Oil and Gas Wastewater Reuse in California: Considerations and Risks

Seth B.C. Shonkoff, PhD, MPH

PSE Healthy Energy / University of California, Berkeley / Lawrence Berkeley National Lab

Energy Extraction Webinar

United States Environmental Protection Agency

July 19, 2018

PSE

Bringing science to energy policy

BERKELEY LAB

Disclaimer

The ideas in this presentation are my own and do not necessarily reflect those of the Central Valley Regional Water Quality Control Board, The State Water Board, or the Food Safety Expert Panel.

PSE Bringing science to energy policy

PSE Healthy Energy is an energy research and policy institute that brings scientific transparency to energy policy issues.

We…

Generate

Translate

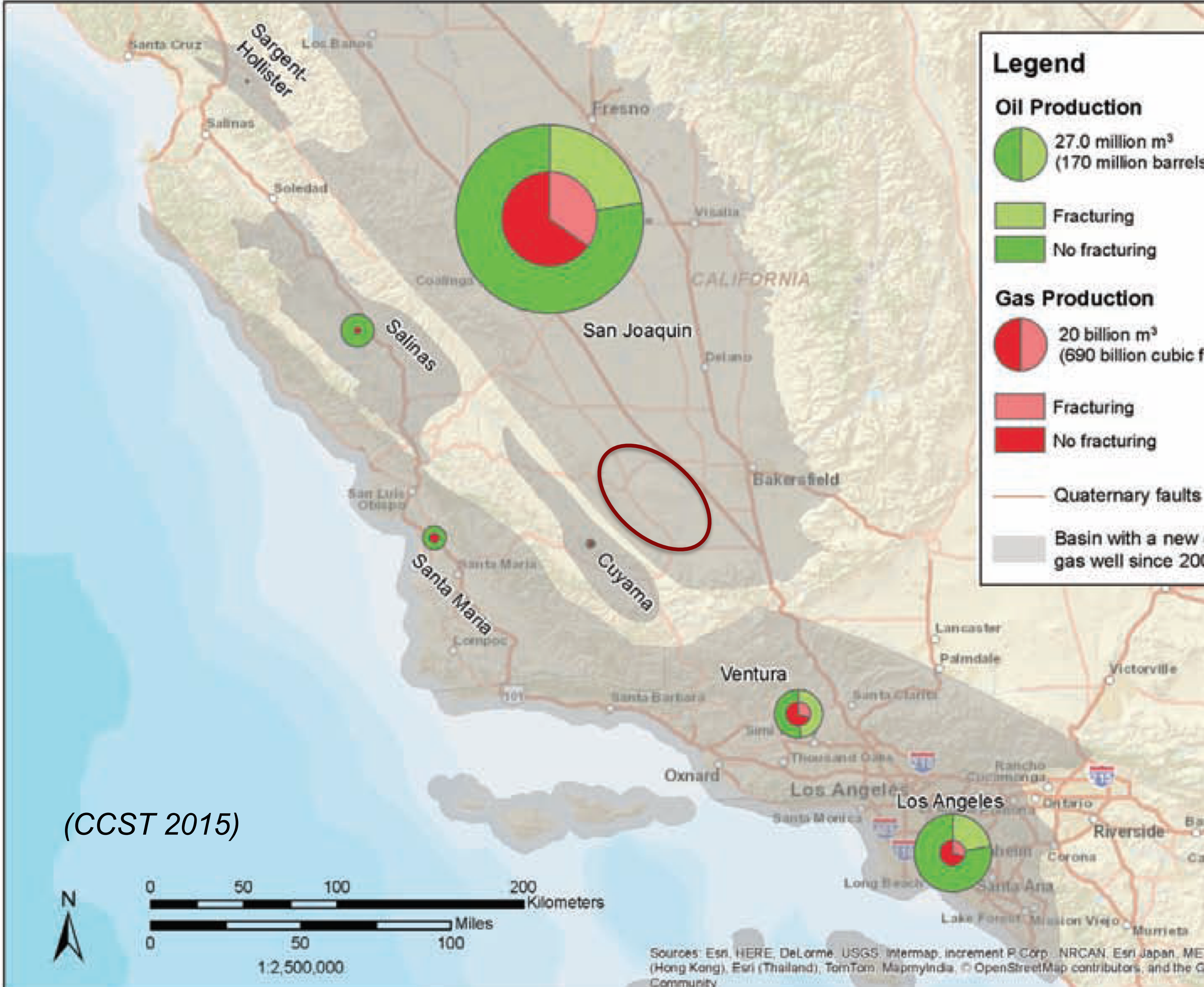
Disseminate

Scientific resources and put them into the places where they are used to ensure responsible energy policy decisionmaking

