The following is general input I'd like to share with LMR staff regarding my perception of the effectiveness of landfill gas collection systems from a broad national perspective for their general understanding of common industry practice. As a matter of introduction, I am an environmental professional with many years of experience with landfills and landfill systems, though primarily outside of California. I feel it necessary to submit these comments anonymously as I work for the industry and believe that submitting public comments could endanger my career. In my opinion, there are significant operational deficiencies in prevailing landfill gas collection practices nationally. Exceptp for some clues in Wisconsin's Best Practices manual, it appears that US EPA and the states are unaware of these issues, to the detriment of their ability to regulate landfill emissions effectively.

To the extent that cover material differences do not explain the observed variability in landfill methane plumes from aircraft and satellite studies, I believe there are other factors that are a blind spot in existing state and Federal regulations regarding landfill gas collection systems. The system engineering is done based largely on final build-out and the presumption that the gas collection systems operate as engineered indefinitely. Nothing could be further from the truth. Landfill gas collection wells have a finite service life and many need to be replaced routinely for several reasons, but not every landfill is eager to spend money to replace aging infrastructure. Common reasons wells should be replaced:

- MSW permeability is low and dropping as plastic films become an increasing part of the packaging world and fraction of MSW. As degradables are removed and rigid plastics are increasingly recycled, impermeable films are a larger and larger part of the waste mass. This means less and less permeability to for leachate and absorbed precipitation to reach liner drainage systems via gravity through the waste itself. The lack of waste permeability increasingly leads to perched liquid masses in waste strata, and the dominant path for liquids to reach the intended drainage plane is to move through vertical gas collection wells. The gas collection wells act as drains through the waste and aid liquid reaching the bottom of the waste and the traditional gravity drainage system for collecting leachate as it approaches the liner system.
- Vertical wells functioning as a de facto drainage system has two major side effects that impact gas collection performance. First, the movement of this liquid carries along silt, primarily from layers such as daily cover, into the vertical wells. The slow movement of liquid out the bottom of the wells creates silt deposits that fill up the bottom of the well, blocking the well perforations that were engineered to serve as the path for gas exchange into the well.
- Collection of silt at the bottom of the well further slows its ability to act as a drain for upper waste strata. Leachate collects in the well on top of the silt and further blocks the perforations necessary for gas exchange.
- At the same time, wells must be extended vertically during the landfill's active period so that they are not lost as additional waste height is added. These vertical extensions are normally completed with solid pipe that cannot contribute to gas exchange because it will be above ground or too near the surface until more waste is added. So the well continues to be visible at the surface, but over time there is a tendency for them to lost most of their gas exchange ability, and what is retained is often too far below the surface to achieve comprehensive emissions control.

The easiest and most straightforward way to manage and visualize gas collection systems is to view them from a static 2D perspective and from an intuitive default that the waste is homogeneous and static. Well spacing appears to be reasonable and wells exist in the locations the engineer specified when viewed from a 2D perspective. However, landfills are highly heterogeneous and dynamic, and a great deal about them can only be understood when applying three-dimensional thinking or visualization that is not normally contemplated by those that have not specialized in landfill gas collection. And although many landfill operators periodically sound gas wells to check for depth to bottom and depth to liquid on a voluntary basis, this data is typically difficult to manage and visualize, and the practice of sounding and the data collected from sounding is rarely ever mentioned to regulators. But visualization of the waste column as a cross-section with real data about the location of perforated pipe versus solid pipe and the height of silt and/or liquid in gas collection wells can often indicate that a gas collection well that apparently meets all applicable requirements is impaired or nonfunctional for the purpose of gas collection, as all or nearly all gas exchange perforation is blocked with a combination of silt and liquid, and/or the available perforations too far below the surface to be effective at collecting gas from newer and faster-degrading waste strata nearer to the surface. Such wells collect a minimal amount of methane. Due to some combination of inexperience, turnover, and lack of complete understanding of the subsurface dynamics, gas system operators often convince themselves that these wells are unproductive because they serve an older area of waste. In many cases, though, greater effort in holistic data analysis (like considering trends in gas productivity, applied vacuum, silt/liquid levels, and the location and span of open perforation available for gas exchange would indicate that the well merits replacement. Construction of an adjacent replacement well, built to the same design standards, is often highly productive.

The prevailing engineering practice for gas collection systems is not directly addressing these measures in documents subject to regulatory supervision. Rather, the design documents show each regulated gas collection well is designed with radius of influence calculations to demonstrate that the well spacing is adequate. The calculation assumptions often rely on open gas well perforations being in the right places in all 3 dimensions, and commonly assume that gas wells are operated under 30" water column of vacuum. For many such gas systems, if effort is put into comparing actual operating conditions, given silt, liquid, well raisings, and applied vacuum levels far below the engineer's assumptions, it can frequently be determined that these systems are not achieving the complete system coverage the design engineer certified they would provide. Yet in the current regulatory scheme, regulators don't have the landfill expertise or time to provide the level of supervision necessary to form an option that certain wells have reached the end of their service lives and need replacement. It's just impractical, given that the factors involved that impair well performance operate at different speeds in different cases. I have clients with 10+ year old wells that are performing perfectly, and have also seen cases were certain wells needed to be replaced almost every year due to raising the well, silt collection, and damage to the well casing from impact by waste disposal and heavy equipment traffic. But I have never yet read a gas collection system design plan in which the engineer described conditions under which a well should have silt vacuumed out, have a submersible pump installed for dewatering, or be replaced. The engineering carefully avoids those issues because doing so would impose a cost and regulatory burden on the customer that pays for the engineering design.

