CoPhysics CORPORATION

Radiological Survey Report

Marcellus Shale Drilling Cuttings

from Tioga and Bradford Counties, Pa.
and
New England Waste Services of N.Y., Inc. Landfill Sites in
Chemung, NY
Campbell, NY
Angelica, NY

April 2010

Performed by:

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Introduction

New England Waste Services of N.Y., Inc. (NEWSNY) operates 3 landfills in the southern tier area of New York State. In the last several years, these landfills have accepted natural gas-related drill cuttings from several wells in New York and Pennsylvania. (Drill cuttings are the ground rock resulting from the drill bit's penetration into the earth.) More recently, deeper Marcellus shale cuttings have been accepted from drilling operations in northern Pennsylvania. Oil and gas companies have been disposing of approximately 1000 to 2000 tons per week of cuttings in the nearby NEWSNY landfills as well as significant quantities in other landfills in Pennsylvania.

Recent advancement in horizontal drilling technology has led to increased interest by the oil and gas industry in Marcellus shale development, both in Pennsylvania and New York State. Possible radioactivity in the drilling process waste streams is receiving public and regulatory scrutiny. Most studies to date have focused on the liquid discharges, termed "produced water", from the gas wells rather than on the drill cuttings. NEWSNY has confirmed that their landfills do not accept liquid waste, produced water, or sludge. Because of the lack of radioactivity data on the rock itself, NEWSNY has contracted CoPhysics Corporation to conduct a radiological investigation of the rock to determine the appropriateness of accepting the drill cutting waste from Marcellus shale for disposal in its New York, non-hazardous, solid waste landfills.

CoPhysics Corporation is a radiological science consulting firm located in Orange County, NY. It is licensed to handle radioactive materials and provide radiological services by the NYS Department of Health. It conducts specialized radiological assessments for government, academia, and business.. The owner is Theodore E. Rahon, Ph.D., a Certified Health Physicist with over 30 years of experience in radiation protection, especially decommissioning and assessment of radium- and thorium-contaminated sites. He has consulted for the USEPA, the Army Corp. of Engineers, several state and local governmental authorities, and numerous university and industrial clients.

Natural Radioactivity

There are 3 main groups of radioactive elements making up the natural radioactivity background in the earth's crust: the uranium-238/radium-226 radionuclide series, the thorium-232 radionuclide series, and potassium-40. These exist in all soil and rock in varying concentrations. There are also minor levels of other radionuclides in soil but these are not important from an environmental health standpoint and will not be discussed here.

The unit of measure for the concentration of radioactivity in soil is picocuries per gram (pCi/g). Typical natural background concentrations of uranium, radium, and thorium in soil and rock in the eastern US are 0.5 to 1 pCi/g each. Some clays are in the range of 1 to 3 pCi/g. Certain commercial minerals, such as gypsum (used for fertilizer and drywall), zirconium and titanium (used in paint), zircon sand & carborundum (used in grinding wheels, sandblasting, and ceramics), are in the range of 5 to 50 pCi/g.

If the concentration of uranium, radium or thorium is much higher than background, the material is termed "NORM", naturally-occurring radioactive material.[1]

The third predominate, naturally-occurring radioactive material is radiopotassium (K-40) which typically ranges from 10 to 30 pCi/g in soil. Potassium-40 is ubiquitous in all potassium-containing materials, including our bodies. It is not commonly regulated.

The accepted safe level for radium and thorium in soil on which homes, schools, and businesses could be built is 5 pCi/g above local background for surface soil and 15 pCi/g for soil greater than 6" deep. This guideline was originally specified for radium-226 in soil around uranium mill sites by the USEPA in 40CFR192. This guideline has been adopted for most cleanup sites across the US for radium and thorium whether or not the site is associated with a uranium mill. Restrictive limits for NORM in landfills have ranged up to 50 pCi/g depending on the state and municipality. In New York, NORM is exempted from regulation under 6 NYCRR Part 380.

