APPENDIX

B ATSDR Guidelines

ATSDR Guidelines for Public Health Actions in Response to Landfill Fires

I. Background

Fires in landfills can occur for a variety of reasons in essentially any type of landfill. These types of fires present complex problems for a variety of specialists. The fire service must contain and extinguish an underground fire with limited firefighting options available. The environmental officials are confronted with complex chemical reactions in progress involving unknown chemicals and quantities. The environmental health official must recommend public health actions to reduce the acute and chronic health impacts of a situation that may last for weeks or months.

This document is intended to provide guidance only; it should not be interpreted as mandatory. Deviations from the procedures by the environmental health professional are expected and desired when the situation does not conform to the constraints and assumptions made herein.

II. Assumptions

Unless there is reasonable evidence otherwise, the environmental health professional should assume that chemicals are involved in the fire. The types of chemicals most likely to be involved are consumer products that may include consumer-grade pesticides, organic chemicals (usually from paints or solvents), and inorganic chemicals resulting from consumer-grade cleaners and additives to the organic compounds. The smoke from such a fire will contain virtually any compound disposed of in the landfill and may contain all products of thermal decomposition, depending on the efficiencies of combustion and the vagaries of the landfill fire. Usually, the concentrations of any one of these compounds will not be sufficient to cause acute symptoms; however, the combination of so many chemicals at one time may produce an unknown human reaction. Fine particulates in the smoke may play a role in drawing some of these pollutants deeper into the lungs than would normally be expected. Respiratory irritation is likely. A prudent public health assumption is that some individuals exposed to the smoke will have a preexisting respiratory condition (e.g. asthma, emphysema) that increases the probability of acute health impact.

III. Air Monitoring

The primary concern in the initial stages of a landfill fire is air contamination. Organic contaminants can be assessed in a qualitative manner by use of real-time monitors such as photoionization detectors, flame ionization detectors, or infrared ionization detectors. Quantitative data from use of either high volume or personal air pumps should also be considered, especially for fires expected to last for more than 1 week.

A. Real-Time Air Monitoring

Ionization detectors are broad spectrum devices used to detect primarily volatile organic compounds, although some models of photoionization detectors may detect some inorganic compounds. It is important to know the ionization energy of the detector used. Any compound with a first or second ionization potential below this energy can be detected by the instrument. Any concentration in the range of 1–5 parts per million (ppm) above background is a matter of concern.

Real-time aerosol monitors that measure the amount of total particulates in the air are also available; these instruments are not capable of differentiating between chemical and other particulates. The instrument usually works on the principle of refracted light around the particulates in its sensor. Based on this refracted light, a measure of the amount of particulates in the air is usually obtained in milligrams per cubic meter (mg/m^3). A concentration in the range of 0.35–3.5 mg/m^3 above background is a matter of concern.

If specific contaminants are known or suspected with some degree of confidence to have been placed in the landfill, compound-specific colormetric tubes may also be used to obtain a qualitative amount in the landfill. Concentrations in the range of the recommended exposure limit (REL) should initiate concern. Some compounds commonly associated with landfills are hydrogen sulfide, carbon monoxide, hydrogen chloride, and vinyl chloride.

The technology of real-time air monitoring is rapidly improving. Improved instrumentation quickly becomes available with better detection limits, better specificity, better sensitivity, and more accurate readings, often comparable to laboratory results. If available, these new technologies should be considered in the design of an emergency air monitoring program for a landfill fire.

B. Quantitative Methods

While real-time monitoring provides a qualitative indication of what types of contaminants are present and an estimate of their concentration, quantitative measures should be taken to determine the exact composition and concentration of any plume. This type of data is always more appropriate when available. The preferred method is the use of high-volume air sampling that employs a silicate filter for inorganics in series with a polyurethane foam filter (PUF). Samples should be collected for 4 to 8 hours at a sample rate of approximately 10 liters per minute. The filters are then analyzed in a laboratory according to various standard methodologies.

An alternate method that is less equipment-intensive and that does not require an external power source is personal air pumps. With these instruments, separate pumps or manifolds of the same pump must be used for organic compounds (usually collected with a charcoal tube) and inorganics (usually collected with a silicate filter). Sampling procedures are essentially the same, except that the sample rate is usually less than 2–3 liters per minute.

