Written Testimony

CONGRESSIONAL HEARING ON ORPHANED WELL LEGISLATION

House Subcommittee on Energy and Mineral Resources

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Chair Lowenthal, Ranking Member Stauber, and distinguished members of the Subcommittee. Thank you for inviting me to testify at today's hearing. My name is Mary Kang and I'm an assistant professor in Civil Engineering at McGill University. My research focuses on characterizing and mitigating methane emissions and other environmental impacts of abandoned and orphaned oil and gas wells.

The definition of abandoned wells varies among states/provinces/territories/countries and there are many well statuses that can be considered as "abandoned". Here, I adopt the broad definition taken by the U.S. Environmental Protection Agency in their Greenhous Gas Inventory (GHGI) that includes suspended, idle, orphaned, plugged, dormant, deserted, inactive, junked, temporarily abandoned, and shut in. Here, I will simply refer to this broad category of wells as "abandoned" or "abandoned and orphaned".

Abandoned oil and gas wells, including those that are orphaned, are a source of methane emissions to the atmosphere (Kang et al., 2014, 2016, Townsend-Small et al., 2016, Riddick et al., 2019, Pekney et al., 2018, Boothroyd et al., 2016, Williams, Regehr, and Kang, 2021, Lebel et al., 2020). According to the GHGI, 0.276 million metric tons (MMT) (14.3 billion standard cubic feet) of methane were emitted from abandoned wells in the U.S. in 2017 alone. They currently rank 10th among anthropogenic methane emission sources in the U.S.

Abandoned and orphaned wells also pose other environmental risks as they can contribute to air pollution, groundwater contamination, ecosystem degradation, which may all be linked to human health impacts (Kang et al., In Press). This is because abandoned and orphaned wells can act as subsurface leakage pathways connecting oil and gas formations, including shallow pockets from which production is uneconomical, to groundwater aquifers and the atmosphere.

The following are three highlights on available information, which I will go into more detail below:

1. There are likely more than two and a half million abandoned oil and gas wells in the U.S. but discrepancies between data sources exist. There are approximately 1.5 million plugged abandoned wells, which implies that there are likely more than one million unplugged abandoned wells in the U.S. Of these wells, there are approximately 56,000 documented orphaned wells, which do not account for the hundreds of thousands of undocumented orphaned wells that are likely to exist across the U.S.

2. Plugging methods currently available and employed are effective at reducing methane emissions from abandoned wells. But vented plugged wells in coal areas (in Pennsylvania for example) are high emitters.
3. High emitters representing <1% of plugged wells and 9-16% of unplugged wells are responsible for >90% of methane emissions.

Research is needed to fill gaps in our understanding of leakage processes and the associated environmental and climate impacts of abandoned and orphaned wells. There should be more research involving:

a. Field measurements of methane emissions from representative samples of abandoned wells to identify predictors of high emission rates.
b. Conjunctive field-based study on methane emissions and other environmental impacts of abandoned wells.
c. Improved methods for well finding, methane emission rate measurements, and recordkeeping.
d. Analysis of temporal variability in methane emissions from abandoned oil and gas wells, both in the short and long term.
e. Development of low-cost mitigation options.

Measurements of methane emission from abandoned oil and gas wells

Abandoned wells act as subsurface pathways connecting oil and gas reservoirs with groundwater aquifers and the ground surface, where gases can be emitted to the atmosphere. Because oil and gas are lighter than fresh and saline water, oil and gas will migrate upward if a sufficiently permeable pathway exists. The measurements discussed in this section mainly capture emissions at the ground surface where the well is located. Therefore, methane emissions from degassing of produced groundwater by households or other users and methane migrated to other surface locations are not discussed here.

Direct measurements of methane emissions from abandoned oil and gas wells have been made in in the U.S. (Pennsylvania, Oklahoma, West Virginia, Ohio, Colorado, Wyoming, Utah, and California), Canada (British Columbia and New Brunswick), the Netherlands, and the U.K. Measured methane emission rates range over more than 7 orders of magnitude, reaching 15 tonnes per year per well (Kang et al., 2019). At a few wells, measurements indicate that the wells and the surrounding soils are sinks for methane to the atmosphere. Measurements of methane emissions from abandoned wells show that high emitters (>0.1 tonnes of methane per year) govern total and average emission rates. Based on analysis of 598 measured wells, high emitters representing <1% of plugged wells and 9-16% of unplugged wells are responsible for >90% of the emissions (Williams, Regehr, and Kang, 2021).

Plugged wells emit less methane than unplugged wells (Kang et al., 2016), when we consider wells without venting in non-coal areas. For plugged and vented wells in coal areas (regions with mineable coal seams), the methane emission rates are as high as the highest-emitting unplugged wells. In addition, gas wells emit at higher rates than oil or combined oil and gas wells. There are a wide range of factors that may be predictors of high-emitting abandoned wells, including well age, well depth, plugging status, gas-to-oil ratio, wellbore deviation, depth, presence of hydrogen sulfide, geology, geographical region, operator, density of wells, regulations, and oil/gas price (Watson and Bachu, 2009). Although there have been studies looking at the role of these variables for leakage along active wells, the role of many of these factors on methane emissions from abandoned wells needs further evaluation.

