pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

April 10, 2024

CERTIFIED MAIL NO. [redacted]

[redacted]

Re: Request for Investigation 359788
Stray Gas Migrating into Water Supply – Positive Determination
Millcreek Township, Clarion County

[redacted]:

The Pennsylvania Department of Environmental Protection ("Department") has completed its investigation of your water supply listed in Exhibit A ("Water Supply"). The Department has determined that oil and gas activities impacted your Water Supply. This information is summarized below.

CASE INFORMATION

Date of Complaint	**Nature of Complaint (odor, taste, quantity, use, color)**	**Pollution**	**Sample Results Above Statewide Standards or Recommended Levels**
October 2, 2021	Gas leak at nearby gas well. Bubbling in Water Supply and loss of water pressure.	Dissolved and free natural gas in Water Supply	aluminum, iron, manganese, and pH below 6.5, in addition to dissolve ethane, methane, and propane

On September 28, 2021, you notified Diversified Production LLC (Diversified) of a potential gas leak at a nearby gas well, H C Markle 4 CLA gas well, Permit Number 031-23533 ("Markle #4 gas well"), and bubbling in your Water Supply. In response, Diversified vented the Markle #4 gas well, which is the closest gas well to your Water Supply. Diversified also contracted Moody and Associates, Inc. ("Moody") to collect water and gas samples from your Water Supply, and gas samples from the Markle #4 gas well and a second nearby gas well, the H C Markle 6 CLA gas well, Permit Number 031-23576 ("Markle #6 gas well"). The sample results indicate that the stray gas migrating into your Water Supply shared similarities with the production gas of the nearby gas wells.

The Department inspected oil and gas wells within 2,500 feet of the Water Supply and discovered gas in the soil outside the conductor of three gas wells. The Department also collected water and gas samples from your Water Supply and gas samples from the Markle #4 gas well. The gas sample results indicated that the stray gas migrating into your Water Supply and the production gas from the Markle #4 shared similarities.

In March and April of 2022, Diversified plugged three gas wells, the H C Markle 3 CLA, Permit Number 031-23532, the Markle #4 gas well, and the Markle #6 gas well, each of these wells are located within 2,500 feet of the Water Supply. Since the plugging of the three gas wells, combustible gas monitoring of your Water Supply, and water sample results from your Water Supply indicate the free and dissolved gas levels are below detection limits.

Based on the review of geologic mapping, inspections of nearby gas wells, the monitoring of the Water Supply, and the water and gas sample results, the Department determines that your Water Supply was impacted by oil and gas activity. It appears that one or more of the gas wells plugged by Diversified during the investigation were contributing to the stray gas migrating into your Water Supply.

Diversified installed a temporary water treatment system on your Water Supply shortly after the complaint was made. The treatment system was installed for approximately fourteen months. Following the removal of the temporary water treatment system, Diversified conducted two consecutive quarterly samplings of the Water Supply to verify that the preexisting water treatment system on the Water Supply would treat the water to drinking water standards without additional maintenance. The results of the pre-treatment and post-treatment samples collected by the Department and Moody are summarized in the table below.

WATER SAMPLE RESULTS

Parameter Description	**Standard or recommended levels**	**DEP sample pre-treatment 10/05/2021**	**DEP sample pre-treatment 2/08/2023**	**DEP sample post-treatment 2/08/2023**	**Moody sample pre-treatment 2/08/2023**	**Moody sample post-treatment 2/08/2023**	**Moody sample pre-treatment 6/28/2023**	**Moody sample post-treatment 6/28/2023**
Alkalinity (mg/l)		2.2	6.8	10.6	<20	<20	<20	<20
Aluminum (ug/l)	200	333.000	95.900	<15.0	69	<10	184	<10
Arsenic (ug/l)	10	<3.00	<3.00	<3.00	<10	<10	<10	<10
Barium (mg/l)	2	0.098	0.186	<0.010	0.25	<0.005	0.088	<0.005
Bromide (mg/l)		<0.2	<0.2	<0.2	<0.100	<0.100	<0.100	<0.100
Calcium (mg/l)		37.670	12.280	<0.100	7.84	<0.500	34.0	<0.500
Hardness (mg/l)		171	60	0	41.2	<1.25	159	<1.25
Iron (mg/l)	0.3	22.310	0.165	<0.100	0.149	<0.0200	8.91	<0.0200
Lithium (ug/l)		39.00	<25.0	<25.0	<500	<500	<500	<500
Magnesium		18.76	7.00	0.01	5.26	<0.500	18.1	<0.500

(mg/l)								
Manganese (mg/l)	0.05	6.095	1.733	<0.010	1.02	<0.005	5.60	0.008
pH field	6.5-8.5	5.15	5.28	5.35			3.81	4.27
pH lab	6.5-8.5	5.1*	5.3*	5.7*	6.1	6.41	5.18	5.82
Potassium (mg/l)		3.32	2.20	<1.00	1.85	<0.500	3.31	<0.500
Selenium (ug/l)	50	<7.00	<4.00	<4.00	<20	<20	<20	<20
Sodium (mg/l)		1.19	0.98	35.52	1.01	34.5	1.20	129
Specific Conductivity (umhos/cm)		455.00	116.60	178.70	113	170	434	649
Strontium (mg/l)		0.144	0.061	<0.010	0.049	<0.010	0.143	<0.010
Total Chloride (mg/l)	250	2.18	2.84	2.98	2.7	2.99	<2.00	3.06
TDS (mg/l)	500	348	74	122	47	96	331	439
Sulfate (mg/l)	250	202.05	32.23	56.41	34.2	57.0	196	251
TSS (mg/l)		20	<20	<20	<5	<5	<5	<5
Turbidity (ntu)	1	17.70	<1	<1	<1	<1	<1	<1
Zinc (ug/l)	5000	74.00	66.00	129.00	98	105	112	73
Ethane (mg/l)		1.150	<0.0124**	<0.0124**	<1.24	<1.24	<1.24	<1.24
Methane (mg/l)	7 mg/l	5.910	<0.0116**	<0.0116**	<0.232	<0.232	<0.232	<0.232
Propane (mg/l)		0.339	<0.0142**	<0.0142**	<1.42	<1.42	<1.42	<1.42

*Exceeded holding time
**Exceeded allowable temperature at lab
< not detected, sample reporting limit

The sample results from October 5, 2021 show dissolved ethane, methane, and propane in the Water Supply and elevated levels of aluminum, iron, manganese, sulfate, and a pH below the reasonable goal of 6.5 to 8.5. In some cases, increases in parameters such as iron and manganese have been attributed to methane gas migrating into a water supply. In this case, topographic mapping and the PA DEP Mine Subsistance Insurance Risk Map show that strip mining and deep mining of coal occurred in the area surrounding the Water Supply. The strip and deep mining of coal in the area and the increased parameters of aluminum, iron, manganese, and sulfate, and a pH below 6.5 suggests that, in addition to being impacted by oil and gas activities, the Water Supply may be impacted by historic mining activity.

