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Sent:	Thursday, May 14, 2009 3:25 PM
To:	McGeehin, Mike (CDC/CCEHIP/NCEH)
Subject:	Fw: CPSC-LBNL wallboard IAG work plan
Attachments:	CPSC Narrative Workplan 90427.doc

FYI
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To: Noonan, Gary (CDC/CCEHIP/NCEH); Gressel, Michael G. (CDC/NIOSH/DART)
Sent: Thu May 14 15:22:47 2009
Subject: CPSC-LBNL wallboard IAG work plan

Hi Gary. Here is the work plan that we developed for the CPSC IAG.

Best
Mike

1   **Background -** This work-plan responds to a need for measured emission factors

2   for sulfur containing compounds in gypsum board as outlined in the informal

3   description of emissions chamber studies provided by the Consumer Products

4   Safety Commission (CPSC) dated 4/9/2009 and subsequent conversations

5   between LBNL and CPSC.

6   According to the CPSC, "the purpose of the chamber studies is to provide

7   quantitative data on gas emissions from drywall." The emission factors need to

8   be presented in a way that is sufficient for deriving exposure concentrations in

9   dwellings and/or in confined spaces containing corrodible materials.

10   The proposed project includes two phases.

11   The objective of the first phase is to screen pristine (fresh) wallboard samples[1] to

12   1) identify the chemicals (primarily volatile sulfur constituents (VSCs) but also

13   VOCs) that are emitted from wallboard (no joint compound, no texture, and no

14   paint); 2) quantify emission factors for the main constituents in the emission

15   stream (reported as micrograms per square meter of material) and 3) calculate

16   and report steady-state indoor concentrations for the major constituents based

17   on archetypal home ventilation and wallboard loading factors per California

18   Specification 01350[2]. An additional objective of Phase I is to provide a screening

19   assessment of the corrosiveness of the emissions from wallboard as it pertains to

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[1] The wall board samples will be provided by CPSC.

[2] In the California Specification 01350 titled "Standard Practice for the Testing of Volatile Organic Emissions from Various Sources using Small-Scale Environmental Chambers" the measured emission factors derived from small chamber experiments are used to estimate steady-state building concentrations for comparison to a concentration of interest (i.e., chronic reference exposure levels, odor threshold, sensory irritation threshold, ...).

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1   household components such as copper wires, receptacles, switches, electronic

2   boards, smoke detectors, gas lines and connectors.

3   The second phase of the study will focus on a limited number of higher emitting

4   materials identified in Phase I to characterize factors that may influence long-

5   term emissions such as temperature, moisture, ventilation, and wall coverings

6   (paint, joint compound, texture, paper) to support the reconstruction of chronic

7   exposure concentrations in both the ventilated and unventilated spaces in

8   dwellings.

9   **LBNL chambers -** LBNL has several existing test systems for characterizing

10   material specific emission factors. These include four small (10.5 L) stainless

11   steel chambers housed in a temperature-controlled environment; a medium sized

12   (395L) continuous stirred emission chamber constructed from low sorption

13   materials; a room-scale (20 m^3) stainless steel test chamber for standardized

14   material testing; and a room-scale "real room" test chamber for characterizing

15   complete wall systems. Well-established test protocols are available for all of the

16   chamber systems. Therefore, minimal effort is anticipated to bring the emission

17   chamber component of the study on-line. However, the reactive nature of many

18   of the reduced sulfur constituents of interest may require that the stainless steel

19   chambers and transfer lines be treated using Sulfinert® surface coating.

20   The small chambers provide the quickest experimental results because multiple

21   samples (up to four) can be tested simultaneously for a given temperature and

22   humidity setting. The medium chamber provides better air mixing control to

23   characterize the relationship between emissions and ventilation and can also be

1   loaded with more material to improve detection limits as needed. The medium

2   chamber may also provide a useful test system for exposing metal and electronic

3   samples to artificial emissions to characterize corrosion rates in-situ. The large

4   chambers provide room scale testing where field relevant loading factors and

5   ventilation rates can be simulated.

