Stray Gas Workshop

November 4–6, 2009

Program with Abstracts

Sheraton Station Square

Pittsburgh, Pennsylvania

Co-sponsored by:
U.S. Geological Survey, Pennsylvania Water Science Center & Eastern Region Science Office and Pittsburgh Geological Society

USGS science for a changing world

Pittsburgh Geological Society 1945

Agencies collaborating with the co-sponsors to plan the technical program:

U.S. Department of the Interior Office of Surface Mining

Office of Surface Mining Reclamation and Enforcement, U.S. Department of the Interior

Pennsylvania Department of Environmental Protection

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Session Schedule for Stray Gas Workshop

DAY 1—WEDNESDAY, November 4, 2009 MORNING SESSIONS

Registration

8:00 am Nametags, registration packets, agenda and program

Plenary Session (Moderator-Fred Baldassare)

Time	*Topic*	*Presenter(s)*	*Affiliation*
9:00 am	Welcome and logistics for the workshop	Dan Hippe	USGS Eastern Region Science Office
		Erica Love	Pittsburgh Geological Society
	Introduce the planning committee and the program	Kevin Breen	USGS Pennsylvania Water Science Center
9:30	"Why are we here?—the need and impetus for this workshop"	Fred Baldassare	Pennsylvania Department of Environmental Protection
9:40	Keynote Presentation-- "From floating golf greens to burning cities, some reflections on the past, present, and future of stray gas identification"	Dennis Coleman	Isotech Laboratories, Inc.
10:45	Break		

Session 1. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-I (Moderator-Kevin Breen)

Time	*Topic*	*Presenter(s)*	*Affiliation*
11:15	"Stray gas migration – Elements of an investigation and case studies"	Fred Baldassare	PADEP
12:15 – 1:30 pm	Lunch "On-your-own" at local eateries in Station Square complex You have 75 minutes for lunch. Please be back and seated by 1:30 pm.		

Plenary Session

Keynote Presentation: "From floating golf greens to burning cities, some reflections on the past, present, and future of stray gas identification." Dennis D. Coleman, Ph.D. Isotech Laboratories, Inc.

Our keynote speaker was raised in northern Wisconsin and received his B.S. from the University of Wisconsin in Madison. He completed an M.S. at the University of Arizona in Tucson and finally a Ph.D. at the University of Illinois, Champaign-Urbana. From 1970 until 1995 he was on the staff at the Illinois State Geological Survey where he held various research and administrative positions. His interest in stray gas identification began during his dissertation research when he learned that you could use stable isotope analysis of methane to identify natural gas that had leaked from underground gas storage reservoirs and that carbon-14 analysis provided a way of identifying landfill methane. Collaboration with researchers at the German Geological Survey (BGR) demonstrated that combined carbon and hydrogen isotope analysis of methane could be used to differentiate the various forms of bacterial methane that occur in nature. That research collaboration also resulting in identifying the changes in carbon and hydrogen isotopic compositions that occur when methane is oxidized by bacteria. To provide analytical support for his consulting activities in the area of stray gas identification, in 1985 Coleman and 3 colleagues founded Isotech Laboratories, Inc. Since that time Isotech has grown to a staff of 39 scientists and support personnel. In 1995, he retired from the Illinois State Geological Survey to devote full time to the operation of Isotech. Although still heavily involved with stray gas identification, Isotech has become the primary laboratory utilized by the oil and gas industry for the isotope analysis of mudgases. The growth in this area has been largely the result of Isotech's development of IsoTubes® for collection and shipment of mudgas samples. IsoTubes® have simplified the collection of samples and have thus increased the application of this new tool for the oil and gas industry. Over the past 35 years Dennis has been involved in numerous investigations and law suits involving stray gas identification. Some of the more interesting case histories and the lessons learned from them will be presented.

Session 1. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-I

"Stray Gas Migration – Elements of an Investigation and Case Studies" Fred Baldassare, Pennsylvania Department of Environmental Protection

Abstract--The migration of stray gases in the shallow subsurface represents an emerging environmental and potentially lethal hazard in some areas of Pennsylvania. The origin of stray gas is often equivocal upon initial investigation. Potential sources may include operating or abandoned gas wells, active or inactive deep mines, permitted or un-permitted landfills, natural gas pipelines, or microbial gas generated in the shallow subsurface. Given this complexity, it is essential for scientists to be methodical in their approach, and that investigations incorporate procedures that provide different lines of evidence. A rapid assessment approach incorporating molecular and isotopic analyses provides powerful geochemical evidence necessary to identify the origin of the stray gas early on in the investigation. Proper interpretation of data generated from these analyses allows the investigator to focus the investigation to concentrate on specific conditions, and the mechanism of migration at the potential source(s). Case studies outlining this approach will be presented.

