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Hydrogen Sulfide Gas Emissions in the Human-Occupied Zone during Disturbance and Removal of Stored Spent Mushroom Compost

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ABSTRACT. *Hydrogen sulfide (H_2S) gas levels were monitored in the human-occupied zone at four spent mushroom compost (SMC) storage sites during removal of SMC for application on agricultural land. During SMC removal operations, H_2S gas monitors were mounted on the outside of the tractor, positioned at the SMC periphery, and worn by individual tractor drivers. The highest H_2S concentrations (10 s average) detected outside the tractor, at the SMC periphery, and for the tractor driver were, respectively, 454, 249, and 100 ppm for the outdoor sites and 214, 75, and 51 ppm for the indoor sites. The highest short-term exposure values (STEV, over a 15 min period) outside the tractor, at the SMC periphery, and for the tractor driver were 147, 55, and 86 ppm for the outdoor sites and 19, 9, and 10 ppm for the indoor sites. The values exceeded the current maximum permissible concentration limit of 10 ppm for all the sites except for the SMC periphery and tractor driver at the indoor sites. Results suggest that H_2S levels detected at indoor storage sites during SMC removal are lower compared to outdoor storage sites. Results indicate that there is a substantial health and safety risk associated with working in the vicinity of stored SMC when it is being disturbed and removed for land application, and that the risk is great for the tractor driver. This article discusses possible control measures and lists recommendations to reduce the risks.*

Keywords. *Hydrogen sulfide, Health and safety, Spent mushroom compost, Tractor driver.*

Hydrogen sulfide (H_2S) is a highly toxic and colorless gas that, at low concentrations (<5 ppm), has a characteristic offensive odor similar to rotten eggs (Guidotti, 2010). At higher concentrations, the health effects at various exposure levels include eye and lung irritation and damage (20 to 50 ppm); olfactory paralysis, severe eye and lung irritation, and pulmonary edema (100 to 500 ppm); and loss of consciousness, depression of neurological and respiratory systems, and sudden death (500 to 2000 ppm) (Costigan, 2003; Guidotti, 2010; Oesterhelweg and Püschel, 2007). H_2S is a common cause of fatal gas inhalation exposures in the agricultural workplace (Shephard, 1999). H_2S is produced as a result of the anaerobic decomposition of organic matter, and it is regularly associated with the disturbance of liquid animal manures and compost (Chénard et al., 2003; Derikx et al., 1990; Scully et al., 2007; Shephard, 1999). In many cases, mul-

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tiple fatalities occur as those who attempt to rescue a stricken individual or animal, without protecting themselves with a self-contained breathing apparatus, may also be overcome by the toxic gas (Guidotti, 2010).

Occupational exposure limits (OELs) are used as an important regulatory instrument to assist in the protection of employees' health from adverse effects of chemical exposures in their workplace (Topping, 2001; Schenk et al., 2008). In many European countries, including Ireland and the U.K., the time-weighted average (TWA) exposure limit for H_2S is currently 5 ppm for a conventional 8 h day, and the short-term exposure limit (STEL) is 10 ppm for a 15 min period, no more than four times per day. These limits are considered adequate to safeguard workers from suffering adverse effects (EC, 2009; HSA, 2010; HSE, 2005). In New Zealand and some Canadian provinces, the limits are 10 ppm (TWA) and 15 ppm (STEL) (NZDOL, 2010; MOL, 2010; OHSD, 2009), while other countries have a "ceiling" or maximum concentration of 10 ppm (or less) to which a worker can be exposed during any part of the work (Arbeidstilsynet, 2010; MOH, 2007; WorkSafeBC, 2010). The American Conference of Governmental Industrial Hygienists (ACGIH, 2010) revised the recommended exposure limits for H_2S to 1 ppm for TWA and 5 ppm for STEL. These lower limits were based on animal and human data that showed measurable metabolic changes in individuals exposed to H_2S at less than 5 ppm, and significant dose-response effects occurring after short-term exposure to around 5 ppm. However, currently these lower limits are health-based values and are not legally binding. The ACGIH recommendations highlight the potential for H_2S to adversely affect human health, even at low levels of exposure.

