited for field analysis of alloys, lead based paints, environmental soils, filters, forensics, archaeometry, etc. An IPAQ (handheld computer or palmtop) is provided to read and store the data, which can be transferred from the IPAQ to the computer for further analysis. (See Figure 4 below)

The XRF (Figure 4) is a portable bench-top energy-dispersive analyzer capable of detecting elements from sodium through plutonium and can be applied in the jewelry, metallurgy, customs, forensics, medical diagnostics, food testing, and environmental testing markets. It can also be used for qualitative or quantitative analysis of metal alloys, liquid food, and biological samples. It can analyze liquids and powders as well as samples deposited on surfaces or filters. The analyzer includes two primary components: an XRF spectrometer and a personal computer. (Innov-X XRF Manual, Alpha Series)

The XRF spectrometer contains a 5-watt X-ray tube excitation source with tungsten, titanium, or rhodium as the anode target material and with an adjustable 4- to 50-kilovolt power supply. The detector is a Peltier-cooled, solid-state silicon-PiN diode with 180-electron volt resolution. The XRF spectrometer may be set up in the field, but must be in a stable environment. However, this equipment for now is only to be used in a laboratory for analyzing metals on the surfaces of filters. The radiation levels during testing are <0.1 millirem/hr on all the surfaces of the analyzer except at or near the exit port for the radiation. This means that if an operator follows standard operating procedures, they will not obtain any detectable radiation dose above naturally occurring background radiation on their hand while holding the analyzer or any area of their body. (Innov-X XRF Manual, Alpha Series)

**Figure 4: X- Ray Fluorescence Metal Analyzer from Innov X Systems**



Source: Figure 4 from Innov-X X-Ray Fluorescence metal analyzer (Alpha Series) Manual

### **2.3 Eight-Stage Non-Viable Anderson Cascade Impactor (Thermo Scientific)**

The Thermo Scientific Andersen eight-stage non-viable cascade impactor is an eight-stage, multi-orifice sampler used in environmental working areas to measure the size distribution and mass concentration levels of solid particulates and liquid aerosols. The combination of a constant flow rate and successively smaller diameter orifices increases the velocity of sample air as it cascades through the sampler, resulting in the impaction of progressively smaller particles in the succeeding stages. Operating at 28.3 liters per minute (LPM) the particle fraction ranges from 0.4 to >10.0 micrometers in diameter. Particles too small to be impacted on the last collection plate are collected in the backup filter. (See Figure 5 below) (Anderson cascade impactor manual)

The sampler is calibrated with unit density ( $1\text{g/cm}^3$ ) spherical particles so that all particles collected, regardless of their physical size, shape, or density, are sized aerodynamically equivalent to the reference particles. Aerodynamic dimensions obtained can be used to determine probable point of respiratory deposition, particle behavior in the air, and type of control equipment needed to collect particles, in compliance with existing threshold limit values and OSHA regulations. (Anderson cascade impactor manual)

## ***Features***

- Sample wet or dry particulates,
- Gravimetric analysis allows reference method precision,
- Ease of operation and calibration,
- Particle bounce and wall losses virtually eliminated,
- High mass collection and high flow rate,
- Gravimetric or chemical sample analysis,
- Stainless steel, glass, and filter substrates available. (Anderson cascade impactor manual)

## ***Applications***

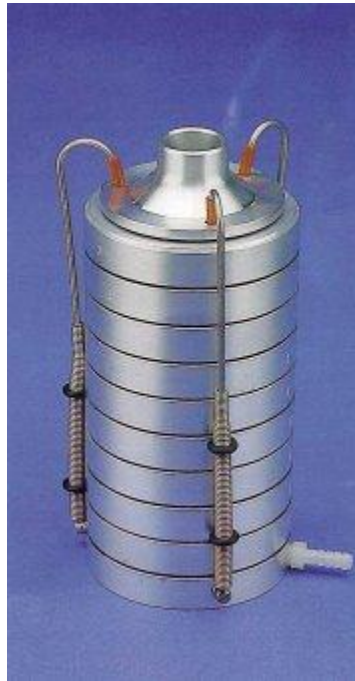
- Pharmaceutical applications,
- Studying ventilation,
- Indoor or outdoor air quality,
- Hazardous waste sites,
- Emergency response situations. (Anderson cascade impactor manual)

An eight-stage cascade impactor (Figure 5) has a high sample rate. This separates airborne particles into aerodynamic size classes. Particles are sampled through a series of stacked stages containing multiple orifices with sequential smaller diameters. Each sampler is composed of eight aluminum stages that are held together by three spring clamps and gasketed with O-ring seals, and contain multiple precision-drilled orifices. Ambient gases enter the inlet cone and cascade through the succeeding orifice stages with successively higher orifice velocities from Stage 0 to Stage 7. Successively smaller particles are inertially impacted onto the collection plates. Submicrometer particles, which are not collected by the last collection plate, are caught in the backup filter, which is an integral part of the impactor immediately downstream from Stage 7. Stage 0 is an orifice stage only, while Stage 8 is a collection stage only. Each sampler requires a flow rate of exactly 28.3L/min. (1 cfm) for maximum efficiency. The air is drawn into the impactor using a vacuum pump controlled at a constant rate (28.3 ALPM/1 ACFM). The unique design of multiple orifice jets in one stage allows for higher sampler sample flow rates and a larger sample substrate to collect greater mass concentration for weighing accuracy and later chemical speciation analysis. (Anderson cascade impactor manual)

## ***Specifications***

- Impactor Size: 19.4 cm height x 10.63 cm diameter,
- Weight: 1.8 kg,
- Vacuum pump of 28.3 ALPM design sample rate, 115 VAC 60 Hz,
- Sample flow rate: 28.3 ALPM at +/-1.5 ALPM,
- Differential pressure 34 cm water at 28.3 ALPM sample rate and glass fiber substrates filter. (Anderson cascade impactor manual)

**Figure 5: Eight Staged Non-Viable Anderson Cascade Impactor (Thermo Scientific)**



Source: Figure 5 from [www.thermoscientific.com](http://www.thermoscientific.com)

## **2.4 Skil 10” Table Cutting Saw**

The Skil table saw (Figure 6) is used for cutting materials like wood, plywood, boards, and concrete. It consists of a table surface size 50 cm x 65 cm made of die-cast aluminum. The table surface is supported on a heavy duty steel stand and provides large working surface to support the work piece. The table surface has a self-aligning rip fence for accurate measurements. The exclusive self-aligning quick-set rip fence can be easily moved or locked in place by simply raising or lowering the lock handle. It has a miter gauge which guides the work pieces when making cross cuts. It has a 15-amp motor that runs at 5,000 RPM, and is equipped with a blade that can be elevated or lowered using an elevation wheel. The anti-kickback pawls have been designed to prevent the work piece from “kicking back” during the cutting operation. The power switch has a design feature allowing the tool to be locked in the OFF position. A circular 25cm in diameter carbide blade is used for cutting, and can even cut concrete. This blade can be raised to the maximum height by turning the control wheel in the counterclockwise direction. (Figure 6 below) (Operation Manual, Feb 2010)

**Figure 6: Skil 10" Table Cutting Saw**



Source: Figure 6 from [www.skilltools.com](http://www.skilltools.com)

## **Chapter 3: Methodology**

This study consists of two major parts:

1. Identification of Chinese drywall using metal analysis,
2. Preliminary assessment of exposure to particulates and heavy metals during the cutting and installation of drywall.

### **3.1 Identification of Chinese Drywall Using Metal Analysis**

This part of the study includes three stages of investigation:

1. Prescreen analysis,
2. In situ H<sub>2</sub>S monitoring,
3. Collection of samples and XRF analysis of samples.

#### **3.1.1 Prescreen Analysis**

Two homes - one affected and one unaffected - were selected for prescreen analysis. This included visual inspection, confirmation of installation of drywall during the period 2005 to 2008, and problems and health issues faced by the residents. During the research investigation when the resident was questioned regarding the installation and the type of drywall, the affected homeowners confirmed that the drywall was installed after Katrina in 2005 hit the Gulf Coast and it was a Chinese made drywall. Though the other home was built in 2006, the drywall they had was American made. After the confirmation of the dates of installation, the two homes were visually inspected, and the affected house showed traces of corrosion and blackening on the following:

- Copper wires, ground wires, electrical connectors, and air conditioning evaporator coils,
- Un-insulated and uncoated copper wires and fittings,
- Chrome plated bathroom fixtures,
- Silver and copper jewelry,
- Mirror backing in bathrooms.