Session Schedule for Stray Gas Workshop

DAY 1—WEDNESDAY, November 4, 2009 AFTERNOON SESSIONS

Session 1. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-I, continued (Moderator-Kevin Breen)

Time	*Topic*	*Presenter(s)*	*Affiliation*
1:30 pm	"Factors affecting forensic analysis and interpretation of impacts from stray gas well hydrocarbons: pressure, mixing, oxidation, and dilution"	Anthony Gorody	Universal Geoscience Consulting, Inc.
2:30	"Methods for locating abandoned wells in populated areas"	Garret Veloski Richard Hammack	DOE-NETL
3:10	Break		
3:40	"Detection of subsurface methane through geophysical methods"	Peter Hutchinson Maggie Beird	The Hutchinson Group, Ltd.
4:20	"Magmatic carbon dioxide emissions – Environmental affects and hazards at Mammoth Mountain, California"	Chris Farrar	USGS
5:00-7:00	**Evening Reception to "Meet the Speakers"**	Posters and Demonstrations (Appetizers, Steamship Round, Pasta Station and cash bar) The reception will be in the Reflections Room overlooking the Waterfront.	

Session 1. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-I --continued

"Factors affecting forensic analysis and interpretation of impacts from stray gas well hydrocarbons: pressure, mixing, oxidation, and dilution" Anthony W. Gorody, Universal Geoscience Consulting, Inc.

Abstract-- Two phases of investigation are needed to address groundwater impacted by fugitive gas from gas well operations. The first phase involves immediate sampling and analysis to conclusively identify migrating gas sources; the second phase involves monitoring impacts to address the efficacy of remediation efforts. Both require a systems approach for applying and evaluating the results of forensic analytical techniques. Sample analysis of water quality, gas composition, and stable isotope analysis of water, methane homologs, produced CO_2, and dissolved inorganic carbon provide the most useful data. Such techniques must be consistently and repeatedly implemented using pre-defined QA/QC sampling and analysis protocols in order to differentiate among the effects of migration, mixing, oxidation, and dilution. The objective of will be to discuss these topics using select case studies from historic gas well impacts in the San Juan, Raton, Piceance, and Wattenberg basins.

"Methods for locating abandoned wells in populated areas" Garret A. Veloski and Richard Hammack, Department of Energy-National Energy Technology Laboratory, Pittsburgh

Abstract-- An estimated 12 million wells have been drilled during the 150 years of oil and gas exploration and production in the United States. Many old oil and gas fields are now populated areas where the presence of improperly plugged wells may constitute a hazard to residents. The conduit created by these improperly abandoned wells can allow stray natural gas emissions to enter dwellings forcing people from their houses and businesses and have caused explosions that injured or killed people and destroyed property. To mitigate this hazard, wells must be located and properly plugged, a task made more difficult by the presence of houses, businesses, and associated utilities. This paper describes well finding methods conducted by the National Energy Technology Laboratory (NETL) that were effective at two small towns in Wyoming and in a suburb of Pittsburgh, Pennsylvania. Recently, the need to find and plug wells has become critical with the advent of carbon dioxide injection into geologic formations for enhanced oil recovery or for carbon sequestration. Improperly plugged wells are the greatest threat to the success of both activities.

Session 1. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-I --continued

"Detection of subsurface methane through geophysical methods" Peter J. Hutchinson and Maggie H. Beird, The Hutchinson Group, Ltd.

Abstract-- Except for the detection of local accumulations of gas in the shallow subsurface through seismic methods, methane in the subsurface is invisible to most geophysical methods. The pathways and habitat of methane in the subsurface, specifically biogenic gas, are easily imaged through geophysical methods. The generation of biogenic gas in the landfill setting can be mapped with a frequency-domain electromagnetic terrain conductivity (EM) meter because methanogenic bacteria generate wastewater that can be readily mapped. The degradation in the aerobic subsurface is also readily mapped through EM methods as the controlled oxidation of methane can be detected through EM methods. The migration of thermogenic gas cannot be readily detected through geophysical method; however, the migration pathways (i.e., fractures and faults) can be mapped. The migration of subsurface thermogenic gas can predicted through VLF (very low frequency) fracture-detecting mapping methods and seismic methods. The VLF and seismic methods do not directly map methane, just the potential pathways.