If the fire is expected to burn for more than a month, consideration should be given to recommending use of one of the air sampling vans developed by EPA and based at the EPA Research Triangle Park, North Carolina, facility or a similar mobile laboratory. These vans sample the air for a variety of compounds and quantitatively analyze at the same time.

In many metropolitan areas, an ambient air monitoring network or station may already be in existence. With little or no modification, these stations may be able to provide quantitative data without additional equipment or operating costs.

As part of the new technology that is affecting the instrumentation fields, new instruments are becoming available that combine the advantages of laboratory accuracy with the mobility and timeliness of real-time instruments. These instruments include portable (i.e., handheld or shoulder carriable) gas chromatographs, infrared-red and/or ultraviolet spectrometers, and bioassay meters. Although there are currently some sacrifices in detection limits, specificity, and sensitivity, the line between field instruments, broad-spectrum devices, and laboratory analysis is rapidly becoming more and more blurred.

With careful consideration, quantitative data may be used to adjust action levels to reflect the actual situation more accurately. Sometimes, the adjustment is to increase the action level, potentially impacting fewer people. At other times, an adjustment can decrease the action level to protect a group previously unknown to be at potential risk.

IV. Rationale for Selection of Action Levels

A. Quantitative Data

Quantitative data should be used if available. If the quantitative data are not readily available, means to acquire these data should be sought to verify the real-time data. Recommendations concerning action levels should be developed as they normally would, according to the exposures present (e.g., people, environment, and contaminants) and the expected duration of the fire.

B. Real-Time Readings from Ionization Detectors

EPA, in its original Standard Operating Safety Guidelines, delineated a method for selecting personal protective equipment (PPE) according to real-time readings of ionization detectors. The following action levels are based on that method. The methodology allows for the uncertainity in using broad-spectrum devices and the relative sensitivity of the instrument for different compounds. The EPA guideline calls for response workers to upgrade to air-purifying respirators at 1 ppm total organics above background and to supplied-air respirators at 5 ppm above background.

If the landfill fire is expected to be of short duration (e.g., no more than a few days), real-time readings of 1 ppm above background levels at the closest downwind residences are probably acceptable. If sustained readings are more than 1 ppm above background, then protection of sensitive populations should be considered. If sustained readings are more than 5 ppm above background at the closest residence, then protection of all residents potentially affected by the plume should be considered. Readings taken upwind of the fire should be considered indicative of background concentrations.

If the landfill fire is expected to be of prolonged duration, protection of all residents should be considered at sustained readings more than 1 ppm above background. With fires of this duration, quantitative data should be obtained.

C. Real-Time Action Levels Based on Total Particulates

Total particulate action levels are based, in part, on the color of the smoke and the suspected contents of the fire. Total particulates are recommended here, rather than fine particulates, because using total particulates avoids the necessity of the air monitoring team's having to stop in one place to collect a reading. The need for lots of data, even if of less than optimum characteristics (e.g., air monitoring versus air sampling, total particulates versus PM-10, etc.), is paramount in estimating the limits of the area and population being affected. Without this information, the response options to the unknown situation become either too extensive or not extensive enough.

If the real-time instrumentation available to the community is more sophisticated than described here or if the ever-increasing technology of real-time meters allows, then more accurate and protective action levels may be considered. However, the speed and mobility of the air monitoring teams should not be unduly sacrificed for this greater specificity and accuracy.

If the smoke is black in color, a significant amount of organic material is likely to be present. Black smoke indicates an increased concentration of soot, which is similar to carbon black, a known human carcinogen. If the smoke is gray or another color, contaminants such as inorganics are likely present; most of these will be acid gases and metallic oxides. The action level of 3.5 mg/m^3 and 0.35 mg/m^3 in the presence of sulfides is based on the OSHA PEL for carbon black and on the case studies of the Great London Fog. The action level of 10 mg/m^3 is based on the American Conference of Governmental Industrial Hygenists (ACGIH) threshold limit value (TLV) for particulates not otherwise classified. The action level of 5 mg/m^3 is based on the occupational standards for various acids. These acids were thought to be more of an acute threat than the metallic oxides, both because they were deemed more likely to be generated and because they were thought to be more mobile in the environment. Because of the variations in the readings of the specific instruments, 5-minute time weighted averages (TWA) are suggested to reduce these variations and to provide an additional safety factor.