Therefore, the purpose of this study is to determine if the gas drilling cuttings have radioactivity in the normal, natural background range or would be considered to be NORM. And, if the cuttings are NORM, at what level would the elevated radioactivity concentrations affect the local environment in and around the landfills.

Methodology

To begin the project, NEWSNY management requested that an initial, early-stage round of sampling be scheduled so that information could be obtained quickly. Such an initial survey is usually termed a "scoping" survey. This would give NEWSNY the ability to modify or limit its acceptance of the drill cuttings as appropriate if high levels of NORM were found. Based on the initial sampling results, additional measurements later could be specified to better characterize any areas of interest that require more in-depth evaluation or a "no further action" designation could be applied to the situation if scoping measurements did not show elevated levels of radioactivity.

To assess the drill cutting waste relative to local background radioactivity, CoPhysics collected three (3) types of samples:

- On-site soils (Collected to establish background radioactivity levels in natural soil and rock in the local landfill area. Both surface samples and subsurface samples from existing monitoring wells were collected.)
- Drill cuttings as delivered to the disposal facility (These were collected to investigate radioactivity levels in material as received. The sample from the pile exhibiting the highest on-site gamma reading was chosen for laboratory analysis.)

[1] This report does not address the extent to which NORM is regulated as a radioactive waste, but rather the extent to which Marcellus shale drill cuttings present a public health concern based upon USEPA cleanup levels for NORM to achieve unrestricted use of property for homes, schools and businesses. A discussion of regulatory standards and exemptions for NORM is beyond the scope of this report.

- Confirmed Marcellus shale samples collected at rig sites in nearby Pennsylvania (The rig sites were geographically separate locations and operated by more than one drilling company. Additional information about the rig site sample was also obtained such as depth of drilling at the time of collection, the geologic formation, the lateral distance into the formation, type of fluid used, etc.)

Samples were analyzed via gamma spectroscopy for the 3 main radionuclides in the naturally-occurring groups: radium-226, thorium-232, and potassium-40. During sample collection, *in situ* gamma radiation measurements were also performed using a hand-held Ludlum Model 12S instrument so that a wider indication of shale-associated radiation levels could be obtained.

Description of Measurements Performed

On March 2, 2010, personnel from CoPhysics Corporation visited the 3 NEWSNY landfills to collect indigenous soil and rock samples and to perform ambient gamma radiation measurements. The field data collected are shown in Appendix B. The data sheets show the locations of sample collection on an aerial photo of each landfill. The CoPhysics field technician collected three types of samples from the landfills; 1) previously collected soil samples from monitoring well drilling , archived by NEWSNY, were obtained as background radioactivity samples, 2) native soil and rock samples from the borrow area, also obtained as background samples, and 3) samples from drill cutting loads recently deposited in the landfill. The local background samples and the cuttings sample that showed the highest field gamma reading were later analyzed via gamma spectroscopy to determine radionuclide concentrations (pCi/g).

On March 11, 2010, personnel from CoPhysics Corporation visited 3 drilling rigs in Bradford County, Pa. and on March 19, 2010, visited a fourth rig in Tioga County, Pa. The four oil and gas company drilling sites visited use sensory technology linked to a computer system to monitor and record drilling activity. The rig operator was able to provide information, pertinent to this assessment, such as depth, lateral distance, etc. from the computerized, real time data acquisition system at the site. Rock cuttings were sampled at the point of discharge from the rigs. Fresh piles of the cuttings were scanned with the Ludlum model 12S gamma radiation detector. As a relative comparison, local background readings were also recorded.

Analysis

The samples collected were analyzed via gamma spectroscopy at the CoPhysics laboratory. Analysis instrumentation consisted of a Princeton GammaTech HPGe detector and Ortec PC-based Trump multichannel analyzer. Instrument calibrations are maintained using NIST-traceable radioactivity standards and laboratory intercomparison samples from the International Atomic Energy Agency (IAEA) and the former US Department of Energy's Environmental Measurements Laboratory.