Figures 7, 8, and 9, below, show the blackening of metal coils and wires and the corrosion of pipes, respectively. These pictures were taken at the site of the affected home.

**Figure 7: Showing Blackening of Insulation Coils**



**Figure 8: Blackening of Wires**



**Figure 9: Corrosion of Metal Pipes**



After the visual inspection of the home, the residents were investigated about the health issues they were facing since the installation of Chinese drywall in their home. The common problems faced by them were:

- Eye irritation,
- Dry eyes,
- Sore throat,
- Stuffy nose/rhinitis,
- Cough,
- Nausea,
- Headaches,
- Fatigue,
- Irritability,
- Dizziness,
- Insomnia.

The Chinese drywall home exhibited a foul odor of rotten eggs, whereas the American-made drywall home had no such odor.



### 3.1.2 In Situ H<sub>2</sub>S Monitoring

Many theories have been proposed referring to the gypsum as the main source of contamination in Chinese drywall. The gypsum used in the manufacture of Chinese drywall mainly comes from mines rich in elemental sulfur; or rich in elemental strontium; the mined gypsum contains metal sulfides like iron pyrite and strontium sulfide. Impurities were introduced either during the manufacturing process or during the chemical treatment post production. Also, it may be due to bacteria that attack sulfur containing compounds, which produces sulfurous gases like H<sub>2</sub>S. Sulfur compounds are the main cause of the health problems of the residents, the corrosion and blackening of the metal wires and coils in the house, and the rotten egg odor or smell matching that of fireworks.

After the prescreen analysis, the homes were investigated for the presence of H<sub>2</sub>S gas using the Jerome 631-X H<sub>2</sub>S gas analyzer. Two homes, one with Chinese drywall and one with American drywall, were monitored. As the homes were available for a limited time for monitoring, they were monitored only to check if there were any traces of H<sub>2</sub>S gas. To avoid air exchange or the mixing and dilution of gas, the A/C vents were closed and the A/C was switched off. Then the closed rooms were monitored with the Jerome 631-X H<sub>2</sub>S gas analyzer. The home with Chinese drywall observed traces of H<sub>2</sub>S gas. The H<sub>2</sub>S concentration in the Chinese drywall home was found to be 0.003 PPM to 0.002 PPM, whereas the home with American made drywall had no traces of H<sub>2</sub>S gas or were below detection levels. The presence of H<sub>2</sub>S gas in the home paved the way for further investigation on the composition of drywall.

### 3.1.3 Collection of Samples and XRF Analysis

Samples were collected from two homes, one from Chinese and one from American-made drywall. The rest of the four samples of Chinese drywall were collected from public insurance adjusters who are working on the Chinese drywall complained homes. Two of the samples of American-made drywall were collected from The Home Depot for testing.

Heavy metal concentrations in the drywall samples were analyzed by XRF analysis using a portable XRF metal analyzer from Innov-X Systems. Drywall samples were analyzed for heavy metals, as strontium is one of the indicators in the identification of Chinese drywall.

Analyzing strontium as a marker source for problematic drywall was done for two specific reasons. The first is to determine the precision and accuracy of strontium concentration measurements made using portable XRF analyzers. The second was to evaluate the sensitivity and specificity of strontium as a marker of problematic drywall. Strontium, as measured using portable XRF analyzers, has been proposed as a useful marker for identifying Chinese drywall. Homes that contained sheetrock with the strontium marker (strontium measured by XRF) were found to have significantly higher hydrogen sulfide concentrations and corrosion than homes that did not have this marker present (EH&E Report 16512, 2010).

### 3.1.3.1 XRF Analysis for Heavy Metals

For analyzing heavy metal concentrations in the composition of drywall samples, each collected drywall sample board, both Chinese and American-made, were divided into ten equally sized small pieces for intra-board variability. The paint from all the sample pieces was chipped. Each piece was placed on the Innov-X testing stand window for testing. Each sample was tested for one minute. This testing was carried out for all the pieces of all the samples. The first set was done with the top paper on the drywall sample pieces. The second set of testing was done without the top paper on the sample pieces. The data was then transferred from the IPAQ to the computer. All the concentrations are in units  $\mu\text{g}/\text{cm}^2$ , Which were then converted into  $\text{mg}/\text{kg} = \text{PPM}$ . This conversion was done using the weight of the sample  $\text{mg}/\text{cm}^2$  of area. This weight of the sample/ $\text{cm}^2$  was measured, and then the concentration of metal was divided by  $\text{weight}/\text{cm}^2$ .

*Formula:*

$$(\mu\text{g}/\text{cm}^2) / (\text{g}/\text{cm}^2) = \text{mg}/\text{kg} = \text{ppm}$$

After the conversion of the units, the concentrations were averaged for each with and without the top paper set of samples of the same brand. The heavy metals were also analyzed in two sampling homes in situ and then their concentrations were also averaged. The concentrations of strontium metal, which is the primary indicator for Chinese drywall, ranged from 150 - 220 PPM. For American-made drywall, the range was from 15 - 45 PPM.

Tables 2, 3, 4, and 5 in the following Chapter 4, Results, present the XRF- analysis data for this part of the study

## 3.2 Preliminary assessment of exposure to particulates and heavy metals during cutting and installation of drywall

This part of the study includes the following steps:

1. Collection of PM using an eight-stage cascade impactor,
2. X-ray fluorescence metal analysis of filters after sampling,
3. Calculation of work space concentration and mass fraction of metals and PM.

### 3.2.1 Collection of PM using eight-stage cascade impactor:

Drywall sample boards of approximately the same weight and same size were collected. Two drywall samples were chosen for two runs. The drywall sample had to be free from any paint, as the paint on the boards gives increase levels of titanium concentrations. To avoid this error, the samples chosen were without any paint. Initially, two drywall board samples for two runs were weighed.

Glass micro fiber sample filters of 81 mm were used for collection of PM using a Thermo Scientific Andersen eight-stage non-viable cascade impactor. Eight filters for each run were initially weighed. The initial weights were noted. Then 8 filters of the first run were placed on each stage of the eight-staged cascade impactor. The cascade impactor was then connected to a 15-amp motor. The first sample board weighed was placed on the Skil 10" table saw for cutting. The cascade impactor was placed on the path of the plume to be generated during cutting at a distance of about three feet for the collection of PM. After setting everything, the cascade impactor pump and the cutting of the sample board were started at the same time. While the cutting was done using a timer, the time was noted. The sample time for the first run was 4:01 minutes. The cutting of the drywall and the sampling was stopped at the same time. The filters were taken out from each stage and the final weights of the filters were noted. All the filters after weighing were sealed in air tight zip lock bags for further X-ray fluorescence analysis of metals. The mass of the cut sample was weighed. The difference between the mass of the sample before and after cutting gave the mass of the material cut.

Formula:

$$\text{Mass of material cut} = \text{mass of material before cutting} - \text{mass of material after cutting}$$

The cascade impactor was cleaned to remove all dust. The second set of filters were weighed and placed in each stage of the impactor for the second run. Then the second run of sampling was repeated with the second drywall board for cutting. The sampling run time for the second run was 4:06 minutes. After the sampling, the filters were weighed for the final weights used for calculating the mass collected on the filters.

Formulas:

$$\text{Mass collected on filter (gm)} = \text{initial mass of filter (gm)} - \text{final mass of filter after sampling (gm)}$$

### ***3.2.2 X-Ray Fluorescence metal analysis of filters after sampling***

Metals were analyzed using the Innov-X XRF analyzer. The two sets of filters of the two sampling runs were analyzed for metals. Each filter was folded into a quarter circle. Each folded filter was placed on the Innov-X testing stand window for testing. Each filter was tested for one minute. This testing was carried out for all the filters for at least 5 times so that the entire area of the filter was covered. The data was then transferred from the IPAQ to the computer. All the concentrations are in units  $\mu\text{g}/\text{cm}^2$ . After the data was transferred, the concentrations of each metal identified on each filter were averaged. The metals identified in XRF analysis of filters were lead, iron, molybdenum, zinc, rubidium, and strontium.