The most recent pre-treatment water sample results (Moody June 28, 2023) indicate that your water quality exceeds statewide standards for iron and manganese. Iron and manganese occur naturally in many water supplies in Western Pennsylvania due to the types of rocks the groundwater encounters as it flows to wells. These levels can naturally fluctuate throughout the year. Levels can also fluctuate year over year due to climate variability and other influences. Based on the latest post-treatment sample of your Water Supply, your current water treatment is reducing the iron and manganese levels to statewide standards.

The most recent post-treatment water sample (Moody June 28, 2023) indicates that the post-treatment sulfate level is 251 mg/l, which is above the 250 mg/l secondary standard and above the pre-treatment sample result for sulfate of 196 mg/l. The Department's February 8, 2023 sample results also show an increase in sulfate from the pre-treatment sample to the post-treatment sample from 32.23 mg/l to 56.41 mg/l. The sample results indicate that the post-treatment sulfate level is increasing over the pre-treatment level. You may wish to discuss the increase in sulfate levels in the treated water with a water treatment professional to better understand why this is occurring and if there are remedies available to you.

As previously noted, the secondary standard for sulfate in 250 mg/l. Secondary standards are set for aesthetic considerations, such as taste, odor, color. Sulfate levels above 250 mg/l may impart a bitter taste to the water.

It is the Department's understanding that you and Diversified have come to an agreement regarding the oil and gas related impacts to the Water Supply and that no further action is needed by the Department at this time. If you have any questions about any of the above, please contact Aaron O'Hara at 814-308-3118.

Sincerely,

Scott M. Dudzic

Scott M. Dudzic
Northwest District Oil and Gas Manager
District Oil and Gas Operations

Enclosures:

DEP Fact Sheet: Methane Gas and Water Wells
DEP Fact Sheet: Methane Migration into Occupied Buildings
PSU: Iron and Manganese in Private Water Systems
PSU: How to Interpret a Water Analysis Report
PADEP: MCLs April 2006

c: Joe Lichtinger (email)
Steve Lencer (email)
Dave Adams (email)
Jennifer McDonough (email)
Paul Strobel (email)
File through Aaron O'Hara
CONFIDENTIAL

Exhibit A

[redacted]

pennsylvania
DEPARTMENT OF ENVIRONMENTAL PROTECTION

Methane Gas and Your Water Well

Residents of the coal and natural gas producing regions of Pennsylvania need to be aware of the potential dangers from the accumulation of microbial gas, coal bed methane, or natural gas, in their water wells.

High concentrations of methane in water wells, water well enclosures and other confined spaces could cause an explosion.

What Is Methane?

Methane (CH_4) is a naturally occurring hydrocarbon gas found underground. It is present in shallow and deep coal beds as well as other rock units, and is the main hydrocarbon found in natural gas, coal bed gas. Methane can occur dissolved in the groundwater or as a gas in the soil and rock zones below the surface.

Methane migrates from areas of high pressure to areas of low pressure. Mining and well drilling operations can affect the pressure in the subsurface and cause the migration of methane to areas of lower pressure such as shallow aquifers, and water wells used as water supplies. Gas migration in the subsurface can also be influenced by an increase or decrease in the water level of an aquifer.

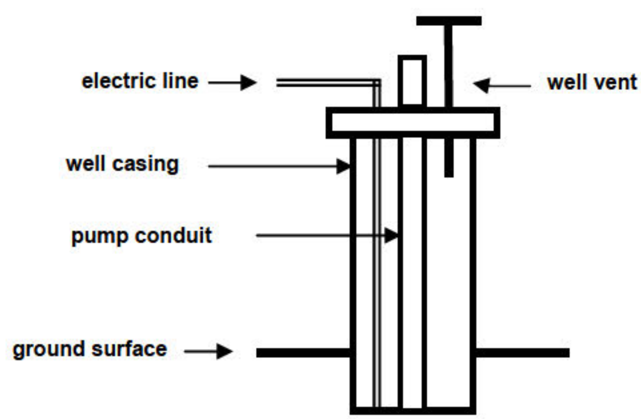
Active underground mining operations can lower groundwater levels, reducing pressure in aquifers occurring above and adjacent to the area of coal extraction. This reduction in pressure can allow gases within the overlying rock layers to migrate into nearby water wells. Methane can also be released from abandoned deep mines, and from abandoned gas wells that are prone to leakage. These releases can also migrate into nearby water wells.

Methane can migrate into water wells in a gaseous phase or dissolved in the ground water. At atmospheric pressure, methane is soluble in water between 26-32 mg/l. It is some times recognizable as effervescent gas bubbles in water drawn from a faucet. In some cases, the release of methane in a water well may be recognized by a sound similar to that of boiling water. However, methane is a colorless and odorless gas, and may accumulate undetected in water well bores and water well enclosures that are not properly vented. Methane may also move into basements of homes and other structures through plumbing and piping containing electrical connections. These conditions could lead to an explosion.

What Can You Do?

Methane is lighter than air with a specific gravity of .555. As such, methane will not accumulate in the water well bore if the water well is properly vented to the atmosphere. Venting is an inexpensive and effective way to prevent methane accumulation in water wells, water well enclosures and other confined spaces, such as basements. Proper venting eliminates the potential for methane gas to seep into homes or structures from water wells.