In 2005 in Ireland, a 14-year-old youth died as a result of H_2S gas poisoning when SMC, which had been stored outdoors for up to a year, was being loaded into a trailer for application on farm land (Khan, 2006; HSA, 2006). This incident identified an unforeseen and unquantified health risk associated with this outdoor farm activity. More information was needed in order to educate the industry on H_2S emissions and exposure risks for personnel involved in the handling of SMC. Subsequently, research was undertaken with two objectives: (1) to characterize the H_2S emissions from stored SMC at four sites during its disturbance and removal for application on farm land, and (2) to monitor H_2S levels in the immediate vicinity of the operators who were directly involved in the handling and removal of the stored SMC (i.e., inside/outside the tractor cab and at the periphery of SMC storage facilities). Results for objective 1 are reported by Velusami et al. (2013); the maximum H_2S concentrations detected at the SMC face were 680 and 2083 ppm for two outdoor SMC sites and 687 and 89 ppm for two indoor SMC sites. These concentrations indicate that there can be a substantial health and safety risk associated with working in the vicinity of stored SMC when it is disturbed and removed for land application, in particular for tractor operators who may be working at SMC sites for several hours or days at a time. This article describes the results for objective 2 and reports the H_2S levels in the immediate vicinity of the operators who were involved in the SMC handling and removal operations described by Velusami et al. (2013). A hierarchy of control measures to reduce the risk of H_2S exposure during this activity is proposed.

Materials and Methods

SMC Storage Sites

Four SMC storage sites were visited between February 2008 and October 2009. Two

were uncovered outdoor sites (sites 1 and 2), and two were indoor sites under cover (sites 3 and 4). The site conditions are described in detail by Velusami et al. (2013). Sites 1, 2, and 3 are relatively large (1450 to 5000 m^3), while site 4 is smaller (about 600 m^3).

SMC Removal Process

The SMC removal process at each site is described in detail in Velusami et al. (2013). In summary, an industrial tractor with front-end loader removed SMC from the face of the heap and tipped it into a manure spreader (fig. 1). At sites 1 and 4, filling the spreader took approximately 5 min, and 10 to 15 min were required to apply the SMC on nearby land (fig. 2), with the same driver for both vehicles. At site 3, one loader and one spreader were used from 9:00 h to 14:15 h on the first day, and three spreaders were used thereafter, each with a dedicated driver. Consequently, the loader driver was working continuously at the SMC face from 14:15 h to 18:00 h on day 1 and all day on day 2. In addition, the tractor cab of the loader had no glass in one side window. At site 2, the SMC was turned continuously for periods of approximately 1.5 h at a time to facilitate degradation and was not removed for land application.

H_2S Monitoring during SMC Removal

QRAE II and QRAE+ gas monitors (www.raesystems.eu) with data loggers were used over the course of these studies. These monitors are accurate to 100 and 500 ppm, respectively, with resolution of 0.1 or 1 ppm. The data loggers were set to automatically calcu-

Figure 1. SMC is tipped into a spreader by the front-end loader at indoor site 4. Stored SMC is visible in the background. The white arrow indicates where the monitor was attached to the outside of the loader.

Figure 2. SMC is applied onto agricultural land.

late the average concentration at 10 s intervals for the duration of the SMC removal operations. A QRAE+ gas monitor was mounted on the front of the tractor close to the loading bucket (fig. 1), and a second monitor was positioned at the SMC periphery. The monitor at the SMC periphery was repositioned at regular intervals to maintain a certain distance from the receding SMC face (5 m at site 1, 30 m at site 2, and 10 m at sites 3 and 4). A personal monitor was worn continuously by the tractor operator during all operations. In addition to recording the 10 s average H_2S concentration, the monitors also calculated and recorded the short-term exposure value (STEV, 15 min average) and the time-weighted average value (TWAV, 8 h average) throughout the operations. Before the start of each site visit, all gas monitors were calibrated according to the manufacturer's instructions using a cylinder of H_2S gas of known concentration.

Personal Safety

H_2S exposure in the workplace is governed by EU Framework Directive (89/391/EEC) on Health and Safety, which is implemented in Ireland under the Code of Practice for Safety, Health, and Welfare at Work (Chemical Agents) Regulations (HSA, 2010). When it became apparent that H_2S concentrations at the SMC face were high (Velusami et al., 2013), operators were advised not to park the front-end loader near the SMC heap when they dismounted to drive the spreader. A full-face gas mask (EN 136:1998 CL 1) fitted with an H_2S filter (EN 141 A1B1E1K1, www.northsafety.com) was provided to the tractor driver during the second visit at site 2.

Weather Data

Weather data (hourly average wind direction and speed) and weather conditions for the days when the SMC sites were visited were obtained from the nearest Met Éireann weather station for each site (www.met.ie), as described by Velusami et al. (2013).

Results

H_2S Levels outside Tractor Cabs during SMC Removal

H_2S gas was generally detected outside the tractor cabs when the SMC was disturbed or turned. The pattern of detection was similar at all sites, with peaks of high concentration occurring at the times when the SMC was actively disturbed and troughs of low concentration occurring when the disturbance ceased. The magnitude of the concentrations differed from site to site and with the age of the SMC.