### 3.2.3 Calculation of work space concentration and mass fraction of metals and PM

For calculating work space concentration and mass fraction:

1. Average Sampling time = 4.035 mins

Run 1	4.01
Run2	4.06
Average	4.035

2. Mass of material cut = Mass of material (before cutting – after cutting)

S. No	Before	After	Mass of Material Cut (Kg)	gm	mg
Mass of Material cut Trial 1	0.95	0.82	0.13	130	130000
Mass of Material cut Trial 2	0.92	0.8	0.12	120	120000
Average Mass of material cut			0.125	125	125000

3. Flow rate = 1 acfm = 0.0283 m<sup>3</sup>/min (actual)

4. Air Volume Sampled = Flow rate x Time (sampling)

$$\text{Air Volume Sample} = 0.0283 \text{ m}^3/\text{min (actual)} \times 4.035 \text{ min} = 0.1142 \text{ m}^3$$

5. Filter Area =  $\pi d^2 / 4 = 51.53 \text{ cm}^2$

$$\text{Filter Diameter} = 81 \text{ mm} = 8.1 \text{ cm}$$

6. Work Space Concentration of PM (gm/ m<sup>3</sup>) = Mass of PM Collected (gm)/Air volume sampled (m<sup>3</sup>)

Mass of PM collected (Average of 2 runs) = Mass of PM Collected (Run1); Mass of PM collected (Run 2) on each stage filter

$$\text{Mass of PM Collected} = \text{Initial mass of filter} - \text{Final mass of filter (after sampling)}$$

7. Mass fraction of PM (µg/g) = Mass of PM Collected(gm)x10<sup>6</sup>/ Mass of material cut (gm)

8. Work Space Concentration of Metals (gm/ m<sup>3</sup>) = Mass of Metal detected (µg)x10<sup>-6</sup>/ Air volume sampled (m<sup>3</sup>)

$$\text{Mass of Metal detected (µg)} = \text{Area of filter (cm}^2\text{)} \times \text{Avg. XRF concentrations of metal (µg/cm}^2\text{)}$$

9. Mass fraction of Metal ( $\mu\text{g/g}$ ) = Mass of metal detected ( $\mu\text{g}$ ) / Mass of material cut (gm)

The results for the calculations of work space concentration and mass fraction of PM and metals (Pb, Fe, Mo, Zn, Ru, and Sr) are presented in the following Chapter 4. Tables 6, 7, 8, 9, 10, 11 and 12 present the results for this part of the study.

## Chapter 4: Results

This chapter presents the results of the complete study:

Tables 2, 3, 4, and 5 present the results of the XRF analysis of the first part of the study, i.e., the identification of the Chinese drywall.

Tables 6, 7, 8, 9, 10, 11, and 12 present the results of the second part of the study, i.e., the tables present the results of the calculations of work space concentration and mass fraction of PM and metals found in the plume when the drywall board was cut using the Skil table saw and the plume was captured using the eight-staged cascade impactor. Table 6 presents the results of PM, whereas Tables 7, 8, 9, 10, 11, and 12 present the results of lead, iron, molybdenum, zinc, rubidium, and strontium, respectively.

### 4.1 Identification of Chinese Drywall Results (First Part of the Study)

#### Table 2: Heavy Metal Concentration of American Drywall (XRF Analysis)

Table 2, below, lists the results of XRF analysis of the American drywall samples with and without paper. All the concentrations of metals are converted to PPM (parts per million) = mg/kg, i.e., one milligram concentration of metal per kilogram of drywall sample. Most of the metals are <LOD (lower than detection levels). The most important metal that was considered is strontium, as it is the indicator for a comparison between Chinese and American drywall.

#### Table 3: Heavy Metal Concentrations of Chinese Drywall (XRF Analysis)

Table 3, below, lists the results for XRF analysis of the Chinese drywall samples. Each different type of sample is numbered as 1, 2, 3, 4, and 5. All the metal concentrations are in PPM (parts per million).

Both American and Chinese drywall show traces of titanium metal in the XRF analysis results. This is due to the remains of paint on the samples tested, if any.

**Table 2: Heavy Metal Concentration of American-made Drywall (XRF Results)**

<i>Metals</i>	<b>US Made Drywall (ppm)</b>											
	<i>With Paper</i>						<i>Without Paper</i>					
	Sample Number						Sample Number					
	1	2	3	4	5	6	1	2	3	4	5	6
<b>Arsenic (As)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.35	<LOD	<LOD	<LOD
<b>Barium (Ba)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Cadmium (Ca)</b>	<LOD	28.47	<LOD	<LOD	<LOD	<LOD	28.04	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Lead (Pb)</b>	0.71	0.83	0.90	0.96	1.04	0.93	0.67	<LOD	0.82	<LOD	<LOD	<LOD
<b>Cobalt (Co)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Chromium (Cr)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Copper (Cu)</b>	0.54	0.56	<LOD	0.72	0.56	0.46	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Iron (Fe)</b>	18.81	13.25	23.39	20.55	20.74	19.46	12.41	9.75	23.29	20.41	19.40	21.58
<b>Mercury (Hg)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Manganese (Mn)</b>	<LOD	0.98	<LOD	1.42	1.17	<LOD	<LOD	0.81	<LOD	<LOD	<LOD	<LOD
<b>Molybdenum (Mo)</b>	2.18	3.14	2.75	3.05	2.90	2.35	1.44	1.25	1.86	2.06	1.80	1.88
<b>Nickel (Ni)</b>	<LOD	<LOD	<LOD	<LOD	0.55	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Selenium (Se)</b>	0.21	<LOD	<LOD	0.25	<LOD	<LOD	0.19	0.16	<LOD	<LOD	0.28	<LOD
<b>Titanium (Ti)</b>	20.98	12.74	41.64	10.79	20.69	35.64	5.48	<LOD	<LOD	<LOD	7.62	12.50
<b>Zinc (Zn)</b>	14.73	1.95	0.89	1.94	1.79	0.94	<LOD	0.70	<LOD	0.75	<LOD	<LOD
<b>Silver (Ag)</b>	<LOD	<LOD	<LOD	<LOD	5.42	<LOD	15.05	14.21	21.52	<LOD	<LOD	<LOD
<b>Rubidium (Rb)</b>	0.56	0.70	0.73	0.69	0.72	0.71	0.36	0.32	0.48	0.42	0.46	0.45
<b>Stibium (Sb)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Stannum (Sn)</b>	34.81	<LOD	<LOD	<LOD	<LOD	<LOD	36.06	<LOD	52.95	50.18	<LOD	<LOD
<b>Strontium (Sr)</b>	40.20	19.62	37.41	30.13	29.81	31.44	45.72	21.47	42.40	35.39	34.10	38.98

<b>Table 3: Heavy Metal Concentrations of Chinese Drywall (XRF Analysis)</b>										
<i>Metals</i>	<b>Chinese Drywall (ppm)</b>									
	<i>With Paper</i>					<i>Without Paper</i>				
	Sample Number					Sample Number				
	1	2	3	4	5	1	2	3	4	5
<b>Arsenic (As)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Barium (Ba)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Cadmium (Ca)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Lead (Pb)</b>	1.13	1.08	1.27	1.02	1.06	<LOD	0.88	1.13	0.91	0.91
<b>Cobalt (Co)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Chromium (Cr)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.75	<LOD	<LOD	<LOD
<b>Copper (Cu)</b>	0.63	0.74	0.77	0.69	0.70	<LOD	<LOD	0.55	0.58	0.53
<b>Iron (Fe)</b>	17.14	34.63	35.22	29.36	31.69	12.18	29.43	30.57	20.51	28.67
<b>Mercury (Hg)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Manganese (Mn)</b>	1.32	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	1.21	<LOD
<b>Molybdenum (Mo)</b>	1.72	2.13	1.68	1.56	1.77	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Nickel (Ni)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Selenium (Se)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Titanium (Ti)</b>	15.44	9.44	8.86	10.54	9.96	<LOD	<LOD	6.63	5.75	9.11
<b>Zinc (Zn)</b>	1.26	1.28	1.11	0.79	0.93	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Silver (Ag)</b>	LOD	<LOD	<LOD	<LOD	<LOD	<LOD	15.53	<LOD	18.28	<LOD
<b>Rubidium (Rb)</b>	0.59	0.68	0.71	0.52	0.72	<LOD	<LOD	0.55	<LOD	<LOD
<b>Stibium (Sb)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Stannum (Sn)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	46.58	<LOD	<LOD	<LOD	<LOD
<b>Strontium (Sr)</b>	106.88	166.04	174.20	158.96	156.32	129.93	203.74	216.49	193.40	197.16