Recommended Venting Procedures



Proper design is extremely important. Water well vents should be installed by a qualified water well driller or plumber.

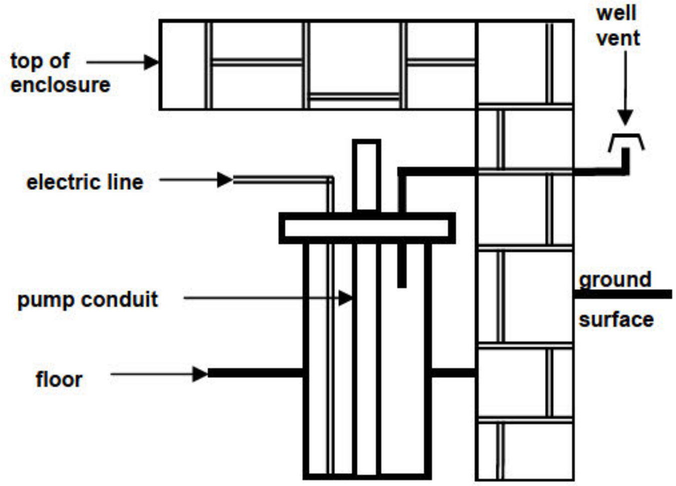
The vent should extend above any possible flood level, potential ignition sources, and areas of exposure (above the roof line for water wells adjacent to buildings), and should have watertight connections to prevent surface water from entering. The well vent should be at least one (1) inch diameter or larger to facilitate gas flow. The end of the vent pipe should have a down-turned "gooseneck" or "T" and be capped with corrosion-resistant screening. If the vent is not screened, it can become a potential entry point for debris and small animals. In addition, conduits from the water well that carry electrical lines or waterlines into the building should be sealed so that the air in the conduit does not vent into the building. Well venting will not appreciably remove methane dissolved in the groundwater, however, properly designed water aeration systems are an effective way to lower the concentration of methane dissolved in the water.

Enclosed Wells

When the top of the water well is buried in a covered pit or enclosed in a basement, the vent pipe must vent gas to the outside air, as shown in the diagram below.

The vent pipe should be screened, and extend above any possible flood level, potential ignition sources, and areas of exposure.

In cases where the water well is located in an enclosure, it should have a tight-fitting well cap, and all openings through the cap should be properly sealed to prevent methane from escaping into the water well enclosure.



Play It Safe

When a water well is no longer in service, the plumbing connections should be disconnected and sealed to prevent methane from entering the home or building.

NOTE: Your water well may differ considerably from the wells depicted in the diagrams. Also, well venting requirements may vary from place to place due to differences in local plumbing codes. Therefore, water well owners are encouraged to contact a professional water well specialist or a local building code enforcement officer to determine the proper venting procedures required under the local plumbing code.

For more information on methane and water wells, please contact the DEP Office in your area.

Southwest Regional Office

400 Waterfront Dr.
Pittsburgh, PA 15222
Telephone: 412-442-4000
Counties Served: Allegheny, Armstrong, Beaver, Cambria, Fayette, Greene, Indiana, Somerset, Washington and Westmoreland.

Southcentral Regional Office

909 Elmerton Avenue
Harrisburg, PA 17110
Telephone: 877-333-1904
Counties Served: Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry, and York.

Southeast Regional Office

2 East Main Street
Norristown, PA 19401
Telephone: 484-250-5900
Counties Served: Bucks, Chester, Delaware, Montgomery, and Philadelphia

Northeast Regional Office

2 Public Square
Wilkes-Barre, PA 18711-0790
Telephone: 570-826-2511
Counties Served: Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne, and Wyoming

Northcentral Regional Office

208 West Third Street, Suite 101
Williamsport, PA 17701-6448
Telephone: 570-327-3636
Counties Served: Bradford, Cameron, Centre, Clearfield, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga, and Union

Northwest Regional Office

230 Chestnut Street
Meadville, PA 16335
Telephone: (814) 332-6945
Counties Served: Butler, Clarion, Crawford, Elk, Erie, Forest, Jefferson, Lawrence, Mckean, Mercer, Venango, and Warren.

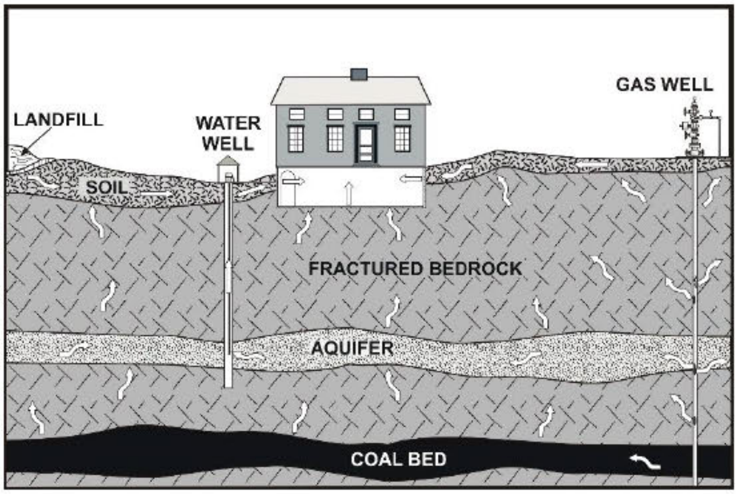
For more information, visit www.depweb.state.pa.us, keyword: Wells.

Methane Migration into Occupied Buildings

Recovery and utilization of Pennsylvania's mineral resources by mining and drilling for oil and gas has a long history that continues today with the extraction of natural gas from the Marcellus Shale and other formations. These activities can directly or indirectly increase levels of methane gas in buildings from deeper sources such as coalbed methane or other geologic formations, or shallower sources in soil and groundwater. Although modern mining and well drilling practices have reduced the risk of environmental impacts; releases from wells, pipelines, and deep mines can and do occur. Methane migration can also occur naturally or in response to other human activities such as water well drilling or landfilling. The prevalence and amount of methane in the subsurface varies across the state depending on many factors. When gases migrating in the soil or water come into contact with man-made structures, the resulting accumulation of gas can cause unsafe conditions for building occupants.