There is a persistent perception that any deficiencies in system design and operation will be caught through periodic surface methane monitoring, though US EPA has always insisted that surface methane monitoring should only be an additional assurance that the systems are being designed and operated adequately. I have observed in many cases that a surprising amount of gas collection system impairment can occur without excessive surface methane exceedances, but the recent aircraft and satellite data suggest that the impairment may have a detectable impact. I have developed several hypotheses for the reasons for this mismatch between surface methane monitoring results and other indications of gas collection performance:

- Existing cover systems already have some oxidative capacity, such that some gas leakage at the surface that may have started as methane may not always be released as methane
- Based on the stages of waste decay, leakages may also not be detected because they are primarily hydrogen and/or CO2 rather than methane at the moment the probe checks that location, but the same leakage point may release methane from different strata at other times.
- Fugitive emissions are inherently dynamic with respect to the pressure differentials that encourage or discourage them- both within the waste and as barometric pressure changes. Gas collection itself is highly dynamic as liquid moves through the waste, liquid collection system, gas collection system, and portions of the liquid collection system that is interconnected with gas collection vacuum. Pipes and in-waste gas pathways are constantly blocking and unblocking as the waste generates leachate, generates gas, compacts, settles and shifts, as evidenced by how tuning of gas collection wells shows constant change in these systems. A surface methane monitoring walk path can easily miss leakages that start and stop intermittently and move around the landfill depending on these factors, and there is little reason to believe that all but the most severe problems will leak steadily.
- The ability of the current surface methane monitoring techniques to detect leaks is also highly dependent on weather conditions. If these tests could be conducted in consistently calm weather conditions, the effective stringency of the method would be wildly different than it is during normal breezes that disperse leakage. This is supported by how the plumes detected by satellite and aircraft studies are often diffuse, detected at height and some distance downwind of the landfill rather than directly on top of the landfill, even though the operators of those techniques attempt to monitor during relatively calm conditions. Real landfill gas leakage is almost always released at temperatures above ambient (so with buoyancy) and into non-calm weather conditions. In hindsight, there is no reason we should assume that a ground-level surface probe can detect anything but the most consistent, concentrated, and severe leaks.

I have formed these opinions after more than 10 years of managing landfill gas collection systems, manually and holistically mining that data for understanding and root cause analysis for purposes such as improving collected gas quality to enable renewable natural gas projects. I don't believe that adequate data exists in the public sphere to fully understand these issues, especially from a California-specific perspective given local variation in the composition of cover soils and low rainfall rates relative to the rest of the US. However, I do not believe significant further progress to control landfill methane plumes can be made without acknowledgment and significant public study of differences between the engineering intent of these gas collection systems and the actual operational conditions. My sense is that the difference between high-emitting and low-emitting landfills will have some relationship to cover material types, but will also have significant dependence on the system operator's relative diligence in ensuring that the gas collection wells are maintained in a manner consistent with the design intent for those wells. Certainly in my experience (which is primarily in other states), I have seen many operators struggle to "tune" many a gas collection well without recognizing that it is functionally no longer a well. It looks like a well, and it used to be a well, but over time it became a close-ended pipe that happens to be inserted into the ground, with no functional subsurface connection to the surrounding waste for gas conveyance. With required gas collection wells that are not serving as wells, it is entirely reasonable to expect that pressure will build, that the pressure will find dynamic paths to the atmosphere through a dynamic waste mass, and that those releases are not well suited to be detected using ground-level detectors in an outdoor environment. The industry must move toward a model where if a gas system was designed to have a functional vertical well serving a given area of waste that that the well is maintained in functional state consistent with effective gas collection continuously until a well is no longer a required. Under the current system of state and Federal regulations, it is possible and common for nonfunctional wells to create an appearance of compliance without serving the purposes of the underlying regulatory programs, and this must stop. A required gas collection well is a required air pollution control device, and I know of no other area of air emissions control where nonfunctioning pollution controls can so readily go undetected.

I hope that those reading these comments understand that I have no ill will toward the solid waste industry or landfills; they are my livelihood, and those that design and operate them are no more guilty of environmental wrongdoing than are the consumers that dispose of waste that is sent to the landfills. I simply believe that as part of our responsibility to design and operate landfills as best we are able, and am no longer comfortable with allowing air regulators to not fully understand their blind spots in how gas systems do and don't work. The blind spots have been convenient to the industry in some ways that used to seem harmless, but that illusion has been broken by aircraft studies. The landfill operators that have quietly been maintaining their gas collection wells at a high level of function have been paying extra to do the right thing, but at a certain point we have to help our regulators see the big picture so that the playing field can be level.

Sincerely,

A 20+ Year Environmental Professional