**Table 4 : In situ XRF Analysis of American Drywall Home**

Table 4, below, lists the in situ XRF analysis results of the American drywall home. The sample numbers 1 to 15 represent 15 different points where the XRF analyzer was shot to test metal concentrations

<b>Table 4: In situ XRF Analysis of American Drywall Home (ppm)</b>															
<b>METALS</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>	<b>10</b>	<b>11</b>	<b>12</b>	<b>13</b>	<b>14</b>	<b>15</b>
<b>Arsenic (As)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Barium (Ba)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Cadmium (Ca)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Lead (Pb)</b>	0.87	<LOD	<LOD	2.31	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Cobalt (Co)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Chromium (Cr)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Copper (Cu)</b>	0.59	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Iron (Fe)</b>	19.33	19.38	18.17	<LOD	132.09	20.75	124.58	19.10	14.09	20.62	20.04	16.98	17.58	14.23	2.06
<b>Mercury (Hg)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Manganese (Mn)</b>	1.58	<LOD	<LOD	2.46	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Molybdenum (Mo)</b>	2.00	<LOD	<LOD	17.23	<LOD	2.11	<LOD	1.08	<LOD	<LOD	<LOD	<LOD	<LOD	1.57	<LOD
<b>Nickel (Ni)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Selenium (Se)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Titanium (Ti)</b>	7.35	<LOD	4.43	12.22	2135.03	69.81	2066.49	<LOD	<LOD	5.81	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Zinc (Zn)</b>	1.53	<LOD	0.67	2.12	9.46	1.25	3.47	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	0.79	0.50
<b>Silver (Ag)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Rubidium (Rb)</b>	0.60	<LOD	0.30	2.97	0.49	0.71	<LOD	<LOD	<LOD	<LOD	<LOD	0.40	<LOD	<LOD	<LOD
<b>Stibium (Sb)</b>	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD
<b>Stannum (Sn)</b>	<LOD	<LOD	34.84	<LOD	<LOD	<LOD	<LOD	<LOD	<LOD	45.12	<LOD	<LOD	<LOD	<LOD	38.78
<b>Strontium (Sr)</b>	27.83	33.19	30.30	5.49	9.66	33.94	20.43	32.17	23.70	66.16	64.44	29.02	30.83	27.77	14.51

**Table 5: In Situ XRF Analysis of Chinese Drywall Home**

Table 5, below, lists the results for in situ XRF analysis of the Chinese drywall home. Sample numbers 1, 2, and 3 represent three different places where the XRF was shot for metal analysis and the concentrations are the average of 10 readings at each place. All the results are in PPM.

<b>Table 5: In Situ XRF Analysis of Chinese Drywall Home</b>			
<b><i>Metals (PPM)</i></b>	<b><i>1</i></b>	<b><i>2</i></b>	<b><i>3</i></b>
<b>Arsenic (As)</b>	<LOD	<LOD	<LOD
<b>Barium (Ba)</b>	<LOD	<LOD	<LOD
<b>Cadmium (Ca)</b>	<LOD	<LOD	<LOD
<b>Lead (Pb)</b>	0.91	0.85	<LOD
<b>Cobalt (Co)</b>	<LOD	<LOD	<LOD
<b>Chromium (Cr)</b>	<LOD	<LOD	2.04
<b>Copper (Cu)</b>	<LOD	0.78	1.06
<b>Iron (Fe)</b>	10.67	21.08	196.48
<b>Mercury (Hg)</b>	<LOD	<LOD	<LOD
<b>Manganese (Mn)</b>	<LOD	<LOD	<LOD
<b>Molybdenum (Mo)</b>	1.50	1.94	1.10
<b>Nickel (Ni)</b>	<LOD	<LOD	<LOD
<b>Selenium (Se)</b>	<LOD	<LOD	<LOD
<b>Titanium (Ti)</b>	8.71	18.71	1472.33
<b>Zinc (Zn)</b>	0.66	1.34	6.48
<b>Silver (Ag)</b>	<LOD	<LOD	<LOD
<b>Rubidium (Rb)</b>	<LOD	0.60	0.62
<b>Stibium (Sb)</b>	<LOD	<LOD	<LOD
<b>Stannum (Sn)</b>	<LOD	<LOD	<LOD
<b>Strontium (Sr)</b>	97.71	103.26	28.23

#### 4.2 Preliminary assessment of exposure to particulates and heavy metals during cutting and installation of drywall results (Second part of the study)

**Table 6: Work Space Concentrations and Mass Fractions for Particulate Matter**

Table 6, below, presents the work space concentrations and mass fractions for PM during the cutting of the drywall. All the calculations are explained in Chapter 3: Methodology, in Section 3.2.3, Calculation of work space concentration and mass fraction of metals and particulate matter.

<b>Table 6: Work Space Concentrations and Mass Fractions for Particulate Matter</b>														
Casca de Impact or Stages	Aerodyna mic Diameter of Particle (µm)	Run1			Run2			Average of 2 runs						
		Initial Mass (gm)	Final Mass (gm)	Mass Collect ed (gm)	Initial Mass (gm)	Final Mass (gm)	Mass Collect ed (gm)	Mass of PM collect ed (gm)	Time (min)	Air Volume Sample d (m <sup>3</sup> )	Work Space Concen tration gm/m <sup>3</sup>	Mass fraction = PM Collect ed/ Materi al Cut (µg/g)	% PM present in size range	% PM present that is less than upper dia in range
1	9.0-10	0.308	0.321	0.013	0.312	0.334	0.022	0.0175	4.035	0.1142	0.1532	140	33.33	100
2	5.8-9.0	0.335	0.341	0.006	0.34	0.35	0.01	0.008	4.035	0.1142	0.07005	64	15.24	66.67
3	4.7-5.8	0.334	0.339	0.005	0.339	0.344	0.005	0.005	4.035	0.1142	0.0438	40	9.52	51.43
4	3.3-4.7	0.336	0.343	0.007	0.338	0.348	0.01	0.0085	4.035	0.1142	0.0744	68	16.19	41.91
5	2.1-3.3	0.334	0.339	0.005	0.337	0.343	0.006	0.0055	4.035	0.1142	0.0482	44	10.48	25.72
6	1.1-2.1	0.339	0.343	0.004	0.336	0.34	0.004	0.004	4.035	0.1142	0.035	32	7.62	15.24
7	0.7-1.1	0.338	0.339	0.001	0.337	0.34	0.003	0.002	4.035	0.1142	0.0175	16	3.81	7.62
8	0.4-0.7	0.308	0.31	0.002	0.31	0.312	0.002	0.002	4.035	0.1142	0.0175	16	3.81	3.81
<b>Total PM</b>								<b>0.0525</b>			<b>0.459</b>	<b>420</b>		

**Table 7: Work Space Concentrations and Mass Fractions Lead (Pb)**

Table 7, below, presents the results of work space concentrations and mass fractions of lead detected during the cutting of drywall boards.

