Energy & Environmental Research Center

Category: Environmental Partnership

BRIEF EXPLANATION OF THE PROJECT

The Energy & Environmental Research Center (EERC), in close coordination with several of the Williston Basin's premier petroleum producers and the North Dakota Industrial Commission (NDIC), is engaged in a research program with the goal of improving Bakken system oil recovery while simultaneously reducing its environmental footprint: the Bakken Production Optimization Program. The results of the 3-year program will increase well productivity and the economic output of North Dakota's oil and gas resources, decrease environmental impacts of wellsite operations, and reduce demand for infrastructure construction and maintenance. Anticipated specific results include:

- Greater understanding of Bakken–Three Forks reservoirs and attendant significant increases to estimates of recoverable hydrocarbons.
- Less truck traffic, resulting in decreased diesel emissions, road dust, and spills.
- Reduced road maintenance costs, wastewater production, disposal costs, and freshwater use.
- Reduced land use impacts.
- Increased revenue from added product streams, captured earlier in the well life cycle.

As a partner in this ongoing research program, NDIC committed $8.5 million in matching funds over 3 years to support a consortium of industry partners conducting research focused on improving the efficiency and reducing the environmental footprint of oil production in North Dakota.

As a large part of this EERC-led program, Continental Resources, Inc., is engaged in a multimillion-dollar effort to develop a data set that will help answer the question of whether the oil reserves of the second and third benches in the Devonian Three Forks Formation in North Dakota should be considered separate and unique reserves from those of the first bench. This portion of the program is already yielding results that will help determine optimal well spacing for development in the Middle Bakken and the first, second, and third benches of the Three Forks and will help predict areas of future reservoir sweet spots. It is anticipated that these data will substantiate significant increases in estimates of recoverable oil from the Bakken–Three Forks system.

In parallel, activities focused on the optimization of wellsite operations have been developed and prioritized by consortium members and include projects in the following topic areas:

- Hydrocarbon utilization
- Waste management, minimization, and reuse

- Water management
- Soil remediation
- Land reclamation
- Public outreach and education

PURPOSE OF THE PROJECT

The purpose of this program is to provide solutions in a public–private partnership to wellsite productivity and environmental impact issues affecting all Bakken stakeholders. Employing a consortium approach for these issues minimizes corporate financial and staffing input, makes solutions quickly available to consortium members, and partners with the state of North Dakota to ensure transparency and continued cooperation to assist producers in optimizing wellsite economics.

PROCESS TAKEN TO COMPLETE THE PROJECT

The EERC is responsible for overall project management, periodic collaboration to define new scopes of work for emerging priorities, and effective communication of progress and results of all ongoing tasks between or among program partners. Task-specific scopes of work, schedules, and task budgets for emerging priorities are developed periodically in consultation with all program partners by an informal voting process. This collaborative environment is assisted by periodic EERC-led program advisory meetings to which all program partners are invited to send representatives. A cooperative atmosphere is maintained programwide to achieve maximum results for funds invested by each program partner and the consortium as a whole.

CONTRIBUTIONS MADE TO THE ENVIRONMENT

The Bakken Production Optimization Program maximizes oil production from Bakken–Three Forks wells by employing an "all of the above" approach, including advanced reservoir characterization, improved drilling/stimulation/completion/production techniques, and optimized wellsite surface operations that reduce development and operational impacts to surrounding landowners and reduce demands on surrounding infrastructure and water sources. Currently, 1 year into the 3-year program, the program has already resulted in significant contributions to optimized well-drilling plans that minimize land impacts, flared gas reduction plans that minimize air emissions and minimize wasted gas resources, and improved naturally occurring radioactive material (NORM) disposal plans in North Dakota. Ongoing work to optimize selection of locally appropriate spill remediation and land reclamation practices tailored for North Dakota biomes will soon result in improved spill cleanup efforts and more rapid restoration of affected soils to productive use in the agriculturally dominated state of North Dakota.