What is Methane and How Is It Mobilized?

Methane (CH4) is a naturally-occurring hydrocarbon gas found underground. It is lighter than air, colorless, odorless, and flammable. Methane is present in shallow organic-rich deposits and deep coal beds as well as other rock units, and is the primary hydrocarbon found in natural gas and coalbed gas. Gas migration may cause methane to accumulate undetected inside basements of homes and other structures. Mobilized gas can enter man-made structures through utility connections, porous surfaces, and basement walls. These conditions may present a life-threatening safety hazard and could lead to an explosion.



Methane migrates from high-pressure to low-pressure areas through available pathways. Migration through rock is typically slow. Fractures in the rock provide faster migration pathways. Mining and well drilling operations can affect the pressure as well as increase the pathways in the subsurface, allowing the migration of methane to areas of lower-pressure such as shallow aquifers and water wells. Gas migration in the subsurface can also be influenced by an increase or decrease in the water level of an aquifer. Active underground mining operations can lower groundwater levels, reducing pressure in aquifers occurring above and adjacent to the area of coal extraction. This reduction in pressure can allow gases within the overlying rock layers to migrate into nearby water wells or enclosed structures. Methane can also be released from abandoned deep mines and abandoned gas wells. The Department of Environmental Protection (DEP) has no evidence that the well completion process of hydraulic fracturing alone creates a pathway for methane to communicate with groundwater.

Gas Migration Investigations

DEP Oil and Gas Well regulations (25 Pa. Code, Chapters 78 and 78a) and DEP policy require a timely investigation into complaints alleging impacts to water supplies from oil and gas drilling. All complaint information reported to DEP is kept confidential. The purpose of the investigation is to determine the nature of the incident, assess the potential for hazards to public safety, and mitigate any hazard posed by concentrations of stray natural gas. When investigations are conducted by DEP and/or by an oil or gas operator, they typically include a site visit and interview; a field survey; and, if necessary, monitoring at potential sources, potentially impacted structures, and the subsurface. DEP uses multiple sources of evidence to determine if methane migration or other impacts to water supplies are attributable to drilling. This includes working to identify the origin of the gas through various methods which may include chemical and isotopic gas analysis, evaluating nearby gas well integrity through pressure and well logging, tests and understanding the local geology and its relationship to the water supply in question.

Detailed investigations to confirm the source(s) of impacts to water supplies or the interior of a structure are time consuming and often require soil, water, and air sample collection for chemical analysis. DEP reviews the results of investigations conducted by oil and gas operators, consultants, and others; provides technical assistance and may conduct an independent investigation. When investigations indicate the need for engineering controls to mitigate impacts, DEP works with all involved parties to ensure that timely, effective solutions are implemented. DEP will also issue temporary water supply replacement orders as necessary during investigations.

Public Health and Safety

If methane gas infiltrates any enclosed structure, it can build up to dangerous levels. Concentrations of methane at five percent in air constitute an explosion hazard. A spark from a furnace or a faulty wire, a cigarette or a lit match can cause the gas to explode. Oil and gas industry professionals, local fire departments, and DEP staff are trained in the use of methane gas meters and explosimeters that measure airborne gas concentrations. As a safety precaution, DEP recommends that occupants vacate any building that has methane concentrations at 10 percent or greater of the lower explosive limit (0.5 percent methane in air). There are no known health impacts from drinking water that contains methane, nor is there an established federal safe drinking water level for methane.

Protections of Private Water Supplies

In cases where water supplies near oil and gas wells have been impacted by gas migration, there are significant enhanced protections for those water supply owners, including a presumption that the operator of the nearby oil or gas well is liable for the impact. This presumption applies if the water supply is within 2,500 feet of the vertical wellbore and the pollution occurs within one year from unconventional well drilling and completion of hydraulic fracturing. For conventional well drilling, the presumption of liability applies within 1,000 feet of the well and six months of the completion of drilling or alteration. Operators may rebut the presumption of liability by raising one of several defenses, including demonstrating the impact was pre-existing or not due to drilling-related activities.

Should DEP determine that an operator has impacted a water supply (regardless of the distance or time limitations of the presumption), the law requires those operators to restore or replace the water supply to its pre-existing condition or to federal safe drinking water standards, whichever is of higher quality.

DEP encourages you to report any cases of suspected water contamination that may be associated with the development of oil and gas resources or any other environmental complaint, please call toll-free 1-866-255-5158. For more information on methane gas migration, please contact the DEP office in your area.

Southwest Regional Office
400 Waterfront Dr.
Pittsburgh, PA 15222-4745
Telephone No. 412-442-4000

South-central Regional Office
909 Elmerton Avenue
Harrisburg, PA 17110-8200
Telephone No. 877-333-1904

Southeast Regional Office
2 East Main Street
Norristown, PA 19401-4915
Telephone No. 484-250-5900

Northwest Regional Office
230 Chestnut Street
Meadville, PA 16335-3481
Telephone No. 814-332-6945

North-central Regional Office
208 West Third Street, Suite 101
Williamsport, PA 17701-6448
Telephone No. 570-327-3636

Northeast Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915
Telephone No. 570-826-2511

For more information, visit www.dep.pa.gov.

How to Interpret a Water Analysis Report

What is the significance of the parameters listed in the water test report? This article outlines some of the major parameters you may see on the analysis and assists you in understanding the report.

Whether your water causes illness, stains on plumbing, scaly deposits, or a bad taste, a water analysis identifies the problem and enables you to make knowledgeable decisions about water treatment.

Features of a Sample Report

Once the lab has completed testing your water, you will receive a report that looks similar to Figure 1. It will contain a list of contaminants tested, the concentrations, and, in some cases, highlight any problem contaminants. An important feature of the report is the units used to measure the contaminant level in your water. Milligrams per liter (mg/l) of water are used for substances like metals and nitrates. A milligram per liter is also equal to one part per million (ppm)—that is one part contaminant to one million parts water. About 0.03 of a teaspoon of sugar dissolved in a bathtub of water is an approximation of one ppm. For extremely toxic substances like pesticides, the units used are even smaller. In these cases, parts per billion (ppb) are used. Another unit found on some test reports is that used to measure radon—picocuries per liter. Some values like pH, hardness, conductance, and turbidity are reported in units specific to the test.