If the fire is expected to be of short duration and the color of the smoke is black, protection of sensitive populations should be considered at concentrations above a 5 minute TWA of 0.35 mg/m^3 above background at the closest residence downwind. Protection of general populations should be considered at a 5 minute TWA concentration of 3.5 mg/m^3 or more above background at the closest residence. If sulfide compounds are detected with a colormetric tube or other real-time instrument, then the 5 minute TWA for the general population should be reduced by an order of magnitude to 0.35 mg/m^3 to allow for the known synergistic effects of that combination. If the color of the smoke is other than black, protection of sensitive populations should be considered at concentrations above a 5 minute TWA of 5 mg/m^3 above background. Protection of general populations should be considered at 5 minute TWA concentration of 10 mg/m^3 above background. Again, background concentrations can be indicated by readings upwind of the fire.

If the fire is expected to be of prolonged duration, protection of all residents should be considered when the 5 minute TWA reaches 0.35 mg/m^3 for sooty fires and 5 mg/m^3 for less sooty fires. Again, for fires of this duration, quantitative data should become available.

D. Compound Specific Qualitative Data

When there is real-time information indicating the presence of a specific compound at an estimated concentration, the action levels suggested above should be modified accordingly.

V. Other Public Health Concerns

Not infrequently, landfill fires produce other health issues. These issues include deposition of contaminants from the smoke, runoff from the fire or firefighting operations into residential areas or surface and subterranean water supplies, and bio-uptake of either of these. Such concerns are often overlooked, with good reason, during the crisis; however, they should be addressed after the fire. During the fire, there are often simple measures to reduce these longer term threats, each with various drawbacks and advantages; some of these are discussed below. It is usually best to deal with these issues as soon as time and resource limitations permit; however, there is often time to characterize the situation better and arrive at a more considered and accurate choice.

VI. Other Response Actions

Although response actions are the responsibility of risk managers, at times local health officials may be asked to provide technical assistance to the local fire department. If requested, ATSDR should provide background information to these health officials while referring them to the regional EPA office.

One of the first actions that may be recommended is air plume/smoke suppression by use of a water mist or fog. This option would probably result in a large quantity of potentially contaminated water, which should be contained until sampled and disposed of appropriately. However, the air plume/smoke may be substantially reduced, reducing the threat to downwind residents.

Another action that may be proposed is the application of firefighting foam in an attempt to smother the fire. In most landfills, sufficient subterrean voids exist that render this technique largely ineffective. However, the air plume/smoke may be reduced.

Excavating the burning areas of the landfill may be suggested; this is effective but resource-intensive. As portions of the landfill are excavated, concentrations in the air plume may increase and the constituents may change, causing problems for the protection of public health. This disadvantage is offset by the increased rate of burning and the subsequent reduction of time spent in extraordinary measures to protect the public health.

Allowing the fire to burn itself out may also be suggested. This option can be effective, and it uses the least amount of emergency response resources. However, depending on the duration of the fire, the extraordinary measures to protect the public health may have to remain in place for a prolonged period of time.

Sheltering in place (remaining inside buildings and homes) versus evacuation is essentially a risk management decision. Depending on the air concentrations, sheltering in place for most people is usually effective in these situations; however, voluntary evacuations and corresponding shelters should be offered. If specific persons or population groups are sensitive to the health effects of exposure, environmental health professionals should recommend evacuation rather than sheltering. If a given population is relatively immobile, sheltering-in-place should be considered.
If there is an individual who is both sensitive and relatively immobile, the likelihood of sheltering-in-place's failing must be considered in choosing an alternative. That evaluation can be most effectively accomplished at the scene. If the duration of exposure to smoke from a landfill fire is expected to be longer than a few days or if unusual weather conditions prevent normal dispersion of the contaminants (e.g., a temperature inversion), then evacuation is generally the more protective and best recommended action.