Samples were analyzed in their "as collected" or *in situ* state, i.e., samples were not dried or concentrated before analysis. However, they were ground into a more homogenous mixture for placement into an analysis geometry that matched calibration standard geometry. The determination of *in situ* concentrations allows the results to be used more appropriately in environmental transport analysis and dose assessments.

Drill cutting sample consistency ranged from a fine mixture (cement-like) to larger particle sizes (up to 0.5 cm) which were slightly moist with cutting fluid. Background soil samples appeared to be of a dry clay-like consistency. Background rock samples collected consisted of pieces of surface shale.

Results and Discussion:

Results from sample analysis, local gamma readings, depth of collection, and other data are shown in Appendix A. The results are separated into 2 groups: drill cuttings and background soil/rock. Also shown for comparison purposes are radionuclide concentrations in common building and industrial materials. The results shown in Appendix A are summarized below in Table 1:

Table 1 - Summary of Radionuclide Analysis Results

Material Type	Average Radionuclide Concentration ± 1 SE		
	Radium-226 (pCi/g)	Thorium-232 (pCi/g)	Potassium-40 (pCi/g)
Gas Drill Rig Cuttings	2.1 ± 1.2	0.7 ± 0.3	14.2 ± 4.8
Landfill Local Background Soil and Rock	0.9 ± 0.1	1.2 ± 0.2	24.1 ± 4.8
EPA recommended cleanup level (40CFR192):	5 over bkg	5 over bkg	not regulated
Typical landfill limits for NORM:	5 to 50	5 to 50	not regulated

Table 1 shows that the Pennsylvania drill cuttings sampled during this project have radium-226 concentrations that are slightly greater than the local background at the New York NEWSNY sites. Conversely, the thorium-232 and radiopotassium levels in the Pennsylvania cuttings are less than New York site background. While the radium levels are slightly greater than background, they do not necessitate the classification of the cuttings as NORM. The radium levels observed are less than the EPA cleanup guideline for unrestrictive use (< 5 pCi/g above background). The EPA uses this guideline for cleanups of sites contaminated with radium or thorium so that they may be used by the general public for homes, schools, businesses, etc.

The rock cuttings from the gas drilling operations, as sampled during this project, have radionuclide levels that do not pose any environmental health problem even if they were deposited in areas accessible by the general public. Therefore they are certainly acceptable for landfill disposal.

However, pipe scale, brine filtrates and associated sludges, not considered in this study, have been known to contain elevated levels of NORM. It was not the purpose of this study to evaluate those materials. To prevent disposal of such materials at its landfills, NEWSNY has ordered the installation of the most sensitive gamma radiation detection system available (Ludlum Measurements, Inc. Model 375-1000) at its truck scales. The purpose of the detection system is to ensure that only the acceptable drill cutting rock is received and no pipe scale, filtrates or sludges containing NORM are inadvertently disposed. After installation, CoPhysics will perform calibration of the monitors' alarms so that any levels of radioactivity exceeding regulatory limits are appropriately detected. CoPhysics will also assist in procedure development and training as necessary to ensure proper use of the monitors.

Given the very low levels of radioactivity found in the Marcellus drill cuttings during this investigation and the landfill's installation of portal radiation monitors as additional assurance against acceptance of NORM, no further study by NEWSNY is warranted.

Appendix A - Radioactivity Measurement Results - Marcellus Shale Drill Rig Cuttings - March, 2010

