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Report to the Clean Air Council
on
8 June 2012 Field Inspection and Methane Sampling Survey
of
Parts of Leroy, Granville and Franklin Townships Bradford County, Pennsylvania

NOTE: Specific location identification information is avoided in this report pending approval of involved or potentially involved parties.

SUMMARY
A portable laser-based methane measurement system was used to survey methane levels in northeastern Leroy Township, Bradford County, Pennsylvania and adjacent parts of Granville and Franklin Townships on 8 June 2012. The methane system reports methane levels in air to the nearest part per billion (ppb) every 3-4 seconds. During the survey over 7,600 methane measurements were made. The survey data indicated one or more substantial methane emissions were occurring in an area near and to the west of H Rockwell Road and Route 414 giving rise to a ground level plume that expanded to cover at least 4.2 square kilometers over a period of 3.5 hours. The size and rate of expansion of the plume suggested large amounts of methane were being emitted to the atmosphere. Heavily methane contaminated residential water wells occurred in and around the same area, and documentation indicated heavy contamination has existed for at least several months. Bubbling gas in Towanda Creek suggest fugitive gas from shale gas wells may be travelling through faults and fractures, which also carry local ground water, hence, impact local water wells. Collectively the data and observations suggest natural gas has pervaded an extensive subsurface area beyond the area where elevated ground-level methane was found during this survey effort. If that is correct, then more surface emissions are likely and should be expected. The issues and concerns presented in this report require more thorough investigation for confirmation and quantification.

BACKGROUND

A number of dramatic fugitive methane emissions were reported to have begun in Leroy Township on 19 May, 2012. Reports suggested a substantive loss of control of natural gas flows from one or more of the shale gas wells in the Township may have occurred. In the interest of verifying and developing independent documentation of the reportedly large increases in natural gas emissions, the Clean Air Council ("CAC", Philadelphia, PA) contracted Gas Safety, Inc. ("GSI", Southboro, MA) to do a one-day sampling and area visit to ascertain the locations of observed or suspected natural gas emissions. The intention was for GSI to use a customized, portable Cavity Ring-Down Spectrometry (CRDS) methane measurement instrument to investigate and document the occurrence (or not) of the reported emissions.

A major concern was to perform the assessment as soon as possible to better ascertain the possible initial intensity and extent of the event; that is, this would preferably be a short notice, rapid response effort. Other concerns were GSI instrument availability and efficient use of field time with the instrument. In order to assure a one-day effort would be as productive as practical, GSI and CAC contacted various parties in pursuit of information regarding specific locations of reported point-source gas emissions. Like the survey trip itself, such requests for information had to be short notice, rapid response efforts. In the interest of openness and sharing of information GSI proposed to provide through CAC its findings to cooperating parties. GSI contacted the Emergency Management Agency of Bradford County, which preliminarily offered to share its own records regarding the initial reports of the sudden onset gas emissions event. CAC and GSI also contacted various private parties with similar data sharing offers and rapid response requests for information and property access. Within 24 hours of such requests, and despite initially positive responses, only 3 private parties agreed to provide information or access to suspected emissions or impacted areas on private property. Ultimately no specific identification of or authorization for access to the actual point locations of ongoing natural gas emissions was obtained in time for the survey. Hence, work was limited to surveying methane levels on public roadways and verifying methane in well water in three residences and collecting anecdotal reports on three others.

Weather conditions were mild and favorable. Barometric pressure was steady. Winds were from the west-northwest increasing steadily throughout the day from nearly calm to a few miles per hour by the end of the survey work.

The group involved in the methane sampling survey (listed just below) met at the junction of Routes 414 and 514 in the northwest corner of Franklin Township at approximately 09:15 AM on 8 June 2012.

Carolyn Knapp, Bradford County resident
Dan Natt, Bradford County resident

Matt Walker, Clean Air Council
Ron Kanter, videographer, Clean Air Council
Dr. Brian Redmond, PG, Wilkes University,
Dept. of Environmental Engineering and Earth Sciences
Bob Ackley, Gas Safety, Inc.
Dr. Bryce F. Payne Jr., Gas Safety, Inc.