Issues regarding containment of runoff will likely come up. General practice is that the runoff should be contained, analyzed, and disposed of accordingly; however, there will be times when containment is not practicable (e.g., heavy rains), not timely (e.g., water flows too high), or too resource intensive (e.g., too large an area to contain or too deep to dig). In those cases, containment of the harm rather than containment of the polluted runoff may have to be undertaken. Containing the harm may include shutting down water intakes for a period of time, using underflow or overflow dams, or using vacuum truck shuttles. Options to implement these kinds of measures will usually be discussed by the cognizant risk managers. As long as the ultimate plan covers the most likely contingencies and uncertainties and still protects the population at risk, then it is probably acceptable from a public health standpoint.

ATSDR Guidelines for Evaluating Gases Migrating from Landfills

I. Background

Landfills, especially those that were operating before the stringent requirements of the Resource Conservation and Recovery Act (RCRA) became effective, may pose a health problem as they age. The problems center on the gases generated by the decomposition of the waste in the landfill. Most of the health concerns of landfill gases typically focus on the gases other than methane that may be part of the landfill gas "stream" and that can produce health effects at much lower concentrations than the fire and explosion hazard of methane.

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II. Assumptions

Unless there is reasonable evidence otherwise, environmental health professionals should assume that hazardous substances were disposed of in any landfill that operated near an industrial area before the effective date of RCRA (~1977). If portable instruments indicate combustible gas readings, the combustible constituents of the landfill gas should be considered to be largely methane (~75%), with the remainder being other flammable or combustible vapors or gases such as benzene.

III. Migration Patterns

In general, there are two pathways by which landfill gases may migrate offsite. The first of these is vertically through the cover; the second is horizontally through the soil. The two pathways are not mutually exclusive; the landfill gases will follow the path of least resistance. Consequently, construction details of the landfill and the geology/hydrogeology of the site will have a bearing on this migration pattern.

Typically, vertical migration is not a concern unless structures have been built on the cover or public access is unrestricted. The gases tend to dissipate in the open environment. However, for people living or working on or adjacent to the landfill, the concentration of landfill gases in the ambient air may pose a concern and may contribute to local air quality problems, odor problems, greenhouse effects, and ozone depletion.. If the gases enter a structure built on the landfill cover, the contaminants can collect in the structure, and the resulting concentrations can reach a level of potential health concern. Depending on the size of the structure and the volume of confined space in relation to the volume of landfill gas entering the structure, a fire or explosion hazard could develop.

Horizontal migration is usually a concern, primarily for off-site structures. The landfill gases will follow the horizontal path of least resistance until they find an avenue to the surface. Because a major constituent of landfill gas is methane, that gas will usually be detected first. If the avenue to the surface accesses the open environment, the gases will dissipate, as they do in the vertical migration pathway. If the avenue intercepts a structure, the gases can build up in the structure as described. According to the data collected by EPA, this horizontal migration is usually limited to about 300 meters from the landfill boundary. [1]

IV. Target Compounds

At any disposal site that accepted industrial waste in its lifetime, the list of analytes should be targeted at the industrial wastes and their environmental degradation products. If leachate or groundwater data are available, the results of this analysis should be considered in determining the target compounds of the landfill gas analysis. Whenever an environmental investigation of a landfill has been prompted by odorous compounds and/or explosive gases, the possible presence of toxic substances should be evaluated as well. With all landfills, alkyl benzenes, sulfur compounds (both organosulfides and acid gases), benzene, vinyl chloride, and methane should be included in an analysis. These are common gases that may be associated with industrial wastes, construction and debris waste, consumer products, normal organic wastes, and/or their degradation products.

V. Sampling Strategy and Locations

As with any form of sampling, the objectives of the sampling effort have to be understood prior to a determination of the sampling strategy. For landfill gases, common objectives may be to:

- determine if an fire or explosion hazard exists
- identify the source of odors
- determine if a toxic substance is being released
- determine if a toxic substance is attaining concentrations of health concern

Depending on the issues arising from any given landfill, other objectives not considered here could arise as well.

Sampling locations are selected based on these objectives and the history and construction of the landfill, the location of receptor populations, and other sources of contamination in the area (i.e., control samples or background concentrations). Fire and explosion hazards are usually a concern only when the gases collect in a confined space such as a building or a basement. Odor concerns arise most commonly in ambient outdoor air. Toxic substances may be a concern in both confined spaces and in ambient air, depending on the human exposure pathway and scenario.