<b>Table 7: Work Space Concentrations and Mass Fractions Lead</b>											
Cascade Impactor Stages	Aerodynamic Diameter of Particle (µm)	Run 1	Run 2	Average	Mass (µg) = area of filter (cm <sup>2</sup> ) * Avg XRF Concentrations (µg/cm <sup>2</sup> )	Time (min)	Air Volume Sampled (m <sup>3</sup> )	Work Space Concentration (gm/m <sup>3</sup> )	Mass fraction = Mass of metal Collected/ Material Cut (µg/g)	% Metal present in size range	% Metal present that is less than upper dia in range
		XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>							
1	9.0-10	0.425	0.42	0.423	21.77	4.035	0.1142	0.0001906	0.17	12.36	100
2	5.8-9.0	0.405	0.398	0.401	20.68	4.035	0.1142	0.0001811	0.16	11.74	87.64
3	4.7-5.8	0.34	0.47	0.405	20.87	4.035	0.1142	0.0001827	0.17	11.85	75.9
4	3.3-4.7	0.373	0.54	0.457	23.53	4.035	0.1142	0.0002061	0.19	13.36	64.05
5	2.1-3.3	0.6	0.497	0.548	28.26	4.035	0.1142	0.0002474	0.23	16.05	50.68
6	1.1-2.1	0.397	0.44	0.418	21.56	4.035	0.1142	0.0001888	0.17	12.24	34.64
7	0.7-1.1	0.347	0.364	0.355	18.31	4.035	0.1142	0.0001603	0.15	10.4	22.4
8	0.4-0.7	0.41	0.41	0.41	21.13	4.035	0.1142	0.000185	0.17	11.99	11.99
<b>Total</b>								<b>0.001542</b>	<b>1.41</b>		

**Table 8: Work Space Concentrations and Mass Fractions Iron (Fe)**

Table 8, below, presents the results of work space concentrations and mass fractions of iron detected during the cutting of drywall boards.

<b>Table 8: Work Space Concentrations and Mass Fractions Iron (Fe)</b>											
Cascade Impactor Stages	Aerodynamic Diameter of Particle (µm)	Run 1	Run 2	Average	Mass (µg) = area of filter (cm <sup>2</sup> )* Avg XRF Concentrations (µg/cm <sup>2</sup> )	Time (min)	Air Volume Sampled (m <sup>3</sup> )	Work Space Concentration (gm/m <sup>3</sup> )	Mass fraction = Mass of metal Collected/ Material Cut (µg/g)	% Metal present in size range	% Metal present that is less than upper dia in range
		XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>							
1	9.0-10	3.616	4.324	3.97	204.57	4.035	0.1142	0.001791	1.64	14.77	100
2	5.8-9.0	3.126	3.294	3.21	165.41	4.035	0.1142	0.001448	1.32	11.95	85.23
3	4.7-5.8	3.238	3.23	3.234	166.65	4.035	0.1142	0.001459	1.33	12.04	73.28
4	3.3-4.7	3.478	3.334	3.406	175.52	4.035	0.1142	0.001537	1.4	12.67	61.24
5	2.1-3.3	3.15	3.366	3.258	167.88	4.035	0.1142	0.00147	1.34	12.13	48.57
6	1.1-2.1	3.302	3.32	3.311	170.62	4.035	0.1142	0.001494	1.36	12.32	36.44
7	0.7-1.1	3.124	3.294	3.209	165.36	4.035	0.1142	0.001448	1.32	11.94	24.12
8	0.4-0.7	3.488	3.058	3.273	168.66	4.035	0.1142	0.001477	1.35	12.18	12.18
<b>Total</b>								<b>0.01213</b>	<b>11.07</b>		

**Table 9: Work Space Concentrations and Mass Fractions Molybdenum (Mo)**

Table 9, below, presents the results of work space concentrations and mass fractions of metal molybdenum detected during the cutting of drywall boards.

<b>Table 9: Work Space Concentrations and Mass Fractions Molybdenum (Mo)</b>											
Cascade Impactor Stages	Aerodynamic Diameter of Particle (µm)	Run 1	Run 2	Average	Mass (µg) = area of filter (cm <sup>2</sup> )* Avg XRF Concentrations (µg/cm <sup>2</sup> )	Time (min)	Air Volume Sampled (m <sup>3</sup> )	Work Space Concentration (gm/m <sup>3</sup> )	Mass fraction = Mass of metal Collected/ Material Cut (µg/g)	% Metal present in size range	% Metal present that is less than upper dia in range
		XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>							
1	9.0-10	1.152	1.136	1.144	58.95	4.035	0.1142	0.0005162	0.47	13.29	100
2	5.8-9.0	1.126	1.204	1.165	60.032	4.035	0.1142	0.0005257	0.48	13.54	86.71
3	4.7-5.8	1.024	1.004	1.014	52.25	4.035	0.1142	0.0004575	0.42	11.78	73.17
4	3.3-4.7	0.918	1.012	0.965	49.73	4.035	0.1142	0.0004354	0.39	11.21	61.39
5	2.1-3.3	0.848	1.268	1.058	54.52	4.035	0.1142	0.0004774	0.44	12.29	50.18
6	1.1-2.1	1.072	1.092	1.082	55.75	4.035	0.1142	0.0004882	0.45	12.57	37.89
7	0.7-1.1	0.874	1.018	0.946	48.75	4.035	0.1142	0.0004268	0.39	10.99	25.32
8	0.4-0.7	1.362	1.104	1.233	63.54	4.035	0.1142	0.0005564	0.51	14.35	14.35
<b>Total</b>								<b>0.003884</b>	<b>3.55</b>		

**Table 10 : Work Space Concentrations and Mass Fractions Zinc (Zn)**

Table 10, below, presents the results of work space concentrations and mass fractions of zinc detected during the cutting of drywall boards.

<b>Table 10 : Work Space Concentrations and Mass Fractions Zinc (Zn)</b>											
Cascade Impactor Stages	Aerodynamic Diameter of Particle (µm)	Run 1	Run 2	Average	Mass (µg) = area of filter (cm <sup>2</sup> )* Avg XRF Concentrations (µg/cm <sup>2</sup> )	Time (min)	Air Volume Sampled (m <sup>3</sup> )	Work Space Concentration (gm/m <sup>3</sup> )	Mass fraction = Mass of metal Collected/ Material Cut (µg/g)	% Metal present in size range	% Metal present that is less than upper dia in range
		XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>	XRF Conc µg/cm <sup>2</sup>							
1	9.0-10	2.09	2.058	2.074	106.87	4.035	0.1142	0.0009358	0.85	13.53	100
2	5.8-9.0	1.73	2.062	1.896	97.7	4.035	0.1142	0.0008555	0.78	12.37	86.47
3	4.7-5.8	1.744	1.79	1.767	91.05	4.035	0.1142	0.0007973	0.73	11.53	74.1
4	3.3-4.7	1.922	1.71	1.816	93.58	4.035	0.1142	0.0008194	0.75	11.85	62.57
5	2.1-3.3	1.728	1.992	1.86	95.85	4.035	0.1142	0.0008393	0.77	12.14	50.72
6	1.1-2.1	1.92	2.038	1.979	101.98	4.035	0.1142	0.000893	0.82	12.91	38.58
7	0.7-1.1	1.81	1.748	1.779	91.67	4.035	0.1142	0.0008027	0.73	11.61	25.67
8	0.4-0.7	2.32	1.986	2.153	110.94	4.035	0.1142	0.0009715	0.89	14.06	14.06
<b>Total</b>								<b>0.006914</b>	<b>6.32</b>		

**Table 11 : Work Space Concentrations and Mass Fractions Rubidium (Rb)**

Table 11, below, presents the results of work space concentrations and mass fractions of rubidium detected during the cutting of drywall boards.

<b>Table 11 : Work Space Concentrations and Mass Fractions Rubidium (Rb)</b>											
<b>Cascade Impactor Stages</b>	<b>Aerodynamic Diameter of Particle (µm)</b>	<b>Run 1</b>	<b>Run 2</b>	<b>Average</b>	<b>Mass (µg) = area of filter (cm<sup>2</sup>)* Avg XRF Concentrations (µg/cm<sup>2</sup>)</b>	<b>Time (min)</b>	<b>Air Volume Sampled (m<sup>3</sup>)</b>	<b>Work Space Concentration (gm/m<sup>3</sup>)</b>	<b>Mass fraction = Mass of metal Collected/ Material Cut (µg/g)</b>	<b>% Metal present in size range</b>	<b>% Metal present that is less than upper dia in range</b>
		<b>XRF Conc µg/cm<sup>2</sup></b>	<b>XRF Conc µg/cm<sup>2</sup></b>	<b>XRF Conc µg/cm<sup>2</sup></b>							
1	9.0-10	0.412	0.42	0.416	21.44	4.035	0.1142	0.0001877	0.17	14.22	100
2	5.8-9.0	0.334	0.416	0.375	19.32	4.035	0.1142	0.0001692	0.15	12.82	85.78
3	4.7-5.8	0.356	0.344	0.35	18.04	4.035	0.1142	0.0001579	0.14	11.96	72.96
4	3.3-4.7	0.308	0.35	0.329	16.95	4.035	0.1142	0.0001485	0.14	11.24	61
5	2.1-3.3	0.302	0.368	0.335	17.26	4.035	0.1142	0.0001512	0.14	11.45	49.76
6	1.1-2.1	0.378	0.374	0.376	19.37	4.035	0.1142	0.0001697	0.15	12.85	38.31
7	0.7-1.1	0.302	0.354	0.328	16.9	4.035	0.1142	0.000148	0.14	11.21	25.46
8	0.4-0.7	0.432	0.402	0.417	21.49	4.035	0.1142	0.0001882	0.17	14.25	14.25
<b>Total</b>								<b>0.00132</b>	<b>1.2</b>		



**Table 12: Table 12: Work Space Concentrations and Mass Fractions Strontium (Sr)**

Table 12, below, presents the results of work space concentrations and mass fractions of strontium detected during the cutting of drywall boards.