6   Recommendation – Assuming we are able to achieve adequate detection limits

7   (see below), the preferred approach would be to use the small chamber system

8   to determine standard emission factors following established protocols. The need

9   for treating the chambers and sample handling components to reduce loss of

10   reactive sulfur constituents will be determined after the analytical methods are

11   established. Results from the small chambers will provide initial, and relatively

12   rapid (compared to the larger chambers) estimates for emission factors for all

13   samples. Single samples can be run first to identify potential high emitters with

14   follow-up experiments including replicates of samples that are found to have

15   higher emissions.

16   To improve sample throughput, it is anticipated that up to 16 pre-conditioning

17   chambers will be constructed to provide a controlled environment for bringing

18   fresh samples into equilibrium with test conditions prior to installation in the

19   emissions chambers. This is expected to increase sample throughput by

20   approximately a factor of four because the emission factors can be measured

21   from samples either the same day that they are installed or the following

22   morning. Without the pre-conditioning chambers it would be necessary to wait

23   several days to a week before fresh samples had equilibrated to the standard

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1 temperature and humidity conditions used for testing. The pre-conditioning

2 chambers may also provide a testbed for assessing the rate and extent of

3 corrosion on household components exposed to the emissions from wallboard as

4 described below.

5 **LBNL sampling and analysis** - LBNL has well established methods for

6 collection and analysis of volatile organic chemicals, low molecular weight

7 aldehydes and organic acids, both in field samples and in experimental

8 chambers. However, we have not previously focused on the volatile sulfur

9 containing constituents that are of interest in this study. Therefore we will need

10 to identify appropriate methods and/or modify our existing methods to assure

11 adequate detection limits to meet the project objectives.

12 *Target experimental sensitivity* – To estimate the target detection limits, we note

13 that a report prepared by Unified Engineering Inc. for the Bureau of Community

14 Environmental Health, Florida Department of Health measured sulfur

15 components in headspace over gypsum and paper after the materials were

16 subjected to high humidity and found three primary sulfur containing chemicals –

17 carbonyl sulfide, hydrogen sulfide and trace amounts of carbon disulfide. These

18 chemicals are rarely measured in homes but when detected, the carbon disulfide

19 and carbonyl sulfide have been found to be approximately 5 ppb (~ 15 μg/m^3)

20 (Larkin et al., 2008; Wiesel et al., 2008).

21 Assuming steady state conditions, only one source material, and no contribution

22 from outside air, the indoor concentration C_{ss} (μg/m^3) of a pollutant is related to

23 the material specific emission factor EF_i for material i (μg/m^2/h) as

4

1 $$EF_i = \frac{C_{ss} \times ACH}{L_i} \qquad (1)$$

2 where L_i (m^2/m^3) is the loading factor or surface area of material per volume of

3 dwelling and ACH (h^{-1}) is the air exchange rate in the dwelling. The approximate

4 surface to volume ratio for gypsum board in homes is 1.2 m^2/m^3 (Hodgson et al.,

5 2004) and a typical air exchange rate is 0.5 (h^{-1}). Therefore, assuming gypsum

6 board is the primary source of sulfur containing compounds, the emission factor

7 that would result in a concentration of 15 μg/m^3 is 6 μg/m^2/h.

8 Applying this emission factor to a material in the small experimental chamber

9 with a material loading factor of approximately 2 and a ventilation rate of 5 would

10 result in a steady state concentration of 2.5 μg/m^3, per Equation 1. For VOC

11 analysis, we typically sample up to 6 liters of air. Assuming we can achieve

12 acceptable collection efficiency and recovery, this sample volume would collect

13 15 ng of analyte, which is well within the typical range of quantification for other

14 VOCs. Therefore, we expect to be able to analyze carbon disulfide using a

15 modified version of our VOC method. However, carbonyl sulfide and hydrogen

16 sulfide have very low boiling points so may be difficult to collect on

17 thermodesorption tubes under ambient conditions. We will construct a

18 cryotrapping system to attempt to collect all analytes with the same sample but if

19 this is not successful, we will adapt an existing aldehyde method for collection

20 and analysis of carbonyl sulfide and apply OSHA Method 1008, which utilizes

21 silver nitrate coated silica gel for collection and analysis of hydrogen sulfide.