Outdoor SMC Sites

At site 1 in 2008, H_2S concentrations outside the tractor cab were frequently >75 ppm when 3 to 4 month old SMC was disturbed but mostly <75 ppm when 1 to 2 month old SMC was disturbed (fig. 3a). In 2009, a similar pattern was observed, but H_2S concentrations were generally lower than in 2008 (fig. 4a). The highest concentrations were 243 and 266 ppm in 2008 and 2009, respectively. At site 2 in 2008 and 2009, H_2S concentrations outside the tractor cab were much higher than at site 1, with peaks of >200 ppm recorded on a regular basis (figs. 5a and 5b). The highest concentrations were 422 and 454 ppm in 2008 and 2009, respectively.

The STEV outside the tractor cab during disturbance and removal of SMC at the outdoor sites was >10 ppm on many occasions at site 1 in 2008, especially for 3 to 4 month old material, and in 2009 for 7 to 8 month old material, thus exceeding the STEL of 10 ppm (figs. 3a and 4a). At site 2, the STEV outside the tractor cab was >10 ppm for most of the time in both 2008 and 2009, thus exceeding the STEL of 10 ppm most of the time (figs. 5a and 5b). The maximum TWAV outside the tractor cab during SMC disturbance was 7 and 1.5 ppm at site 1, and 12 and 9 ppm at site 2, in 2008 and 2009, respectively, thereby exceeding the TWA of 5 ppm on three out of four occasions (table 1).

Table 1. Maximum short-term exposure values (STEV) and time-weighted average values (TWAV) recorded outside the tractor cab, at the periphery of the SMC storage area, and by the personal monitor of the tractor driver during SMC disturbance operations.

		Outside the Tractor Cab		Periphery of SMC Storage Area (5 to 30 m distance)		Tractor Driver's Personal Monitor	
SMC Storage Site and Visit		Max. STEV	Max. TWAV	Max. STEV	Max. TWAV	Max. STEV	Max. TWAV
Site 1 (outdoor)	Visit 1	38[a]	7[b]	55[a]	5	7	1
	Visit 2	21[a]	1.5	12[a]	1	5	0.4
Site 2 (outdoor)	Visit 1	147[a]	12[b]	19[a]	1	86[a]	7[b]
	Visit 2	121[a]	9[b]	30[a]	2	40[a]	3
Site 3 (indoor)	Visit 1	19[a]	4	9	1	10	3
Site 4 (indoor)	Visit 1	0.4	0.1	1	0	0	0

[a] Exceeds the STEL of 10 ppm.
[b] Exceeds the TWA of 5 ppm.

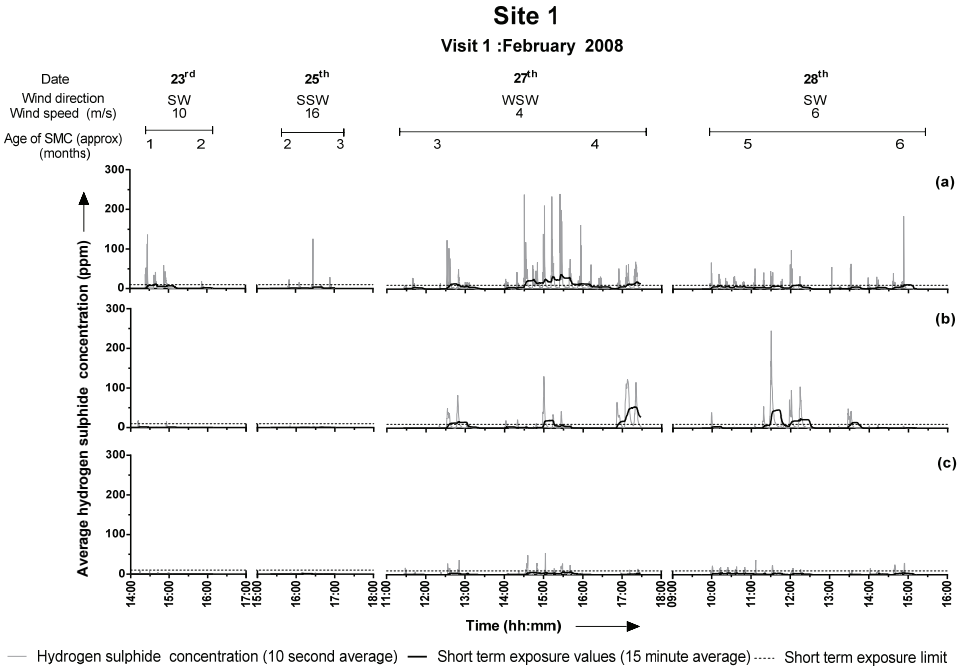

Figure 3. Average H_2S concentrations at site 1 visit 1: (a) outside the tractor cab, (b) at the SMC periphery (5 m), and (c) at the driver's personal monitor. Short-term exposure values, short-term exposure limit, date, wind direction, wind speed, and approximate age of SMC are also indicated.