<b>Table 12: Work Space Concentrations and Mass Fractions Strontium (Sr)</b>											
<b>Cascade Impactor Stages</b>	<b>Aerodynamic Diameter of Particle (µm)</b>	<b>Run 1</b>	<b>Run 2</b>	<b>Average</b>	<b>Mass (µg) = area of filter (cm<sup>2</sup>)* Avg XRF Concentrations (µg/cm<sup>2</sup>)</b>	<b>Time (min)</b>	<b>Air Volume Sampled (m<sup>3</sup>)</b>	<b>Work Space Concentration (gm/m<sup>3</sup>)</b>	<b>Mass fraction = Mass of metal Collected/ Material Cut (µg/g)</b>	<b>% Metal present in size range</b>	<b>% Metal present that is less than upper dia in range</b>
		<b>XRF Conc µg/cm<sup>2</sup></b>	<b>XRF Conc µg/cm<sup>2</sup></b>	<b>XRF Conc µg/cm<sup>2</sup></b>							
1	9.0-10	0.952	1.068	1.01	52.05	4.035	0.1142	0.0004557	0.42	14.98	100
2	5.8-9.0	0.828	0.946	0.887	45.71	4.035	0.1142	0.0004002	0.37	13.16	85.02
3	4.7-5.8	0.766	0.762	0.764	39.37	4.035	0.1142	0.0003447	0.32	11.34	71.86
4	3.3-4.7	0.762	0.78	0.771	39.73	4.035	0.1142	0.0003479	0.32	11.44	60.52
5	2.1-3.3	0.714	0.944	0.829	42.72	4.035	0.1142	0.0003741	0.34	12.3	49.08
6	1.1-2.1	0.85	0.952	0.901	46.43	4.035	0.1142	0.0004065	0.37	13.37	36.78
7	0.7-1.1	0.714	0.684	0.699	36.02	4.035	0.1142	0.0003154	0.29	10.37	23.41
8	0.4-0.7	1.008	0.75	0.879	45.29	4.035	0.1142	0.0003966	0.36	13.04	13.04
<b>Total</b>								<b>0.003041</b>	<b>2.79</b>		

## Chapter 5: Discussion

### 5.1 Discussion of results for first part of study (Identification of Chinese Drywall)

From the results in Chapter 4.1, above, we can observe that the strontium concentration is much higher for Chinese drywall than for the American drywall. The strontium concentrations of both drywalls are compared in Table 13.

**Table 13: Strontium Concentrations (PPM)**

Table 13, below, lists the minimum, maximum, and median strontium metal concentrations in parts per million for the Chinese drywall (CDW) and the American drywall (NCDW) samples with and without the top paper. As we can see, the strontium concentrations of NCDW are very much less when compared to the Chinese drywall. As the Chinese drywall has elevated levels of strontium concentrations, this can be considered one of the indicators after the prescreen analysis, such as visual inspection.

<b>Table 13: Strontium Concentrations (ppm)</b>						
<b>Sample No</b>	<b>Minimum</b>		<b>Maximum</b>		<b>Median</b>	
	<i>CDW</i>	<i>NCDW</i>	<i>CDW</i>	<i>NCDW</i>	<i>CDW</i>	<i>NCDW</i>
With Paper	106.88	19.62	174.19	40.20	158.96	30.13
Without Paper	129.93	21.47	216.49	45.72	197.16	37.18

As strontium is the only metal seen in elevated levels of Chinese drywall composition, exposure to strontium may have effects on people.

#### 5.1.1 Strontium and Its Effects

Strontium can be released into the air (mainly as strontium oxide) by natural processes like the weathering of rocks, particle entrainment, wind resuspension, and sea spray, or as a result of human activities like milling, processing, coal burning, and fertilizer use. In air, the oxide rapidly forms the hydroxide or carbonate. Atmospheric strontium is returned to the ground by deposition. Strontium is released to surface water and groundwater by the natural weathering of rocks and soils. Like calcium, strontium has moderate mobility in soils and sediments, and absorbs moderately to metal oxides and clays. Strontium has similar properties like calcium. Naturally occurring strontium is not radioactive. There are four stable isotopes  $^{84}\text{Sr}$ ,  $^{86}\text{Sr}$ ,  $^{87}\text{Sr}$ , and  $^{88}\text{Sr}$ . The most important radioactive isotopes are  $^{89}\text{Sr}$  and  $^{90}\text{Sr}$  formed during nuclear reactor explosions and operations (CICAD77, 2010).

Under normal environmental conditions strontium is not considered to be toxic to humans. OSHA and NIOSH have not set any regulatory exposure limits for strontium. Strontium has a low order of toxicity. Acute exposure may cause:

- Excessive salivation, vomiting, colic, diarrhea,
- Inhalation of powder or dust may cause irritation,
- On contact with eyes and skin may cause irritation,
- Skin contact may cause dermatitis. (MSDS – Strontium)

Strontium follows the calcium stream and deposits in the skeleton. Exposure to high concentration levels of strontium may cause bone disorders, bone disease, or disruption of bone development in children and infants.

There are no harmful effects of stable strontium in humans at the levels typically found in the environment. Problems with bone growth may occur in children due to ingestion of unusual high levels of strontium, especially if the diet is low in calcium and protein. However developing children, particularly those with poor nutrition, are vulnerable to the toxic effects of strontium on bone mineralization in the developing skeleton. The primary toxicological effect of absorbed excess strontium is abnormal skeletal development also called rickets. (ASTDR, April 2004)

Ordinary strontium salts are not considered harmful when inhaled or placed on the skin. However, it is not known whether stable strontium affects reproduction in people. The effect of stable strontium on reproduction in animals is not known. (ASTDR, April 2004)

The chemical form of stable strontium that is carcinogenic by inhalation is strontium chromate, due to the known human carcinogen, chromium. The Department of Health and Human Services has determined that strontium chromate is expected to be a carcinogen. Even in small quantities, strontium chromate is known to cause lung cancer.

Radioactive strontium is much more of a health risk than stable strontium. When the uptake is very high, it may cause anemia and oxygen shortages, and at extremely high concentrations, it is even known to cause cancer as a result of damage to the genetic materials in cells.

## **5.2 Discussion of results for second part of study (Preliminary assessment of exposure to particulates and heavy metals during cutting and installation of drywall)**

From the results presented in Chapter 4.2, above, it can be seen that the most toxic metal found in the composition of the dust created during the cutting of drywall boards is lead. The metal which is present in excess concentration is iron. But OSHA and ACGIH do not have any exposure limits established for iron. OSHA and ACGIH have limits only for lead and molybdenum. Iron, zinc, rubidium, and strontium are not considered to be harmful in their stable states. But, all metals are toxic if exposed for prolonged duration. Total work space concentration of the PM and metals found in the dust of drywall boards are presented in Table 15, below. Total mass fractions of the metals and PM are presented in Table 16, below.

Iron and zinc are considered to be toxic only when they are in their oxide state, i.e., zinc oxide fume and iron oxide fume are considered to be toxic on inhalation.

One of the rubidium isotopes is radioactive. Because it is impossible to separate this isotope from non-radioactive rubidium, nearly all processed rubidium is slightly radioactive. Rubidium reacts readily with moisture to form rubidium hydroxide, which is severely corrosive to tissue. Corrosive materials are acutely destructive to the respiratory tract, eyes, skin, and digestive tract.

