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– monitoring and mitigation of methane at landfill sites

JAMES X JAMES

ISWA International Solid Waste Association

INTERNATIONAL SOLID WASTE ASSOCIATION

Promoting sustainable waste management worldwide

by **Mike McLaughlin and Eric Peterson**

Methane mitigation

Monitoring and mitigation of methane at landfill sites

The landfill gas mixture containing methane is potentially explosive. So the detection and mitigation of methane becomes is important if a former landfill site is to be used for development. What site factors should be taken into account, and how effective are mitigation measures?

Methane is found in areas where buried organic materials decompose in the absence of oxygen. It is produced when methanogenic microbes convert organic materials into methane (CH_4) and carbon dioxide (CO_2). The composition of the gas mixture produced varies depending on the nature of the organic material being decomposed. Unaltered decomposition gas contains about 50%–55% methane, with the remainder being carbon dioxide, together with traces of other gases. In its pure form, methane – a colourless and odourless gas – is lighter than air. In decomposition gas, the mixture has a density near that of air, and this mix is potentially explosive.

Nature of the fill material

It is of paramount importance to determine the nature of the landfilled material when a landfill site is being considered for development. A site that contains mostly inert materials (such as glass, bricks and inorganic soils) will produce relatively little methane. However, a fill site with large amounts of plant-derived materials, organic top soils or municipal solid waste will produce relatively large amounts of methane, often over decades. The rate of methane generation will decrease over time, with the rate of decrease determined by the nature of the decomposing materials and environmental conditions such as precipitation and temperature. (Even 'inert' fill soils can contain traces of roots, topsoil and other organic materials. For deep soil fills [more than 3 metres deep] where anaerobic conditions may be created, these small amounts of organic materials can create small amounts of decomposition gas containing methane. Most of the time these small amounts of decomposition gas go undetected and without incident.)

Subsurface gas pressure

An indication of how rapidly decomposition gas is formed in the subsurface can be found in subsurface gas pressure. The more gas is formed, the more cubic metres of gas per day must find its way from the point of generation to removal points. The larger this gas flux, the greater the potential for subsurface gas to migrate into nearby buildings and other structures. If decomposition gas is producing significant subsurface pressures over an extended period of time, then subsurface gas migration via advection should be considered in addition to migration via dispersion and diffusion.

Geological conditions can dramatically affect the migration of decomposition gas. Where soil is homogeneous, it is less likely that pressure gradients could drive decomposition gas long distances. However, where layers of relatively porous soils are covered by relatively less porous ones, decomposition gas under pressure can move significant distances.

Measurement of subsurface gas pressures generally requires the use of special monitoring probes and a meter. When the probes are first installed they can yield deceptive pressures, as air pockets can be created during construction of the landfill.

Site investigation

Several approaches can be taken to measure decomposition gas at a site. One method is to install relatively deep probes to determine methane and other gas concentrations at depth, such as just above the water table. Another approach is to install relatively shallow probes, often with a 'slam bar', to a depth of about one metre or less. Either approach can yield useful information. Shallow probes are better suited as a screening mechanism for determining whether methane is a concern if the source of the methane is beneath the site (as opposed to an offsite source).

Changing composition

As noted above, unaltered decomposition gas contains about 50%–55% methane, with the remainder being carbon dioxide, together with traces of other gases. When investigators report higher methane (such as above 70%) and lower carbon dioxide concentrations (such as less than 30%), there are several possible explanations:

- operator error
- leakage from a nearby natural gas pipeline
- instrument interference
- decomposition gas has been altered naturally to remove carbon dioxide.

The most common way that carbon dioxide can be removed from decomposition gas is in the presence of moist or saturated soil conditions. Decomposition gas formed slowly beneath the water table will lose both methane and carbon dioxide as these gases dissolve in water. Since carbon dioxide is about 75 times more soluble than methane in water, much more carbon dioxide is lost through this mechanism than methane. The result is altered decomposition gas with relatively high methane and relatively low carbon dioxide concentrations.