METHANE IN RESIDENTIAL WATER WELLS

A total of four residences (referred to as house1, house2,…) were visited, all served by on-site wells with an interview at house 5 regarding houses 5 and 6. House1 was vacant. It was reported that the residents had vacated due to the inconvenience of and health concerns related to elevated levels of methane and contamination in well water. The house could not be entered, and due to lack of power, no well water could be sampled. Concentrations of methane in the air on the property were normal (normal background ambient air methane 1.75-1.95 ppm).

House2 was located on a farm near a gas well pad (Morse 3H and 5H wells). Most of the area had elevated ambient air methane levels that appeared most likely associated with animal manure accumulations on the farm. Upslope from the farm building area ambient air methane levels were normal. Directly downwind of the gas well pad methane levels were normal. Downslope, toward Towanda Creek methane levels were elevated, with two locations showing >100 ppm in the ambient air just above the surface of the creek bank. In these instances the methane could have been biogenic or fugitive thermogenic, but sampling conditions did not permit collection of samples for isotope analysis.

The water at the kitchen tap in house3 and house4 was supersaturated with methane. Upon flowing from the faucet the water appeared "milky" due to the large amount of fine methane bubbles present. The fine bubbles coalesced over a period of several seconds causing a pronounced effervescence. High levels of methane in the gas evolved from the tap water were confirmed with the CRDS instrument. No attempt was made to verify initial methane concentration in the tap water, but reports of analyses of samples previously collected by PaDEP or contractors indicated that the well water in these homes had been confirmed to contain methane levels from 50 to 100 milligrams per liter, much greater than saturation under atmospheric pressure (about 28 milligrams per liter). Ongoing supersaturation of well water can only occur if there is substantial water "head" pressure in the well and the methane is under sufficient pressure to reach aquifers under such pressure. It should also be noted that such methane levels are sufficient to pose asphyxiation hazards if used for showering or other high water uses in close quarters, symptoms of which the residents of these properties reported.

An additional inquiry was made at another residence (designated house 5). This was a no-notice contact initially to request information on ownership of the

adjacent property. The occupant at house5 reported the well water at that house was similarly heavily contaminated, as well as the well of a close relative who lived in another nearby house (house6).

The wellheads at houses 3-6 had been equipped with passive or wind turbine vents, reportedly by either PaDEP or gas company contractors. Such vents are not designed to prevent or treat contamination of water in wells with conditions and methane exposures of the type that can cause such super-saturation with methane. Presumably the passive vents were installed to prevent pressure driven flow of methane into the homes through possible underground pathways. Though clearly better than the risk of not venting, the application of only passive vents leave the residents under continuing risk of exposures to asphyxiating concentrations of methane, ignore the at least substantial nuisance of having to use methane-super-saturated water, and the potential for serious eruptive releases of methane up through the water well. In addition, such levels of methane contamination necessarily imply the possibility of indirect effects on water quality due to induced biological and chemical changes in the ground water and the mineral medium through which it flows. Such effects might take months or years to become fully apparent, and present a serious concern with regard to long term degradation of aquifers in areas where even less intensive methane contamination occurs.

In summary, of 6 houses visited or about which information was obtained, 5 had well water that was supersaturated with methane. All 5 of those in which methane contamination was observed or reported lie north of Towanda Creek. Four of the five contaminated residences were occupied at the time of this inquiry, and at all 4, passive vents had been installed with the foreseeable lack of effect on methane contamination of the water. The intensity of the methane contamination seems to require more definitive treatment measures as well as efforts to identify the source or sources of the contamination and actions to prevent long-term degradation of aquifers.

SURVEY OF THE AREA FOR METHANE IN THE AIR

Cavity Ring-Down Spectrometry and Baseline Ground-Level Methane Data

The CRDS instrument is extremely sensitive, runs continuously, and is robust. Consequently the unit quickly generates large volumes of highly reliable methane measurements on a continuous basis. During the one-day area survey reported here, the instrument generated 7,697 methane measurements. In combination with similar quantities of data from prior surveys in the eastern Marcellus Shale region, GSI has determined that a reliable (99.99% confidence level) upper bound for background methane levels in ground level air is 1.95 parts per million (ppm). GSI also has identified thousands of gas leaks in commercial pipelines in a variety of settings and based on that experience has concluded that CRDS measured levels of methane in excess of 2.05 ppm reliably indicate a natural gas leak in the

surrounding area. Based on these findings, GSI interprets methane levels above 1.95 ppm as presumptive, and above 2.05 ppm as highly probable methane contamination. There is potential for some biogenic sources to generate enough methane to cause such readings, but such potential biogenic sources are usually readily identifiable, and limited in both extent and intensity in comparison to fugitive natural gas from wells or infrastructure. When more definitive evidence is needed, gas samples are collected and analysed for isotopic composition for comparison to similar data for suspected sources of contaminating gas.