Exposure limits of molybdenum are OSHA Permissible Exposure Limit (PEL) -  $15 \text{ mg/m}^3$ , ACGIH (TLV) is  $10 \text{ mg/m}^3$ . The NIOSH recommended exposure limit is  $5,000 \text{ mg/m}^3$  (IDLH - immediately dangerous to life or health).

The exposure limits for lead are given by OSHA/PEL -  $0.05 \text{ mg (Pb)/m}^3$ , ACGIH/TLV -  $0.15 \text{ mg (Pb)/m}^3$ .

In an effort to reduce and maintain employee exposure at or below the permissible exposure limit (PEL), OSHA's hierarchy of controls requires the implementation of engineering controls. Employers must first determine if lead is present in the workplace. If so, then an exposure assessment (air monitoring) must be conducted in the workplace. Respiratory protection must be provided during the exposure assessment. If an employee's exposure is  $>30 \text{ } \mu\text{g/m}^3$  (Action Level), employers must conduct biological monitoring and training. If exposure is  $>50 \text{ } \mu\text{g/m}^3$  (Permissible Exposure Limit), employers must install engineering controls and use respiratory protection accordingly (Lead exposure strategies, Dec 2001).

The occupational exposure limits for dust mandated by OSHA is  $15 \text{ mg/m}^3$  (total),  $5 \text{ mg/m}^3$  (respirable), and the TLV for dust is  $10 \text{ mg/m}^3$ . The PM emitted during any construction work is considered as dust. Dust consisting of an excess amount of crystalline silica (which is a naturally occurring contaminant in gypsum) is considered to be toxic. Prolonged and repeated exposure to airborne free respirable crystalline silica can result in lung disease (i.e., silicosis) and/or lung cancer. (National Gypsum MSDS, Oct 2009)

**Table 14: Total Work Space Concentrations of PM and Metals**

The results of the total work space concentration of the PM and metals found in the dust of drywall boards are presented in Table 14, below.

<b>Total Work Space Concentrations of PM and Metals</b>		
<i>S.No</i>	<i>gm/m3</i>	<i>mg/m3</i>
<i>Particulate Matter</i>	0.459	459
<i>Lead (fe)</i>	0.001542	1.542
<i>Iron (Fe)</i>	0.01213	12.13
<i>Molybdenum (Mo)</i>	0.003884	3.884
<i>Zinc (Zn)</i>	0.006914	6.914
<i>Rubidium (Rb)</i>	0.00132	1.32
<i>Strontium (Sr)</i>	0.003041	3.041

**Table 15: Total Mass Fraction of PM and Metals collected per gram of material cut**

The total mass fraction of metals and PM collected in micrograms per gram of material cut is presented in the Table 15, below.

<b>Table 15: Total Mass Fraction of PM and Metals Collected per Gram of Material Cut</b>	
<i>S.No</i>	<i>µg/g</i>
<i>Particulate Matter</i>	420
<i>Lead (Pb)</i>	1.41
<i>Iron (Fe)</i>	11.07
<i>Molybdenum (Mo)</i>	3.55
<i>Zinc (Zn)</i>	6.32
<i>Rubidium (Rb)</i>	1.2
<i>Strontium (Sr)</i>	2.79

### ***5.2.1 Effects of Particulate Matter emitted during cutting of drywall boards***

Inhalable PM includes both fine and coarse particles. These particles can accumulate in the respiratory system and are associated with numerous health effects.

- The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.
- Exposure to coarse particles is primarily associated with:
  - increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty in breathing;
  - decreased lung function;
  - aggravated asthma;
  - development of chronic bronchitis;
  - irregular heartbeat;
  - nonfatal heart attacks; and
  - Premature death in people with heart or lung disease. ( USEPA Health Effects PM)
- Fine particles are mostly associated with health effects as increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function, and even premature death.
- Sensitive groups that appear to be at greatest risk to such effects include the elderly , individuals with cardiopulmonary disease, such as asthma, and children.
- Acute exposure to dusts generated in excess of the PEL/TLV during the handling or use of drywall boards may cause coughing, dyspnea, wheezing, general irritation to eyes, skin, nose, throat, and upper respiratory tract. Labored breathing may occur after excessive inhalation.
- Dust can cause temporary irritation of eyes.
- Excessive inhalation may result in obstruction or temporary irritation of the digestive tract.
- Continued and prolonged contact may result in dry skin. Contact with dust or glass fibers may produce itching, rash, and/or redness. Repeated or prolonged exposure may result in dermatitis.
- Chronic (prolonged and repeated) exposure to crystalline silica (a naturally occurring contaminant in gypsum) in the respirable size may cause silicosis, a debilitating lung disease. The development of silicosis may increase the risks of additional health effects. The risk of developing silicosis is dependent upon the exposure intensity and duration. In addition, the International Agency for Research on Cancer (IARC) classifies crystalline silica inhaled in the form of quartz or cristobalite from occupational sources as carcinogenic to humans. OSHA does not regulate crystalline silica as a human carcinogen.

### ***5.2.2 Effects of Lead on Exposure***

Lead exposure in the workplace and the related toxic effects are very common. Lead in the human body serves no useful purpose. Therefore, when lead enters the body it may damage any organ or body system. Lead compounds are carcinogens for the lungs and kidneys. Lead is a cumulative poison. Increasing amounts build up in the body and eventually reach a point where symptoms and disability occur. It may be possible that lead taken in extremely large doses can cause encephalopathy, a brain condition that results in seizures, coma, and death. Exposure to such high concentrations is not common. Chronic exposure may result in damage to the blood-forming, nervous, urinary, and reproductive systems. Common symptoms of overexposure to lead include loss of appetite, anxiety, constipation, nausea, pallor, excessive tiredness, weakness, insomnia, headache, nervous irritability, muscle and joint soreness, tremors, dizziness, abdominal pain, and irritation of eyes and skin.

Lead exposure may also cause weakness in fingers, wrists, or ankles, Small increase in blood pressure, particularly in middle-aged and older people, anemia. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage. High-level exposure in men can damage the organs responsible for sperm production and normal function. (ASTDR, Aug 2007)

#### **Acute Effects**

- Inhalation may cause irritation of the upper respiratory system, insomnia, dryness of the mouth, and a metallic taste.
- Ingestion may cause constipation and abdominal pain, colic, tremors, nausea, vomiting, diarrhea, metallic taste, loss of appetite, irritability, anxiety, and muscle pain. (MSDS – Lead).

#### **Chronic Effects**

- Inhalation of lead may cause chronic lead toxicity, and may be toxic to the central and peripheral nervous system affecting the cerebellum, spinal cord, and motor and sensory nerves.
- Ingestion may cause anemia, gingival lead line, paralysis in the wrist, and permanent neurological injury. Ingestion may also cause chronic lead toxicity, as well as nephritis, scarring, and shrinking of the kidney tissue (MSDS – Lead)

Children are more affected to lead, as their growing bodies absorb more lead. Their brains and nervous systems are more sensitive to damaging effects of lead. Children with high levels of lead in their body may suffer from:

- Damage to the brain and nervous system;
- Behavior and learning problems, such as hyperactivity;
- Slowed growth;
- Hearing problems;
- Headaches. (USEPA – Health effects of lead)

High levels of lead in adult also have harmful effects:

- Reproductive problems (in both men and women);
- High blood pressure and hypertension;
- Nerve disorders;
- Memory and concentration problems;
- Muscle and joint pain. (USEPA – Health effects of lead)

### ***5.2.3 Effects of Iron on exposure***

Iron compounds have varying toxicity. Some iron compounds are suspected carcinogens. In general, ferrous compounds are more toxic than ferric compounds. Acute exposure to excessive levels of ferrous compounds can cause liver and kidney damage, altered respiratory rates, and convulsions. Iron compounds may cause vomiting, diarrhea, pink urine, black stool, and liver damage. Iron compounds may also cause damage to the kidneys. Irritating to the respiratory tract, iron compounds may cause pulmonary fibrosis on inhalation of dusts.