"Magmatic carbon dioxide emissions--environmental effects and hazards at Mammoth Mountain, California" Christopher D. Farrar, U.S. Geological Survey

Abstract-- Mammoth Mountain, a Pleistocene volcano in eastern California, although dormant is underlain by an active magmatic system. CO_2, degassing from magma that intrudes the shallow crust, has resulted in high concentrations of CO_2 in soils (up to 95% vol) and high CO_2 emission rates (1000s $g/m^2/d$) in several areas around the mountain. High CO_2 concentrations in the root-zone of soils have caused the total die-off of about 35 ha of coniferous forest. High CO_2-emission rates create hazardous conditions for humans and other animals entering enclosed spaces or depressions in the snow-pack surface. This ongoing release of CO_2 was triggered by seismic unrest during 1989. Anomalous CO_2 emission rates were not recognized until 1994, but later were inferred to have begun in 1990 on the basis of carbon-14 analyses of annual tree rings. The first areally extensive measurements of diffuse emissions, made in 1996, showed about 500 tonnes/day (T/d) of CO_2 were emitted from the entire mountain. Estimates of CO_2 emitted from the three largest areas were made annually from 2005 to 2008 and ranged from 59 to 81 T/d compared to 490 T/d from the same areas in 1996. Although the large decrease between 1996 and 2005 followed by smaller decreases during 2005-2008 suggest an exponential decline in emissions, potentially hazardous levels of CO_2 emissions will likely persist for decades. The anomalous CO_2 emissions at Mammoth Mountain can be used as an analog for studying the potential environmental effects of unintended CO_2 releases from carbon sequestration in geologic reservoirs and from the release of pressure on deep aquifers in conjunction with methane or oil extraction.

Evening Reception to "Meet the Speakers"

Posters

"Methane in West Virginia Groundwater" Melvin Mathes and Jeremy White, U.S. Geological Survey

Abstract--Methane was detected as a dissolved gas in groundwater from 131 of 170 wells sampled in West Virginia for the period 1997 to 2005. Methane concentration exceeded 10 milligrams per liter in groundwater from 26 of these wells and exceeded 28 milligrams per liter in groundwater from 13 of these wells. Methane was detected in wells in 43 of 47 counties sampled, but methane concentrations exceeding 10 milligrams per liter were limited to wells in 11 counties, with 22 of these 26 samples from 8 counties located in the southern coal fields of West Virginia. Groundwater with methane concentrations exceeding 10 milligrams per liter were predominantly from water-bearing zones in rocks of Pennsylvanian age.

"Methane in West Virginia Groundwater--Preliminary Evaluation of Aqueous Geochemistry" Charles A. Cravotta, III, U.S. Geological Survey

Abstract-- The objectives of the study are to 1) document relations among methane and other dissolved gases in 170 groundwater samples, and 2) evaluate major geochemical factors that can be identified with elevated concentrations of dissolved methane. Methane concentrations were inversely related to concentrations of other gases in groundwater. Depth of the water column in the well was correlated with observed gas pressures in water samples. Principal components analysis showed groundwater that had elevated methane was either brine influenced and associated with mixed redox processes or methanogenic and associated with strongly reducing processes. In methanogenic groundwater, elevated methane concentrations (N=10, and concentration of methane = 6 to 56 mg/L) could indicate the accumulation of methane from microbial processes or the influence of stray methane gas.

"Preventing Elevated Concentrations of CO_2 in Homes Built on Reclaimed Mine Spoils" Kwame Awuah-Offei, Missouri University of Science and Technology, Fred Baldassare, P.G., Pennsylvania Department of Environmental Protection, and Moagabo Mathiba, Missouri University of Science and Technology

Abstract--The objectives of the study are to 1) explore the potential for using chamber-based trace gas measurements to quantify CO_2 flux variability over reclaimed coal mine spoil and 2) develop a soil CO_2 flux sampling protocol for reclaimed coal mine spoils. Results for a Somerset County, Pa. test site show large variability in soil CO_2 flux over reclaimed mine lands; however, CO_2 flux measurements show potential for use in estimating and monitoring CO_2 emissions from reclaimed mine spoil. Topics for future research include use geo-statistical analysis to explain CO_2 flux spatial variation and estimate CO_2 emissions. A goal is to work with regulatory authorities to develop reclamation strategies appropriate for mine spoils destined for residential or commercial post-mining land-use.