Indoor SMC Sites

At site 3, H_2S concentrations outside the tractor cab were frequently >25 ppm for 1 to 4 month old material but <25 ppm for 5 to 6 month old material (fig. 6a). The highest concentration detected outside the tractor cab was 214 ppm, but concentrations were generally lower than at outdoor sites 1 and 2. At site 4, H_2S concentrations outside the tractor cab were much lower than at any other site (fig. 7a), with the highest concentrations no more than 5 ppm. The STEV outside the tractor cab exceeded the 10 ppm STEL a few times at site 3 (fig. 5a) but did not exceed this level at site 4 (fig. 7a). The TWAV outside the tractor cab did not exceed the TWA of 5 ppm at either site 3 or site 4 (table 1).

H_2S Levels at SMC Periphery during SMC Removal

H_2S was detected at the SMC periphery in a peak-trough pattern that was less well defined compared to the pattern outside the tractor cab (figs. 3 through 7). Most of the time, the concentrations were lower than outside the tractor, but occasionally they were higher. The highest concentrations of H_2S detected at the SMC periphery were 249 ppm (site 1), 100 ppm (site 2), 75 ppm (site 3), and 9 ppm (site 4). The STEV at the SMC periphery during disturbance and removal was >10 ppm on many occasions for site 1 in 2008 and when 4 month old material was disturbed in 2009 (figs. 3b and 4b). At site 2, the STEV at the SMC periphery was >10 ppm for most of the time in 2009, and when 9 to 12 month old material was disturbed in 2008 (figs. 5c and 5d). The TWAV at the SMC periphery of sites 1 and 2 in 2008 and 2009 exceeded the recommended TWA of 5 ppm (table 1).

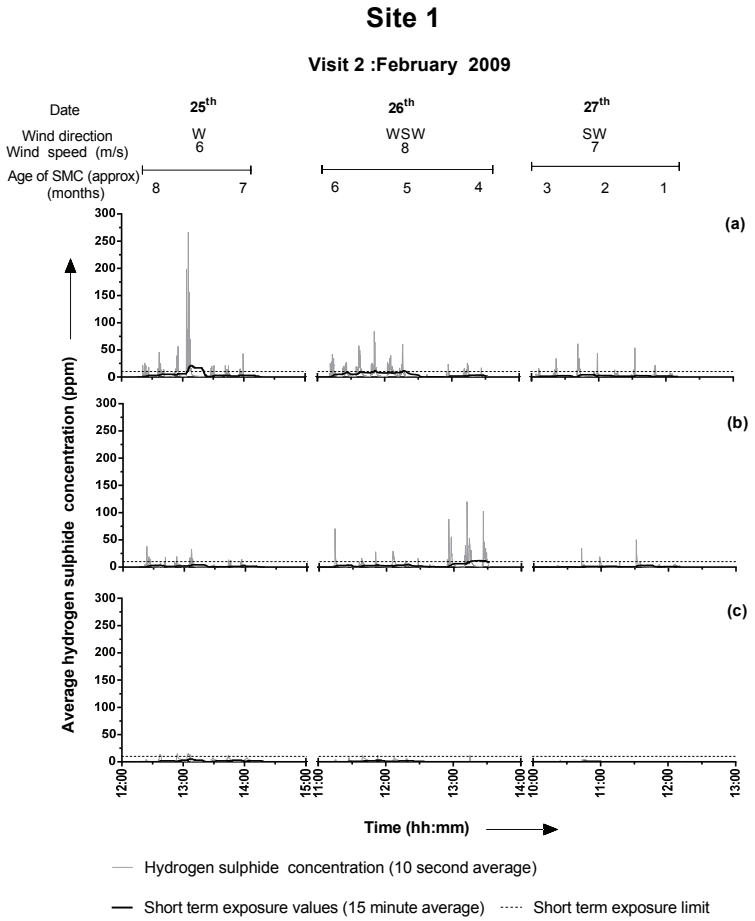

Figure 4. Average H_2S concentrations at site 1 visit 2: (a) outside the tractor cab, (b) at the SMC periphery (5 m), and (c) at the driver's personal monitor. Short-term exposure values, short-term exposure limit, date, wind direction, wind speed, and approximate age of SMC are also indicated.

At indoor site 3, the STEV at the SMC periphery during disturbance and removal was always <10 ppm (fig. 6b), and at site 4 it did not exceed 1 ppm (fig. 7b). The TWAV at the SMC periphery did not exceed the TWA of 5 ppm at either site 3 or site 4 (table 1).

