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Portable Gas Detectors **for Landfill Gases**

The key to success is understanding the monitoring environment, and the specific benefits and limitations of the sensors selected

Anyone who has ever visited or driven by a sanitary landfill is aware that they are frequently associated with the presence of (often) very smelly gases. As unpleasant as the odours can be, there is far more going on than can be detected by human senses.

Landfill gas is potentially explosive, oxygen deficient and often highly toxic. Unfortunately, many of the most dangerous gases associated with landfills have very poor warning properties or are completely invisible to human senses. One of the most common protective measures at landfill sites is to utilise portable atmospheric monitors to keep workers safe. Choosing the best instrument requires a good understanding of the gases that need to be measured, as well as the capabilities and limitations of the sensing technology used by the instrument to obtain readings.

What is landfill gas composed of?

'Landfill gas' is a complex mixture of hundreds of different types of individual gases and vapours. However, by far the most common components are methane (CH_4) and carbon dioxide (CO_2). According to the USA Agency for Toxic Substances and Disease Registry (ATSDR), landfill gas typically contains 45% to 60% methane and 40% to 60% carbon dioxide. Landfill gas often also includes small amounts of ammonia, sulphides (such as hydrogen sulphide and mercaptans), carbon monoxide, hydrogen, and volatile organic compounds (VOCs) such as trichloroethylene, benzene, and various solvent vapours. Besides the importance of what landfill gas contains, it's equally important to understand what's missing. Landfill gas includes very little oxygen and nitrogen. Besides the explosion threat due to the presence of very high levels of methane, landfill gas also represents a significant threat of asphyxiation to unprotected workers.

How is landfill gas produced?

Sanitary landfills are sites where waste is isolated from the environment until it is safe - in other words, when it has completely degraded biologically, chemically and physically. Typically, non-hazardous waste landfills are confined to as small an area as possible, compacted to reduce their volume, and covered (usually daily) with layers of soil to reduce nuisance odours and facilitate microbial decomposition.

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Most landfill gas is produced by bacterial decomposition of organic waste. Bacteria decompose organic waste in four phases, and the composition of the gas changes during each phase. Since landfills often accept waste over a period of several decades, waste in different locations or vertical layers in the landfill may be undergoing different phases of decomposition at the same time. The gases produced by older waste in one area might be quite different to those produced by more recently buried waste in another area.

Fresh air contains 20.9% oxygen, and about 79% nitrogen. That is the starting point for the atmospheric changes that occur during the decomposition process. During the first phase of decomposition, aerobic (oxygen using) bacteria consume oxygen while breaking down the organic waste. The primary by-product of this process is carbon dioxide. Although nitrogen is not consumed by this process, it tends to be displaced by the heavier than air carbon dioxide and other gases being produced. Over time the concentration of nitrogen in the landfill gas declines to ever lower concentrations.

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Aerobic decomposition continues until all the oxygen is used up. Depending on environmental conditions such as compaction and the amount of oxygen initially present, the process can take from a few days to months to complete.

Once the oxygen has been used up, the second phase of anaerobic decomposition can begin. Anaerobic bacteria do not require oxygen. In fact, they can only exist in an active state in environments that contain little or no oxygen. Anaerobic bacteria produce a variety of by-products including hydrogen, alcohols (e.g. ethanol and methanol), organic acids (e.g. acetic and lactic acid) and sulphides (e.g. H_2S and mercaptans). During this phase of decomposition the landfill becomes increasingly acidic. The primary by-products during phase two are hydrogen and carbon dioxide.

In the third phase other types of anaerobic bacteria consume the organic acids produced in the second phase to produce acetate as their main metabolic by-product. This has the effect of lowering the acidity of the landfill, and creating the conditions necessary for yet another category of anaerobic bacteria, the methanogens, to flourish. Methane producing bacteria consume acetate and carbon dioxide produced by the other types of anaerobic bacteria. The whole process requires a 'healthy' ecosystem of many different types of bacteria that interact with each other through their metabolic by-products. Conditions which are deleterious to the existence of one of the necessary members of this complex ecosystem can slow or even shut down the decomposition process.

In the fourth phase, a stable ecosystem of anaerobic bacteria develops that can persist and produce gas at a steady rate over decades. Phase four landfill gas usually contains approximately 45% to 60% methane by volume, 40% to 60% carbon dioxide, and 2% to 9% other gases including H_2S and other sulphides. Not only does landfill gas represent a significant threat with regards to explosion and asphyxiation hazards, it is also often extremely toxic. A single breath of 1,000 ppm H_2S is enough to kill.

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Besides bacterial action, several other landfill processes can act to produce gas and vapours. Certain wastes, particularly the organic compounds in paints, solvents and other petrochemicals can change over time - especially in the hot underground landfill environment - from a liquid or a solid into a vapour. The process is known as 'volatilisation.' Many volatile organic chemicals (VOCs) are highly toxic. Besides representing an atmospheric hazard, VOCs such as benzene and trichloroethylene can also contaminate the water table, presenting yet another challenge to landfill operators. VOCs and toxic chemicals can also be created by the reactions of chemicals present in the waste. Simple household cleaners, such as ammonia and chlorine bleach, can react together to form highly toxic chemical by-products. Not only are the chemicals potentially toxic to humans, they can also be toxic to the landfill's microbial ecosystem. >

What happens to the landfill gas after it is produced?