Evening Reception to "Meet the Speakers"--continued

Demonstrations

"Water Well Venting Practices" Kevin McCray, National Ground Water Association
Abstract—Well construction and venting options with associated hardware will be displayed.

"Sampling for Gases" Steve Pelphrey and Todd Coleman, Isotech Laboratories, Inc.
Abstract—This poster and demonstration will highlight the containers and techniques commonly used for collection of stray gas samples from various sources. Advances in bag and tube sampling devices will be illustrated with several types of containers on display. Steve and Todd will be available to discuss all aspects of sample collection from container selection to shipment of samples to the laboratory.

"Emergency Response Mobile Operations Center and Field Laboratory"
Pennsylvania Department of Environmental Protection
Abstract—Plan to tour the PADEP's mobile operations truck that is designed to respond to stray gas and other emergency situations. The vehicle will be parked in front of the Sheraton and tours with small groups will be conducted by expert DEP personnel.

Session Schedule for Stray Gas Workshop

DAY 2--THURSDAY, November 5, 2009 MORNING SESSION AND LUNCHEON

Session 2. a.m. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II (Moderator-Bill Ehler)

Time	*Topic*	*Presenter(s)*	*Affiliation*
8:30 am	"Covariation of carbon and hydrogen isotopic compositions of hydrocarbon gases: Distinguishing biogenic, thermogenic, and inorganic CO_2-reduction (abiotic) sources"	Robert Burruss Chris Laughrey	USGS Pa. Geol. Survey
9:10	"Noble gases in natural gas of Western New York State and implications for hydrocarbon migration in the Northern Appalachian Basin"	Andrew Hunt Robert Poreda	USGS University of Rochester
9:50	Break		
10:30	"Carbon and hydrogen isotopic evidence for the origin of combustible gases in water-supply wells in North-Central Pennsylvania"	Kinga Revesz Kevin Breen Fred Baldassare	USGS USGS PADEP
11:10	"Effect of fugitive migration of methane on quality of shallow groundwater"	Martha Jagucki Rod Sheets	USGS
11:50	Luncheon Provided with featured "Science for Dessert" speaker		Admiral Room
12:40 pm	"Science for Dessert" Lecture "Gas cloud kills thousands at Lake Nyos, Africa: Identifying the culprit and saving lives in the future"	Michele Tuttle	USGS
1:30	Break…Move back to classroom		

Session 2. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II

"Covariation of carbon and hydrogen isotopic compositions of hydrocarbon gases: Distinguishing gases from biogenic, thermogenic, and inorganic CO_2-reduction ("abiotic") sources"

Robert C. Burruss, U.S. Geological Survey; Christopher D. Laughrey, Pennsylvania Geological Survey

Abstract-- Correlating hydrocarbon gases in shallow groundwater, shows, and seeps to subsurface accumulations or possible source rocks can be difficult due to the range of processes that affect the gas composition and the limited number of independent parameters that were used to characterize gases in the past. Recent analytical advances have made compound-specific analysis of carbon and hydrogen isotopic compositions of methane through pentane possible on a routine basis, providing the maximum possible information on the origin, mixing, and alteration of hydrocarbon gases. *Ab-initio* modeling of isotopic fractionation and empirical studies of carbon and hydrogen isotopic compositions of thermogenic gases show that carbon and hydrogen isotopic compositions become heavier with increasing carbon number. Variations in this trend in gases from different geologic environments provide a framework for interpretation of the origin of hydrocarbon gases in both shallow and deep crustal environments. Analyses of gases by USGS and the Pennsylvania Geological Survey from deep reservoirs of Cambrian through Silurian age in the central and northern Appalachian basin combined with published carbon and hydrogen isotopic compositions of source rock organic matter allow us to correlate gases to sources, identify mixing, and identify thermal alteration of gas compositions. These interpretations shed new light on the processes that affect the compositions of hydrocarbon gases in the shallow subsurface that may occur in groundwater or at greater depth as shale gas resources. New USGS work on hydrocarbon gases in groundwater in fractured basement in New England will also be used to illustrate these concepts.