ACCOMPLISHMENTS

The following provides a list of major accomplishments:

- Determination of optimal well density in the Bakken pool, leading to optimized well counts for minimal land impacts (Continental Resources' tasks managed through the Bakken Production Optimization Program), including collection of VSPs (vertical seismic profiles), monitoring of ten newly drilled wells with versatile seismic imager tool arrays, completed facture modeling of

completion operations, postfracture pulse testing, and petrophysical evaluation of pilot hole logs for determining OOIP (original oil in place) and reservoir properties.

- Hydrocarbon utilization, including analytical support for the North Dakota Petroleum Council (NDPC) Flaring Task Force, creation of a Web-based information database housing technologies and services capable of utilizing wellhead gas and improving gas utilization, analysis of flaring reduction strategies and proffering recommendations to the North Dakota Governor's Office and North Dakota legislative management, and initiation of a laboratory study to evaluate the potential for utilization of rich Bakken gas for enhanced oil recovery in the Bakken.

- Waste management, including support of the NDPC NORM Task Force, providing information on field-based radiation measurement technology as well as compiling materials for an educational campaign.

- Public outreach and education, including development and distribution of three educational fact sheets on key Bakken issues, namely flaring, water management, and NORM, with two additional fact sheets that focus on spills and reclamation that are in final review and can be made available in late August (see attached).

FORWARD PLANNING

Preliminary scopes of work for several wellsite optimization projects are currently under review by program members, including the following:

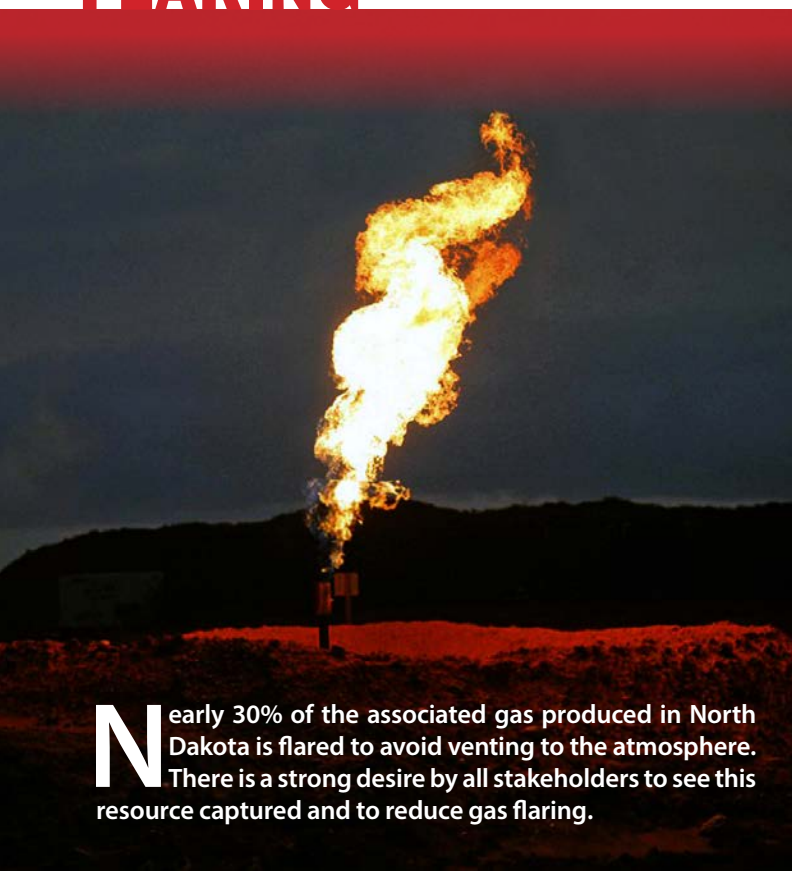
- *Waste Stream Characterization and Inventory:* This project will develop a baseline set of data quantifying solid waste streams derived from Bakken production activities and characterize the waste streams to support development of appropriate and cost-effective disposal options.

- *NORM Waste Characterization and Inventory:* The goal of this project is to quantify and characterize NORM wastes, as defined by current North Dakota regulations (>5 pCi/g).

- *Well Failure Investigation and Analysis:* This project intends to minimize well failure in North Dakota by identifying recurring production and operations problems, developing mitigation strategies, sharing the information, and implementing solutions.

