Introduction

There is a need to raise awareness of the community and occupational health issues associated with construction and demolition (C&D) debris landfills. C&D debris includes materials from building demolition, renovation, new construction, and disaster-related waste such as post-hurricane wastes. These materials were once thought to be inert. However, health agencies are becoming increasingly aware of the potential community exposures and health risks from C&D landfill contaminants. The exposure concerns include: 1) inhalation of hydrogen sulfide and other sulfur gases emitted from the landfill; 2) inhalation of smoke and dust from surface and subsurface fires; 3) inhalation of dust from vehicle traffic, and 4) ingestion of contaminated private well water from landfill leachate. In addition, unrestricted public access onto landfills can result in physical injury. Depending on state and local regulations, correcting problems once they occur is potentially difficult. The following is a summary of C&D issues meant to raise the awareness of the Florida health officials, the medical community, and state and local governments. Recommendations are made that may prevent or reduce the impact of these landfills on public and worker health and safety.

Regulations: There are no federal regulations that apply to C&D landfills. State-based regulatory requirements for these facilities vary widely from state to state [1]. In Florida, permits for new C&D landfills are reviewed and approved by the Florida Department of Environmental Protection (Florida DEP). The location of landfills are approved by county governments and elected officials. Florida DEP C&D facility requirements include operator training, waste screening, groundwater monitoring, and height/slope restrictions upon closure of the facility. Closure regulation requirements include covering the landfill with 2 feet of material, construction of a surface water runoff collection system, and continued groundwater monitoring for a 5-year period. Although part of the state recommended management practices, Florida regulations do not require landfill liners, leachate collection and treatment systems, gas extraction or treatment systems, or air monitoring. In March, 2005, 112 C&D facilities were located in Florida [3].

Contaminants of concern at C&D landfills: One of the materials accepted at C&D landfills is wallboard or gypsum drywall. When gypsum drywall is exposed to water, the calcium sulfate component dissolves. As conditions in the landfill become anaerobic (without oxygen), sulfate reducing bacteria digest the sulfate and release hydrogen sulfide [4]. Lower levels of other sulfur compounds (e.g., mercaptans, carbonyl sulfide) are also produced. Exposure to these other sulfur compounds is also a public health concern; however, hydrogen sulfide is emitted at much higher levels and is therefore of greater concern. Methane gas is also produced under the same anaerobic conditions by other bacteria as they degrade organic material in the landfill. All of these processes are exothermic (heat-generating). Hydrogen sulfide, the other sulfur compounds, and methane are all flammable gasses. When gases build up to flammable concentrations, both surface and underground fires can result. Inhalation of particulate matter from smoke and dust from trucks and other construction vehicles (e.g., excavators, loaders) impacts those with cardiac or pulmonary health problems.

Contaminants typically found in groundwater surrounding C&D landfills include cadmium, lead, iron, manganese, several chlorinated volatile organic compounds, and other chemicals.

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Elevated levels of chromium and arsenic are found if chromated copper arsenate–treated wood is disposed of in the landfill [5]. These contaminants can reach levels that exceed the U.S. Environmental Protection Agency’s (EPA) primary and secondary drinking water standards. Contaminated groundwater has the potential to migrate to private wells used for drinking water.

**Overview on hydrogen sulfide and health effects:** Hydrogen sulfide has an odor similar to rotten eggs. It is a colorless gas that is heavier than air. People can smell hydrogen sulfide at concentrations beginning in the low parts per billion (ppb) range. At concentrations of 10 parts per million (ppm) or higher people can no longer smell the gas due to olfactory fatigue (inability to detect hydrogen sulfide odors) [6]. In the U.S., an average of 0.11 to 0.33 parts per billion (ppb) is found in the air. In undeveloped areas, levels range between 0.02 and 0.07 ppb [7].

**Occupational Exposures:** Exposure to hydrogen sulfide at 50 to 100 ppm can cause conjunctivitis and respiratory irritation after one hour. Short-term exposure to high concentrations (170 to 300 ppm) of hydrogen sulfide is the maximum occupational concentration endurable for one hour without serious consequences [8]. Exposure above 500 ppm results in unconsciousness and death [9]. The National Institute for Occupational Safety and Health (NIOSH) has an immediately dangerous to life and health (IDLH) value of 100 ppm based on acute inhalation of hydrogen sulfide. The IDLH is defined as the ability of a worker to escape an area without loss of life or irreversible health effects [10]. The NIOSH recommended 40-hour permissible exposure value and the 10-minute ceiling value for this gas is 10 ppm [11]. The American Conference of Governmental Industrial Hygienists (ACGIH) has established a 40-hour work week exposure guidance value of 10 ppm, with a 15-minute ceiling value of 15 ppm [12]. The Occupational Safety and Health Administration (OSHA) permissible exposure limit is 20 ppm with a maximum (10 minute) peak exposure value of 50 ppm [13].