"Noble gases in the natural gas of Western New York State: implications for hydrocarbon migration in the Northern Appalachian Basin" Andrew G. Hunt, U.S. Geological Survey, and Robert J. Poreda, University of Rochester

Abstract-- The natural gas occurrences in the Silurian and Devonian reservoirs in New York State represent unconventional gas accumulations within the Northern Appalachian Basin. The gas in these accumulations is a mixed thermogenic gas that emanates from a deeper source rock (Jenden et al., AAPG Bull. (1993), 77(6)). Noble gas data in conjunction with carbon isotopic data from the hydrocarbons supports the existence of two separate gas sources. One type of gas was generated *in-situ* and is characterized by isotopically light methane with a noble gas composition dominated by atmospheric isotopes. The second type of gas consists of isotopically heavy methane with a distinct noble gas composition characterized by radiogenic/nucleogenic noble gases (^{4}He, ^{21}Ne, ^{40}Ar).
The second, overly mature source gas has migrated upward from a possible Lower Ordovician source rock into the Lower Silurian Medina or Clinton sands as well as into the Upper Devonian Canadaway and Marcellus shales. Whereas the Lower Silurian reservoirs preserve the key isotopic signatures of the overly mature gas, the Devonian reservoirs contain a mixture of an *in-situ* generated gas and a component from deeper sources. Reference: Jenden, P.D., Drazan, D.J., and Kaplan, I.R. (1993) Mixing of thermogenic natural gases in Northern Appalachian Basin. *AAPG Bull.* 77(6), 980-998.

Session 2. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II --continued

"Carbon and hydrogen isotopic evidence for the origin of combustible gases in water-supply wells in North-Central Pennsylvania" Kinga Revesz and Kevin Breen, U.S. Geological Survey, and Fred Baldassare, Pennsylvania Department of Environmental Protection

Abstract-- The origins of the natural gas in water-supply wells at Tioga Junction, Tioga County, were investigated by the USGS in cooperation with the PADEP using compositional and isotopic characteristics of methane and ethane in gas and water wells. A review of geologic literature identified four plausible origins for natural gas: 1) deep native gas in the Oriskany Sandstone; 2) shallow native gas in Devonian shale bedrock; 3) microbial (drift) gas from organic debris in unconsolidated sediments; and 4) non-native gas in a gas-storage field. Gases from the Oriskany and the gas-storage field were similar in chemical composition with methane (CH_4) and ethane (C_2H_6) predominant; however, the gases had different isotopic compositions. Water wells with high methane concentrations occurred in clusters along the flank of an anticline and along the anticline axis near a gas-storage field. The $\delta^{13}C_{CH4}$ values in groundwater were measurable in 35 out of 91 sampled waters. The isotopic composition of methane in water samples from 14 wells supported the microbial origin (drift gas). The isotopic composition of methane in water samples from the other 21 wells supported a thermogenic origin. The $\delta^{13}C_{CH4}$ and $\delta^{13}C_{C2H6}$ values of thermogenic gases from water wells either matched or were intermediate between the samples of non-native storage-field gas from injection wells and the samples of gas from storage-field observation wells. Processes responsible for the presence of microbial gases in groundwater could be elucidated with further geochemical study.

"Effect of fugitive migration of methane on quality of shallow groundwater" Martha Jagucki and Rodney Sheets, U.S. Geological Survey

Abstract-- Accidental releases of gases from natural gas wells to shallow aquifers sometimes occur. The reactivity of these "fugitive" gases with the shallow aquifer environment does not seem to be well understood. A survey of literature indicates two hypotheses: (1) Methane, a primary component of natural gas, is not reactive and is biologically inert—particularly in anoxic environments. (2) Oxidation of fugitive methane can be linked to bacterial iron and (or) sulfate reduction, which in turn leads to increased hydrogen sulfide and alkalinity in groundwater. A survey of case studies from Texas, Ohio, and Alberta will be presented. These studies support the hypothesis that the introduction of methane to shallow aquifers instigates bacterial reduction reactions. Some of these studies found that iron, manganese, and (or) sulfide minerals precipitated (along with various trace metals) when fugitive methane was introduced into shallow aquifers.