- *Evaluation of Water Treatment and Recycling Options:* This project will provide industry with data and information on the technical and economic potential to recycle hydraulic fracturing flowback and/or produced water.

FLARING



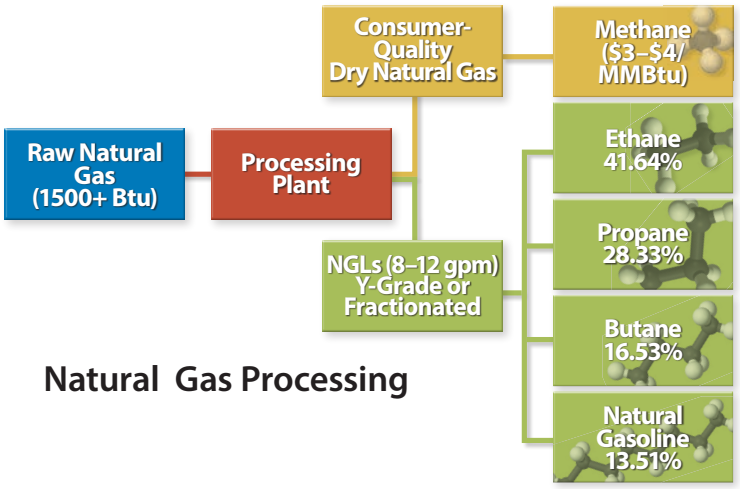
Nearly 30% of the associated gas produced in North Dakota is flared to avoid venting to the atmosphere. There is a strong desire by all stakeholders to see this resource captured and to reduce gas flaring.

What Is Associated Gas?

Crude oil extracted from geologic reservoirs contains a mixture of hydrocarbon molecules. When pumped to the surface, liquid crude oil is separated from hydrocarbon gases at the well site. Oil is stored in tanks until it can be transported from the well site by pipeline or truck. The gaseous fraction or "associated gas" cannot be stored in tanks as easily as liquid hydrocarbons and is typically "gathered" via small, low-pressure pipelines. This associated gas is transported to large gas-processing facilities where the natural gas (methane and some ethane) is separated from the various other gases. The other gases include propane, butane, pentane, and small amounts of hexane and heptane and are called natural gas liquids (NGLs). These can be marketed for further processing in the petrochemical industry.

Why Does Flaring Occur?

Associated gas is flared when oil is produced, but gas-gathering infrastructure (including pipelines, compressor stations, and gas-processing facilities) is insufficient to accommodate the amount of associated gas. This can happen when gas-gathering pipelines



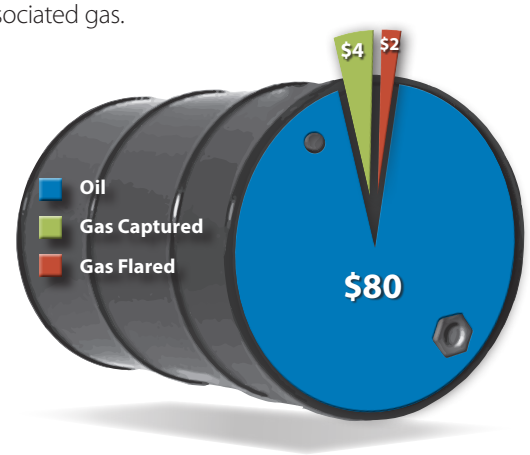
Natural Gas Processing

have not been connected to a well site, when gas-gathering infrastructure has insufficient capacity, or when a process upset temporarily interrupts operation. Under these circumstances, gas separated from produced oil is directed to a flare, to burn unused gas to prevent release to the atmosphere.

Utilizing gas upstream of traditional gathering/processing systems is difficult because of the distributed and transient nature of flared gas. The location of flares changes as new wells are drilled and gathering pipelines installed. Additionally, gas production rates can drop as much as 65% over the first year of production. This dramatic change makes selecting appropriately scaled equipment difficult.

