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Water Produced with Coal-Bed Methane

Introduction

Natural gas produced from coal beds (coal-bed methane, CBM) accounts for about 7.5 percent of the total natural gas production in the United States. Along with this gas, water is also brought to the surface. The amount of water produced from most CBM wells is relatively high compared to conventional natural gas wells because coal beds contain many fractures and pores that can contain and transmit large volumes of water. In some areas, coal beds may function as regional or local aquifers and important sources for ground water. The water in coal beds contributes to pressure in the reservoir that keeps methane gas adsorbed to the surface of the coal. This water must be removed by pumping in order to lower the pressure in the reservoir and stimulate desorption of methane from the coal (fig. 1). Over time, volumes of pumped water typically decrease and the production of gas increases as coal beds near the well bore are dewatered.

The need to decrease CO_2 emissions favors the increased use of natural gas as an alternative to coal. The contribution of CBM to total natural gas production in the United States is expected to increase in the foreseeable future (Nelson, 1999). Estimates of the amount of recoverable CBM have increased from about 90 trillion cubic feet (TCF) 10 years ago to about 141 TCF, spurred by advances in technology, exploration, and production (Nelson, 1999). As the number of CBM wells increases, the amount of water produced will also increase. Reliable data on the volume and composition of associated water will be needed so that States and communities can make informed decisions on CBM development. Most data on CBM waters have been gathered at two historically large production areas, the San Juan Basin in Colorado and New Mexico (sparse data) and the Black Warrior Basin in Alabama (extensive data). Rapid development in basins with limited data on CBM waters—i.e., the Powder River Basin in Wyoming and Montana—is currently a concern of producers; land owners; Federal, State, and local agencies; coal mining companies; and Native Americans.

Volumes and Compositions of CBM Water

As shown in table 1, the amount of water produced, as well as the ratio of water to gas, varies widely among basins with CBM production. Causes of variations include the duration of CBM production in the basin, original depositional environment, depth of burial, and type of coal. Relatively recent regulations concerning disposal and withdrawal of produced water have led to more accurate reporting of water data. Volume data for produced water from specific coal beds has the potential to provide information on exploration and production of CBM. Compositional data is commonly limited to the major dissolved ion species in water (cations and anions), whereas information on trace metals and isotopic composition is sparse.

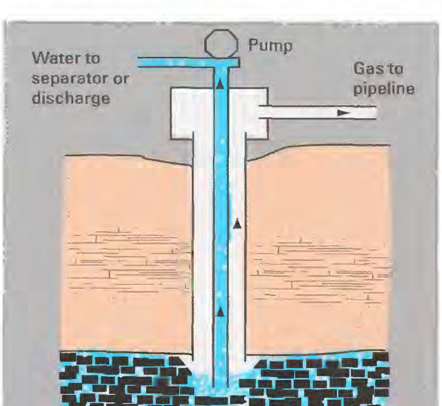


Figure 1. Simplified illustration of a coal-bed methane production well.

Table 1. Water production in some major coal-bed-methane-producing basins.

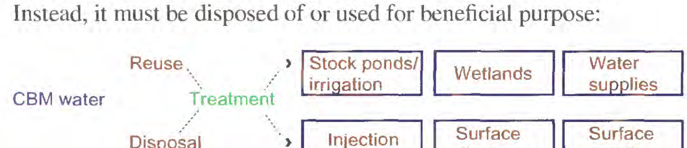
[Bbl, barrel (42 gallons); MCF, thousand cubic feet; No., Number; Avg., Average; disch., discharge. Data for Black Warrior Basin from Alabama State Oil and Gas Board as of 5/00; data for Powder River Basin from Wyoming Oil and Gas Commission as of 5/00; data for Raton and San Juan Basins from Colorado and New Mexico Oil and Gas Commissions as of 2/00; data for Uinta Basin from Utah Division of Oil and Gas as of 6/00]

Basin	State	No. of wells	Avg. water production (Bbl/day/well)	Water/gas ratio (Bbl/MCF)	Primary disposal method
Black Warrior	Ala.	2,917	58	0.55	Surface disch.
Powder River	Wyo., Mont.	2,737	400	2.75	Surface disch.
Raton	Colo.	459	266	1.34	Injection
San Juan	Colo., N. Mex.	3,089	25	0.031	Injection
Uinta	Utah	393	215	0.42	Injection

Generally, dissolved ions in water coproduced with CBM contain mainly sodium (Na), bicarbonate (HCO_3), and chloride (Cl). The composition is controlled in great part by the association of the waters with a gas phase containing varying amounts of carbon dioxide (CO_2) and methane. The bicarbonate component potentially limits the amount of calcium (Ca) and magnesium (Mg) through the precipitation of carbonate minerals. CBM waters are relatively low in sulfate (SO_4) because the chemical conditions in coal beds favor the conversion of SO_4 to sulfide. The sulfide is removed as a gas or as a precipitate. The total dissolved solids (TDS) of CBM water ranges from fresh (200 mg/L or parts per million) to saline (170,000 mg/L) and varies among and within basins. For comparison, the recommended TDS limit for potable water is 500 mg/L, and for beneficial use such as stock ponds or irrigation, the limit is 1,000–2,000 mg/L. Average seawater has a TDS of about 35,000 mg/L. The TDS of the water is dependent upon the depth of the coal beds, the composition of the rocks surrounding the coal beds, the amount of time the rock and water react, and the origin of the water entering the coal beds. Trace-element concentrations in CBM water are commonly low (<1 mg/L) as are volatile organic compounds (Gas Research Institute, 1995; Rice, 2000). In general, most CBM water is of better quality than waters produced from conventional oil and gas wells.