DAY 2--THURSDAY, November 5, 2009 "SCIENCE FOR DESSERT" LUNCHEON LECTURE

"Science for Dessert" Session

Luncheon Presentation: "Gas cloud kills thousands at Lake Nyos, Africa: Identifying the culprit and saving lives in the future" Michele L.W. Tuttle, Ph.D. U.S. Geological Survey

Abstract-- In 1986, Lake Nyos, Cameroon released a cloud of CO_2 that killed 1,700 people and devastated domestic herds and wildlife for many square kilometers. Was this the work of lake spirits or a geologic phenomenon previously unrecognized? This talk answers this question, forecasts future degassing events, discusses mitigation strategies to save lives, and takes us on a tour of the mysteries surrounding Lake Nyos immediately following the disaster. Our speaker will describe the unique conditions observed at this dangerous lake and present the clues collected to identify the culprit responsible for so many lives being lost. The current working model of gas accumulation and catastrophic release is based on data collected over nearly 20 years since the disaster. The model provides the fundamental knowledge about this rare and newly recognized natural hazard--carbon dioxide accumulation in, and catastrophic release from crater lakes. Application of this knowledge has been used to predict immediate and longer range hazards, not only in Lake Nyos, but in other CO_2-charged African lakes as well.

Speaker Profile--Our "Science for Dessert" speaker is a research geochemist with the USGS in Denver. She did her undergraduate work in chemistry at the University of Colorado and earned a master's and doctorate in geochemistry at the Colorado School of Mines. Michele's current research focuses on environmental geochemistry with studies on the weathering of black shale and the mobilization, transport, and fate of metals during weathering. She serves as a scientific consultant to the U.S. State Department and the United Nations for hazards associated with CO_2-charged crater lakes in Africa. In 1986, Michele was part of the State Department's disaster response team, and arrived at Lake Nyos 7 days after the disaster. She continued monitoring the lake for a decade. Michele has given talks on Lake Nyos at universities throughout the country as a Distinguished Lecturer for the Association of Women Geologists.

Session Schedule for Stray Gas Workshop
DAY 2--THURSDAY, November 5, 2009 AFTERNOON SESSION

Session 2. p.m. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II (Moderator-Dan Hippe)

Time	*Topic*	*Presenter(s)*	*Affiliation*
1:40 pm	"Isotope geochemistry for determining sources of stray carbon dioxide gas"	Chris Laughrey Fred Baldassare	Pa. Geol. Survey PADEP
2:20	"Geostatistical modeling of CO_2 flux spatial variation"	Kwame Awuah-Offei, Fred Baldassare, Moagabo Mathiba	Missouri Univ. of Sci. & Tech. PADEP Missouri Univ. of Sci. & Tech.
3:00	Break		
3:30	"Dangerous atmosphere created by strip mine spoil"	Bill Ehler	OSMRE
4:10	"The occurrence and mitigation of carbon dioxide in residential structures"	Bret Robinson	USGS
4:50	Looking ahead to Day 3	Dan Hippe	USGS

Session 2. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II --continued

"Some applications of isotope geochemistry for determining sources of stray carbon dioxide gas" Christopher D. Laughrey, Pennsylvania Geological Survey and Fred Baldassare, Pennsylvania Department of Environmental Protection

Abstract-- High concentrations of stray carbon dioxide in buildings are an emerging environmental hazard in certain areas of the Appalachian coalfields. In western Pennsylvania, potentially lethal concentrations of CO_2 (up to 25%), attended by low volumes of O_2 (<10%), have driven families from their homes. This CO_2 is primarily anthropogenic in origin, although the specific source is often uncertain. Multiple potential sources of CO_2 necessitate detailed geological investigations to positively identify their origins. Isotope geochemistry provides the most accurate technique for identifying the specific gas source. Both organic and inorganic processes in the Appalachian coalfields generate carbon dioxide. Carbon dioxide derived from organic substrates by microbial activity is enriched in ^{12}C. Carbon dioxide derived from carbonate materials is enriched in ^{13}C. Variations in $^{13}C/^{12}C$ of CO_2 facilitate the differentiation of stray gas from organic or inorganic sources. The activity of ^{14}C can support the identification of geologically recent microbial gas generation. Groundwater chemistry can support interpretations of an inorganic CO_2 source based on stable isotope data. Three case studies from western Pennsylvania demonstrate the ambiguity of compositional gas data alone for determining a gas source, and the power of isotopic analyses to confidently identify specific sources of stray CO_2 in buildings.