In addition to the test results, a lab may make notes on any contaminants that exceeded the PA DEP drinking water standards. For example, in Figure 1 the lab noted that total coliform bacteria and iron both exceeded the standards.

Retain your copy of the report in a safe place as a record of the quality of your water supply. If polluting activities such as mining occur in your area, you may need a record of past water quality to prove that your supply has been damaged.

PennState Extension

*** ANALYTICAL LABORATORY REPORT ***

Client: Client's name	Collected by: KM
Project: Analytical Laboratory Services	Project Number: CL000001
Date Collected: 08/28/90	Time Collected: 7:35 am
Sample Identification: Kitchen Tap	Lab Number: 01000

Analysis	Results	Units
Total Coliform Bacteria	50	# /100ml
Nitrate-Nitrogen	4.55	mg/l
pH	7.50	units
Iron	0.55	mg/l
Hardness as CaCo3	280	mg/l
Sulfate Sulfur	32.0	mg/l
Chloride	25.4	mg/l
Specific Conductance	344	umhos/cc

On the basis of the above test result(s), this water sample DOES NOT MEET PaDER drinking water standards

The following notes apply to this sample:

The Total Coliform Bacteria exceeded the max. lev. of 1 colony/100ml.
The Iron level exceeded the limit of 0.3 mg/l.

Submitted by:______________________
Laboratory Manager

Figure 1. A sample water analysis report.

Water test parameters

The following tables provide a general guideline to common water quality parameters that may appear on your water analysis report. The parameters are divided into three categories: health risk parameters, general indicators, and nuisance parameters. These guidelines are by no means exhaustive. However, they will provide you with acceptable limits and some information about symptoms, sources of the problem and effects. To find out more about how to treat the water or eliminate the contaminant at the source, see related publications at: http://extension.psu.edu/natural-resources/water/drinking-wate r.

Health Risk Parameters

The parameters in Table 1 are some commons ones that have known health effects. The table lists acceptable limits, potential health effects, and possible uses and sources of the contaminant.

Contaminant	Acceptable Limit	Sources/Uses	Potential Health Effects at High Concentrations
* Recommended level in water at which remedial action should be taken. No mandatory standards have been set.			
Atrazine	3 ppb or.003 ppm	used as a herbicide; surface or ground water contamination from agricultural runoff or leaching	heart and liver damage
Benzene	5 ppb or.005 ppm	gasoline additive; usually from accidental oil spills, industrial uses, or landfills	blood disorders like aplasticaremia; immune system depression; acute exposure affects central nervous system causing dizziness, headaches; long term exposure increases cancer risks
Lead at tap	0.015 ppm or 15 ppb	used in batteries; lead gasolines and pipe solder; may be leached from brass faucets, lead caulking, lead pipes, and lead soldered joints	nervous disorders and mental impairment, especially in fetuses and infants; kidney damage; blood disorders and hypertension; low birth weights
Nitrates (NO_3)	10 mg/l (nitrate-N) 45 mg/l (nitrate)	soil by-product of agricultural fertilization; human and animal waste leaching to groundwater	methemoglobinemaia (blue baby disease) in infants (birth to 6 months); low health threat to children and adults
Total Coliform	<1 coliform/100 ml	possible bacterial or viral contamination from human sewage or animal manure	diarrheal diseases, constant high level exposure can lead to cholera and hepatitis
Radon	300 pCi/l*	naturally occurring gas formed from uranium decay; can seep into well water from surrounding rocks and be released in the air as it leaves the faucet	breathing gas increases chances of lung cancer; may increase risk of stomach, colon and bladder cancers

Table 1: Standards, symptoms, and potential health effects of regulated contaminants.

General Water Quality Indicators

General Water Quality Indicators are parameters used to indicate the presence of harmful contaminants. Testing for indicators can eliminate costly tests for specific contaminants. Generally, if the indicator is present, the supply may contain the contaminant as well. For example, turbidity or the lack of clarity in a water sample usually indicates that bacteria may be present. The pH value is also considered a general water quality indicator. High or low pHs can indicate how corrosive water is. Corrosive water may further indicate that metals like lead or copper are being dissolved in the water as it passes through distribution pipes. Table 2 shows some of the common general indicators.

Indicator	Acceptable Limit	Indication
pH value	6.5 to 8.5	An important overall measure of water quality, pH can alter corrosivity and solubility of contaminants. Low pH will cause pitting of pipes and fixtures or a metallic taste. This may indicate that metals are being dissolved. At high pH, the water will have a slippery feel or a soda taste.
Turbidity	<5 NTU	Clarity of sample can indicate contamination.
Total Dissolved Solids (TDS)	500 mg/l	Dissolved minerals like iron or manganese. High TDS also can indicate hardness (scaly deposits) or cause staining, or a salty, bitter taste.

Table 2. General water quality indicators.

Nuisance contaminants are a third category of contaminants. While these have no adverse health effects, they may make water unpallatable or reduce the effectiveness of soaps and detergents. Some nuisance contaminants also cause staining. Nuisance contaminants may include **iron bacteria, hydrogen sulfide, and hardness**. Table 3 shows some typical nuisance contaminants you may see on your water analysis report.

Contaminant	Acceptable Limit	Effects
Chlorides	250 mg/l	salty or brackish taste; corrosive; blackens and pits stainless steel
Copper (Cu)	1.3 mg/l	blue-green stains on plumbing fixtures; bitter metallic taste
Iron (Fe)	0.3 mg/l	metallic taste; discolored beverages; yellowish stains, stains laundry
Manganese (Mn)	0.05 mg/l or 5 ppb	black stains on fixtures and laundry; bitter taste
Sulfates (SO_4)	250 mg/l	greasy feel, laxative effect
Iron Bacteria	present	orangeish to brownish slime in water

Table 3. Common nuisance contaminants and their effects.