1   *Sampling and Analysis Method Development* – We will start by adapting and

2   optimizing our VOC method, which is based on EPA Method TO-17, for

3   quantification of volatile sulfur compounds. We will determine whether carbonyl

4   sulfide and hydrogen sulfide can be collected and quantified with the VOC

5   method. Analyzing the highly volatile and reactive sulfur constituents may require

6   a specially formulated GC column, inert surface treatment of transfer lines, ultra-

7   cold sample collection tubes and GC inlet, and a water management system for

8   cold trap sampling. We will test the use of cold trap conditions for sample

9   collection and the use of drying tubes or two-stage cold trap protocols to remove

10   water from the sample air stream. Having as many analytes included in the same

11   analysis stream is advantageous because it reduces labor and supply costs but if

12   we cannot analyze for all the volatile sulfur compounds (VSCs) using a modified

13   version of the TD-GCMS method then chemical specific methods will be applied.

14   For example, if we cannot achieve the desired detection limits for the carbonyl

15   sulfide and/or hydrogen sulfide using the modified VOC method, we will use an

16   existing aldehyde method with DNPH coated samplers that derivitize the

17   carbonyl compound which is then analyzed by HPLC. For the hydrogen sulfide,

18   we will evaluate the applicability of a test method based on OSHA method T-

19   1008 which uses silver nitrate coated silica gel to collect hydrogen sulfide. This

20   method is similar to our existing method for sampling and analysis of volatile

21   organic acid compounds. Once the appropriate method(s) are identified and

22   optimized, we will develop basic QA/QC criteria for collection efficiency, method

23   detection and quantification limits and analyte recovery.

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2   **Measurements of emission factors** – Once the instrumental analyses are

3   optimized for the VSCs, we can proceed with emission testing. Using the small

4   emissions chambers we can process 12 samples per month for standard

5   emission factors if the small chambers are also used for pre-conditioning the

6   samples. Our small chamber protocol generally follows ASTM Standard Guide D-

7   5116-97 and CDHS 2004 "Standard Practice for the Testing of Volatile Organic

8   Emissions from Various Sources Using Small-Scale Environmental Chambers".

9   The objective is to screen a large number of samples for material-specific

10   emission factors so to increase sample throughput a set of pre-conditioning

11   chambers will be constructed to allow samples to be brought to equilibrium with

12   environmental conditions prior to being installed in the emission chambers.

13   Previous work with building materials indicates that samples equilibrate within a

14   few days after chamber conditions are changed so if we use pre-conditioning

15   chambers before loading the materials then the air-sampling in the small

16   chambers can begin within approximately 6 air changes after installing the

17   material. This will allow us to process materials at a rate of four samples per day

18   (four days per week) or an average of 16 samples per week.

19   The tests will be conducted in four 10.5-L stainless steel chambers maintained at

20   23 ± 1 °C in a controlled environmental chamber. If necessary, the chambers will

21   be surface coated with Sulfinert® treatment prior to use to minimize surface

22   interactions with the reactive sulfur constituents. A 0.06-m^3/h inlet flow of carbon-

1   filtered preconditioned air at 50% ± 5% relative humidity[3] will be supplied

2   continuously to each test chamber. The relative humidity within the test

3   chambers will be controlled by a flow of mixed streams of dry- and water-

4   saturated air. The RH can be adjusted over a wide range so the Phase I

5   experiments can be conducted at a selected RH based on needs of CPSC (i.e.,

6   conditions relevant to Gulf Coast states). The backs and raw edges of the

7   gypsum board samples will be sealed by pressing (snug fit) into stainless steel

8   trays and the samples will be placed face up on screens that rest slightly below

9   the center of the test chamber. For each material, the emitting area, A (m^2), will

10 be 0.023; the loading factor, L (m^2/m^3), will be 2.2; and the area-specific flow rate

11 ($m^3/m^2/h$) will be approximately 2.6 ($m^3/m^2/h$). The total sampling rate for all

12 samples collected from the chamber exhaust stream will be maintained at less

13 than 90% of the inlet air stream to prevent introduction of room air into the

14 samplers. These conditions may need to be adjusted depending on the final

15 analytical methods used but the values will be used to guide the initial setup of

16 the experiments.