"Geostatistical modeling of CO_2 flux spatial variation" Kwame Awuah-Offei, Missouri University of Science & Technology and Fred Baldassare, Pennsylvania Department of Environmental Protection

Abstract-- Potentially lethal concentrations of CO_2 have been recorded in homes situated on or adjacent to reclaimed or active surface mines. In most cases, these high concentrations have been attributed to CO_2 from acid mine drainage (AMD) and mineral carbonate reactions. Geostatistical methods, like kriging, have been proven to be effective in modeling the spatial variability of environmental contaminants. However, the feasibility of using geostatistics to model the spatial variation of CO_2 on reclaimed mine land from AMD-mineral carbonate reactions has not been adequately explored yet. The objective of this presentation is to use a case study to illustrate the benefits, and future research directions, of CO_2 flux modeling using geostatistics. Flux measurements were collected on a reclaimed mine site in Pennsylvania, known to have caused high CO_2 concentrations in a home. The data was then analyzed and used in kriging estimation. The maximum flux of replicate samples from the sample points ranges from 2.2 to 14.46 $\mu mol/m^2/sec$ with a mean of 7.67 $\mu mol/m^2/sec$. A map of the CO_2 flux, and its probability to exceed a threshold of 5.5 $\mu mol/m^2/sec$, was derived from the kriging results for the 57-acre site. The work shows there is great potential for modeling CO_2 flux spatial variability using kriging, and other geostatistical methods. The threshold mapping methodology will be valuable in developing zoning guidelines to prevent the occurrence of CO_2 accumulation in buildings on or adjacent to reclaimed or active mines. Further research should address optima grid spacing and covariance models.

Session 2. Fugitive and Stray Gases—Investigation Strategies, Tools, and Case Studies-II --continued

"Dangerous atmosphere created by strip mine spoil"
William C. Ehler, Office of Surface Mining Reclamation and Enforcement

Abstract-- Dangerous, low oxygen levels, commonly referred as blackdamp, are often caused by carbon dioxide (CO_2) and nitrogen produced from abandoned underground coalmines. The blackdamp atmosphere from adjacent underground mine voids displaces normal air in homes through changes in air pressure. Three homes near and on a recently reclaimed strip mine are affected by blackdamp with no obvious association to deep underground mining. During periods of low barometric pressure, atmospheric levels of 12 to 25% CO_2 and near 10% oxygen (O_2) by volume entered the basements of these homes for periods exceeding 12 hours. Drilling indicated that CO_2 was concentrated throughout the permeable mine spoil beneath one of the homes. The other two homes were adjacent to the strip mine but not undermined. The source of the CO_2 production in the strip mine was initially unknown. However, three potential sources were identified: 1) deep, open mine entries encountered during surface mining activities; 2) organic and landfill waste disposed in the mine pits; or 3) the dissolution of carbonate materials from reactive waters deep in the spoil. The source of the blackdamp needed to be identified to allow Abandoned Mine Lands funding for abatement of the project. Stable isotopic analysis ($^{13}C/^{12}C$) of the CO_2identified that the gas was inorganic in origin, specifically, from dissolved carbonate material in the spoil. The water chemistry also supports a high capacity to dissolve carbonate material. The overburden analyses of the mine spoil showed a significant source of carbonate material in a glacial till at the site. The normally attractive neutralization potential of this glacial till combined with the waters from the adjacent abandoned mine to produce a detrimental source of CO_2.

"The occurrence and mitigation of carbon dioxide in residential structures"
Bret Robinson, U.S. Geological Survey

Abstract-- In recent years it has been recognized that hazardous concentrations of carbon dioxide (CO_2) may accumulate in homes constructed on or near reclaimed coal mines. At many sites where CO_2 accumulation has been identified as a health threat, standard radon-mitigation systems have provided satisfactory solutions. However, at one particularly problematic home in Pike County, Indiana, building-foundation characteristics were not compatible with a standard radon-mitigation system, and therefore no CO_2 mitigation system was constructed. This site has represented an ongoing health hazard for its occupants. To investigate the phenomenon of CO_2 accumulation, a broad range of environmental data is being collected at the home. These include: documenting CO_2 flux from soils across the study-site landscape; determining the chemistry of spoil samples and masonry materials collected at the study site; establishing an on-site continuously recording meteorological observation station; measuring ground-water level fluctuations within on-site nested monitoring wells; and evaluating CO_2 data collected within the study-site home. Additionally, data are being collected to evaluate the effect that several soil-gas-mitigation approaches have on reducing CO_2 levels within the study-site home. To complete this phase of the investigation, mechanical systems were constructed which can create low-pressure or high-pressure within the basement walls, under the basement slab, and under the garage slab. These systems can be run individually or in any combination and documenting CO_2 levels within the home will allow us to evaluate the potential that these systems have to reduce in-home CO_2 concentrations to acceptable levels.