Hardness is one contaminant you will also commonly see on the report. Hard water is a purely aesthetic problem that causes soap and scaly deposits in plumbing and decreased cleaning action of soaps and detergents. Hard water can also cause scale buildup in hot water heaters and reduce their effective lifetime. Table 4 will help you interpret the hardness parameters cited on your analysis. Note that the units used in this table differ from those indicated in Figure 1. Hardness can be expressed by either mg/l or a grains per gallon (gpg). A gpg is used exclusively as a hardness unit and equals approximately 17 mg/l or ppm. Most people object to water falling in the "hard" or "very hard" categories in Table 4. However, as with all water treatment, you should carefully consider the advantages and disadvantages to softening before making a purchasing a water softener.

Concentration of hardness minerals in grains per gallon (GPG)	Hardness Level
* level at which most people find hardness objectionable	
below 1.0	soft
1.0 to 3.5	slightly hard
3.5 to 7.5	moderately hard
7.5 ti 10.5*	hard
10.5 and above	very hard

Table 4. Hardness classifications.

Additional Resources

For more detailed information about water testing ask for publication *Water Tests: What Do the Numbers Mean?* at your local extension office or from this website.

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Iron and Manganese in Private Water Systems

Iron and manganese are metals that occur frequently in private water systems in Pennsylvania. In some parts of the state these metals exist naturally in groundwater that originates from certain types of rock.

Sources of Iron and Manganese

Natural sources of iron and manganese are more common in deeper wells where the water has been in contact with rock for a longer time. In coal mining regions of the state, these metals may also occur from both deep and surface mining activities. Iron and manganese often occur together in groundwater but manganese usually occurs in much lower concentrations than iron.

Both iron and manganese are readily apparent in drinking water supplies. Both impart a strong metallic taste to the water and both cause staining. Water coming from wells and springs with high iron and/or manganese may appear colorless initially but orange-brown (iron) or black (manganese) stains or particles quickly appear as the water is exposed to oxygen (see Water Testing).

Although iron and manganese can occur in wells and springs throughout Pennsylvania, they are most common in northern and western counties. A survey by Penn State found excessive iron concentrations in 17% of the private water supplies sampled in the state.

Drinking Water Standards

Iron and manganese are not health concerns in drinking water. Instead, they both have secondary or recommended drinking water standards because they cause aesthetic problems that make the water undesirable to use in the home and a bitter metallic taste that can make the water unpleasant to drink for both humans and farm animals.

Iron can also cause an orange or brown stain in sinks and in the laundry. Manganese often results in a dense black stain or solid. For these reasons, it is recommended that drinking water have no more than 0.3 mg/L (or 0.3 parts per million) of iron and less than 0.05 mg/L of manganese. Remember that private water systems serving individual homes are not subject to state or federal drinking water standards. Thus, these standards only provide guidelines for the proper management of these types of water supplies.

Water Testing

The presence of stains, particulates, and metallic taste often make it obvious that iron and manganese are present in a water supply even without water testing. Still, it is a good idea to have your water tested to determine the exact concentration of each of these metals. The concentration will determine the most practical and economical water treatment options to solve the problem.

In addition to the concentration, it is also important to determine the form of the iron and manganese. If water collected from the well or spring is initially clear but then forms orange-brown or black solid particles over time, the iron and manganese are dissolved in the water. This is known as the “reduced” form of these metals. Dissolved or reduced iron and manganese are most common in groundwater with a pH less than 7.0.

Sometimes, solid particles of iron and manganese will be apparent immediately in water from the well or spring. In this case, the metals are already in the oxidized form. This is more common in higher pH water supplies or where oxygen is readily available to the water, such as a shallow spring.

If you notice orange-brown or black stains with your water or a metallic taste, you should arrange to have your water tested for iron and/or manganese. Iron and manganese are common water pollutants that can be tested by many commercial laboratories in Pennsylvania. Have your water thoroughly tested at a DEP-accredited lab to make an overall treatment plan; see Water Testing for more information.

Removing Iron and Manganese from Water

Iron and manganese can be effectively removed from water using a number of treatment processes depending on both the form and concentration of the metals. Since iron and manganese are aesthetic problems that affect all potential uses of the water, they must be removed from all water entering the home using Point-of-Entry (POE) treatment devices.

When multiple treatment processes are applicable to your problem, make sure you shop around and compare treatment units and prices among several reputable dealers that carry a variety of treatment devices. Be sure to understand the maintenance requirements for each unit and get a written warranty for any device you decide to purchase. See Tips for Buying Water Treatment Equipment for more guidance.

Water Softening (Ion Exchange)

Conventional water softeners are sometimes effective for removing iron and small amounts of manganese. Water softeners are typically used to remove calcium and magnesium hardness in water by an exchange process. The calcium and magnesium are removed from the water and sodium is added in their place. Iron and manganese removal is accomplished in the same way by exchanging the iron and manganese for sodium. The iron and manganese are then removed from the softener resin bed through backwashing and regeneration.

Removal efficiencies by softeners will vary depending on the iron concentration, water hardness and pH. Softeners are generally only recommended when the water pH is greater than 6.7, the water hardness is between 3 and 20 grains per gallon (50- 350 mg/L) and the dissolved iron concentration is less than 5 mg/L.

Oxidized forms of iron and manganese will foul the softener resin. Thus, it is critical that the raw water not come in contact with any oxidizing agents like air or chlorine before entering the softener. Using the softener resin bed as a mechanical filter for oxidized iron and manganese is generally not recommended. This could damage the resin bed and require much more frequent backwashing. If oxidized iron and/or manganese are present in the raw water, filtration should be used for removal.

Additional information about softeners and their maintenance is available in the article on Water Softening.

Polyphosphate Addition

Water containing dissolved iron concentrations less than 2 mg/L may be treated using polyphosphate addition. Phosphate addition is generally ineffective in treating manganese. The phosphate is fed into the water using a chemical feed pump that often requires trial and error dose adjustments. In this case, the iron is surrounded or "sequestered" by the phosphate and is not actually removed from the water.

There are some major drawbacks to this process. Although the sequestered iron will not cause objectionable stains, it will still give the water a metallic taste. In addition, if too much phosphate is added to the water, it will give the water a slippery feeling and it may also cause diarrhea. The polyphosphate may also be degraded in a water heater resulting in release of sequestered iron.