Lighter than air landfill gases such as methane tend to move upward through interstices or pores in the soil and landfill material, and eventually reach the landfill surface. Once they reach the surface, unless the gas is collected and contained, it diffuses into the general atmosphere. The upward movement can be slowed by compacting and/or covering the landfill with soil. When the path for upward movement is blocked, the gas tends to migrate horizontally. Eventually the gas finds a route to the surface. This could be in another area within the landfill, or in an area outside the landfill. Heavier than air gases such as carbon dioxide also migrate laterally, and are particularly prone to collect in voids or spaces in the landfill, producing pockets of high concentration. CO_2 is particularly prone to collecting in utility vaults, basements and passages around (or adjacent to) the landfill site.

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People can be exposed to landfill gases either at the landfill or in their communities. Once landfill gases reach the surface, they spread into the general atmosphere, where they can be carried by air currents and breezes to anywhere downwind. Gases may also move through the soil underground and enter homes, basements, trenches, vaults and other enclosed or confined spaces. Many landfill sites have systems to collect the gas before it has a chance to escape. Collection systems can significantly reduce the amount of methane and other gases (and odours) released to the atmosphere.

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Portable atmospheric monitors for measuring landfill gases

Landfill monitoring applications involve a number of unique requirements. The anaerobic decomposition of the organic material in the buried waste has the potential for generating massive quantities >

G460 sensors

G460 instruments are compact, easy to use and provide a comprehensive solution for all gas detection applications

of methane and carbon dioxide, as well as potentially lethal concentrations of hydrogen sulphide.

'Wheatstone Bridge' type LEL sensors detect gas by catalytically oxidizing or 'burning' the gas on an active bead or 'pellistor' located within the sensor. The 'active' bead is treated with a platinum or palladium-based catalyst that facilitates the oxidation of combustible gas on the bead. Even trace amounts of gas or vapour in the air surrounding the sensor can be catalytically oxidised on the active bead. As oxidation occurs the bead is heated to a higher temperature. A 'reference' bead in the circuit that has not been treated with catalyst provides a comparison value. Since heating due to oxidation of the combustible gas only occurs on the active bead, the difference in temperature between the two beads is proportional to the concentration of gas in the area where the sensor is located.

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An important limitation of this type of sensor is that it requires the presence of oxygen in order to oxidise the gas being measured. Most manufacturers stipulate that the atmosphere must contain at least 10% O_2 in order for the LEL sensor to detect gas accurately. Readings are increasingly affected as the concentration drops below this level. In zero percent O_2 pellistor type combustible sensors cannot detect gas at all. For this reason confined space instruments that contain catalytic pellistor type LEL sensors should also include a sensor for measuring oxygen.

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Another concern is the high concentrations of combustible gas that may be present. Landfill instruments need to be able to measure in the percent volume as well as percent LEL ranges. Unfortunately, the 'high range' concentrations of methane present in landfill gas (40% or higher) can rapidly damage or destroy catalytic pellistor sensors.

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An alternative approach is to replace the catalytic pellistor sensor with a non-dispersive infrared (NDIR) sensor that measures gas as a function of the absorbance of infrared light. NDIR sensors measure gas as a function of the absorbance of infrared light at a specific wavelength or range of wavelengths. In the case of combustible gas, the wavelength most frequently used is 3.3 μm (micrometres). An active detector in an NDIR combustible gas sensor measures the amount of infrared light absorbed at this wavelength. A reference >

Portable multi-sensor landfill gas monitors can be equipped with standard pellistor LEL, NDIR combustible gas, NDIR CO_2, PID and a wide range of other sensors for the direct measurement of toxic gases

detector measures the amount of light at another wavelength where there is no absorbance. The greater the concentration of combustible gas, the greater the reduction in the amount of light that reaches the active detector when compared to the reference signal.

The other most prevalent hazard associated with landfill gas is carbon dioxide. It should be noted that CO_2 is not a 'simple asphyxiant' that harms workers only by displacing oxygen. Carbon dioxide is a recognised toxic gas, with an exposure limit of 5,000 ppm (8 hour TWA) in most jurisdictions. Carbon dioxide is much heavier than air, and can easily accumulate in excavations, trenches and other localised areas. Besides the danger to workers, these localised areas of oxygen deficiency may not contain enough O_2 for catalytic bead LEL sensors to accurately detect combustible gas. The most widely used technique for real-time CO_2 measurement is also by means of an NDIR sensor. Carbon dioxide has an absorbance peak at a wavelength of 4.3 microns (μm). Absorbance of infrared light at this wavelength is proportional to the concentration of CO_2 present in the sensing chamber of the sensor.

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If the landfill gas is associated with the presence of toxic VOCs, it may be advisable to include a photoionisation detector (PID) in the instrument as well. Photoionisation detectors use high-energy ultraviolet light from a lamp housed within the detector as a source of energy used to remove an electron from neutrally charged VOC molecules, producing a flow of electrical current proportional to the concentration of contaminant. Photoionisation detectors are able to measure VOC concentrations from the parts-per-billion range up to 10,000 ppm.

If the landfill gas is associated with the presence of a specific gas like H_2S, ammonia or carbon monoxide, the instrument should ideally include substance specific electrochemical sensors for the direct measurement of these gases.

Yet another consideration is that landfill instruments are often used to obtain readings from 'bore holes' drilled into the buried material. This type of usage requires the instrument to be available for use with a motorised pump.

An optimal solution in this case would be an instrument equipped with a dual-channel infrared sensor that measures absorbance at two different wavelengths, 3.3μm for combustible gas, and 4.3μm for CO_2. The infrared sensor is 'dual-range' as well as dual-channel. Combustible gas can be measured in either of two user-selectable ranges: 1 - 100% LEL or 1 - 100% volume. Ideally the instrument should also be equipped with substance-specific sensors for measuring O_2, CO and H_2S, and a photoionisation detector (PID) for measuring toxic VOCs.

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Author

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