To understand the potential for temporal variability in emission rates, up to 10 measurements of methane flow rates were made at individual wells over a three-year period (Kang et al., 2016). The measurements show that seasonal and other variations are most pronounced in the lower-emitting wells and that higher-emitting wells continue to emit at the same order of magnitude. However, other studies have shown that shorter term variability over hours and days can be significant (Riddick et al., 2020). Therefore, temporal variability of methane flow rates over multiple years and at the decadal scale requires further study.

Geochemical and isotopic analysis have frequently been used to determine the source of the leaking methane, which was generally found to be of thermogenic origin (Kang et al., 2014, 2016). Emitted gases can originate from the production reservoir or from shallower pockets of thermogenic gas. Abandoned wells can also act as a pathway for non-thermogenic sources of methane, which would otherwise stay in the subsurface.

Methane emission rates at control sites (typically located 1 to 10 meters away from the well depending on site conditions) are generally orders of magnitude lower than at the corresponding well. Methane emission rates at controls are influenced by land cover with negative methane flow rates, indicating a sink for methane, observed in forests and grasslands and positive methane flow rates, indicating emissions to the atmosphere, observed in wetlands.

Number of Abandoned, Orphaned, and Otherwise Inactive Oil and Gas Wells

There are >4 million oil and gas wells drilled in the U.S. Of these, approximately 2.7 million are abandoned and approximately half (1.2 million) of these wells remain unplugged (Kang et al., In Press). There are discrepancies between various sources of well counts. The total number of oil and gas wells in the U.S. according to state databases is 4,700,000; however, using historical references and data from the EPA (which uses data provided by Enverus' DrillingInfo), the total number of oil and gas wells in the U.S. is 4,072,000.

There are many efforts to find abandoned and orphaned wells (Saint-Vincent et al., 2020, de Smet et al., 2021) using remote sensing with magnetometry, LiDAR, and georeferencing historical photos. According to a recent study by Saint-Vincent et al. (2020), "the average number of wells in the continental United States is 6.04 ± 19.97 million wells with 1.16 ± 3.84 million of those designated as abandoned wells".

Monitoring and Mitigation Strategy

A cost-effective strategy for mitigating methane emissions from abandoned wells is to focus on high emitters. However, this requires high emitters to be identified and located, which in turn, requires monitoring of representative samples. Representative samples should cover different types of wells, production levels, age, technology, climate, level of development, geology and more. Currently, approximately 1,000 abandoned wells out of ~2.5 million (or 0.4%) abandoned wells in the U.S. have been measured.

Methane emission rates from high-emitting abandoned wells are currently too low to determine using aerial or satellite measurements. To efficiently monitor abandoned wells, a multi-level monitoring approach that combines atmospheric concentration screening and detailed ground-based measurements of high-emitting wells needs to be developed and tested in a wide range of environments. Detailed measurements using chamber-based methods have produced reproducible results and the methods are well-established (Kang et al., 2014). Nevertheless, questions remain as to the type of sensors required to adequately determine methane emission rates, partly because popular scientific instruments are likely to be too costly for many state programs. Another disadvantage of chamber-based methods is that they are labour-intensive, requiring in some cases, custom-built enclosures that require testing. Atmospheric concentration measurements coupled with atmospheric dispersion modeling has been used to measure methane emissions from sites that are challenging to enclose or access (Riddick et al., 2019). These measurements also require costly scientific instruments and specialized training to operate and analyze the data.

It is important to note that prioritization of wells for reducing methane emissions will be different from state plans for mitigating orphaned wells. States that do not have funds to plug all of their orphaned wells (wells for which a responsible party, other than the state, is no longer available) often prioritize wells that pose the greatest risk to human health and safety – such as wells in highly populated regions. In contrast, methane is well-mixed in the atmosphere and from a climate perspective, the total amount of methane emitted, regardless of where the wells are located, are important.

Plugging

Wells are required to be plugged at abandonment by government regulations. The cost of plugging a well according to regulations ranges from ~$1,000 to ~$1,000,000 per well, with most averages in the order of $10,000 per well (Kang et al., 2019). Plugging intervals are specified by regulations with the aim of isolating formations bearing protected groundwater, oil, and gas but they rarely require all intervals to be fully cemented. There is a possibility that plugged zones may fail or zones containing oil and gas may not be isolated such that the wells act as subsurface pathways to formations in which other wells are drilled. In some cases, the result can be methane being emitted at other surface locations or elevated methane concentrations in groundwater that can degas when produced for drinking, irrigation, or industrial purposes.

Although methane emission measurements show that plugging appears to be effective at the per-well level, plugs have been known to fail (Abboud *et al.*, 2021). However, the rate and extent to which plugs can degrade with time and how this degradation affects methane emission rates, groundwater quality, and other environmental components are unquantified. Moreover, the definition of protected groundwater can vary with jurisdiction and change over time but the plugging interval is set to the definition at the time of plugging. For most cases, there exists technology to remedy leaks from abandoned wells. One barrier to reducing methane emissions and other environmental impacts of abandoned wells is cost.

Conclusion

Even after society transitions away from fossil fuels, abandoned and orphaned wells may be emitting methane and impacting our water, air, and ecosystems for many years, decades, and possibly centuries. Therefore, it is important that we mitigate abandoned and orphaned wells. Plugging and remediation work will likely have climate and environmental benefits, however, there is a need for more research to understand the full suite of climate and environmental impacts of abandoned and orphaned wells so that we can design effective mitigation strategies.

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