Oxidizing Filters

Oxidizing filters both oxidize and filter iron and manganese in one unit. The filter is usually comprised of manganese treated greensand although other materials such as birm can also be used. In the case of a manganese greensand filter, the filter media is treated with potassium permanganate to form a coating that oxidizes the dissolved iron and manganese and then filters them out of the water. Because these units combine oxidation and filtration, they can be used to treat raw water with dissolved and/or oxidized iron and manganese.

Manganese greensand filters require significant maintenance including frequent regeneration with a potassium permanganate solution as it is consumed during oxidation of the dissolved metals. In addition, these units require regular backwashing to remove the oxidized iron and manganese particles. The potassium permanganate solution used for regeneration is toxic and must be handled and stored carefully using specific safety measures.

When properly maintained manganese greensand filters are extremely efficient for moderate levels of both dissolved and oxidized iron and manganese. They are generally recommended when the combined iron and manganese concentration is in the range of 3 to 10 mg/L. Keep in mind that the frequency of maintenance (backwashing and regeneration) will increase as the metals concentration increases.

Birm filters are similar to manganese greensand but they do not require regeneration because they utilize oxygen present in the raw water to oxidize the metals. As a result, the raw water must contain a certain amount of dissolved oxygen and the pH should be at least 6.8 for iron removal and 7.5 for manganese removal. Even under ideal conditions, manganese removal efficiency is highly variable with birm filters. Birm filters do require backwashing to remove accumulated oxidized metal particles.

Oxidation Followed by Filtration

When combined levels of iron and manganese exceed 10 mg/L, the most effective treatment involves oxidation followed by filtration. In this process, a chemical is added to convert any dissolved iron and manganese into the solid, oxidized forms that can then be easily filtered from the water. Chlorine is most commonly used as the oxidant although potassium permanganate and hydrogen peroxide can also be used. A small chemical feed pump is used to feed the chlorine (usually sodium hypochlorite) solution into the water upstream from a mixing tank or coil of plastic pipe. The mixing tank or pipe coil is necessary to provide contact time for the iron and manganese precipitates to form. It may be necessary to install an activated carbon filter to remove the objectionable taste and odor from the residual chlorine. Chlorine is not recommended as an oxidant for very high manganese levels because a very high pH is necessary to completely oxidize the manganese.

Significant system maintenance is required with these units. Solution tanks must be routinely refilled and mechanical filters need to be backwashed to remove accumulated iron and manganese particles. If a carbon filter is also installed, the carbon would need to be replaced occasionally as it becomes exhausted. The frequency of maintenance is primarily determined by the concentration of the metals in the raw water and the amount of water used.

Other Treatment Methods

The methods described above are the most common processes for removing iron and manganese but others like aeration, ozonation, and catalytic carbon may also be effective. While these units may successfully treat iron and/or manganese, their cost should be carefully compared with more traditional treatment methods and, as always, you should obtain a written guarantee of their effectiveness.

Aeration units may work by cascading, bubbling, or stripping the gas from the water. Aeration may be advantageous because it does not add chemicals to the water. Maintenance costs are low for aeration units but the initial purchase costs are often higher then other treatment options. Aeration units also require a filter for removal of the oxidized iron and manganese which must be backwashed. The water should also be disinfected to keep bacteria from colonizing the aerator.

Catalytic carbon adsorbs then oxidizes and filters dissolved iron in one unit. It is effective for concentrations of dissolved iron less then 1.0 mg/L. Maintenance requirements are less than oxidizing filters because no chemicals are added, but backwashing is still necessary. Catalytic carbon requires a minimum of 4.0 mg/L of dissolved oxygen in the source water. Some groundwater supplies may need pretreatment to increase the dissolved oxygen concentration.

In recent years, ozonation has received more attention as a method for treating numerous water quality problems. Like chlorine, ozone is a strong oxidant but it is a much more unstable gas that must be generated on-site using electricity. Once the ozone is produced, it is injected into the water where it oxides dissolved metals which must then be filtered. Ozone units are usually more expensive than other more conventional treatment options but they may be useful where multiple water quality problems must be treated (i.e. bacteria and metals).

Other Options for Avoiding Iron and Manganese

While treatment devices are available to reduce iron and manganese from water, other options should not be overlooked. In some cases, a municipal water supply line may be nearby. Hooking into a municipal water supply may seem expensive initially but it may be economically preferable given the long-term costs and hassles associated with purchasing and maintaining a water treatment device. Hooking into a municipal water supply will also usually increase the real estate value of your home.

Another option may be to develop an alternate private water supply. Other sources of water like a shallow groundwater spring or a rainwater cistern could be developed to avoid iron and manganese but they may both present other water quality and quantity problems. Alternative sources of water should be thoroughly investigated along with treatment options when choosing a strategy to avoid iron and manganese in water.

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PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF DRINKING WATER MANAGEMENT
MAXIMUM CONTAMINANT LEVELS (MCLs)
MAXIMUM RESIDUAL DISINFECTANT LEVELS (MRDLs)

PRIMARY CONTAMINANTS

Volatile Organic Chemicals (VOCs):

BENZENE	0.005	mg/L
CARBON TETRACHLORIDE	0.005	mg/L
o-DICHLOROBENZENE	0.6	mg/L
para-DICHLOROBENZENE	0.075	mg/L
1,2-DICHLOROETHANE	0.005	mg/L
1,1-DICHLOROETHYLENE	0.007	mg/L
cis-1,2-DICHLOROETHYLENE	0.07	mg/L
trans-1,2-DICHLOROETHYLENE	0.1	mg/L
DICHLOROMETHANE	0.005	mg/L
1,2-DICHLOROPROPANE	0.005	mg/L
ETHYLBENZENE	0.7	mg/L
MONOCHLOROBENZENE	0.1	mg/L
STYRENE	0.1	mg/L
TETRACHLOROETHYLENE	0.005	mg/L
TOLUENE	1	mg/L
1,2,4-TRICHLOROBENZENE	0.07	mg/L
1,1,1-TRICHLOROETHANE	0.2	mg/L
1,1,2-TRICHLOROETHANE	0.005	mg/L
TRICHLOROETHYLENE	0.005	mg/L
VINYL CHLORIDE	0.002	mg/L
XYLENES (Total)	10	mg/L