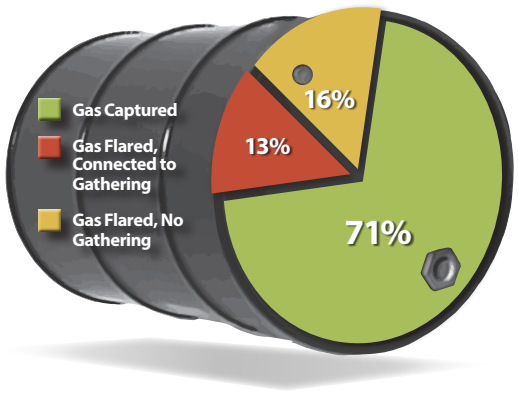
The Bakken is first and foremost an oil play. Associated gas, although valuable, is secondary in value and quantity to oil. A produced barrel of oil in North Dakota contains approximately $80 of oil and $6 of gas. Although the amount and value of gas are lower than oil's, the presence of valuable NGLs creates an incentive to gather and process the associated gas.

Value of Products from One Produced Barrel



In North Dakota, 29% of associated gas produced is flared (as of March 2013). Analysis conducted by the North Dakota Pipeline Authority suggests that nearly one-half of the flared gas is a result of capacity constraints within existing gathering systems. The remainder is flared at wells without pipelines. The flaring rate is down from a peak of 36% in September 2011 and is expected to continue to decrease as more infrastructure is installed. Nearly $4 billion has been spent to expand associated gas-related infrastructure in North Dakota, increasing gas-processing capacity 389% from 2006 to 2012. Today, North Dakota has sufficient gas-processing plant capacity to meet the nearly 900,000 Mcfd of gas production. Additionally, planned expansion will exceed expected gas production over the next several years.

Gas Production, Captured and Flared



There is a desire by all parties to see all associated gas captured and marketed: maximizing profits ensuring efficient use and minimizing environmental impacts. As the Bakken play matures, it is expected that nearly all produced gas will be captured.

How Is Flaring Regulated?

The North Dakota Industrial Commission Oil and Gas Division implements and enforces oil- and gas-related regulations. Typically, state law allows oil production to occur at varying rates during the first several months of operations to determine production rates. Gas can be flared while data are collected to assess the viability and determine gas-gathering capacity requirements. After 12 months of production, the well must be capped, connected to a gas-gathering system, equipped with a value-added process, granted an exemption from the Industrial Commission Oil and Gas Division or must pay taxes and royalties on the flared gas (Section 38-08-06.4 of the North Dakota Century Code, http://northdakotapipelines.com/natgasfacts/).

What Is Being Done to Reduce Flaring in North Dakota?

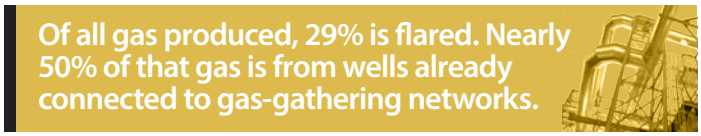
Rapid Infrastructure Buildout by Industry. As activities in the Bakken continue transitioning from single well pads to in-fill drilling (in which additional wells are drilled at already-producing well sites), gathering infrastructure should be more readily available and reduce the necessity for flaring.

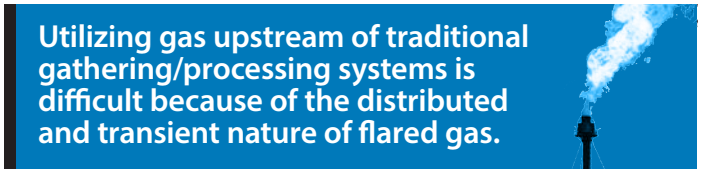
New Technology Investigations. The Energy & Environmental Research Center (EERC) conducted an assessment of alternative gas uses upstream of traditional gas-processing plants. The study investigated using associated gas for power production, transportation fuel, and chemical production, as well as analyzed small-scale gas processing to recover NGLs. Although intriguing, the economic viability of these alternatives was complicated by the distributed and transient nature of flared gas, requiring innovative approaches to effective implementation.