H_2S Levels Detected by Personal Monitors during SMC Removal

Outdoor SMC Sites

H_2S was detected by the personal monitors of the tractor drivers when outdoor-stored SMC was disturbed. At site 1 in 2008, H_2S concentrations in the immediate vicinity of the tractor driver were frequently >10 ppm and showed a peak-trough pattern. In 2009, a similar pattern was observed, but H_2S concentrations were generally lower than in 2008 (figs. 3c and 4c). The highest concentrations of H_2S detected by the personal monitors were 56 and 15 ppm in 2008 and 2009, respectively. At site 2, the H_2S concentrations detected by the personal monitors were much higher than at site 1, with peaks of 25 to

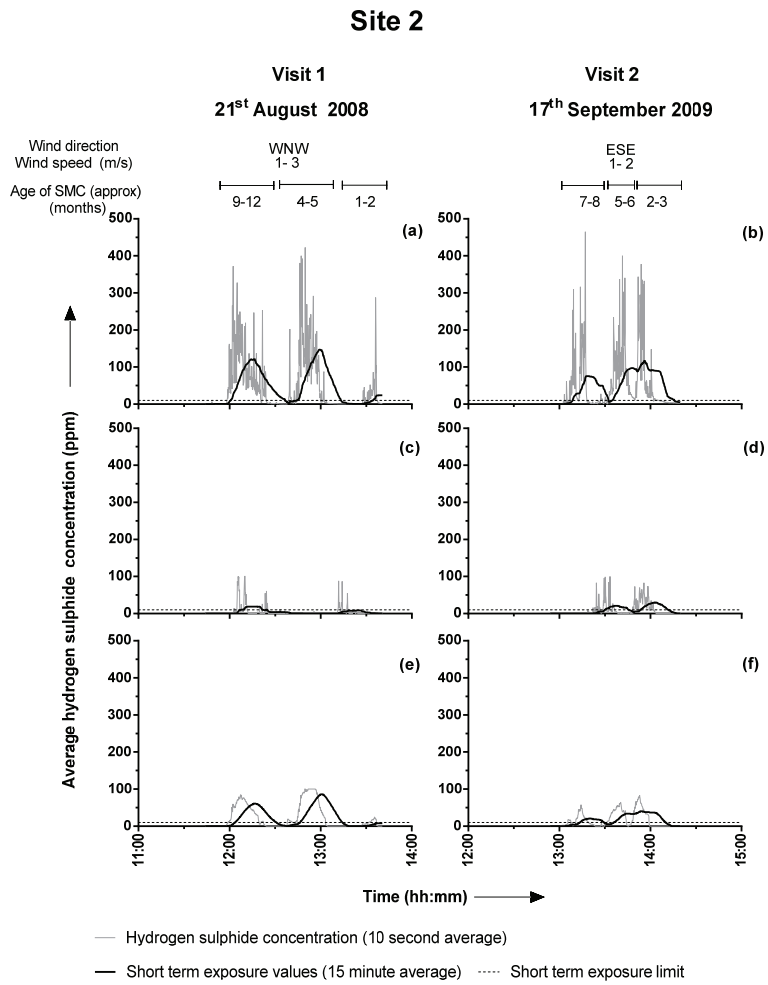

Figure 5. Average H_2S concentrations at site 2: (a and b) outside the tractor cab, (c and d) at the SMC periphery (30 m), and (e and f) at the driver's personal monitor during visits 1 and 2, respectively. Short-term exposure values, short-term exposure limit, date, wind direction, wind speed, and approximate age of SMC are also indicated.

100 ppm (limit of detection) recorded consistently in both 2008 and 2009 (figs. 5e and 5f). The STEV for the tractor driver at site 1 did not exceed the STEL of 10 ppm in either 2008 or 2009 (figs. 3c and 4c). However, at site 2, the STEV for the tractor driver was >10 ppm most of the time in both 2008 and 2009, exceeding the recommended STEL of 10 ppm (figs. 5e and 5f). This highlights a real risk for the tractor drivers at this site. The TWAV for the tractor driver at site 1 was ≤1 ppm in 2008 and 2009, which did not exceed the TWA of 5 ppm. However, at site 2, the TWAV for the tractor driver was 7 and 3 ppm in 2008 and 2009, respectively, thus exceeding the TWA of 5 ppm in 2008 (table 1).