#### **Acute Effects**

- Inhalation of dust or powder may cause irritation to the respiratory system and possibly acute iron poisoning. Large amounts of iron may cause iron pneumoconiosis.
- Inhalation may also cause irritation of the skin and eyes. (MSDS Iron)

#### **Chronic Effects**

- Inhalation of finely divided powder may cause pulmonary fibrosis, as well as chronic iron poisoning and pathological deposition of iron in the body tissue.
- Ingestion of iron may cause damage to the liver. (MSDS Iron)

Large amounts of ingested iron can cause excessive levels of iron in the blood. High blood levels of free ferrous iron react with peroxides to produce free radicals, which are highly reactive and can damage DNA, proteins, lipids, and other cellular components. Damage to the cells of the gastrointestinal tract can also prevent them from regulating iron absorption leading to further increases in blood levels. Iron typically damages cells in the heart, liver and elsewhere, which can cause significant adverse effects, including coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, long-term organ damage, and even death. Humans experience iron toxicity above 20 mg of iron for every kilogram of mass, and 60 mg per kilogram is considered a lethal dose.



#### ***5.2.4 Effects of Molybdenum on exposure***

Acute toxicity has not been seen in humans

##### **Acute Effects**

- Inhalation may cause irritation to the upper respiratory system.
- Ingestion may cause acute molybdenum poisoning.
- The skin and eyes may also become irritated. (MSDS Molybdenum)

##### **Chronic Effects**

- Inhalation may cause pneumoconiosis, anemia, hyperthyroidism, abnormal liver function, and increased susceptibility to gout.
- Ingestion may cause chronic molybdenum poisoning. (MSDS Molybdenum)

High levels of molybdenum can interfere with the body's uptake of copper, producing copper deficiency. Molybdenum prevents plasma proteins from binding to copper, and it also increases the amount of copper that is excreted in urine.

#### ***5.2.5 Effects of Zinc on exposure***

Acute and chronic toxicity of zinc is not fully known.

##### **Acute and Chronic Effects**

- Inhalation may cause irritation of upper respiratory tract, headache, nausea, vomiting, diarrhea, chills, fever, and aching muscles.
- Ingestion may cause headache, nausea, vomiting, dizziness, and gastrointestinal irritation.
- Prolonged contact with the skin may cause dermatitis.
- Powdered zinc is irritating to the eyes. (MSDS Zinc)

Inhaling large amounts of zinc (as zinc dust or fumes from smelting or welding) can cause a specific short-term disease called metal fume fever, which is generally reversible once exposure to zinc ceases. However, very little is known about the long-term effects of breathing zinc dust or fumes. (ASTDR, Aug 2005)

Although zinc is an essential requirement for good health, excess zinc can be harmful. Excessive absorption of zinc suppresses copper and iron absorption. Taking too much zinc into the body through food, water, or dietary supplements can also affect health. The levels of zinc that produce adverse health effects are much higher than the Recommended Dietary Allowances (RDAs) for zinc of 11 mg/day for men and 8 mg/day for women. If large doses of zinc (10-15 times higher than the RDA) are taken by mouth even for a short time, stomach cramps, nausea, and vomiting may occur. Ingesting high levels of zinc for several months may cause anemia, damage the pancreas, and decrease levels of high-density lipoprotein (HDL) cholesterol. (ASTDR, Aug 2005).

### ***5.2.6 Effects of Rubidium on exposure***

Chemical, physical and toxicological properties of rubidium have not been thoroughly investigated and reported. Toxicity of rubidium compounds is generally due to the anion. Indications are that overexposure could lead to muscle and red blood cell accumulation with possible neuromuscular effects, hyper irritability, and muscle spasms. No cases of industrial injury have been reported.

Acute Effects (Rubidium reacting with moisture to form rubidium hydroxide is very corrosive to tissues.)

- Inhalation may cause irritation to the respiratory system.
- Ingestion will cause burns and perforations of the gastrointestinal tract, and may cause ataxia and hyper-irritability.
- Severe thermal burns, corrosion, and ulceration may occur on direct contact with the eyes and skin.(MSDS Rubidium)

## Chapter 6: Conclusions

- The most important prescreening criteria of problematic drywall are the homes suspected of containing drywall due to the complaints of odors, corrosion, health complaints, and the homes that were constructed during the time period 2005 to 2008.
- Strontium can be measured in situ and rapidly using XRF. Therefore, strontium measurements are useful in identifying problematic drywall after the prescreening criteria are met.
- Strontium alone is not a specific marker of problematic drywall.
- After the prescreening criteria, if the complaint homes have high levels of strontium greater than 1,200 PPM, then the drywall can be tested for S<sub>8</sub> (orthorhombic sulfur) concentrations for confirmative analysis. If this is greater than 10 PPM, then the drywall can be confirmed as problematic drywall.
- Strontium is not a toxic or carcinogenic metal.
- Due to the elevated levels of strontium concentrations in the Chinese drywall tested versus American drywall, strontium can be noted as an important indicator of Chinese drywalls, but not a specific marker.
- XRF analysis results of drywall tested do not show any other carcinogenic or toxic metals in higher concentrations.
- Strontium in human body follows the calcium stream and deposits in skeleton. Ingestion or inhalation of unusual high level of strontium may affect bone growth in children or may cause rickets.
- The corrosion and the odor caused in the problematic drywall homes are due to the sulfur compounds.
- The presence of H<sub>2</sub>S gas is the indicator of a sulfur compound in the homes, which also causes the rotten egg smell.
- The total work space concentration of particulate matter generated during the cutting of drywall boards is 460 mg/m<sup>3</sup>. The PEL by OSHA for dusts generated is 15mg/m<sup>3</sup>. Though the total work space concentration cannot be compared to the PEL's by OSHA, this result can be used as reference to understand the work space concentration generated and the workers exposed during the cutting and installation of drywall boards.
- Pb, Fe, Zn, Rb, Mo and Sr are the metals that have been observed in the dust generated during the cutting of drywall boards. Though all the metals do not have regulatory limits from OSHA and ACGIH, deposition of metals is cumulative, and may be harmful or toxic if exposed for prolonged duration or present in excessive concentrations within the body.
- Workers exposed to PM 10 micrometers or less for prolonged duration or in excessive quantities may lead to respiratory irritation of the tracts, breathing problem, and irritation of the eyes and skin, chronic bronchitis, aggravated asthma, heart attacks and even premature deaths.

- Generated dust containing crystalline silica may be harmful to the workers.
- If an employee's exposure of lead is  $>30 \mu\text{g}/\text{m}^3$  (Action Level), employers must conduct biological monitoring and training. If exposure is  $>50 \mu\text{g}/\text{m}^3$  (Permissible Exposure Limit), employers must install engineering controls and use respiratory protection accordingly.
- The work space concentration of lead is  $1.542 \text{ mg}/\text{m}^3$ . Therefore, care should be taken during the cutting of drywall boards. Work space concentrations have to be thoroughly checked.
- The score and snap method of cutting is recommended to minimize dust generation, as sawing, drilling, or machining will produce dust. (MSDS – US and National Gypsum Boards)
- Local and general exhaust ventilation must be provided to maintain a dust level below the PEL/TLV.
- Wet methods, when appropriate, must be used to reduce the generation of dust.
- A NIOSH approved particulate respirator is recommended in poorly ventilated areas or if the PEL/TLV of dust is exceeded. Respirator recommendations for all substances (carcinogens and non-carcinogens) is governed by the following selection criterion:

$$\text{APF} > (\text{Workplace Airborne Concentration} / \text{NIOSH REL})$$

Where, the APF: Assigned Protection Factor, a measure of the protection provided by a class of respirators and where REL: NIOSH Recommended Exposure Limit. In the absence of an REL, NIOSH recommends the user may apply appropriate exposure limit. (NIOSH, Sep 1995)

- Safety glasses or goggles should be used by the workers to avoid dust.
- Gloves, protective clothing, and/or barrier creams may be utilized if conditions warrant.

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Vandana Karap was born in 1985, in the city of Secunderabad, India. She earned her undergraduate degree in Civil Engineering from Osmania University, Hyderabad, India in 2007. In fall 2008 she started her master's in environmental engineering at the University of New Orleans. She was a Dean's scholar for two years and worked with Dr. Bhaskar Kura as a Research Assistant in the Civil and Environmental Engineering department for all her years of graduate study and completed her masters in May 2011 with the present research on preliminary assessment of identification of chinese drywall and exposure to particulates and metals during the cutting and installation of drywalls, and a cumulative GPA of 3.78.