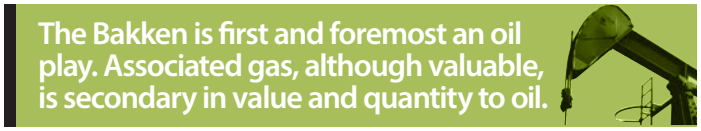
Another project completed by the EERC demonstrated the use of wellhead gas as a fuel for the diesel generators powering drilling rigs. Results from the project indicated that 1.8 billion cubic feet of gas could be used annually to power 200 drilling rigs in North Dakota, saving over $72 million in fuel cost.

Currently, the EERC, Continental Resources, Whiting Petroleum, Marathon Oil, and others are working collaboratively to further improve the efficiency of wellsite operations, including gas use and flaring.

What Should the Public Know about Bakken Flaring?







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North Dakota oil & gas research program

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WATER

Water is a critical ingredient for oil and gas development within the unconventional oil reservoirs of western North Dakota. Because of the current high costs for acquisition, disposal, and transportation of existing potable water resources in the region, treatment and/or use of nontraditional water supplies may be an economically viable alternative. The Energy & Environmental Research Center (EERC) is currently engaged in a project to investigate and accelerate development of new options to reduce fresh water consumption in Bakken production operations and decrease water costs to production operations.

How Is Water Used in Oil and Gas Production?

Development of one of the largest unconventional oil and gas plays in North America is occurring in North Dakota and Montana, with oil from the Bakken and Three Forks Formations being produced at over 800,000 barrels a day. It is estimated that there are hundreds of billions of barrels of oil in these formations. Robust development is expected to continue for at least another decade. While development of these resources clearly enhances the nation's energy security, a number of challenges are associated with that development, including the need for substantial volumes of water for hydraulic fracturing operations.

How Much Water Are We Talking?

Hydraulic fracturing is a process that injects a blend of mostly water with minor amounts of various additives at high pressure into these deep formations to create fractures and flow paths necessary for oil and gas extraction from rocks with very low permeability. A Bakken well requires 1 million to 5 million gallons of water for hydraulic fracturing. The North Dakota Department of Mineral Resources estimates that 20 million to 30 million gallons of water a day, or 7.3 billion to 11 billion gallons of water a year, will be needed over the next few decades.

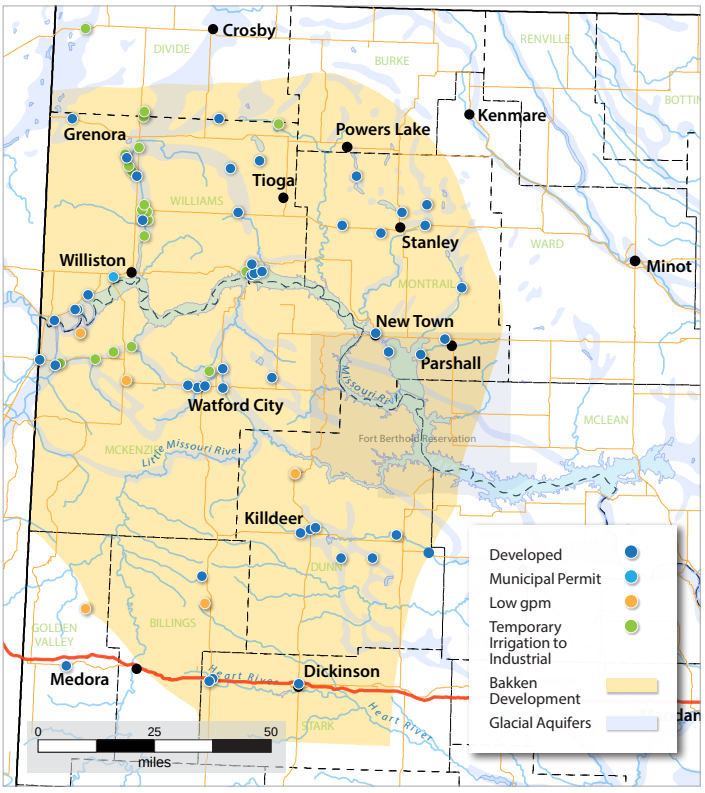
Center pivot irrigation in North Dakota requires about 4 million gallons of water a day for a 1-square-mile section of land.

Where Do Producers Get the Water?