LAB ID#	Sample#	Date Collected	Sample Location	Material Type	Depth (feet)	Gamma[1] (uR/hr)	Radionuclide Concentration[2] ±1 SD: Radium-226 (pCi/g)	Thorium-232 (pCi/g)	Potassium-40 (pCi/g)
Gas Drill Rig Cuttings									
738-1	31110A	3/11/2010	Bradford Co., Pa.	Marcellus shale	5942	8 / 10	2.4 ± 0.2	0.5 ± 0.1	12.9 ± 1.0
738-2	31110B	3/11/2010	Bradford Co., Pa.	Hamilton Limestone	6562	5 / 5[3]	1.1 ± 0.1	0.9 ± 0.1	17.8 ± 1.0
738-3	31110C	3/11/2010	Bradford Co., Pa.	Marcellus shale	6687	11 / 8	4.3 ± 0.2	0.9 ± 0.1	15.8 ± 0.9
738-5	31910A	3/19/2010	Tioga County, Pa.	Marcellus shale	6101	5 / 10	2.8 ± 0.2	0.9 ± 0.1	17.4 ± 1.0
738-6	31910B	3/19/2010	Tioga County, Pa.	Marc. shale with Bayrite	6101	5 / 10	0.6 ± 0.1	0.2 ± 0.0	3.4 ± 0.2
738-13	1-M1	3/2/2010	Landfill, Lowman, NY	transported gas rig cuttings	unk.	12 / 5	2.3 ± 0.1	0.7 ± 0.1	17.2 ± 1.1
738-11	2-M2	3/2/2010	Landfill, Painted Post, NY	transported gas rig cuttings	unk.	12 / 8	0.9 ± 0.1	1.2 ± 0.1	16.7 ± 1.1
738-12	3-M1	3/2/2010	Landfill, Angelica, NY	transported gas rig cuttings	unk.	12 / 8	2.7 ± 0.2	0.8 ± 0.1	12.6 ± 0.8
					AVERAGE ± 1 SE :		**2.1 ± 1.2**	**0.7 ± 0.3**	**14.2 ± 4.8**
Landfill Local Background Soil and Rock									
738-16	1-LS1	3/2/2010	Landfill, Lowman, NY	local soil	0 - 1	15	1.0 ± 0.1	1.5 ± 0.2	20.2 ± 1.4
738-7	1-LR1	3/2/2010	Landfill, Lowman, NY	local rock	1	17	1.0 ± 0.1	1.5 ± 0.2	16.9 ± 1.1
738-17	1-W1	3/2/2010	Landfill, Lowman, NY	local well cutting MW23	22-70	7 / 5	0.9 ± 0.1	1.6 ± 0.2	20.1 ± 1.4
738-18	1-W2	3/2/2010	Landfill, Lowman, NY	local well cutting EB04	37	7.5 / 5	0.5 ± 0.1	0.9 ± 0.1	8.2 ± 0.6
738-15	2-LS1	3/2/2010	Landfill, Painted Post, NY	local soil	0 - 1	22	1.1 ± 0.1	1.6 ± 0.2	18.2 ± 1.2
738-14	2-LR1	3/2/2010	Landfill, Painted Post, NY	local rock	8	22	0.8 ± 0.1	1.1 ± 0.1	16.4 ± 0.8
738-19	2-W1	3/2/2010	Landfill, Painted Post, NY	local well cutting MW03	10-12	6.5 / 8	0.9 ± 0.1	1.1 ± 0.1	24.4 ± 1.7
738-20	2-W2	3/2/2010	Landfill, Painted Post, NY	local well cutting MW0	28-30	6.5 / 8	1.1 ± 0.1	1.4 ± 0.1	26.1 ± 1.4
738-10	3-LS1	3/2/2010	Landfill, Angelica, NY	local soil	6	22	0.8 ± 0.1	1.0 ± 0.1	24.9 ± 1.3
738-4	3-LR1	3/2/2010	Landfill, Angelica, NY	local rock	6	22	0.8 ± 0.1	1.0 ± 0.1	30.2 ± 1.5
738-8	3-W1	3/2/2010	Landfill, Angelica, NY	local well cutting MW47A	18-20	5.5 / 8	1.0 ± 0.1	1.2 ± 0.1	29.3 ± 1.5
738-9	3-W2	3/2/2010	Landfill, Angelica, NY	local well cutting MW42A	30-32	5.5 / 8	0.8 ± 0.1	1.1 ± 0.1	23.1 ± 1.2
					AVERAGE ± 1 SE :		**0.9 ± 0.1**	**1.2 ± 0.2**	**24.1 ± 4.8**
Comparisons									
yellow brick			purchased Orange Co, NY	yellow brick (fire brick)			4.3 ± 0.5	5.4 ± 0.6	31.9 ± 3.1
red brick			purchased Orange Co, NY	red brick			1.1 ± 0.1	1.1 ± 0.1	25.8 ± 1.3
705-5			steel working factory	grinding wheel			2.3 ± 0.1	2.8 ± 0.2	n/a ±
705-9			steel working factory	800 Grit sand blast media			19.1 ± 1.0	27.2 ± 1.5	n/a ±
				EPA recommended cleanup level (40CFR192):			5 over bkg	5 over bkg	not regulated
				Typical landfill limits for NORM:			5 to 50	5 to 50	not regulated