Expected migration patterns are commonly used to determine the orientation of the sampling locations. For instance, “downgradient” locations are usually more numerous and the primary focus of the screening effort. However, “upgradient” samples should also be collected for use as a verification of the migration pattern; to determine if “upstream” diffusion is occurring; or for use as a control or background sample in the event that the migration pattern is well known.

Ambient air sampling locations should be designed through use of predicted prevailing weather conditions. However, the air sampling network should be flexible enough to allow sampling stations in any individual sampling effort to be established according to the actual weather conditions encountered on the day of sampling.

VI. Screening Sampling Techniques

A screening effort is usually the first step. Locations for sampling for a screening effort typically should include vents from the landfill, adjacent structures, and simplistic soil gas sampling between the landfill and the structures. Fourier-transformed infrared-red (FTIR) or Ultra-Violet (UVS) sampling (see below) along the boundary of the landfill should also be considered. In addition to monitoring wells and pre-existing source control (i.e., ventilation and/or “flare”) systems, landfill gases may be sampled from cracks in the landfill cover, from leachate "springs," and from cracks in adjacent structures and paved parking areas.

Several broad spectrum real-time monitors are useful in landfill screening investigations. These monitors include combustible gas indicators (CGI), ionization detectors, and compound-specific monitors (e.g., hydrogen sulfide or sulfur dioxide meters, methane meters, carbon monoxide meters, etc.). These meters are important for detecting changes in the work environment of site investigators and for identifying sampling locations with good prospects of detecting landfill gases. However, the limitations of these monitors need to be clearly understood in any evaluation of the data obtained through their use. For instance, some ionization detectors suffer significant degradation under some conditions common in landfill gases. Methane can reduce the sensitivity of the photoionization detector (PID) by up to 90%[2]. The flame ionization detector (FID) requires enough oxygen in the sampled gas to maintain combustion (oxygen levels > ~ 12% by volume).

For screening efforts, sweep surveys of the landfill surface and adjacent areas by use of FIDs and CGIs to identify areas where fissures and cracks permit landfill gas to escape naturally may be advantageous for locating a well. During the survey, the team must give attention to identifying "flame out," the emission of methane at such a rate that no oxygen gets to the flame to permit ionization of the methane.

Grab samples are also useful as indicators of potential trouble spots. Grab samples may be collected in Tedlar® bags or in SUMMA® or other evacuated canisters. Using real-time monitors to coordinate the timing, team members may find grab samples useful in evaluating peaks in the emissions. The results of the grab sampling can also be useful in modifying the target analytes of future sampling efforts.

Soil gas sampling, both on the landfill and off-site, can be extremely useful. In a screening effort, this type of sampling is normally accomplished with punchbars to varying depths, usually no more than 10 feet and often no more than 3–5 feet in depth. The punchbars should be deep enough to permit obtaining data below any cap on the landfill. After the sampling, the hole should be resealed to prevent inadvertent creation of a new vent for the landfill gases. Because pressure within the landfill is critical to predicting landfill gas migration, pressure measurements at these locations should also be considered.

FTIR and UVS sampling are spectroscopic sampling techniques that detect and identify contaminants in the air along a straight line (e.g., the boundary of a landfill). UVS is typically set up for specific compounds (usually inorganic gases), but FTIR can be used for multiple compounds (usually organic gases). The principle is that the infrared or UV light is generated and then passed to a receptor in a line-of-sight position along a boundary of concern. The receptor either analyzes the spectrography of the light or reflects it to another receptor, which then does the analysis. This second receptor may be part of the source instrument. The spectroanalysis can identify specific compounds and concentrations in the space between the source and the receptor. However, the units are usually given in a concentration of volume per unit distance (e.g., ppm-m) or mass per area of the beam (e.g., mg/m^2). The identified constituents can be added to the list of target analytes [3].

VII. Landfill Gas Characterization

According to the results of the screening effort, a more comprehensive sampling effort can be planned. Sample locations in this expanded sampling would be designed to better characterize the gas streams at those locations identified in the screening effort, in similar locations, and near sensitive receptors (e.g., adjacent structures).

Any of the standard methods for ambient air, indoor air, and/or soil gas that attain the desired level of detection for the target analytes are appropriate for use in characterizing landfill gases over time. The detection limits should be lower than the concentration of health concern. Use of these limits makes protective allowance for the unavoidable errors of any chemical analysis.