While the volumes of water used for hydraulic fracturing are not especially high when compared to those needed for municipal and agricultural use within western North Dakota, in some areas there is a high degree of competition among various users for limited freshwater supplies. As shown below, there are a limited number of locations from which to obtain freshwater. Many such water depots and municipalities have a limited supply. The Missouri River system has an abundant supply of water, but federal concerns over suitable access points have delayed and/or limited access. Most other surface water bodies in the region are small and do not provide a reliable supply of water because of seasonal flow variations.

For water haulers, the limited number of water supply locations translates to long transportation distances and excessive amounts of time spent waiting in lines at water depots, resulting in high water acquisition (and wastewater disposal) costs for Bakken oil producers. Given the current demand for water resources and the high costs of transportation, the oil and gas industry is motivated to explore options for water reuse and/or recycling.

Operating Water Depots (as of September 11, 2012)



WATER-HANDLING COSTS

ACQUISITION COSTS

	Cost, $/bbl	Cost, $/1000 gal
Raw Water	$0.25–$1.05	$5.95–$25.00
Transportation	$0.63–$5.00	$15.00–$119.05

DISPOSAL COSTS

	Cost, $/bbl	Cost, $/1000 gal
Transportation	$0.63–$9.00	$15.00–$214.29
Deep Well Injection	$0.50–$1.75	$11.90–$41.66
Total Costs	$2–$17	$47–$400

Source: Energy & Environmental Research Center Report on Bakken Water Opportunities – Phase II

What Options Do We Have?

As treatment technologies and fracturing fluid systems advance, there may be potential options for treatment, reuse, and/or recycling of nontraditional water supply sources for use in Bakken development, such as:

- Treatment and reuse of the water used for hydraulic fracturing after it returns to the surface (referred to as flowback).
- Treatment and use of wastewater from other nontraditional sources, such as saline groundwater and municipal wastewater.
- Use of hydraulic fracturing fluid systems that work with saline water rather than high-quality water.

The above approaches are not without challenges. For example, Bakken flowback tends to be very salty, and only a portion of it returns to the surface (typically about 25% or less), making treatment difficult and limiting the amount available for reuse. Treatment of other nontraditional water sources may be easier, but transportation costs may be too high. The use of salt-tolerant fracturing fluids may hold promise, but these formulations are just beginning to be developed. While industry recognizes the benefits of water recycling and reuse for Bakken development, these challenges have prevented widespread implementation to date.

How Will Development of New Water Options Benefit North Dakota?

Industry development of new technologies to recycle or otherwise utilize flowback, produced water, or saline groundwater would provide multiple benefits to the state and industry and improve the quality of life for residents impacted by truck traffic and associated dust and road maintenance issues. Some of the key benefits include the following:

- Decreased demand on freshwater resources
- Decreased wastewater disposal costs and associated costs for industry
- Fewer issues associated with the heavy volume of truck traffic in the region, such as road maintenance, dust control, and air emissions
- Increased versatility in water supply options, resulting in decreased production costs
- Decreased environmental footprint for Bakken development

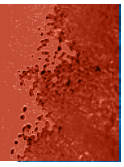
What Does the Public Need to Know about Water Use in Oil Production?

A typical Bakken well requires 1 million to 5 million gallons of high-quality water for hydraulic fracturing.

Locations to obtain freshwater are limited, and many have a limited supply, resulting in high water acquisition (and wastewater disposal) costs.

Potential options for water treatment are being developed to minimize demands on freshwater supply sources.

The use of salt-tolerant fracturing fluids may hold promise, but these formulations are just beginning to be developed.