17 **Assessing corrosiveness of emissions –**

18 The objective of the corrosiveness testing is to characterize the potential for

19 damage of household components exposed to the emissions from the wallboard.

20 The emissions testing will identify wallboard that has the highest emissions of

21 volatile sulfur chemicals as well as other volatile organic chemicals. Based on

22 these results, we will classify the wallboard as high, medium or low emitters.

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[3] Baseline conditions for humidity and temperature will be identified after consulting with the funding agency to insure the values are relevant to the conditions of interest.

1 Samples of these boards will be obtained from CPSC for use in the corrosion

2 testing. The premise is that the actual board will provide a more realistic and

3 relevant emission stream than a custom mixed gas stream designed to mimic the

4 emissions results. The material pre-conditioning chambers developed for the

5 emission testing provide a matrix of test containers that can provide a range of

6 controlled humidity and ventilation conditions. To provide an elevated source in

7 the chambers for accelerated corrosion conditions, four walls within each

8 chamber will be covered with the wallboard that is selected for testing. For a

9 chamber with dimensions of 12×12×18 inches, this results in a loading factor > 5

10 m^2/m^3, which is well above typical values in homes and comparable to what

11 would be expected in an unventilated wall cavity. If needed to accelerate

12 corrosion, we will identify options for installing the test chambers in a controlled

13 temperature environment.

14 Once the chambers are loaded with source materials, a set of sentinel materials

15 will be installed in each container. Sentinel materials include copper test strip,

16 silver test strip, or other metal alloys as requested by CPSC. The test strips will

17 be installed with test face oriented towards the open end of the chamber to allow

18 monitoring of corrosion. The open face of the chambers will be closed using a

19 transparent face material with clamping ring and the conditions in each chamber

20 will be adjusted to a predetermined combination of RH and ventilation. The

21 selection of conditions in the exposure chambers will result in a wide range of

22 humidity and chemical concentration values and at least one chamber will be run

23 without wallboard as a control and at least four chambers will be reserved for

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1   installation of actual household components (i.e., receptacles, switches, smoke

2   detectors, ...).

3   The chemical concentration in each chamber will be periodically monitor for

4   target VSCs and VOCs . This will include at least thee different sampling times

5   over the course of the experiment. Corrosion on the test strips will be tracked

6   using high resolution images. The experiments are expected to run

7   approximately 30 days depending on the rate of corrosion observed. At the end

8   of the experiment, test strips will be remove and characterized by electron

9   microscopy depending on instrument availability or the test strips and household

10   components will be packaged and shipped to CPSC for further evaluation.

11   The experimental matrix will be repeated for at least two wallboard types (high

12   emitter and low emitter) An optional third experimental matrix would include the

13   range of wallboards tested for emission all run at the same conditions so a direct

14   comparison across boards can be made. An advantage of this approach is that it

15   uses real materials for the source of corrosive gas and uses standardized

16   materials as the corroding substrate. Each experiment provides a

17   multidimensional dataset including temperature, concentrations, ventilation and

18   corrosion, which could lead to a detailed semi-empirical model for translating the

19   results to field conditions.

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21   **Phase II emission factor characterization –**

1   The work-plan to address Phase II objectives will be provided after initial results

2   are reported from Phase I. Phase II will likely use a combination of the small and

3   medium chambers to characterize environmental factors and long-term

4   emissions and possibly one or both of the larger chambers to explore the impact

5   of wall coverings and exposure of building materials that may enhance the

6   corrosiveness of the wallboard emissions.

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8   **Estimated Cost**

9   See budget/proposal.

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22 Application Notes

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