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Greenhouse gas emissions from oilfield-produced water in Shengli Oilfield, Eastern China

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ABSTRACT

Greenhouse gas (GHG) emissions from oil and gas systems are an important component of the GHG emission inventory. To assess the carbon emissions from oilfield-produced water under atmospheric conditions correctly, *in situ* detection and simulation experiments were developed to study the natural release of GHG into the atmosphere in the Shengli Oilfield, the second largest oilfield in China. The results showed that methane (CH_4) and carbon dioxide (CO_2) were the primary gases released naturally from the oilfield-produced water. The atmospheric temperature and release time played important roles in determining the CH_4 and CO_2 emissions under atmospheric conditions. Higher temperatures enhanced the carbon emissions. The emissions of both CH_4 and CO_2 from oilfield-produced water were highest at 27°C and lowest at 3°C. The bulk of CH_4 and CO_2 was released from the oilfield-produced water during the first release period, 0–2 hr, for each temperature, with a maximum average emission rate of 0.415 g $CH_4/(m^3 \cdot hr)$ and 3.934 g $CO_2/(m^3 \cdot hr)$, respectively. Then the carbon emissions at other time periods gradually decreased with the extension of time. The higher solubility of CO_2 in water than CH_4 results in a higher emission rate of CH_4 than CO_2 over the same release duration. The simulation proved that oilfield-produced water is one of the potential emission sources that should be given great attention in oil and gas systems.

Introduction

CH_4 and CO_2, the most well-known greenhouse gases (GHGs), are highly associated with global climate change (Glagolev et al., 2008; Rodhe, 1990; Xu et al., 1999). CH_4 contributes more than 20% to global warming and is receiving increased attention. The International Panel on Climate Change (IPCC) reported that on a 100-year time horizon, CH_4 emissions are more potent than CO_2 in terms of global warming potential, because its emissions have 25 times more impact on the atmosphere than CO_2 on a mass basis (Griggs and Noguer, 2002; IEA, 2008). CH_4 and CO_2 emissions from oil and natural gas systems are important sources in GHG inventories, and their relative roles are anticipated to increase in the future (IPCC, 2000; Reilly et al., 2003; EPA, 2006a). In 2006, the Environmental Protection Agency (EPA) estimated that fugitive CH_4 emissions from the oil and gas sector were approximately 130 million tons of CO_2-eq in total, which accounts for approximately 2% of the total GHG emissions in the USA (EPA, 2008). These fugitive emissions of CH_4 are

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generated from disparate sources located throughout the main processes: production, processing, transmission, distribution, and storage processes (EPA, 2006b). As the oil and gas system is large, diverse and complex, and there are numerous types of emission sources, a few poorly known sources have been ignored (Dedikov et al., 1999). Thus assessing the accessible sources is conducive to minimizing the uncertainty of carbon emission values, and reducing these possibly insufficiently considered sources (Guan et al., 2012; Sinton and Fridley, 2000; Streets et al., 2001).

Wastewater, which includes human and industrial wastewater, is listed as one of the CH_4 emission sources in the IPCC Guidelines for National GHG Inventories (IPCC, 2006). As is well known, formation water is an important medium in the process of natural gas and liquid petroleum migration underground (Dhima et al., 1998). Natural gas could be enriched in underground aquifers, and the solubility of natural gas is higher than liquid petroleum in water at reservoir temperature and pressure (Gao et al., 2012). When the formation water is produced at the surface, most gases are released from the water as the temperature and pressure decrease. Thus, formation water has the potential for carbon emissions from an environmental aspect when it is produced at the surface (IPCC, 2006). China is one of the world's major oil producers, and forty-one large- to medium-sized oilfields have been discovered in China (Jin, 2008). With the exploration and development of the oilfields, the amount of oilfield-produced wastewater is increasing. Chen et al. (2014) confirmed by experiment the existence of carbon emissions from gas-field-produced water at atmospheric temperature and pressure. The concentration of CH_4 is generally over 90% in gas fields, but is generally 60%–90% in oilfields. Thus, there is little known about the carbon emissions from large amounts of oilfield-produced water under atmospheric conditions. Scientists have always taken seriously the natural gas dissolved in and exsolved from underground formation water, but have seemed to ignore the contributions to the atmosphere by the gases released from oilfield-produced water as a by-product of the oil extraction process from subsurface geological formations (Weschenfelder et al., 2015). No scientific literature has presented the carbon emissions from oilfield-produced water under atmospheric conditions until now.