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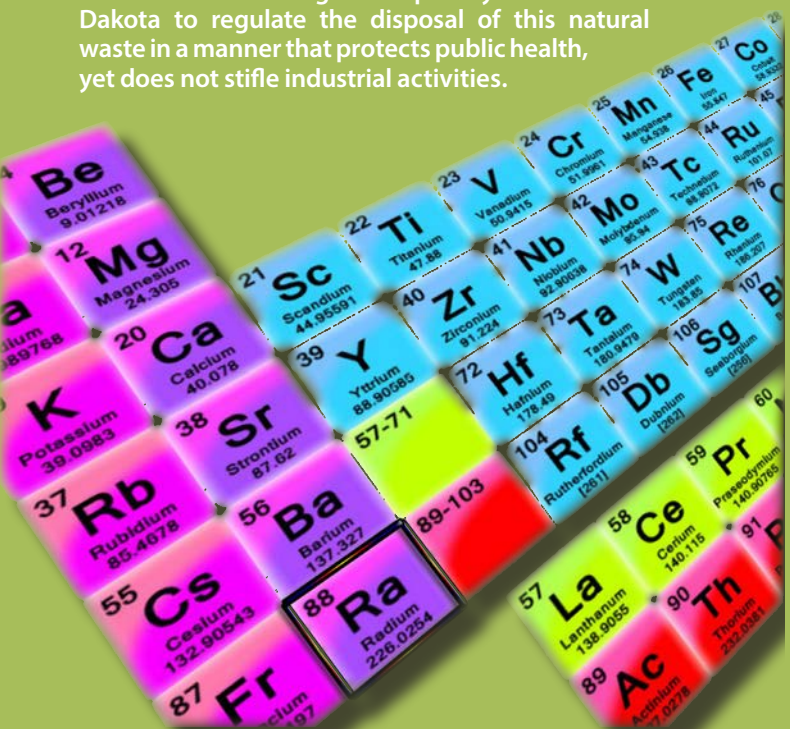
NORM

NORM waste has received increasing levels of attention during the rapid increase in Bakken oil and gas activity. NORM is a new term to many. The Energy & Environmental Research Center (EERC) is working to apply science to rules being developed by the state of North Dakota to regulate the disposal of this natural waste in a manner that protects public health, yet does not stifle industrial activities.



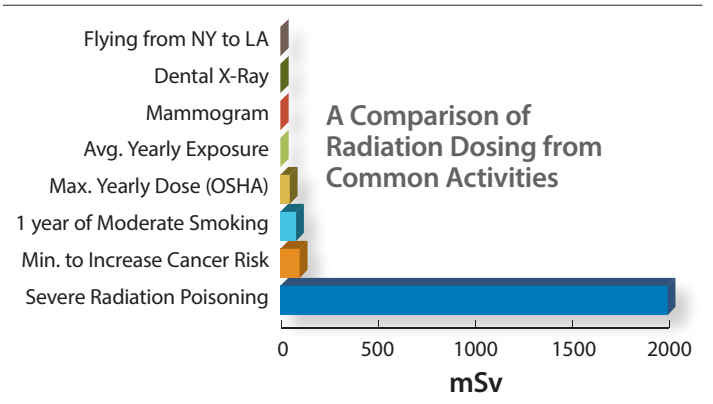
What Is NORM?

Naturally occurring radioactive material (NORM) is present throughout the Earth's crust and can be concentrated by processes associated with the recovery of oil and gas. Also referred to as technologically enhanced NORM (TENORM), this material can be concentrated in oil production wastes such as sludge, drilling mud, used water filtration sleeves, and pipe scale. TENORM radioactivity levels tend to be highest in water-handling equipment.

Some Radiation Fundamentals

Radiation is energy emitted by matter in the form of rays or high-speed particles. Radiation is all around us. There is a natural background radiation level throughout the universe. Radioactive materials in the Earth's crust also contribute to terrestrial background radiation.

Radiation is either ionizing or nonionizing, depending on how it affects matter. Nonionizing radiation (light, heat, radio waves) transfers energy to materials through which it passes but does not break molecular bonds. Ionizing radiation (x-rays, gamma rays, high-energy particles) cuts bonds that hold molecules together, thus leaving molecule pieces, known as ions, in its wake. These ions may cause changes in living tissues or may change physical properties of nonliving materials.



Radiation measurement is a confusing mix of terms and concepts. Radioactivity levels are measured in terms of total activity (emitted from source material), dosage (radiation absorbed), or exposure (e.g., millisievert [mSv]). Although dosage is often the most meaningful in public health discussions, most state rulings on NORM disposal regulate levels of radioactivity per unit weight.