The areas in Leroy, Granville, and Franklin Townships surveyed and reported here had background levels and variations typical for the region, the lowest methane reading being 1.674 ppm (nominal accuracy of the CRDS is 0.001 ppm). Some areas of elevated methane in the air occurred near areas on farms with long-term animal manure loads. No elevated methane levels were found for carcass-handling, and other agricultural areas that might be conventionally considered suspect for biogenic methane production. Interestingly no elevated methane levels were measured downwind of the natural gas well pad (Morse 3H and 5H wells) within the area covered by this survey. This would seem a reasonable finding given the well is new, with limited and new infrastructure.

Elevated methane levels, however, were detected as soon as the instrument was activated at the junction of Routes 414 and 514. All of the initial 157 readings were above 1.95 ppm, 152 were above 2.00 ppm. Such sustained levels above 1.95 indicate a fugitive methane source upwind. An initial drive and walk survey along and near Route 514 covering approximately 2 kilometers to the north and back indicated no methane above reasonable background levels. The initially observed elevated readings at the junction of Routes 414 and 514 had diminished when the instrument was returned to the location just over one hour later.

A driving survey west on Rt 414 (0.6 kilometers), south on Cross Road (0.5 kilometers), and west on South Side Road (2.2 kilometers) again revealed no elevated methane levels, as did a walking survey upslope from South Side Road, downwind from the Morse gas well pad.

Upon descending to the banks of Towanda Creek, methane levels rose above baseline in the vicinity of the creek banks. Random sampling at three locations showed maximum methane levels immediately above the soil surface of 133, 391, and 713 ppm. At the time of the observations there was no basis for inferring whether the methane was more likely biogenic or fugitive thermogenic gas. Methane levels were slightly elevated over most of the surveyed area along the creek.

The next leg of the survey involved a return east on South Side Road, then north across the bridge, and west along Rt 414 (2.2 kilometers) and north on H Rockwell Road (1 kilometer). Methane levels were normal until reaching H Rockwell Road, where elevated levels were again encountered (average of 32 readings = 2.068,

range = 1.967 to 2.184ppm) northbound along the first approximately 500 meters of that road. About an hour later, on the return trip south on H Rockwell Road and east on Rt 414 the methane levels had risen substantially and the affected area expanded south and east. Methane levels began to rise relatively suddenly about 500meters north of Rt 414 from 2.01 ppm to a maximum of 21.979 ppm, then settled into a range of 10 to 14 ppm. The area of elevated methane levels had expanded to the south and east as indicated by measurements along Rt 414 showing levels descending from 4.620 ppm at H Rockwell Road to 2.049 ppm approximately 1 kilometer to the east. Another survey pass was made through the area approximately 1 hour 50 minutes later driving eastbound on Rt 414. The elevated methane levels were then found to have expanded to cover an area from Rockwell Road east along Rt 414 for 2.8 kilometers then north along Rt 514 (2.8 kilometers) at an overall average concentration of 3.8 ppm. The data clearly indicate that one or more methane emissions were present and releasing substantial amounts of methane into the atmosphere probably within 500 meters to the north of Rt 414, near and to the west of Rockwell Road along with other possible emissions occurring or developing within the area enclosed by Rockwell Road and Rts 414 and 514. The measured plume covered an area of approximately 4.2 square kilometers, however, methane data and wind direction indicate the plume probably extended considerably farther to the south and east. Time was insufficient to measure the full extent of the plume to the south and east.