Method: gamma spectroscopy, EPA 901.1 modified
Instrument: Princeton Gamma-Tech Model NIGC-RG15 HPGe detector; Ortec Trump MCA
Uncertainties are based on 1-sigma counting errors and standardization uncertainty.
Standards are traceable to the National Institute of Standards and Technology.
Radioactive Materials License: NYS 2691-3949
Ra-226 via Bi-214; Th-232 via Ac-228 gamma-ray lines

Footnotes:
1 - *in situ* Gamma Exposure Rate
(1-foot from sample collection / local bkg)

2 - per gram as collected (no drying or sample concentration performed)

3 - measurement for 31110B was high up on drill rig, at the cuttings shake

Appendix B - Soil Sampling Field Data Sheets

Soil Sampling - Field Data Sheet

CoPhysics Corporation

Location: CR-60, Lowman, NY 14861

Date: 03/02/2010

Time Arrived: 10:30 AM Time Departed: 12:30 PM

Larry Shilling, Landfill District Manager \ Karen Flanders, EH&S
Office # (585) 466-7271
Cell # (716) 560-7915 8 total samples

Radiation Bkg: 8 uR/hr Surface , Coordinates, Longitude 78° 17' 29" Latitude 42° 17' 29"

Manufacturer	Model	Serial	Probe Model / Serial	Cal. Date
Ludlum	12	83334	44-2 / 83334A	1/19/2010

Sample No.	Type	uR/hr	Depth
1-LS1	Local Soil 1	15	SURFACE TO 4'
1-W1	Well Cuttings 1	7	MW23 22-70'
1-W2	Well Cuttings 2	7.5	EB-04 37'
1-LR1	Local Rock Sample 1	17	SURFACE TO 6 '
1-M1	Marcellus Shale sample 1	10	cell 3A, black
1-M2	Marcellus Shale sample 1	10	grey
1-M3	Marcellus Shale sample 1	10	grey
1-M4	Marcellus Shale sample 1	10	black

Soil Sampling - Field Data Sheet

CoPhysics Corporation

Location: 4376 Manning Ridge Rd, Painted Post, NY 14870

Date: 03/02/2010

Time Arrived: 1:20 PM Time Departed: 3:00 PM

Larry Shilling, Landfill District Manager \ Karen Flanders, EH&S
Office # (585) 466-7271
Cell # (716) 560-7915 7 total samples

Bkg. 8 uR/hr at Surface, Coordinates, Longitude 77° 06' 46" Latitude 42° 12' 07"

Manufacturer	Model	Serial	Probe Model / Serial	Cal. Date
Ludlum	12	83334	44-2 / 83334A	1/19/2010

Sample No.	Type	uR/hr	Depth
2-LS1	Local Soil 1	22	Surface to 1'
2-W1	Well Cuttings 1	6.5	MWH-03 IN ORGINAL JAR
2-W2	Well Cuttings 2	6.5	MW-0 IN ORIGINAL JAR
2-LR1	Local Rock Sample	22	3'
2-M1	Marcellus Shale sample 1	9	BLACK, AMERICAN WASTE
2-M2	Marcellus Shale sample 2	12	BROWNISH,TALISMAN ENERGY
2-M3	Marcellus Shale sample 3	5	GREY,CHESAPEAKE ENERGY