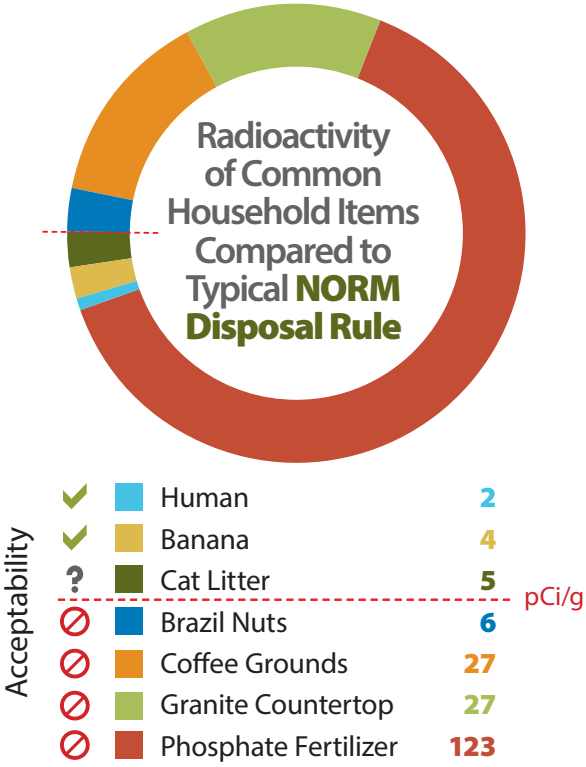
What Level of Radioactivity Is Hazardous?

To understand how much radiation is dangerous, we need to focus on equivalent dose numbers. Equivalent dosages accumulate over time of exposure, so intensity and duration are equal factors. More of either increases the risk of adverse health effects. A nuclear reactor core may trap huge amounts of total radioactivity, but because of engineered shielding between the reactor core and personnel operating the nuclear power plant, the personnel do not absorb hazardous levels of radioactivity. When the personnel must enter a zone of higher radioactivity, their exposure time is strictly limited. Comparing radioactivity with equivalent doses is like comparing apples and oranges.

Generally speaking, TENORM must be inhaled or ingested to pose a radiation health risk. This is because a vast majority of radiation emitted from TENORM is in the form of alpha particles, easily stopped by the outer layers of human skin. Because these wastes are typically landfilled or otherwise buried, there is little risk from external exposure.

How Is NORM Regulated?

Wastes containing NORM are not regulated by federal agencies. Instead, it has been left to states to regulate handling of NORM. Currently, 15 states specifically regulate NORM, while other states more generally regulate radioactive wastes. Of course, the language of these NORM regulations varies, but many states have similar regulations limiting disposal of NORM-containing waste in municipal landfills to less than 5 picoCuries/gram (pCi/g) above the normal background level of ^{226}Ra or ^{228}Ra, two radioactive isotopes of radium that can be found in oil field wastes. The table below suggests a comparison between common landfill wastes and their radioactivity levels against this common NORM rule. It is not suggested that these wastes fall under NORM disposal rules, but it does present an interesting comparison.



How Is NORM Disposed Of?

Disposal protocols differ greatly across states and across oil and gas producers. Generally, NORM-contaminated equipment is tagged, sent to a decontamination service, decontaminated, and then shipped to a landfill. Alternately, some companies opt to send low-level contaminated material directly to licensed NORM disposal sites, often out of state. Occasionally, companies unwittingly transport NORM-contaminated waste to local landfills not approved to accept this waste. Most oil patch landfills have their own radioactivity monitoring protocol in place to prevent this.

This, of course, leads naturally to the question of what threshold of radioactivity defines "NORM contamination" in the first place? Here is where science is currently working to provide answers. The oft-employed 5-pCi/g rule is extremely conservative, in the estimation of many. Work is ongoing to determine an appropriate threshold.

What Should the Public Know about NORM?

Radiation is everywhere around us and is emitted from a great many common household items.

NORM is not nuclear waste; it is naturally occurring waste with a very low level of radioactivity.

NORM does not pose a direct threat to public health when proper disposal protocols are followed.

North Dakota does not currently specifically regulate NORM-containing waste disposal but is looking into prudent rulemaking to ensure all producers live up to the responsible protocols currently employed by a majority of producers in the Williston Basin.

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