A bentonite slurry dam is being installed in a utility trench to prevent gas migration

Decomposition gas is also altered as it moves upward into the shallow (aerated) soil horizon. The methane component of decomposition gas is subject to dilution, oxidation and microbial degradation in the aerated zone. When the gas is moving relatively slowly in the unsaturated soil zone, these mechanisms can significantly reduce methane concentrations. This helps explain why methane present at ambient pressures in the subsurface might not reach buildings constructed directly above the decomposition gas, even if no specific steps are taken to protect the buildings.

Dilution, oxidation and microbial degradation can significantly reduce methane concentrations

Methane gas mitigation

When decomposition gas containing methane is found at significant concentrations at a building site, local building officials or the professional engineer responsible for the development will be required to design and install methane mitigation measures. Several basic approaches to mitigation are available:

- building systems
  - passive systems, using foundation vents, barriers or combinations of vents and barriers
  - active systems, using mechanical extraction or air injection systems
  - alarms
- non-building systems
  - passive cut-off trenches, including vents and barriers
  - utility trench dams
  - active gas extraction systems (can be combined with gas utilization, if gas quantity and quality are sufficient)
  - active air curtain barriers.

It is important to match the mitigation approach to the particular circumstances of a site and development. Sites

ABOVE LEFT A passive system with a PVC membrane barrier at a building site of single-family houses **ABOVE RIGHT** Foundation vents

with large amounts of organic fill are candidates for more elaborate mitigation systems, including active systems. If there is no potential for lateral migration of decomposition gas, then non-building systems may be unnecessary. Buildings constructed on sites with small amounts of organic fill are probably best protected using simple passive systems.

At some sites, buildings are constantly monitored for the presence of methane, with alarms set to sound in the event methane concentrations exceed some low threshold. For other sites, such alarm systems are not needed – a better approach is to design and construct proper engineering controls to protect site structures and then to perform periodic monitoring as necessary to confirm that the mitigation systems are working as designed. Again, the frequency and duration of monitoring should be tailored to match the needs of the site.

At some sites, buildings are constantly monitored for the presence of methane

There is little information available on the long-term performance of mitigation systems. One of the most comprehensive of such studies was performed for the Canada Mortgage and Housing Corporation (CMHC) by CH2M Hill Engineering in 1995. Unfortunately, due to the lack of subsurface gas pressures for the methane concentrations found at the various test sites, it was not possible to use methane concentrations to determine whether the mitigation systems were working as designed.

Instead, a tracer gas was used in the CMHC study to determine how well membranes resisted gas migration several years after they were installed. The tracer gas was introduced inside the home, and a vacuum of about 2.8 inches w.c. (water column) (or 5.25 mm Hg) was placed on the ventilation system below the membrane. Based on limited testing, it appears that reductions of up to four orders of magnitude in the amount of gas migration through the system were attributed to the concrete and underlying membrane.

Critical measures

Although there have been many successful real estate development projects constructed on and near landfills, there has been little research on the long-term performance of methane mitigation systems. Some take the view that such systems are prone to failure, despite the fact that no engineered methane mitigation system has ever failed to the extent that injury resulted.

A wide variety of structures have been safely constructed on and near municipal solid waste landfills and other fill sites. Methane mitigation measures are critical to the safety of those living or working in these structures. Determining what measures are appropriate for a given site requires careful investigation into the nature of the fill materials and site geology, as well as a determination of the decomposition gas composition and pressure. Mitigation measures are important when developing a former landfill. How effective these measures are depends on the system used, the amount of decomposition gas and the soil.

Michael W. McLaughlin, P.E., is Senior Vice President and **Eric R. Peterson, P.E.**, is Vice President of SCS Engineers, a US-based environmental engineering and construction firm.
e-mail: mmclaughlin@scsengineers.com
epeterson@scsengineers.com

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