Gas was reported to have been bubbling up in Towanda Creek beneath the Cross Road bridge. The bridge was visited to view the gas bubbling, if present. Upon arrival the bubbling proved to be relatively easily observed. Batches of bubbles were rising to the surface at consistent time intervals and locations, fairly regularly spaced along a line running roughly east-northeast for the entire distance visible from the bridge, about 100 meters west to a somewhat shorter distance east. The directional orientation of the line of bubbles and regular spacing between bubbling points suggested association with a local fault or related subsurface structure. The volume of bubbles per batch were very roughly estimated to be at least 300 cubic centimeters. Over the visible length of the bubble line the bubbling was nearly always occurring at one or more of the locations. Hence, the observed bubbling area was estimated to have been releasing at least 300 cubic centimeters per second, or 18 liters per minute, or 38 cubic feet per hour.

The volume and spatial distribution of the bubbling locations make other potential explanations, e.g., a biogenic methane source in the creek bottom, seem implausible. When the direction of the bubbling line under the bridge was extended to the west-southwest, it intersected the area where methane had been measured in the creek bank soils earlier in the day, suggesting the possibility that methane emissions may have been occurring along a fault line, but due to lack of access and time there was no opportunity to evaluate this possibility.

It is important and useful to note that the gas released in the creek under the bridge could not be confirmed to be methane with the CRDS instrument due to wind

conditions and no access to the bubbling points in the creek due to the high elevation of the deck of the bridge. Further, there is the possibility that the gas in the bubbles is comprised of other gases besides methane. This could presumably be due the air normally present in local faults and fractures being displaced by methane intruding under pressure. If this is the case, then the methane content of the gas in the bubbles would initially contain little or no thermogenic methane, with relatively sudden increase in methane concentration once the fracture is effectively purged by intruding methane

The data available from 3 survey drive-by passes over this area spanned a period of 3.5 hours. Assuming the measured concentration is consistent from the ground surface to 2 meters above, the volume of ground level air in the plume area is 4.2 square kilometers X 2m = 4,200,000 square meters x 2m = 8,400,000 cubic meters. A methane concentration increase of 1.8 ppm would require 15.2 cubic meters of methane. Given the 3.5 hours over which this accumulation occurred, the implied emission rate is 4.3 cubic meters, or 150 cubic feet per hour. This, however, is a major underestimation of the likely volume of gas being released in the identified plume. Methane is a low density gas, about half the density of air. Consequently, methane will tend to rise in the air relatively rapidly and the lowest methane concentrations in the vicinity of a surface methane emission will be expected to occur at ground level. It follows, therefore, that an estimate of the likely methane emission rate in the identified plume area that includes the vertical extent of the plume would be orders of magnitude greater than the above estimate (150 cubic feet per hour) based on ground level methane only. Application of air contaminant diffusion models appropriate to estimating the full-height methane emission rate were beyond the scope of this effort. The most definitive and reliable approach would be direct investigation of methane emissions through water and soil surfaces using the CRDS instrument and appropriate related equipment. However, this approach requires direct access to the properties on which the methane emissions are occurring, which could not be obtained for this effort. Further, emissions through soil surfaces typically are invisible and may occur for prolonged periods with no recognition until vegetation is damaged or killed by asphyxiation of the roots. Hence, many property owners may be heavily impacted but be unaware, and, therefore, reluctant to participant in methane emission survey efforts.

In summary, the methane survey data collected on 8 June 2012 in parts of Leroy, Granville, and Franklin Townships, Bradford County, Pennsylvania indicated one or more substantial methane emissions were occurring in an area centered roughly on the intersection of H Rockwell Road and Route 414. A ground level plume was detected that increased in area substantially over a period of 3.5 hours, which, when expanded to account for above ground level methane, suggests large amounts of methane were being emitted to the atmosphere. Heavily methane contaminated residential water wells occurred in and around the same area, and documentation indicated heavy contamination had existed for at least several months. Bubbling gas in Towanda Creek suggested fugitive gas from shale gas wells might be travelling through faults and fractures, which also carry local ground water, hence, impact

local water wells. Collectively the data and observations suggest natural gas has pervaded an extensive subsurface area beyond the area where elevated ground-level methane was found during this survey effort. If that is correct, then more surface emissions should be expected. The issues and concerns presented in this report require more thorough investigation for confirmation and quantification.