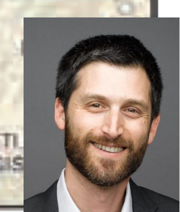
PSE Bringing science to energy policy

Food Safety Expert Panel

- Convened by the Central Valley Regional Water Quality Control Board
- To provide technical expertise on the range of topics associated with the reuse of oilfield produced water for irrigation of food crops
- Convened in 2016
- Composed of representatives and experts in oil and gas, public health, agriculture and aquatic ecology


Legend
Oil Production
27.0 million m³ (170 million barrels)
Fracturing
No fracturing
Gas Production
20 billion m³ (690 billion cubic feet)
Fracturing
No fracturing
Quaternary faults
Basin with a new oil or gas well since 2001
Sargent-Hollister
San Joaquin
Salinas
Santa Maria
Cuyama
Ventura
Los Angeles
CALIFORNIA
Fresno
Bakersfield
Oxnard
Riverside
0 50 100 200 Kilometers
0 50 100 Miles
1:2,500,000
N
Sources: Esri, HERE, DeLorme, USGS, Intermap, increment P Corp., NRCAN, Esri Japan, METI, Esri China (Hong Kong), Esri (Thailand), TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

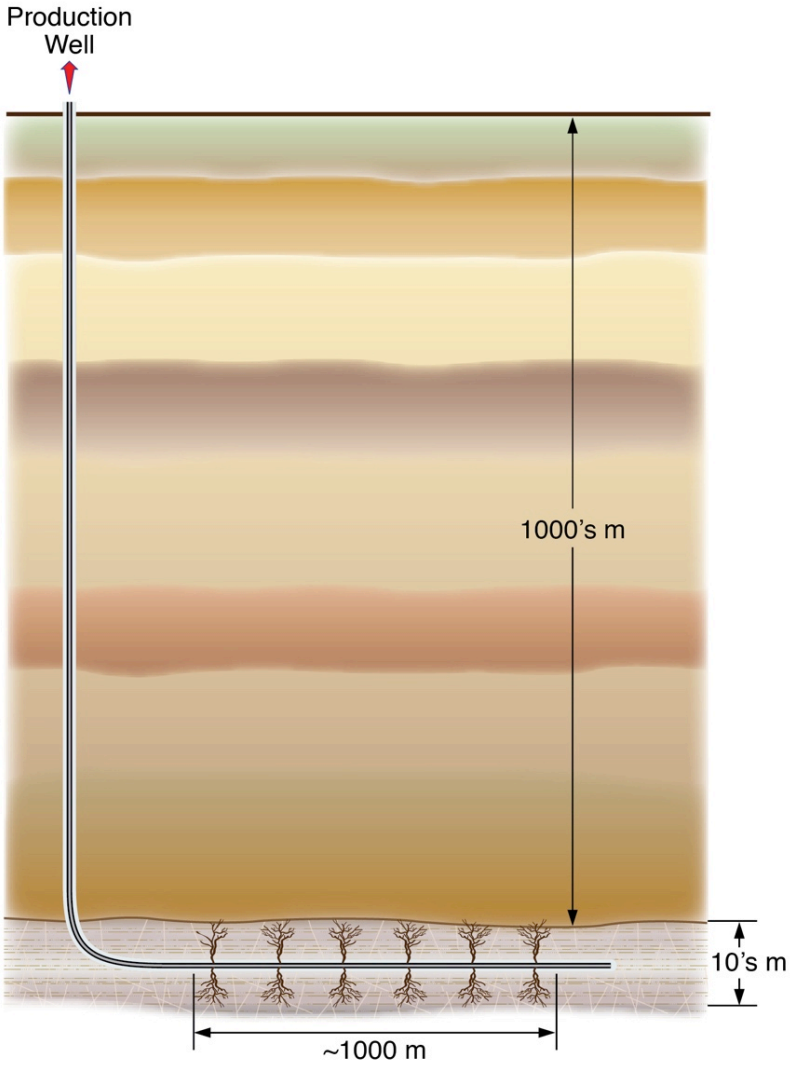
(CCST 2015)