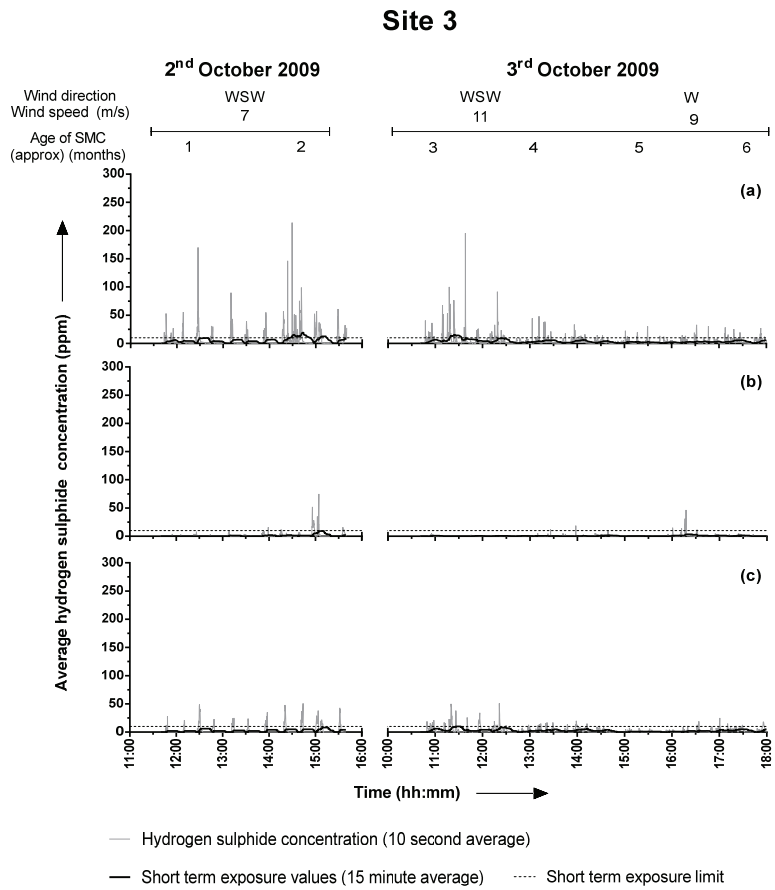

Figure 6. Average H_2S concentrations at site 3: (a) outside the tractor cab, (b) at the SMC periphery (10 m), and (c) at the driver's personal monitor. Short-term exposure values, short-term exposure limit, date, wind direction, wind speed, and approximate age of SMC are also indicated.

Indoor SMC Sites

At site 3, H_2S was consistently detected by the personal monitor of the tractor driver, who was working continuously at the SMC face for most of the day. The H_2S concentration was frequently >10 ppm and reached 50 ppm on a number of occasions (fig. 6c). The STEV for the tractor driver at site 3 was between 1 and 10 ppm for most of the time but did not exceed the recommended STEL of 10 ppm (fig. 6c). The TWAV for the tractor driver also did not exceed the TWA of 5 ppm (table 1). At site 4, the H_2S concentrations detected by the personal monitor of the tractor driver were very much lower than at sites 1, 2, and 3, with the highest peak being 1 ppm and no H_2S detected most of time (fig. 7c). The STEV and TWAV for the tractor driver at site 4 were zero (table 1).

Weather during SMC Removal

Wind speeds during the SMC removal operations were particularly low at sites 2 and 4 (1 to 3 m s^{-1}) and on day 3 at site 1, where the wind speed was 4 m s^{-1}. At all other times, wind speeds were 6 to 16 m s^{-1} (figs. 3 to 7). In 2009, there was intermittent drizzling rain

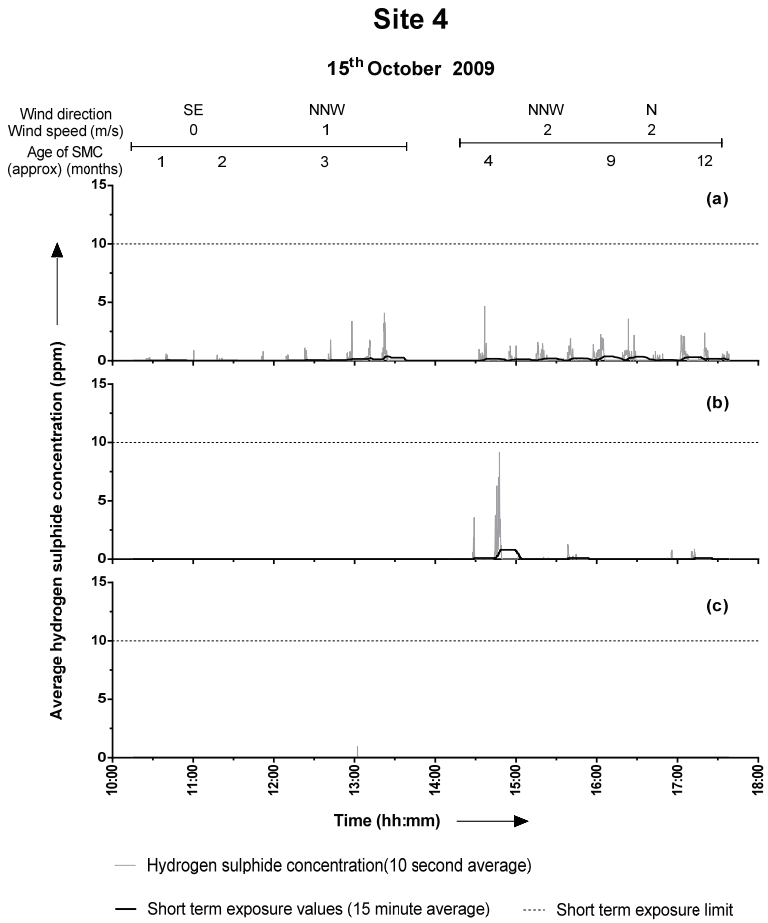

Figure 7. Average H_2S concentrations at site 4: (a) outside the tractor cab, (b) at the SMC periphery (10 m), and (c) at the driver's personal monitor. Short-term exposure values, short-term exposure limit, date, wind direction, wind speed, and approximate age of SMC are also indicated.

during removal operations at site 1.