Soil Sampling - Field Data Sheet

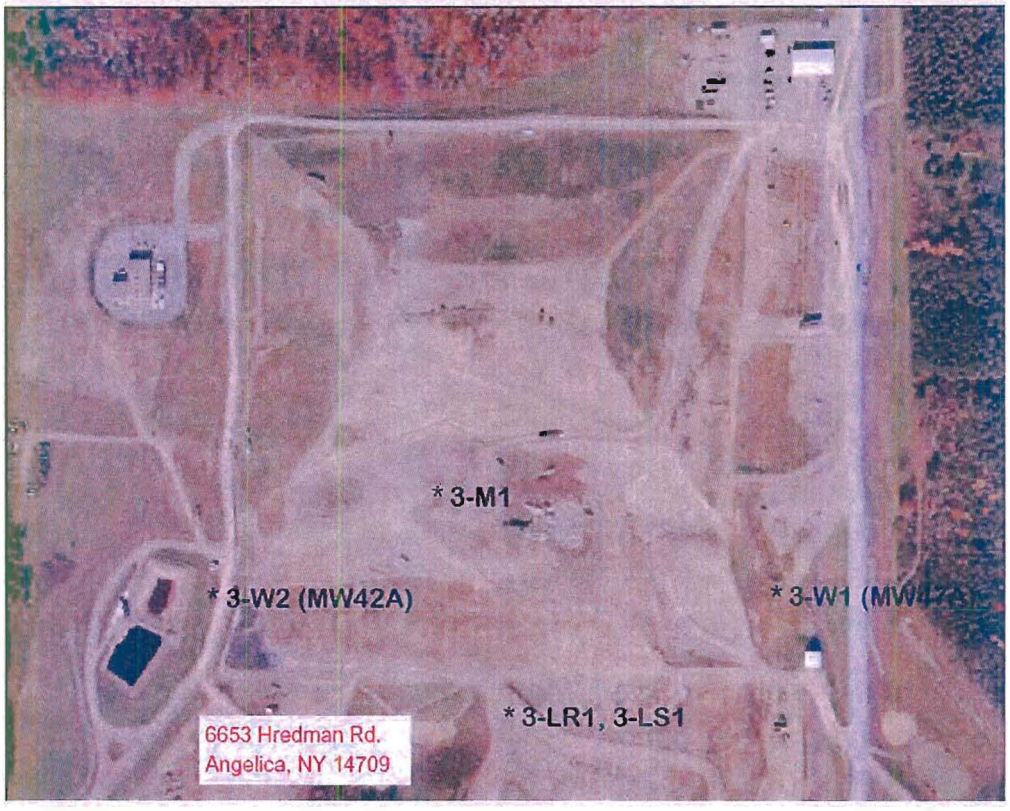
CoPhysics Corporation

Location: Herdman Road, Angelica, NY 14709

Date: 03/02/2010 Time Arrived: 4:04 PM Time Departed: 5:15 PM

Larry Shilling, Landfill District Manager \ Karen Flanders, EH&S Office # (585) 466-7271 Cell # (716) 560-7915

5 total samples



Radiation Bkg: 8 uR/hr Surface , Coordinates, Longitude 78° 17' 29" Latitude 42° 17' 29"

Manufacturer	Model	Serial	Probe Model / Serial	Cal. Date
Ludlum	12	83334	44-2 / 83334A	1/19/2010

Sample No.	Type	uR/hr	Depth
3-LS1	Local Soil 1	22	SURFACE TO 6'
3-W1	Well Cuttings 1	5.5	MW47A
3-W2	Well Cuttings 2	5.5	MW42A
3-LR1	Local Rock Sample 1	22	SURFACE TO 6 '
3-M1	Marcellus Shale sample 1	12	BLACK OILY, UNKOWN ORIGIN