Most Chinese giant oilfields are distributed in the sags rich in oil and gas. Shengli Oilfield, located in Dongying Sag of the Bohai Bay Basin (Fig. 1), is the second largest oilfield in China. After several decades of development, it has entered the mid-and-late part stages. The moisture content of crude oil has increased by up to 90% in the Shengli Oilfield, as a mass of water has been injected back into the wells. When the large quantity of formation water was drained during the extraction of crude oil and natural gas, most of the gases were released from the water as the temperature and pressure decreased quickly. Before the water reached the well mouth, three phases (oil, gas and water) were separated by an oil–gas–water separator. Most of the gas was released, except for a small quantity of gas that remained in the water after it rose to the surface. However, the quantity of produced water has now reached, on average, tens of thousands of cubic meters a day in the Shengli Oilfield. The fugitive emissions of CH_4 and CO_2 from the oil and gas system are an important component of the GHG emission inventory (IPCC, 2006). It is also of scientific importance to assess the possible contribution of GHGs released from oilfield-produced water into the atmosphere and to reduce the uncertainty of estimating carbon emissions in oil and gas systems. Shengli Oilfield is believed

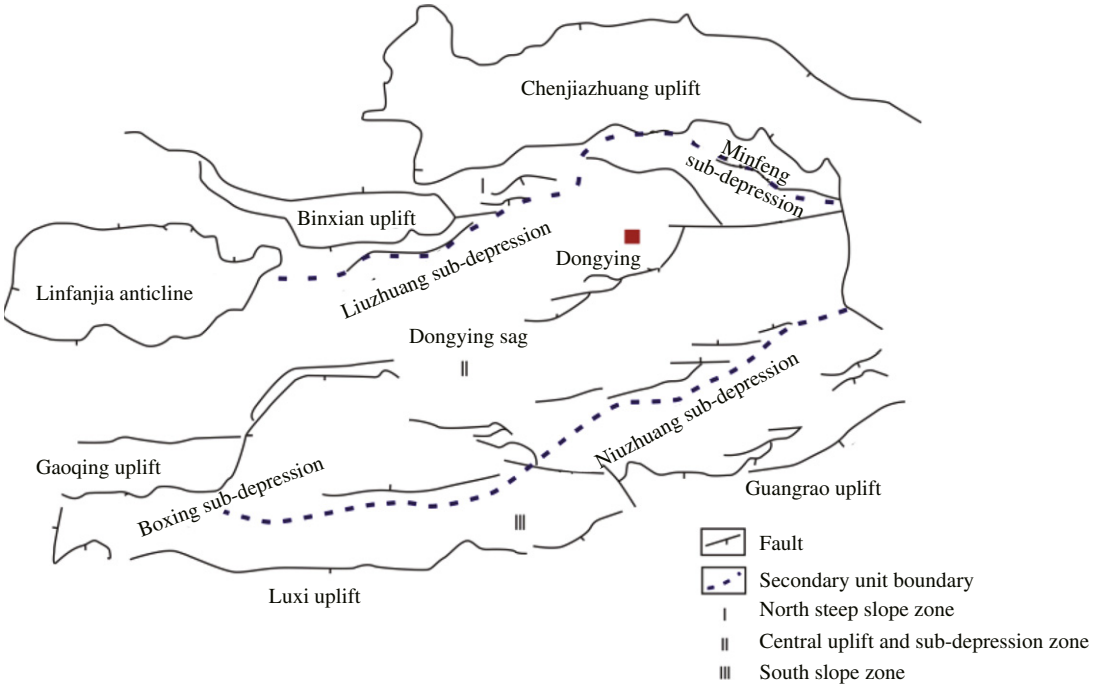

Fig. 1 – Dongying Sag and its secondary structural units, modified from the work by Zhang et al. (2014).