Discussion

The results presented here identify a clear risk of exposure to toxic H_2S gas for tractor drivers who are involved in SMC removal under normal operating conditions. A health and safety risk assessment regarding potential exposure to toxic H_2S gas should be conducted at SMC storage sites and the necessary steps taken to safeguard operators from H_2S exposure. The risk varies from site to site and is dependent on a number of factors associated with the SMC storage conditions. Velusami et al. (2013) report on the effects of storage conditions and SMC removal practices on H_2S emissions at the four sites in this study. They identify a consistent peak-trough pattern of emissions from stored SMC that reflects the activity of the removal process. Peaks of high concentration occurred as the SMC was excavated from the face of the heap, and troughs of low concentration oc-

curred when the tractor driver was performing a different task, that of driving the spreader containing the removed SMC and applying it on nearby land.

In this study, the site with the greatest risk to tractor operators was site 2, where the H_2S concentration inside the tractor cab was continuously between 10 and 100 ppm for periods of up to 20 min as the driver worked continuously at turning the SMC. A peak concentration of 2083 ppm, which is immediately life threatening (Guidotti, 2010), was detected above the SMC face at this site. This was the highest concentration detected in this study. The very low wind speeds during the SMC turning operations would have contributed to the high concentrations detected, as the released gas would not be dispersed by atmospheric motion. Stored SMC at this site also had a high average moisture content of between 68% and 71% (Velusami et al., 2013). At site 2, SMC storage and handling procedures should be reviewed with a goal of reducing the risks of H_2S exposure. Practical steps that should be considered include: (1) erecting a roof over the SMC storage area to prevent rainfall from landing on the SMC, thereby decreasing the moisture content and the potential for excessive H_2S accumulation; (2) SMC disturbance and removal should only be done when wind speeds are at least >6 m s^{-1} (moderate breeze) to facilitate dissipation and dilution of the H_2S emissions; (3) the tractor driver should wear a personal H_2S monitor and be trained in its operation; (4) the tractor driver should take a short break every hour away from the SMC storage site when working continuously at the SMC face; and (5) the tractor driver should carry a full-face gas mask fitted with an appropriate H_2S filter in the tractor cab when working with SMC, and be trained in its use and maintenance.

Site 3, a large covered storage site, also presented significant risks to the loader operator, as indicated by the readings from the personal monitor, with H_2S concentrations of 10 to 50 ppm detected regularly on day 1 and on the morning of day 2. At this site, the driver operating the loader worked continuously at the SMC face for several hours at a time with no break, as there were three other operators driving the spreaders for land application. The exposure of the loader operator was further exacerbated by the fact that the glass was missing from the main side window of the tractor cab. Thus, the driver had little protection from the high levels of H_2S emissions in the immediate vicinity of the cab, which were regularly between 25 and 200 ppm. Velusami et al. (2013) reported that this SMC heap had a lower moisture content than site 2 because it was covered and protected from rainfall, and the lower moisture content would have reduced the levels of H_2S emissions during disturbance (Velusami et al., 2011). However, despite lower H_2S levels, there was still considerable risk to the operator due in part to the continuous removal practices at this site as well as the missing tractor cab window. At site 3, SMC storage and handling procedures should also be reviewed with a goal of reducing the risks of H_2S exposure. In addition to the five steps listed above for site 2, the following precautions should be considered at all SMC storage sites: (6) tractor cabs should be maintained in a good state of repair, and (7) when several operators are involved in SMC loading and application, the job of loader operator should rotate so that no one person works continuously at the SMC face, especially if the size of the SMC heap requires that the work be done over several days.

