



Research article

End-of-life management of corrosive drywall

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ABSTRACT

Recently, gypsum drywall products imported to the United States (US) were found to cause metal corrosion and tarnishing in some homes, often necessitating that this drywall be discarded. Research assessed the potential implications of recycling and landfilling corrosive/imported drywall. Samples of corrosive drywall were collected from homes in Florida, US and these characteristics were assessed relative to domestically-produced drywall purchased from retail outlets. The total and synthetic precipitation leaching procedure (SPLP) leachable heavy metal concentrations were measured and compared to risk-based regulatory thresholds to assess the possible land application risk. In a majority of samples, concentrations were below levels of regulatory concern. The mean concentration of several elements exceeded the thresholds in a few samples for the direct exposure assessment (As) and the groundwater leaching assessment (Al, B, Hg, Mn, Sr and V); but the results did not suggest that corrosive drywall would present a greater risk than domestic drywall. To assess landfilling concerns, the potential for sulfur gases emissions upon disposal was evaluated. Experiments indicated that corrosive drywall would not pose a greater risk of long-term H₂S emissions compared to domestic drywall.

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1. Introduction

The research presented here was motivated by reports of off-gassing from drywall products in residential homes in the US. Beginning in 2008, some homeowners, particularly in the South-eastern US, reported failure of copper air conditioner coils, extreme tarnishing of exposed metal surfaces (copper, silver, plated metal fixtures), and failure of electrical appliances (Allen et al., 2012; Freeman et al., 2011). Many homeowners noted unpleasant odors, and in some cases, health impacts were reported. The occurrence of these problems was ultimately attributed to gas emissions from drywall imported into the US from China and utilized in new home construction. These drywall products were subsequently described in the media as corrosive drywall.

A number of different organizations investigated the corrosive drywall off-gassing phenomenon (CPSC, 2010; USEPA, 2009) and by and large, a consensus was reached that the primary gases being emitted and causing problems belong to a class of chemicals known as reduced sulfur compounds (RSCs). Several different RSCs, most

notably hydrogen sulfide (H₂S), carbonyl sulfide (COS), and carbon disulfide (CS₂), were reported as being emitted from corrosive, imported drywall.

The primary ingredient in drywall is gypsum (CaSO₄·2H₂O), thus sulfur is a natural component of drywall. The sulfur in gypsum, however, occurs as sulfate, an oxidized form of sulfur and is not expected to release RSCs in the absence of a reduction mechanism. The biological reduction of sulfate to sulfide and the formation of other RSC has been well documented for landfills disposing large amounts of drywall (Lee et al., 2006; Yang et al., 2006).

One consideration when making end-of-life (EOL; e.g., landfilling, recycling) decisions with respect to drywall are S life cycle carbon emissions. Drywall is manufactured from raw or recycled gypsum slurry with a paper backing on either side. At EOL, drywall is disposed in a landfill, recycled into new drywall, or land applied for beneficial reuse. Life Cycle Assessment (LCA) tools have quantified both production and end-of-life (EOL) emission factors for drywall. For example, the USEPA's Waste Reduction Model (WARM; USEPA, 2015) identifies 243 kg CO₂e/Mg drywall manufactured and an additional 132 kg CO₂e/Mg drywall landfilled. Gypsum drywall has historically been viewed as a non-hazardous waste and can generally be landfilled at municipal landfills or construction and demolition (C&D) debris landfills. Additionally, the material has often been land applied to agricultural fields as a soil supplement; this EOL option results in 11 kg CO₂e/Mg emitted in WARM.

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The most common solution for problem homes with corrosive drywall has been to remove the material and install new drywall, thus resulting in a large amount of demolition debris requiring disposal. Given the issues faced by the homeowners and the known problems at C&D debris landfills as a result of normal drywall disposal, questions were raised by the regulatory community and the solid waste industry as to whether EOL options should be any different than the manner in which normal drywall debris is managed. This research reports the results of testing to examine what concerns, if any, might be present if corrosive drywall were recycled by land application or disposed of in a landfill. Recycling was assessed by comparing total and leachate metal concentrations to risk-based land application thresholds. Disposal was assessed by evaluating hazardous waste status and evaluating RSC emissions (mostly H₂S) under anaerobic landfill conditions.

2. Materials and methodology

2.1. Sample description

The drywall samples were collected and used for this research. Details of drywall samples and selected photos of collected drywall samples are presented in [Table S1](#) and [Fig. S1 in the Supplementary Material](#). Seven domestically-manufactured (US) drywall products were purchased from retail outlets (identified as D1-8). Eight corrosive drywall samples were collected from homes in South Florida (identified as I1-8). The majority of these products had markings indicating “China” or “Knauf,” a company known to have imported corrosive drywall from China into the US. Finally, two samples of new drywall were purchased from retail outlets in China (I9-10).

All of the samples were tested for total and leachable metal concentrations. A subset of the samples was tested for H₂S gas emissions (denoted with “b” in [Table S1](#)). All samples were stored in plastic containers until use. The drywall samples were first processed to a suitable size for each test. For leaching tests, samples were size reduced to pieces measuring approximately 0.31 m by 0.31 m (1 ft by 1 ft) using a knife, then crushed within a plastic bag using a hammer and screened using a No. 14 standard sieve (sieve size = 1.4 mm). For the tests concerning the analysis of total metal concentrations (mg/kg) and leachable metal concentrations (mg/L), the paper backing was not included in the analysis; the focus was on the gypsum core. For tests that evaluated the potential to produce reduced sulfur gases in landfill environments, the paper backing was included. Organic matter is known to play a role in the production/release of H₂S from drywall in landfill environments.

2.2. Leaching tests

The leachability of the processed samples was measured using the SPLP and toxicity characteristic leaching procedure (TCLP). Both are standardized leaching procedures developed by the US Environmental Protection Agency (EPA) ([USEPA, 1992a, 1994](#)). The resulting leachates were analyzed for the concentration of targeted heavy metals (listed in next section) using methods outlined in EPA SW-846 3010A (liquid), 3050B (solid), 6010C, and EPA 1631 ([USEPA, 1992b, 1996, 2002b, 2007](#)). Each sample was leached and analyzed in triplicate.

2.3. Gas production tests

Two approaches were used to assess whether corrosive/imported drywall might have a greater propensity to produce sulfur gases than domestic drywall when disposed in a landfill. In one approach, static batches (drywall and moisture) were created in small serum bottles to promote conditions where biological sulfate

reduction would occur; gases in the headspace were then measured over the course of 60 days. In another approach, simulated landfill columns were constructed and the production/release of sulfur gases over time was measured.

2.3.1. Batch tests

Batch tests under anaerobic conditions were conducted to assess whether imported drywall would result in greater H₂S production and/or release compared to domestic drywall. Since no standardized testing protocol existed to meet this experimental objective, a methodology was developed based on previous experiments ([Yang et al., 2006](#)). Since previous research found that sulfate-reducing bacteria (SRB) activity would initiate upon creation of a wet and anaerobic environment, no inoculum was added.

Samples were size reduced to 1 cm by 1 cm coupons, which were considered more representative of the original shape than crushed or sieved drywall. The paper layer was removed on the facing side so that only the paper layer on the back of the drywall remained. The number of bottles depended on the number of samples; duplicates of each sample and blanks (clean sand) were also prepared for control measures. Ten grams of drywall coupons were weighed using a 4-digit scale (Mettler Toledo, US) and placed in the glass serum bottles (270 mL). Samples were wetted with 15 mL of DI water before flushing with nitrogen in an anaerobic chamber (PALS LABS (model No. 818-GB), US). The anaerobic chamber was flushed with nitrogen until the oxygen level was lower than 0.1%. After flushing, the bottles were sealed with a natural rubber stopper and aluminum cap (Wheaton, US). Prepared sample bottles were placed in a 35 °C incubator. A sample of gas was collected from the head space of each bottle of sample and analyzed for H₂S every week for 60 days.

2.3.2. Column tests

Column tests under anaerobic conditions were conducted to assess whether imported drywall would result in greater H₂S production and/or release compared to domestic drywall. The landfill column tests were conducted using PVC columns. Details of the column design are illustrated in [Fig. S2 in the Supplementary Material](#). The pipe length was 90 cm with a diameter of 10 cm. Each PVC column was fitted with 10 cm slip-caps on each end of the column using primer and glue. Two ports with plastic ball-valves were installed onto each slip-cap. The gas samples were collected from the port installed in the center of the column. The top port was used for water addition and the bottom valve was used for leachate collection and nitrogen purging (the process of nitrogen purging is described as part of gas analysis). A geotextile was fitted inside the column to prevent loss of support material during leachate draw off. Acid-rinsed, organic-free sand was used as support material. The organic-free sand was prepared by removing organic matter at 550 °C for 2 h. Two domestic drywall samples (D1 and D3) and two corrosive drywall samples (I1 and I3) were used for the test. Eight columns were constructed; duplicate columns were used for each sample tested.

Each column was filled with a representative C&D debris mixture: wood, drywall, concrete and an additional inert material (non-calcareous river rock). Waste composition percentages by weight for this study, size and their sources are summarized in [Table 1](#). Each column was prepared with same amount of each waste component. Each waste component was size reduced and manually homogenized in clean 5-gallon buckets. River rocks were utilized to represent the miscellaneous fraction of the waste stream and were purchased at local retail outlets. The pore volume was measured by the addition of DI water into the column after loading.

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