Synthetic Organic Chemicals (SOCs):

ALACHLOR	0.002	mg/L
ATRAZINE	0.003	mg/L
BENZO(a)PYRENE	0.0002	mg/L
CARBOFURAN	0.04	mg/L
CHLORDANE	0.002	mg/L
2,4-D	0.07	mg/L
DALAPON	0.2	mg/L
DIBROMOCHLOROPROPANE (DBCP)	0.0002	mg/L
DI(2-ETHYLHEXYL) ADIPATE	0.4	mg/L
DI(2-ETHYLHEXYL) PHTHALATE	0.006	mg/L
DINOSEB	0.007	mg/L
DIQUAT	0.02	mg/L
ENDOTHALL	0.1	mg/L
ENDRIN	0.002	mg/L
ETHYLENE DIBROMIDE (EDB)	0.00005	mg/L
GLYPHOSATE	0.7	mg/L
HEPTACHLOR	0.0004	mg/L
HEPTACHLOR EPOXIDE	0.0002	mg/L
HEXACHLOROBENZENE	0.001	mg/L
HEXACHLOROCYCLOPENTADIENE	0.05	mg/L
LINDANE	0.0002	mg/L
METHOXYCHLOR	0.04	mg/L
OXAMYL (Vydate)	0.2	mg/L
PCBs	0.0005	mg/L
PENTACHLOROPHENOL	0.001	mg/L
PICLORAM	0.5	mg/L
SIMAZINE	0.004	mg/L
2,3,7,8-TCDD (Dioxin)	3×10^{-8}	mg/L
TOXAPHENE	0.003	mg/L
2,4,5-TP (Silvex)	0.05	mg/L

Disinfection Byproducts:

TOTAL TRIHALOMETHANES (TTHMs) (Chloroform, Chlorodibromomethane, Bromoform & Bromodichloromethane)	0.080	mg/L
HALOACETIC ACIDS (HAA5) Monochloroacetic Acid, Dichloroacetic Acid, Trichloroacetic Acid, Monobromoacetic Acid, & Dibromoacetic Acid)	0.060	mg/L
BROMATE	0.010	mg/L
CHLORITE	1.0	mg/L

Disinfectants (MRDLs): *Note 2*

CHLORINE (as Cl_2)	4.0	mg/L
CHLORAMINES (as Cl_2)	4.0	mg/L
CHLORINE DIOXIDE (as ClO_2)	0.8	mg/L

MRDL = Maximum Residual Disinfectant Level

Radionuclides:

GROSS ALPHA	15	pCi/L
COMBINED RADIUM (226 + 228)	5	pCi/L
BETA PARTICLE & PHOTON ACTIVITY	4	mrem/yr

Gross Alpha MCL excludes Radon and Uranium particle activity.
Beta Particle & Photon Activity MCL is for man-made radionuclides.

URANIUM	30	µg/L

Inorganic Chemicals (IOCs):

ANTIMONY	0.006	mg/L
ARSENIC	0.010	mg/L
ASBESTOS (Fibers longer than 10µm)	7	million fibers/L
BARIUM	2	mg/L
BERYLLIUM	0.004	mg/L
CADMIUM	0.005	mg/L
CHROMIUM	0.1	mg/L
COPPER **	1.0	mg/L
CYANIDE (free CN)	0.2	mg/L
FLUORIDE	2	mg/L
LEAD **	0.005	mg/L
MERCURY	0.002	mg/L
NITRATE (as Nitrogen)	10	mg/L
NITRITE (as Nitrogen)	1	mg/L
NITRATE + NITRITE (as Nitrogen)	10	mg/L
SELENIUM	0.05	mg/L
THALLIUM	0.002	mg/L

** The lead and copper primary MCLs are applicable only to bottled, vended, retail and bulk water hauling systems

Microbiological Contaminants:

PRESENCE OR ABSENCE OF TOTAL COLIFORMS BASED ON NUMBER OR PERCENTAGE OF TOTAL COLIFORM POSITIVE SAMPLES/MONTH **OR** FECAL COLIFORM OR E.COLI POSITIVE ROUTINE OR CHECK SAMPLES

Turbidity

1 NTU (applicable only to unfiltered surface water sources)

PENNSYLVANIA DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF DRINKING WATER MANAGEMENT
MAXIMUM CONTAMINANT LEVELS (MCLs)

SECONDARY CONTAMINANTS

ALUMINUM	0.2	mg/L
CHLORIDE	250	mg/L
COLOR	15 color units	
CORROSIVITY	non-corrosive	
FOAMING AGENTS	0.5	Mg/L
IRON	0.3	Mg/L
MANGANESE	0.05	mg/L
ODOR	3 T.O.N	
pH *	6.5 - 8.5	
SILVER	0.1	mg/L
SULFATE	250	mg/L
TOTAL DISSOLVED SOLIDS	500	mg/L
ZINC	5	mg/L

*The pH MCL represents a "reasonable goal for drinking water quality."

Notes:

mg/L = milligrams per liter = parts per million; µg /L = micrograms per liter = parts per billion;
pCi/L = picocuries per liter (particle activity); mrem/yr = millirems/yr (annual dose equivalent)
µm = micrometers; T.O.N. = threshold odor number

Chapter 109, Safe Drinking Water Regulations, defines MCL and MRDL as follows:

MCL (Maximum Contaminant Level) – the maximum permissible level of a contaminant in water which is delivered to a user of a public water system, and includes the primary and secondary MCLs established under the Federal Safe Drinking Water Act, and MCLs adopted under the act. For MCLs incorporated into this chapter by reference, the term refers to the numerical value and the means of determining compliance with that value and does not refer to the EPA applications to specific types of public water systems or sources.

MRDL (Maximum Residual Disinfectant Level) – the maximum permissible level of a disinfectant added for water treatment that may not be exceeded at the consumer's tap without an unacceptable possibility of adverse health effects. The consumer's tap means the entry point for bottled water and vended water systems, retail water facilities and bulk water hauling systems.

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