**Community Exposures:** Hydrogen sulfide in air affects the eyes, lungs, and nervous system. People with pre-existing respiratory problems (e.g., asthma and restrictive lung disease), children, and the elderly are more sensitive to adverse health effects from exposure to mucous membrane irritants such as hydrogen sulfide. In addition, persons with cardiac or nervous system disorders are more susceptible to the effects of hydrogen sulfide [7]. More recent studies indicate that exposure to low levels of hydrogen sulfide may result in adverse health effects. One study found an association between children's unplanned asthma-related hospital visits and days with hydrogen sulfide levels above 0.03 ppm for 30 minutes or more [14]. A controlled exposure study (0.05 ppm, 0.5 ppm, and 5 ppm for 3-hour durations) found increased anxiety in healthy young adults significantly associated with self-reported olfactory irritation. In this study, all three exposure concentrations affected verbal learning [15].

The American Industrial Hygiene Association’s most conservative Emergency Response Preparedness Guideline (ERPG) for hydrogen sulfide is 0.10 ppm. The ERPG is defined as the maximum 1-hour airborne concentration below which nearly all individuals do not perceive a clearly defined objectionable odor [16]. ERPGs are used to make shelter-in-place or evacuation decisions during a chemical release. They are not intended for repeated exposure situations from a stationary source such as a C&D landfill. The Agency for Toxic Substances and Disease Registry’s (ATSDR) acute minimal risk level (MRL) is 0.07 ppm for hydrogen sulfide. This MRL is defined as a 2-week exposure value. The intermediate (>14-364 days) MRL is 0.02 ppm. Exposures below the MRL are not expected to result in non-cancerous health effects [7].

**On-site hydrogen sulfide contaminant levels and occupational health and safety risks:** The University of Florida (UF) conducted extensive air sampling within and near the surface at several C&D landfills [4]. Surface testing for hydrogen sulfide across 10 landfills found hydrogen sulfide levels from below the lower limit of detection (0.003 ppm) to greater than the upper detection limit (50 ppm). Average hydrogen sulfide levels ranged from 0.003 ppm to greater than 4 ppm. Methyl mercaptan, carbonyl sulfide, and carbon disulfide were frequently detected, but at much lower levels than hydrogen sulfide. Methane was found in 45% of the samples collected, with levels up to 47.5% (by volume).

In 2005, EPA conducted on-site air sampling for hydrogen sulfide at 50-foot intervals on a C&D landfill in Trumbull County, Ohio. Levels detected ranged from less than 0.001 ppm up to 165 ppm [17].

In early 2007, a consultant for a C&D landfill in Escambia County, Florida, conducted hydrogen sulfide air sampling in the landfill work areas [18]. Three separate real-time monitoring events occurred within a 1-month period. Numerous fires and a foul odor were reported during the first monitoring event. Levels of hydrogen sulfide detected at ground level ranged from less than 10 ppm (the lower detection limit of the sampling device) up to 140 ppm. Levels found in the breathing zone ranged from less than 10 ppm up to 20 ppm.

Levels of hydrogen sulfide detected during the UF sampling activities as well as sampling at the Ohio and Florida landfills exceeded occupational exposure guidance or regulatory ceiling values. Some values approached or exceeded those known to result in olfactory fatigue. Exposures to these levels could result in permanent neurological effects, worker “knock down” (syncope) and death. OSHA inspected the Escambia County landfill following the early 2007 air sampling. Subsequently, a work stoppage was ordered until employees were properly trained and personal protective equipment was provided to reduce hydrogen sulfide exposure.

**Hydrogen sulfide in residential air and community health and safety risks:** The ATSDR conducted residential
Residents continue to report odors and adverse health symptoms. The EPA recently completed four months of ambient air sampling for hydrogen sulfide around the landfill in Santa Rosa County, Florida. The Florida DOH is currently evaluating the data to determine the appropriate next steps in protecting the community's health. Residents continue to report odors and adverse health symptoms.

Recommendations to avoid community and occupational health issues at C&D landfills: Based on experiences with C&D landfills, Florida DOH and ATSDR offer the following recommendations to avoid creating problems with environmental contamination and community and worker exposures to these contaminants.

1. Avoid siting landfills in or near residential areas.
2. Respond appropriately to reports of odors and smoke.
3. If hydrogen sulfide, methane, and other flammable gases approach combustion levels, implement
measures to reduce the likelihood of surface and subsurface fires.

4. Take measures to ensure minimal water invasion into landfill contents, including groundwater and rainwater.

5. For additional management practice recommendations, please refer to "Recommended Management Practices to Prevent and Control Hydrogen Sulfide Gas Emissions at C&D Debris Landfills Which Dispose of Pulverized Gypsum Debris in Ohio." [23].

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