Session Schedule for Stray Gas Workshop
DAY 3—FRIDAY, November 6, 2009 MORNING SESSION

Session 3. Mitigation and Safety (Moderator-Rod Sheets)

Time	*Topic*	*Presenter(s)*	*Affiliation*
8:00 am	"Carbon monoxide poisoning at a surface coal mine – a case study**"**	Ken Eltschlager, William Shuss, and Thomas Kovalchuk	OSMRE PADEP
8:40	"Pipeline integrity--PUC's investigative and regulatory requirements for assessing natural gas migration from pipelines."	Ralph Graeser	PA PUC
9:20	"Well integrity-vertical & horizontal cement evaluation"	Todd Sutton	Schlumberger Oilfield Services
10:00	Break		
10:20	"Combating air and gas issues in water well construction and water well operations"	Kevin McCray	National Ground Water Association
11:00	Wrap-up and Closing Announcements	Rod Sheets and Planning Team Panel	
11:30	Adjourn		

Session 3. Mitigation and Safety

"Carbon monoxide poisoning at a surface coal mine – a case study"
Kenneth K. Eltschlager, Office of Surface Mining Reclamation and Enforcement,
William Shuss, and Thomas E. Kovalchuk, Pennsylvania Department of Environmental Protection

Abstract-- In April of 2000, two adults and their newborn infant, were poisoned by carbon monoxide in their home and received medical treatment at a Pennsylvania hospital. Carboxyhemoglobin levels were; child - 31%, father - 28%, and mother - 17%. Initially the furnace was blamed but after further review, blasting at a nearby coal mine was determined to be the source. All other sources of carbon monoxide were ruled out. The blasting was about 400 feet from the house. The conditions that led to the migration of gas include: the blasts were highly confined, the geologic structure contained fractures that served as conduits for the carbon monoxide to reach a hand-dug well outside the house, and the well was atmospherically connected to the basement floor drains.

"Pipeline integrity—Pennsylvania PUC's investigative and regulatory requirements for assessing natural gas migration from pipelines."
Ralph Graeser, Gas Safety Division, Pennsylvania Public Utility Commission

Abstract-- The Pennsylvania Public Utility Commission regulates the natural gas utilities for safety and reliability. This presentation will cover the Gas Safety Division's responsibility to find, and evaluate stray gas issues. This presentation also will discuss ways that pipeline companies verify the integrity of their systems.

"Well integrity-Vertical and Horizontal Cement Evaluation"
Todd Sutton, Schlumberger Oilfield Services

Abstract-- Zonal isolation is critical for eliminating water, gas, and oil communication in vertical wells. Cementing provides hydraulic isolation for preventing fluid migration and stimulation containment in vertical and horizontal wells. Modern light weight cement slurries can have acoustic properties similar to liquids and demand new approaches in cement evaluation. This presentation will focus on applications for the new Isolation Scanner technology which adds a new Flexural Attenuation measurement to improve low impedance cement evaluation. Applications for the Cement Bond Log -Variable Density (CBL-VDL), Cement Mapping Tool (SCMT) and UltraSonic Imager (USI) will also be covered.

Session 3. Mitigation and Safety--continued

"Combating air and gas issues in water well construction and water well operations"
Kevin McCray, National Ground Water Association

Abstract-- Some groundwaters will contain gases – carbon dioxide, methane, hydrogen sulfide, radon – that can be problematic at times of water well construction and during well operation and maintenance. For example, methane gas may occur naturally in groundwater, and when it does it may create risk of fire and explosion that endanger personnel at a well site, but also equipment used to construct and/or service a well. While well construction methodologies are limited to mitigate the risk of gases within groundwater flowing into a well, certain well construction features, most notably venting, can help. Another risk to safe and proper water well operation is when air or gas gets into a water well pump, liquid is displaced and the pump can become airbound, resulting in a loss of pump movement and subsequent risk of damage to the pump. Practices to reduce this problem will be discussed. The presentation will also look at the issue of so-called breather wells and their potential risk to well service personnel.

NOTES: