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Can we Treat CO₂ Well Blowouts like Routine Plumbing Problems? A Study of the Incidence, Impact, and Perception of Loss of Well Control

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Abstract

Risk communication literature suggests that for a number of reasons, the public may perceive a risk to be greater than indicated by its statistical probability. Public concern over risk can lead to significant and costly delays in project permitting and operations. Considering these theories, media coverage of CO₂-related well blowouts in 2013 gave rise to the questions: What is the risk of CO₂ well blowouts associated with CCUS through CO₂ EOR? What is the potential public perception of those risks? What information could be used to respond to public concern? To address these questions, this study aims to: 1) provide a framework for understanding the nature of onshore well blowouts, 2) quantify the incidence of such events for three specific geographic regions of Texas, 3) relate this data to CCUS and findings from other studies, and 4) explore the potential implications for public perception of this risk associated with CCUS projects. While quantifying answers to these questions proved to be challenging, the results from this study suggest that (1) the perceived risk of CO₂ well blowouts may exceed the statistical risk and (2) information that could be used to address this gap could be made more readily available to the greater benefit of industry and stakeholders who support the development of CCUS as an option for addressing anthropogenic CO₂ emissions. The study also suggests approaches to best conduct such data inquiries.

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1. Introduction

CO₂ enhanced oil recovery (EOR) is becoming an important bridge to continue the commercial development of carbon capture, utilization, and storage (CCUS) [1]. Where CCUS projects continue to develop in scale through scoping, pilot, and demonstration phases, the CO₂ EOR industry has a wealth of historical operations experience using CO₂ to enhance the production of hydrocarbons in the United States since the 1970's [2]. The US Energy Information Administration (EIA) projects CO₂ EOR will have the largest increase in share of overall oil production from any EOR technology through 2040 in the US [3], with the potential to store billions of cubic feet of anthropogenic CO₂ over this time frame. The increase in CO₂ EOR prevalence will likely have indirect impacts on the public perception of CCUS because continued development will increase public exposure to the concepts and performance of projects that capture, inject, and store CO₂ incidentally or intentionally. This paper explores the potential influence of CO₂ well blowouts on public perception.

Risk communication literature and CCUS project experience show that public perception of risk can play an important role in project implementation [4, 5]. This literature further shows that the social amplification of risk can result in a situation where the public perceives risk to be greater than indicated by statistical evidence showing a risk to be unlikely, preventable, or manageable through project operation and comprehensive regulatory oversight [6]. For example, even though the very small statistical likelihood of complications during operations [7, 8] signifies that the oil and gas industry and their regulators routinely understand and mitigate the risks to well integrity during operations, the public remains largely unaware of such safety practices. The potential for the public to overestimate risk is stronger when the risk is unfamiliar and/or the impact is feared or dreaded [9]. When this is the case, public concern over risk can lead to significant and costly delays in project permitting and operations [5]. Therefore, a key challenge arises when public perception of risk differs from practical experience related to an event that is also unfamiliar or feared. Risk communication literature suggests that proactive engagement based on careful listening and honest, informative responses to concerns may address this challenge by helping stakeholders to put risk into perspective [4].

The term “well blowout” may invoke sensational images of large, acute incidents with the general public. While well blowouts are rare, they do occur and are mitigated. Moreover, as the use of CO₂ EOR increases, so too will the absolute number of CO₂ well blowout events likely increase and potentially attract media coverage. Given the lessons from risk communication theory, it is responsible to consider how the public will perceive the risk of CO₂ well blowouts; how that perception will impact the deployment of CCUS projects, including those involving CO₂ EOR; and whether there is sufficient information to proactively or adequately engage the public on this topic.

A recent chain of events illustrates need for this kind of assessment. In June 2013 there was broad media coverage of two different CO₂ well blowouts, one current and the other during the previous two years. Although most news articles focused on one or the other incident, one article in July 2013 included both incidents in the same story, referenced a third blowout, and described the serious local impacts [10]. In August 2013, a stakeholder filed a comment in the docket of a proposed California CCUS project that cited that article and the broader media coverage in expressing concern regarding the risks from CO₂ well blowouts [11]. Some of the non-cited media coverage pointed out that impacted residents were unhappy because they could not get information about the nature of the incident, the potential risks, and the steps being taken to mitigate. This example gave rise to the questions: What is the risk of CO₂ well blowouts associated with CCUS through CO₂ EOR? What is the potential public perception of those risks? What information could be used to respond to public concern?

Although research has assessed the mechanisms for well blowouts in CO₂-specific applications, few studies have examined real-world frequencies and consequences of CO₂-related blowouts [12]. More broadly, attempts have been made to quantify the risks of well blowouts within the offshore and Gulf Coast [13, 14], and to examine how other analogous oil and gas operations can relate to CO₂-specific risks [7, 8]. There has been little in the way of studies that consider the potential impacts of these events on public perception or review the availability of information to respond to potential concerns. Therefore, this study seeks to: 1) provide a framework for understanding the nature of onshore well blowouts, 2) quantify the incidence of such events for three specific geographic regions of Texas, 3) relate this data and findings from other studies to CCUS, and 4) explore the potential implications for public

perception of this risk associated with CCUS projects. As hinted at by the title choice of this paper, the authors' hypothesis is that CO₂ well blowouts are more analogous to routine plumbing problems than to sensational, scary events. This hypothesis presumes that the incidence of well blowouts can be determined from public information, that it is small, and that there is publicly available information to help put these events into perspective.

2. A Framework for Understand Well Blowouts

2.1. The Lifecycle of EOR Fields and Wells

CO₂ EOR is one of the methods used to enhance the production of hydrocarbons. Primary production is the first stage of the lifecycle of a field where hydrocarbons are produced under buoyancy or natural pressure differences between the surface and reservoir. When reservoir pressure and oil column height declines a source of pressure is needed to maintain economic production. Typically the second stage of recovery involves injecting water, brine, or gas into the production reservoir in order to move a portion of the remaining hydrocarbons towards production wells. The number of injection wells used for secondary recovery is based on field-specific data, and may be converted former production wells or new wells. Production during secondary recovery declines because of decreasing mobility of oil [15]. Tertiary recovery methods to modify the properties of reservoir fluids so that additional oil is mobilized include a number of techniques referred to as EOR, and include the use of CO₂. At suitable pressure and temperatures, CO₂ is partially or wholly miscible with oil, decreasing viscosity and increasing volume, favoring hydrocarbon mobilization and transport to production wells. Such EOR practices can extend the life of a field by 20-25 years or more beyond the end of secondary recovery [16].

In addition to different stages of development of an oil field, wells within an oil field undergo different stages. The typical lifecycle of a well includes the stages of drilling (preparation of the borehole), completion (construction of the well by placing and cementing of long-string casing and installation of tubing, packers, and wellhead), operation (injection or production), workover (repair or retrofit for reuse), and closure (plugging and abandonment). Drilling a well is costly so operators will prolong well life through maintenance and repairs and repurpose wells when the field changes to a different mode (e.g., moving from primary to secondary recovery). Wells can be shut-in or temporarily abandoned so that they can be re-opened at a future date. Typically wells are only permanently plugged and abandoned when they cannot be economically repaired or if there is no more chance of producing oil or other minerals from the subsurface. Note that state regulatory agencies require regular testing and reporting of well construction, status and condition in order to mitigate past practices that could increase risks to people, property, or the environment. This has largely led to a small statistical likelihood of well complications occurring [17].

2.2. Terminology

Several types of events/conditions are grouped into a category defined as "loss of well control" with well blowout perhaps being the most common and sensational term in the lexicology. Loss of well control occurs any time when fluids migrate slowly or rapidly through or along the engineered well system in a manner other than the designed operation into an unintended geologic formation or to the surface. CO₂ adds to well control risk because pressure is usually increased to improve oil-CO₂ miscibility and CO₂ is a buoyant and low viscosity fluid. Within the regulatory community, loss of well control has also been referred to as surface/subsurface releases, mechanical failure, down hole problem, and illegal releases. In the scientific literature, such events have been referred to as well failures, CO₂ leakage [18], and migration and seepage [19]. Some of these names describe symptoms that can identify the occurrence of a blowout (e.g., leakage) rather than the actual event itself. Such events can occur through mechanical failures or failure to identify flawed construction (e.g., corroded or damaged equipment), if a flood encounters previously unaccounted for (i.e., orphan) wells, by operational errors (e.g. operating a well at higher than designed pressures), or even unpredictable circumstances (e.g., livestock) [12, 18, 20].

2.3. Loss of Control Mechanisms, Impacts, and Mitigation

Multiple barriers exist to prevent complications during the lifecycle of a well, including proper design,

construction, and routine maintenance informed by regulations and best practices. Properly constructed and operated wells are designed to isolate fluids in the subsurface so that 1) fluids in different zones do not commingle and 2) the well can be used effectively to produce or inject fluids into the intended zones without interference with other zones. This can be achieved through a number of well-developed technologies used to control fluid migration during drilling, construction, operation, repair, and plugging of a well. During well drilling, construction, and completion, well control is based on an engineered combination of fluid weights and viscosities and well construction materials such as multiple steel casings, packers, tubulars, and cements in order to isolate the reservoir from shallower transmissive zones. Inside the casing, tubing, packers, and wellhead valves are installed to control fluids within the well. When drilling a well where knowledge of downhole pressures and compositions of the fluids potentially encountered is incomplete and the casing has not been set and cemented in place, equipment such as blowout preventers can be installed to mitigate operational risks. Such equipment would be used when drilling a new well into a zone already under CO₂ injection.

Formation pressures will increase during any type of injection in the intended injection formation, adding risk to existing wells, which is widely recognized and regulated during permitting of injection by Federal and/or state regulatory organizations to ensure such pressure increases do not lead to unintended fluid migration into different geologic formations. Corrosion management, with regular inspection and maintenance are standard best practices and required by regulatory authorities.

During workovers, if well control technologies such as parts of the wellhead or the downhole packer are removed, robust technologies are available, such as injection of dense “kill fluid” or lubricators to control fluid migration to maintain control, although errors are possible. When a well is removed from service, isolation equipment such as removable bridge plugs are installed, and scheduled mechanical integrity testing is required. Finally, when a well is prepared for abandonment, multiple barriers are emplaced to isolate the reservoir from shallower geologic formations and the surface, including a regulatory prescribed set of cement plugs, with the intervals between them usually filled with drilling mud.

Unintended migration along wellbores resulting in blowouts can be caused by poorly bonded cement between casing and borehole, mechanical integrity failure of plugged and abandoned wells, casing corrosion, and tubing and packer failures [7, 21, 22]. The quality of the cement job in a well can do much to allow (through corrosion or poor bonds) or inhibit (through self-healing cements) fluid flow to these fast-flow leakage pathways [22, 23, 24]. Slower leakage pathways are also a focus for research, such as diffusion through a caprock [18], or through abandoned wellbores [25]. The process for rectifying well blowouts is dynamic and site-specific, with a number of methods available. Prior to mechanical repair of the well it is necessary to kill (i.e., hydraulically control) the well by injecting high density fluids at a rapid enough rate downhole to increase hydraulic head and well-friction, stopping of blowing fluid [21, 26].

3. Methods and Data Analysis

3.1. Study Area

This study examines the blowout frequency for three regions of Texas. Texas was chosen because it is the world's largest producer of oil through CO₂ EOR, and is the most prolific conventional oil and gas producer in the United States. From 1998-2011, Texas production averaged 21% of all U.S. crude oil, and nearly 26% of all U.S. gross natural gas (Figure 1, [27]). The study uses data from three geographic areas, Texas Railroad Commission (RRC) Districts 3, 8, and 8A (Figure 2). Data is primarily collected online from the RRC databases, which manages and oversees oil and gas operations in the state of Texas and administratively delineates these Districts.

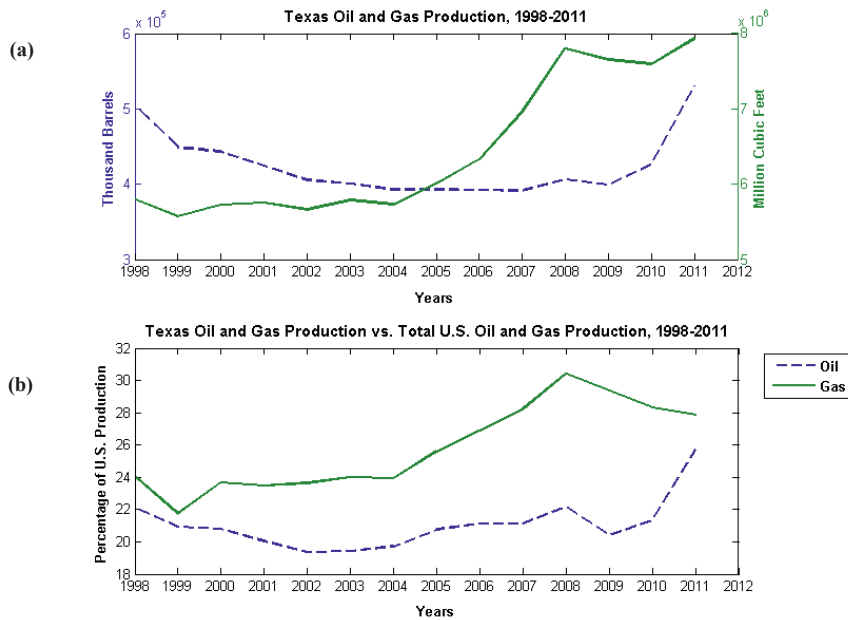


Fig. 1. (a) Texas Oil and Gas Production, 1998-2011 (b) Texas Oil and Gas Production vs. U.S. Total Production, 1998-2011.

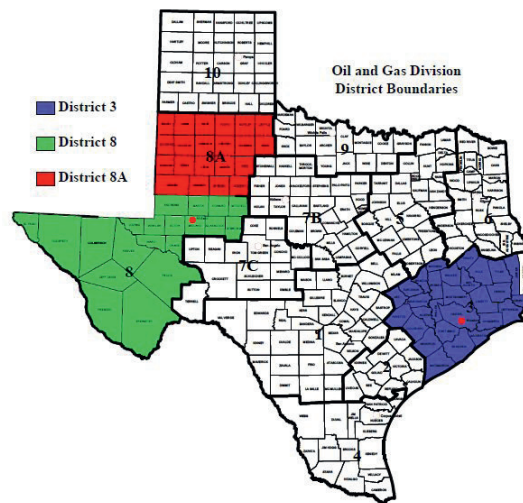


Fig. 2. Texas Railroad Commission Oil and Gas Division Districts Map.

These data include oil and gas well drilling, completion, production and operation, injection, plugging, orphan (i.e., abandoned), and well blowouts for the period 1998-2011 (Tables 1 and 2). However, while the RRC keeps fairly comprehensive records, some data points were lacking, similar to observations made by Skalle and Podio [13]. For example, only three well blowout records in surveyed Districts mention the term “CO₂” in their blowout records, preventing definitive categorization for CO₂-related events. The study therefore was widened to include all blowouts of any type of well as an analogue to the performance of wells in these Districts.

Districts 3, 8, and 8A are chosen because they represent operational and geographical dichotomies. Districts 8

and 8A are located primarily in the Permian Basin in West Texas while District 3 is located in southeast Texas along the Texas Gulf Coast. District 8 had the highest overall activity from 1998-2011 for wells authorized and/or permitted for drilling, completions, injection and plugging (Table 1). Districts 8 and 8A feature the highest amount of active CO₂ injection wells in the state of Texas with 978 and 1,016 respectively. In contrast, District 3 has only 35 currently active CO₂ injection wells. While operators in Districts 8 and 8A produced significantly more oil, operators in District 3 have produced more natural gas from 1998-2011 than Districts 8 and 8A combined. Understanding these contrasts of geography and operations can help to isolate whether CO₂ related injection is a factor for an increase (or decrease) in well blowout frequencies.

Table 1. Texas RRC District Well and Production Numbers, 1998-2011.

| | Wells Drilled | Well Completions (Total) | Workovers | Production Wells | Injection/Disposal Permits (Total) | Secondary Injection Wells (Active, CO ₂) |
|--------------------|---------------|--------------------------|-----------|------------------|------------------------------------|--|
| District 3 | 7,063 | 9,535 | 2,895 | 10,968 | 922 | 35 |
| District 8 | 20,468 | 26,344 | 4,543 | 48,897 | 5,098 | 978 |
| District 8A | 8,523 | 9,831 | 1,622 | 22,622 | 3,804 | 1,016 |
| | Plugged Wells | Orphan Wells | Oil (BBL) | Casinghead (MCF) | Gas Well Gas (MCF) | Condensate (BBL) |
| District 3 | 8,759 | 584 | 4.11E+08 | 1.070E+09 | 8.507E+09 | 2.003E+08 |
| District 8 | 12,541 | 394 | 1.71E+09 | 3.929E+09 | 5.436E+09 | 1.753E+07 |
| District 8A | 6,613 | 38 | 1.74E+09 | 2.540E+09 | 2.684E+08 | 1.210E+06 |

3.2. Well Blowout Data

Using the RRC online blowout database [28] and the RRC's paper records, found at 1701 Congress Ave., Austin, TX, 78701, well blowout data was extracted for Districts 3, 8, and 8A. Data found online includes: date of incident, operator, lease/facility name/ID, permit #, well #, field name, county, if fire or H₂S were present, and the number of deaths and/or injuries. General remarks associated with each event were used to attempt to quantify leaking fluid type, volume of fluid leaked (estimated), and depth of the well failure. Additionally, general remarks were used to organize blowouts based on the stage of development as indicated in section 2.1. These stages include: Drilling, Completion, Production/Operation, Workover, Injection, Abandoned, Other, and Uncategorized. Two categories in particular bear further mention. "Other" includes incidents such as trucks running over wells and contractor equipment error. Uncategorized incidents did not contain enough information either online or in physical records to discern the stage of development at which the blowout occurred. Instead, to quantify the risk of a blowout occurring during a given stage in the surveyed Districts, comparisons were made between the number of blowouts from a given stage to the overall number of wells populated for that stage; this approach loosely followed the methods in Jordan and Benson [8] (Table 2). Finally, weighted averages to calculate District frequencies for all stages, and blowout rates per 100 wells were calculated.

3.3. Reporting Survey Difficulties

An initial goal for this study was to survey multiple states' databases for blowout data. Initial scoping was met with limited success, and results for seven states surveyed are shown in Appendix A. There are no standard formats for reporting loss of control events at the Federal or state level; consequently, many states have varying levels of accessibility for reporting ranging from relatively organized to completely unavailable. With such a wide degree of reporting standards, it was difficult to gather the desired data. Some states had solid datasets for well control incidents, while others had large sets of unorganized data. Others had no data available online for such blowouts, and one state does not keep paper records of any well blowout. Instead, blowouts are dealt with on a verbal basis between the regulatory authority and the operator of the field where the blowout occurs. This presented multiple problems for the quantitative aspects of this study and it became apparent that the fully quantitative dataset being

sought was not available, even after selective supplementary records searching. As such, this shifted the focus of this study to more selective blowout data gathering, supplemented by discussions of social perceptions of CO₂ well blowouts and recommendations for data inclusion for states.

4. Data Analysis Results

4.1. Overall Blowout Populations

As of March 2014, there were 616 recorded blowouts for Districts 3, 8, and 8A from 1942 to 2013 in the RRC records database. Of these, 158 occurred from 1998-2011 with District 3 having the highest number of recorded blowouts at 75, followed by District 8 with 49 and District 8A with 35 (Table 2). Table 2 distinguishes each District's respective categorical breakdown from largest number of occurrences for a given stage to smallest. All Districts shared the same top four development stages for well blowout occurrence: Drilling, Completion, Workovers, and Production/Operation. The largest single blowout population category for Districts 3, 8, and 8A was 29 (Drilling), 28 (Drilling), 11 (Production/Operation) respectively.

Table 2. Texas RRC District Blowouts, 1998-2011.

| Development Stage | District 3 | District 8 | District 8A |
|--------------------------|------------|------------|-------------|
| Drilling | 29 | 28 | 7 |
| Completion | 9 | 5 | 6 |
| Workover | 7 | 7 | 9 |
| Production and Operation | 19 | 3 | 11 |
| Injection | 0 | 1 | 0 |
| Shut in | 0 | 0 | 1 |
| Plugging | 6 | 1 | 0 |
| Abandoned | 1 | 0 | 0 |
| Other | 3 | 2 | 1 |
| Uncategorized | 1 | 2 | 0 |
| District Total | 75 | 49 | 35 |

4.2. Calculated Blowout Frequencies

Table 3 shows the frequency of blowouts during each operational stage for RRC Districts 3, 8, and 8A from 1998-2011. No quantification was possible for shut-in wells as RRC shut-in records could not be organized by date of shut-in. Based on Table 3, the highest frequencies of blowouts for any given District barely exceeded one half percent of the overall population totals for wells at a given stage. Only one-third of all populated fields have frequencies that exceed 0.1%; all remaining categories fall on the hundredth or thousandth (or no frequency at all) percentage scale. For District 3, drilling was calculated to be the riskiest stage for blowouts based on frequency, while in Districts 8 and 8A workover was calculated to be the riskiest stage. District 3 also had the highest blowout frequency per stage of development for completions, production/operation, plugging, and abandoned wells. District 8 had the highest blowout frequency during injection, while District 8A had the highest for workovers.

Table 3. Texas RRC District Blowout Frequencies (1998-2011) with frequency comparisons to Jordan and Benson [8] and Skalle and Podio [13].

| | Percent Frequency | | | | Per 100 Wells | | | |
|------------------------------|-------------------|------------|-------------|-------------------|---------------|------------|-------------|--------------------|
| | District 3 | District 8 | District 8A | CA District 4 [8] | District 3 | District 8 | District 8A | TX Gulf Coast [13] |
| Drilling | 0.411% | 0.137% | 0.082% | 0.048% | 0.411 | 0.137 | 0.082 | |
| Completion | 0.084% | 0.019% | 0.061% | | 0.084 | 0.019 | 0.061 | |
| Workover | 0.242% | 0.154% | 0.555% | 0.058% | 0.242 | 0.154 | 0.555 | |
| Production/ Operation | 0.173% | 0.006% | 0.049% | 0.006% | 0.173 | 0.006 | 0.049 | |
| Injection | 0.000% | 0.020% | 0.000% | 0.011% | 0.000 | 0.020 | 0.000 | |
| Shut in | | | | 0.001% | 0.000 | 0.000 | 0.000 | |
| Plugging | 0.080% | 0.008% | 0.000% | 0.029% | 0.080 | 0.008 | 0.000 | |
| Abandoned | 0.171% | 0.000% | 0.000% | 0.029% | 0.171 | 0.000 | 0.000 | |
| Cumulative Average | 0.174% | 0.038% | 0.062% | | 0.174 | 0.038 | 0.062 | 0.15 |

4.3. Worker Injury and Death

One measure of incident severity is the occurrence of worker injuries or deaths associated with a blowout. Overall, these incident types make up small percentages of the overall frequency totals (Table 4). Only District 3 documented an incident of a death associated with a well blowout which occurred during a drilling stage blowout, equating to a 0.014% frequency. All three Districts had blowouts documenting worker injury with the highest documentations occurring in District 8 with 6. Another means for qualitatively understanding the severity of a well blowout incident is the recording of complications with fire and H₂S onsite during the incident. Districts 8 and 8A featured higher documented cases of H₂S with 9 and 15 cases respectively, while District 3 had more documented fire occurrences with 7 cases (Table 4). However, the highest overall occurrence frequencies for H₂S, fire, and worker injuries all occurred in District 8A at a 0.062%. Such occurrences were not mutually exclusive: there was one instance of both H₂S and injuries reported for a well blowout in 8A.

Table 4. Texas RRC District Blowout Fires, Injuries, Deaths, and H₂S, 1998-2011. Frequency percentages are listed for under each respective populated cell. Operational stage categories with no incidents are not included.

| | District 3 | | | | District 8 | | | | District 8A | | | |
|---------------------------------|------------|------------|------------|------------------|------------|------------|-------|------------------|-------------|------------|-------|------------------|
| | Fire | Injury | Death | H ₂ S | Fire | Injury | Death | H ₂ S | Fire | Injury | Death | H ₂ S |
| Drilling | 3 0.042 | 2 0.028 | 1 0.014 | | 5 0.024 | 8 0.039 | | 7 0.034 | | | | 3 0.035 |
| Completion | | 2 0.023 | | | | | | 3 0.01 | | 2 0.02 | | 1 0.01 |
| Workover | 1 0.035 | | | 1 0.035 | 1 0.022 | 1 0.022 | | 2 0.044 | 1 0.062 | 1 0.062 | | 1 0.06 |
| Production and Operation | 1 0.009 | | | 1 0.009 | | | | 2 | | | | 4 0.018 |
| Plugging | | 1 0.011 | | 1 0.011 | | 2 0.016 | | | | | | |
| Other | | 2 | | 2 | | | | | | | | |
| District Total | 7 | 5 | 1 | 5 | 6 | 11 | 0 | 15 | 1 | 3 | 0 | 9 |

5. Discussion

5.1. Relating Well Blowouts to CCUS

What do these results suggest for the empirical risks of CO₂-related blowouts? Overall, well blowout frequency

in each surveyed RRC District is small, on the order of tenths of a percent or smaller for a given development stage. District 3 had the highest absolute number of blowouts recorded, even with fewer wells drilled, completed, used for injection, and more plugged and abandoned wells than Districts 8 and 8A. As such, District 3, which features little CO₂ EOR production, had higher blowout frequencies in drilling, completion, production, plugging, and abandoned wells. Districts 8 and 8A had higher blowout frequencies than District 3 for the workover and injection stages. While CO₂ injection is a key part of the CO₂ EOR process, comparing these frequencies suggests that a correlation between CO₂-use and well blowout frequency in these RRC Districts is tenuous. For a majority of development stages, the District with the fewest CO₂ EOR operations, District 3, had the highest blowout frequencies. While the dataset was too small to determine if this low frequency can be applied to a broader industry-wide scale, there is no reason to think otherwise.

5.2. Comparisons to Other Studies

The authors were able to find only two comparison studies that featured analogue activities (California steam EOR; [8]) or analogue geographic regions (Texas Gulf Coast; [13]). For comparisons, results from Jordan and Benson [8] were surveyed for drilling, workovers, production, injection, shut-in, plugging, and abandoned wells. Over a slightly longer timeframe (1991-2005), California's District 4, had higher absolute totals for well development stages when compared to RRC District totals for every category except for production, where RRC District 8 had higher totals from 1998-2011. For most instances of comparison (Table 3), RRC Districts had higher blowout frequency percentages for a given stage. This is particularly true for workovers, where all RRC Districts were an order of magnitude higher in blowout occurrence frequency than CA District 4. In fact, for drilling, production/operation, and workover, RRC District blowouts were as frequent as or more frequent than those in CA District 4.

For more geographically similar settings, Skalle and Podio [13] investigations showed that after surveying 310,000 Texas Gulf Coast wells from RRC databases, the overall frequency percentage was 0.15% for well blowouts from 1960-1996. In comparison, District 3 has a higher weighted average and frequency of well blowouts per 100 wells when compared to Skalle and Podio [13]. Districts 8 and 8A have an order of magnitude smaller blowout frequency per 100 wells and weighted average.

5.3. Reporting Assessment Challenges

There were two main challenges to completing the analysis planned for this paper: 1) most states do not have accessible databases reporting loss of control events and those that do contain inconsistent amounts of data; and 2) even in the relatively comprehensive Texas database, significant amounts of data were not included in each report. The standard RRC reporting forms ask the operator to report the depth of the event as well as the type of fluid(s) and volume(s) leaked during the event. A review of the online reports and a subsequent review of select physical copies of reports submitted to RRC show that few reports include this information, possibly because many of these reports were completed during the occurrence of an incident. Consequently, information about depth, fluid type and volume was most likely either not known, or estimations for volumes and depths were difficult to discern during the event. When depths were provided, estimations usually amounted to a geologic formation name. After an incident, operators are required to submit a letter to RRC detailing what happened, per RRC Regulations [29]. However, not all incidents included a follow-up letter and the ones submitted for the most part did not report this information.

5.4. Public Perception Impacts

As indicated in Section 1, this paper considered four simplified lessons from the risk communication literature: (1) the public tends to more negatively perceive the risk of events that are unfamiliar to them or could result in a dreaded outcome; (2) a negative perception can be relatively easily amplified to the point where the perceived risk is significantly greater than statistics indicate; (3) negative public perceptions can cause costly delays in project development; and (4) proactive engagement with honest discussion of risk could help to put public perception of risk into perspective.

Based on the analysis in this paper showing small blowout incidence in areas with available data, it seems that while there is the potential to avoid having the public develop an unfairly negative perception of the risk of onshore CO₂ well blowouts, there are no systematic efforts in place to make this happen. At issue may be something of a “Catch 22” situation. Industry goes to great lengths to avoid well blowouts but appears reluctant to share information about prevention measures and the details of incidents in the rare instances when they occur. This leaves room, as in the case of the California comment referenced in Section 1, for unanswered questions to stimulate negative perceptions, possibly leading to project delays, increased costs, and additional measures to prevent blowouts.

While quantifying answers to these questions posed in Section 1 proved to be challenging, the results from this study suggest that (1) the perceived risk of CO₂ well blowouts may in fact exceed the statistical risk and (2) information that could be used to address this gap could be made more readily available to the greater benefit of industry and stakeholders who support the development of CCUS as an option for addressing anthropogenic CO₂ emissions.

6. Recommendations and Conclusions

The title of this paper was intended to stimulate discussion. As described in the introduction, it was selected because it reflects a starting hypothesis that CO₂ well blowouts are more analogous to routine plumbing problems than to sensational, scary events. This hypothesis is predicated on being able to determine blowout incidence from publicly available information, finding that the frequency is very small, and having access to enough information to help the public put results into perspective. These conditions were only partially met for an analysis in three Districts in Texas; it was not feasible to conduct the analysis on a larger scale.

Given the results of the limited analysis undertaken in this study, it would seem that there would be an overall benefit to implementing improved data reporting standards for well blowouts. The development of this data set could reveal if the existing approaches to prevention and mitigation are largely working, which would build public confidence. Access to this information could be used proactively to engage stakeholders in an effort to help them gain a better perspective on the relative risks and it could be used in permitting procedures where this issue is raised.

It would be useful to have access to the following data: date, time and duration of incident; location (latitude/longitude, town/range, lease area); description of any leak(s) by fluid type(s), estimated fluid volume(s); and a description of known human, property, or environmental impacts. More importantly, in the case that such datasets are already reported, including such data in a simple online database can greatly increase ease of information accessibility. Alternatively, many states already scan forms for existing permits, authorizations to inject, plug, abandon, as well as other procedural paperwork for public access online. Adding well blowouts to the scanning list, based the frequencies discussed above, could be a manageable process with nominal costs to regulatory organizations, and quite possibly benefit the state, industry, and public stakeholders in the long term.

In the case that CCUS operations, however unlikely, have similar complications, robust standards exist for reporting such complications. Ensuring that such information becomes available in an easily accessible database would streamline public and stakeholder access to such information. This in turn would make such incidents more known, which after examining blowout frequencies for RRC Districts that do and do not feature CO₂ EOR operations, is a very small frequency of occurrence. It would be useful for those involved in CCUS outreach and engagement to prepare materials that synthesize this information for public consumption.

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Appendix A. Selected State Well Blowout Reporting Survey Results

| | Agency | Online? | Admin. Location | Date | Operator | Lease/Facility Name | Lease/ID | Permit # |
|--------------------|----------------------------|-------------------|-----------------|---------------------|--|---------------------|----------|----------|
| Texas | Railroad Commission | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Louisiana | Dept. of Natural Resources | Yes | No | Yes | Yes | Yes | Yes | Yes |
| Mississippi | Oil and Gas Board | No | No | No | No | No | No | No |
| New Mexico | Oil Conservation Division | Yes | No | Yes | Yes* | Yes | No | No |
| Wyoming | Oil and Gas Board | No | N/A | N/A | N/A | N/A | N/A | N/A |
| Oklahoma | Corporation Commission | No | N/A | Yes | Yes | Yes | Yes | Yes |
| Colorado | Conservation Commission | Yes | No | Yes | Yes | Yes | Yes | No |
| | Well # | Field Name | County | Fire | H ₂ S | Injuries | Deaths | Depth |
| Texas | Yes | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Louisiana | Yes | Yes | Yes | No | No | No | No | No |
| Mississippi | No | No | No | No | No | No | No | No |
| New Mexico | Yes | No | No | No | No | No | No | Yes* |
| Wyoming | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Oklahoma | Yes | Yes* | Yes | N | No | No | No | No* |
| Colorado | Yes | No | Yes | No | No | No | No | No |
| | Fluid Type | Fluid Vol. Leaked | Event Duration | Workover Contractor | | | | |
| Texas | No* | No | No | Yes | *Remarks column is the only place that mentions fluid types | | | |
| Louisiana | Yes* | No | No | No | *Incident codes are assigned, such as GW for groundwater, or G for gas, but not for all reported incidents | | | |
| Mississippi | No | No | No | No | | | | |
| New Mexico | Yes | Yes | No | No | *Depth to Groundwater, if GW was affected | | | |
| Wyoming | N/A | N/A | N/A | N/A | | | | |

| | Fluid Type | Fluid Vol. Leaked | Event Duration | Workover Contractor | |
|-----------------|-------------------|--------------------------|-----------------------|----------------------------|---|
| Oklahoma | Yes | Yes | Yes | No | * Depth could be mentioned in the operator report under 165: 10-7-5 (c)(B)(v): Circumstances surrounding discharge of deleterious substance(s) and whether discharge was to water or soil |
| Colorado | Yes* | Yes | Yes** | No | *Incident Reports that have been finalized include columns for oil, water, and other types of fluids spilled ** Duration of Events can be gleaned from the Final Resolution dates of the event in question |