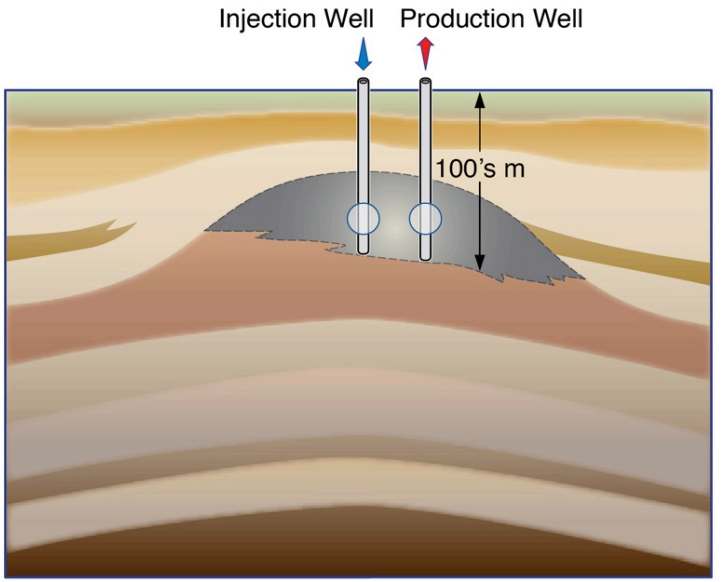
Hydraulic Fracturing in CA is Different

- Shallower, Vertical Wells

Typical Source Rock Stimulation



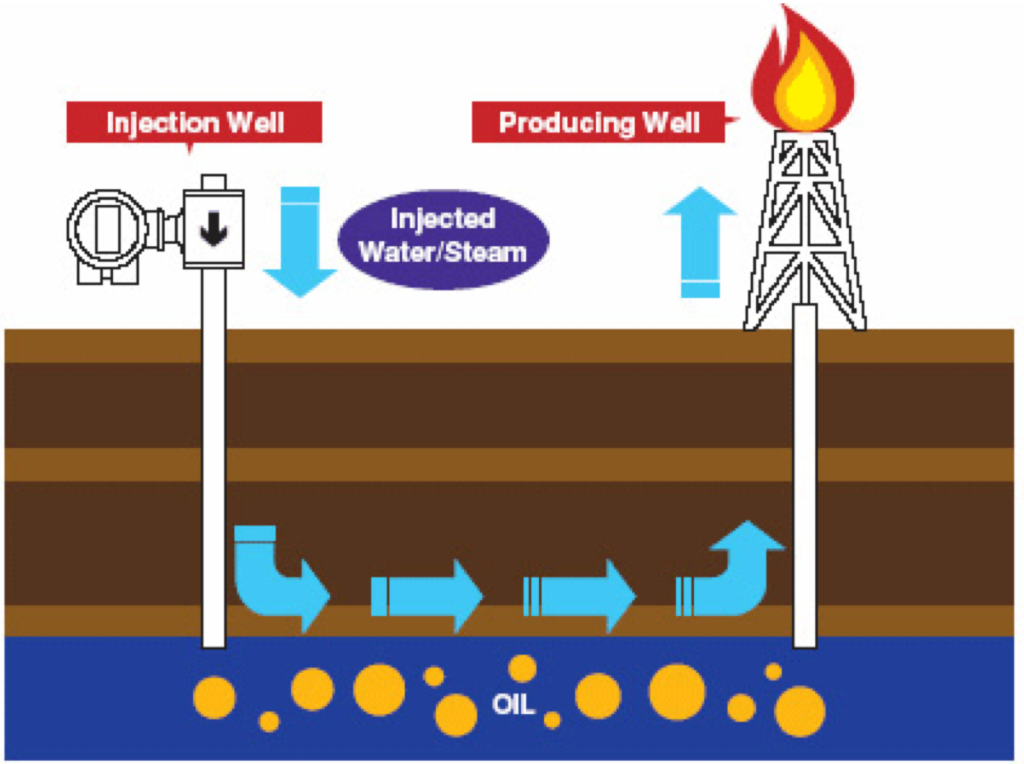
Typical California (Migrated Oil) Stimulation



PSE Bringing science to energy policy

Enhanced Oil Recovery

Steam Cogeneration Plant, Midway-Sunset Field



Source: Yokogawa Corporation of America

Produced water management

- California's oil and gas fields *on average* produce **more than 10-times** as much water as oil