Fate of CBM Water

Water coproduced with methane is not reinjected into the producing formation to enhance recovery as it is in many oil fields. Instead, it must be disposed of or used for beneficial purpose:



The choice depends in large part on the composition of the water. Important composition information should include TDS (often equated to the amount of "salt" a water contains), pH, concentrations of dissolved metals and radium, and the type and amounts of dissolved organic constituents. If, with minor to no treatment, the water is of sufficient quality, it may be used with caution to supplement area water supplies. This water must meet requirements under several Federal and State regulations, including the Clean Water Act, the Safe Drinking Water Act, and the Resource Conservation and Recovery Act. If the water does not meet Federal and State standards for reuse, or if the cost of treatment is excessive, the water is disposed of by injection into a compatible subsurface formation or by surface discharge. Disposal of CBM water is also regulated by Federal and State agencies and must meet criteria for each type of disposal. For example, subsurface injection requires compatibility studies of the proposed injection formation and the water that is injected, whereas discharge to surface streams must meet daily effluent limits on constituents such as chlorides along with other criteria. For any CBM field, the cost of handling coproduced water varies from a few cents per barrel to more than a dollar per barrel and can add significantly to the cost of gas production. In some areas, the volumes of water produced and the cost of handling may prohibit development of the resource.

USGS Studies of CBM-Produced Water

The U.S. Geological Survey (USGS) has ongoing studies designed to provide information on the composition and volumes of CBM water in some of the most active areas of production in the United States. Data obtained on CBM waters provides information on the heterogeneity of the CBM reservoir, the potential flow paths in the reservoir, the source and evolution of the water, and the quality of the water prior to disposal or reuse. The USGS Energy Resources Team is conducting multidisciplinary studies in the Uinta and Powder River Basins that include sampling waters coproduced with CBM (fig. 2). These studies combine investigations of regional geology and hydrology as well as reservoir-specific studies such as coal fracture orientation, coal composition, gas composition and isotopic values, methane desorption, and water composition and isotopic values. Researchers from the USGS, Bureau of Land Management, Bureau of Indian Affairs, State agencies, and private companies are cooperating in an effort to provide a better understanding of CBM resources and associated water.

Figure 2. USGS chemist prepares to sample water from the wellhead of a coalbed methane well. Wellhead sampling and on-site sample preservation and analysis are critical to obtaining good quality compositional and isotopic data. Many parameters, such as pH, alkalinity, and trace-metal content, change rapidly once the water is removed from the well.

Average Water Composition

Uinta Basin (Ferron CBM, Utah) 1				
	mg/L			
Field	TDS	Cl	HCO_3	Br / Cl
Buzzard Bench	11000	2300	8500	0.0063
Drunkards Wash	8900	2500	5500	0.0032
Helper State	26000	14000	5200	0.0013

Powder River Basin (Wyoming) 2					
	µg/L			µg/L	
	CBM	DWS		CBM	DWS
Arsenic	<3	50	Manganese	32	50
Barium	620	2000	Mercury	<0.3	2
Chromium	<2	100	Selenium	<2	50

Figure 3. Concentrations of selected components in CBM water from three fields in the Ferron CBM area, Utah, and from 47 wells in Wyoming. TDS, total dissolved solids; DWS, drinking water standards. 1, Rice (1999); 2, Rice (2000).

CBM water studies include sampling wells throughout a field as well as analyzing the volumes of water that are produced. Analyses include major, minor, and trace constituents, including arsenic (As), selenium (Se), copper (Cu), cadmium (Cd), lead (Pb), molybdenum (Mo), chromium (Cr), mercury (Hg), and zinc (Zn) (fig. 3). The major anions (Cl^-, SO_4^{2-}, and HCO_3^-) are measured as well as selected other constituents, such as ammonia and total organic carbon. Isotopic analyses of the samples for deuterium, oxygen, and carbon provide data to help determine the origin of the water and its solutes as well as the compositional evolution of the water. Volumes of water produced from a CBM field are analyzed to determine trends in production that may be related to reservoir parameters such as permeability. In some areas of CBM development, USGS Water Resources District Offices are cooperating with State and Federal agencies to perform targeted studies such as measuring concentrations of selenium in wetlands and dating waters.

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