# Using a Bayesian statistical model to determine the amount of coalbed natural gas co-produced water in the Powder River, WY and MT

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The Powder River Basin (PRB), Wyoming and Montana, has experienced exponential growth in coalbed natural gas (CBNG) production over the past 15 years. CBNG recovery is associated with production of large volumes of co-produced water, much of which is discharged on the land surface. Montana's concern that this produced water may impact the quality of water used for irrigation led them to institute water anti-degradation regulations. These rules have been challenged and additional scientific evidence is required to assess the impact of CBNG on river water quality.

In this study, we sought to determine the amount of CBNG co-produced water that reaches the Powder River annually using a Bayesian model implemented in WinBUGS. This was accomplished using the dissolved inorganic carbon (DIC) and Sr concentrations as well as the $\delta^{13}C_{DIC}$ and $^{87}Sr/^{86}Sr$ of water collected from the Powder River at 30 locations along its length. We created a two end-member mixing model that accounts for the $^{87}Sr/^{86}Sr$, $\delta^{13}C$, Sr and DIC concentrations of river water unaffected by CBNG production and of CBNG co-produced water. The model allows for all possible combinations of the end-members to account for the measured state of the river and incorporates uncertainty in the measurements as well as process errors.

Beaver Creek and Flying E Creek are permitted to receive 1.84 million gallons (2.84 $ft^3s^{-1}$) and 0.8 million gallons (1.24 $ft^3s^{-1}$) of CBNG co-produced water per day. Model results confirm that Beaver Creek and Flying E Creek are almost entirely composed of CBNG co-produced water. The model indicates that up to 20% of the Powder River is composed of CBNG co-produced water immediately upstream of Flying E Creek and decreases as distance from Flying E Creek increases, to just 1-5% before the confluence with the Yellowstone River. These results indicate that CBM co-produced water can be volumetrically significant fraction of the water carried by the Powder River, particularly at times of low-flow, but this amount of CBNG co-produced water is not enough to significantly affect the sodium adsorption ratio (SAR) or electrical conductivity (EC) of the Powder River.

# The contrasting behavior of As and Sb in the mining waste near Pezinok, Slovakia

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Mineralogical composition of mining wastes deposited in voluminous tailing impoundments around the world is the key factor that controls retention and release of pollutants. On average, the mining waste (tailings) in Pezinok (Slovakia) contain 47.7±8.0 (1σ) g Fe/kg, 6.6±3.0 g Sb/kg, and 6.0±2.1 g As/kg ($n$ = 118). The secondary minerals are dominated by iron although a subordinate amount of Sb-rich grains can also be found. The grains may be a product of a complete replacement of the ores or they may have precipitated from the solutions which circulate through the impoundments. Their Fe/As ratios are limited between 3.0 and 3.5 but they span the entire range of Fe/Sb ratios. Our micro-X-ray diffraction (μ-XRD) data show that the iron oxides with abundant As are X-ray amorphous, made of a ferrihydrite-like phase with copious amount of As. The grains with less As and little to moderate amount of Sb are made of nanoparticulate goethite; the grains with a significant proportion of Sb are nanoparticulate tripuhyite ($FeSbO_4$).

Our results show that the two elements, As and Sb, control the fate and properties of the nanoparticulate iron oxides in a significant way. While As inhibits their transformation to crystalline phases, Sb forms either a separate nanophase (tripuhyite) or allows goethite to form and probably attaches to the surface of these nanoparticles. The role of microorganisms in these seemingly exclusively inorganic processes is not clear. However, we do know that the mining waste is populated by a surprising diversity of bacteria. The population is dominated by oligotrophic arsenic resistant bacteria whose arsenic resistance is in most cases established via arsenate reductases. Furthermore, we found 16S rDNA sequences of sulfur oxidizing and iron reducing strains. In the further work, we will focus on the interplay of the inorganic and biological processes in formation of secondary minerals.