At outdoor site 1, the risk of H_2S exposure for the operator was relatively low, as the STEL of 10 ppm was not exceeded during any of the activities, on any of the days, in either 2008 or 2009. At this site, the owner usually tried to ensure there was at least a moderate wind before handling the stored SMC. However, although the STEL was not

exceeded, the driver was exposed to H_2S concentrations of up to 56 ppm in 2008. Exposure to concentrations of 20 to 50 ppm can lead to eye and lung irritation (ACGIH, 2010; Guidotti, 2010). Exposure to H_2S concentrations above 50 ppm may lead to acute conjunctivitis and irritation of the respiratory tract (ACGIH, 2010; Guidotti, 2010). Thus, the driver is still at risk of an adverse health effect. This is a weakness of the STEL and TWA in that they calculate an average value over time and do not take into account brief exposures to high concentrations. Guidotti (2010) also makes this comment. Therefore, a ceiling value, as used in some countries, is also a good OEL to have in place to protect workers from brief exposures to concentrations that can have non-life-threatening but significant health effects. The highest readings in 2008 coincided with a day when wind speeds were low at 4 m s^{-1}, which may have contributed to the higher level of detection as H_2S gas, which is heavier than air, would have a tendency to settle in the absence of any strong winds to disperse it. This reinforces recommendation 2 above that SMC disturbance and removal should only be done when wind speeds are at least >6 m s^{-1} (moderate breeze) to facilitate the dissipation and dilution of H_2S emissions.

H_2S concentrations at peripheral locations were also high on occasion, especially at sites 1 and 2, but not in any predictable pattern. Peak concentrations of H_2S regularly reached 100 ppm at the periphery of sites 1 and 2, and the STEL of 10 ppm was exceeded for considerable periods of time, with maximum STEVs of 12 to 55 ppm. This highlights the necessity for all operators at facilities with potential H_2S exposure risks to be aware of the dangers of H_2S and to wear personal monitors. Additional recommendations therefore are: (8) all staff working in and around an SMC storage facility should be informed about the toxic nature of the H_2S released when SMC is disturbed and the health and safety risks associated with H_2S, and (9) employers should demonstrate what steps have been taken to prevent and reduce operator exposure to H_2S, and what safeguards are in place to deal with unexpected exposure events.

H_2S exposure risks were substantially reduced at site 4, where the SMC heap was small (<600 m^3) and stored under cover. Small storage heaps that are protected from rainfall are drier, and therefore more aerobic, as well as cooler, and therefore less biologically active (Velusami et al., 2011). This means less H_2S production and accumulation. An additional recommendation therefore is: (10) SMC should be stored in small heaps, where possible, to prevent excessive production and buildup of H_2S, which is associated with larger heaps. There is a need now to educate the mushroom farming community in how to eliminate or reduce the risks associated with H_2S emissions.

Conclusions

There is a substantial H_2S exposure risk associated with working in the vicinity of stored SMC when it is disturbed and removed for application on agricultural land. The level of risk varies considerably depending on the storage conditions and operator activity. The risk is very low when the SMC is stored in small heaps (600 m^3) under cover, allowing it to dry somewhat during the storage period, but larger heaps (>1450 m^3), either covered or uncovered, pose significant risks to loader operators and other personnel in the vicinity. The greatest risks occur when SMC is stored outdoors and exposed to high levels of rainfall, causing it to become anaerobic and prone to high H_2S buildup within the heap. The results from the four storage sites in this study highlight areas where changes can be made to reduce the risks of H_2S exposure associated with SMC disturbance. Given this new information, those who store and handle SMC should review their management

system to eliminate or reduce the risks of worker exposure to H_2S in the workplace. The following recommendations aim to reduce the potential for H_2S emissions and change work practices to minimize H_2S exposure risks:

Recommendations to reduce the potential for H_2S emissions from stored SMC:

- Where possible, SMC should be stored under cover (i.e., open-sided barn construction) to prevent rainfall from reaching the SMC, thereby decreasing the moisture content and reducing the potential for excessive H_2S accumulation.
- SMC should be stored in small heaps where possible to prevent the excessive production and buildup of H_2S associated with larger heaps.
- SMC disturbance and removal should only be done when wind speeds are at least >6 m s^{-1} (moderate breeze) to facilitate dissipation and dilution of H_2S emissions.

Recommendations to minimize H_2S exposure risks when working with stored SMC:

- Tractor cabs should be maintained in a good state of repair.
- Drivers of SMC loaders should wear a personal H_2S monitor and be trained in its operation.
- Drivers of SMC loaders should take a short break every hour away from the SMC storage site.
- Drivers of SMC loaders should carry a full-face gas mask fitted with an appropriate H_2S filter in the tractor cab when working with SMC, in case of emergencies, and be trained in its use and maintenance.
- Where several operators are involved in SMC loading and application, the job of loader operator should rotate so that no one person works continuously at the SMC face, especially if the size of the SMC heap requires that the work be done over several days.
- All staff working in and around an SMC storage facility should be informed about the toxic nature of the H_2S released when SMC is disturbed and the health and safety implications associated with H_2S exposure.
- Employers should demonstrate what steps have been taken to prevent and reduce operator exposure to H_2S, and what safeguards are in place to deal with unexpected exposure events.
- Appropriate signs should be erected warning of the danger of H_2S emissions.

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