Soil gas wells on the landfill, between the landfill and adjacent structures, and near the structures should be considered in any comprehensive sampling program. These wells should include pressure gauges to determine the gas pressure at their locations. This pressure may be used to predict the migration patterns of landfill gases.

VIII. Evaluation of Sampling Data

The health-based interpretation of any sampling data is dependent on the quality of the data obtained, the method of sample collection, the location of the sample, the media of the sample, and the demographics of the surrounding area. Many of the sampling methods, preferably used in conjunction with grab sampling at times most likely to identify peak (or worst-case) emissions, will provide adequate data to characterize the health implications of landfill gases under the conditions of the sample.

As a landfill ages, the constituents and the relative concentration of the constituents in the gas stream will change over time. As environmental conditions change (e.g., the height of groundwater levels), the migration patterns and possibly the constituents of the gas stream may change. Any evaluation of environmental data is valid only for the information reviewed and the conditions during the sample collection. Therefore, once a potential threat is identified at a landfill, continued monitoring or additional sampling may be necessary. If the threat continues, source controls may be required.

Negative results during a screening effort may not mean the characterization effort can stop. More than one screening effort may be required to permit obtaining adequate data to indicate that the landfill does not pose a threat. Multiple screening efforts are particularly appropriate when a screening's results indicate variations in the gas stream so that certain constituents of the stream may pose a threat in the near future.

Conclusions based on sample results should be limited to the capabilities of the sample methodology and the knowledge available about the landfill; other possible impacts should be explored when they could be a concern. For instance, if explosive gases are the original concern prompting an environmental investigation, the bulk of the explosive gases from most landfills will be methane. If the choice is made to investigate combustible gases by use of a CGI only, any assumption as to the constituents of the gas stream and the relative hazard are not warranted. For example, if the explosive level measured by the CGI was 60% of the lower explosive limit (LEL) for methane (3% by volume), technically no fire or explosion hazard exists according to that data. However, there is also a need to consider the possible presence of other explosive gases; if only 1% of the combustible gas is a flammable vapor other than methane—for example, benzene—the landfill gas may contain approximately 300 ppm benzene (3% = 30,000 ppm X 1% = 300 ppm). This value for benzene is well above the OSHA PEL of 1 ppm (8-hour TWA) [4] and the ATSDR acute minimal risk level of 0.002 ppm [5].

Many of the typical landfill gases, notably the alkyl benzenes and the sulfur compounds (both organosulfides and acid gases), may present an odor problem that can cause adverse health effects such as mucous membrane irritation, respiratory irritation, nausea, and stress. If an individual has a pre-existing health condition (e.g., allergies, respiratory illness), these additional health impacts can be significant.

Line-of-sight remote sensor sampling (i.e., FTIR/UVS) yields results that are given in units of volume per distance or mass per area of the beam. A value of 3 ppm-m may mean that the plume attained 3 ppm spread over 1 meter, 300 ppb over 10 meters, or 300 ppm over a centimeter. There are models that can predict, based on the reported values, the emission rate as well as the concentration that may impact downwind receptors.

Given some information in the form of environmental sample results, the environmental health professional should compare the concentrations in the samples to our current state of knowledge about those compounds detected while considering the plausible human exposure scenarios at the site. Whenever possible, the sample results should correspond to the media under consideration in the exposure scenario (e.g., air samples for inhalation exposures). Good quality empirical data should always supercede theoretical predictions (i.e., models), no matter how accurate the theory may be. The exception to that principle is a situation in which an interference or additional source of contamination exists and affects the empirical data. If the empirical data validates a model at a particular location, then that model can be used with confidence as long as the model's conclusions are periodically verified with environmental data. If the model is valid at one site, it does not necessarily mean the model is valid at all sites.

Sampling of two different media at approximately the same time also has inaccuracies, unless the migration rate from the one media to the other is known to approximate the sample collection time. In the example of soil gas to indoor air, the migration rate would be dependent on such factors as the permeability of the gas through the soil and then through the structure, the pressure of the gas in the soil, possible variations in the migration patterns, and other factors unique to the specific type of soil and the environmental conditions at the time of the sampling (e.g., depth to water, ambient temperature, etc.).

IX. References

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