- Produced water from wells contain naturally occurring and added chemicals

Current produced water reuse in California

- **Predominantly in the San Joaquin Valley**
- **Irrigation of food crops**
  - Treatment:
    - Oil-water separation and walnut shells (San Joaquin Valley)
    - Only one operation uses reverse osmosis (Central Coast)
- **Aquifer recharge via percolation**
  - Often no treatment beyond oil-water separation
  - Confirmed contamination of groundwater > 2 miles away (CVRWQCB 2018)
  - Observed intermixing with nearby USDWs – even those previously thought to be zonally isolated (USGS, *forthcoming)*
  - Widespread mixing with groundwater <10,000 mg/l TDS at least within two fields (USGS, forthcoming)

Chemical Use in Hydraulic Fracturing (CCST SB 4 Study)

- Identified ~ 300 chemical or chemical mixtures used for hydraulic fracturing
  - Many chemicals were reported infrequently
- Identified ~80 chemical or chemical mixtures used for matrix acidizing
  - ~1/3 were not on hydraulic fracturing list
- Information needed for complete hazard or risk assessment was often not available

CCST (2015); Shonkoff et al. (2015)

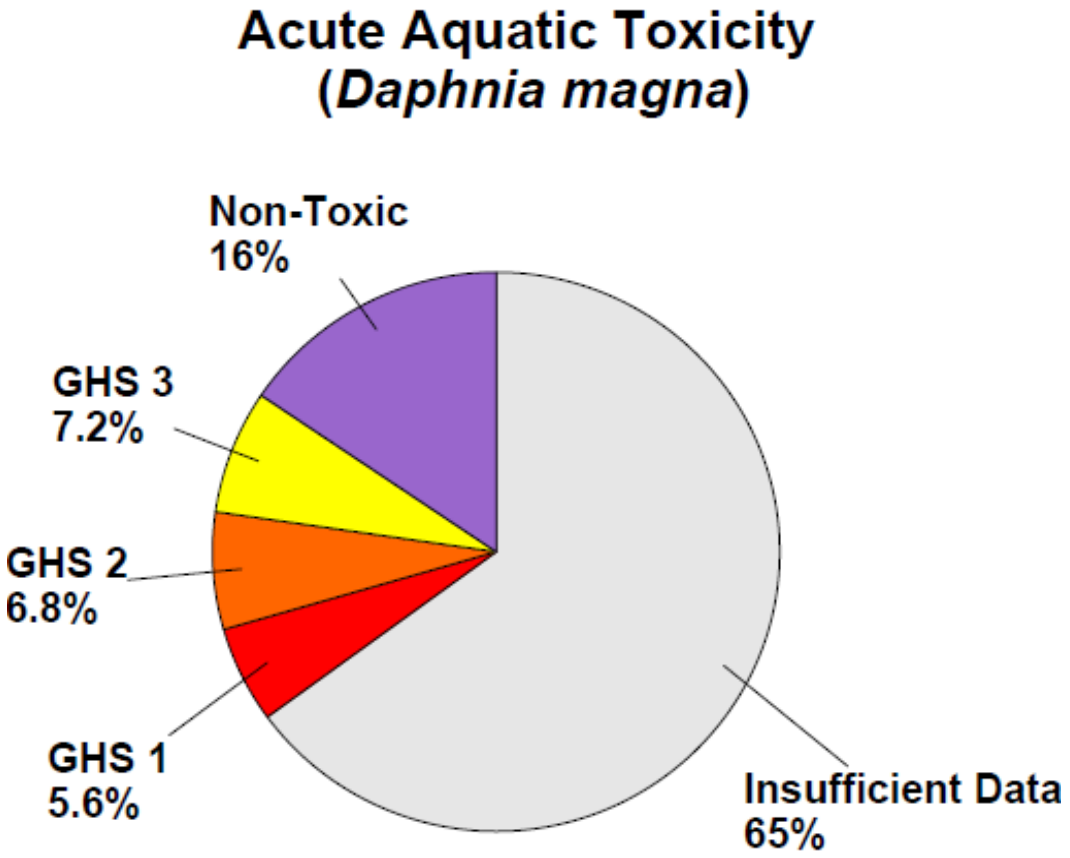
Hydraulic fracturing chemicals: information gaps inhibit our ability to evaluate health risks

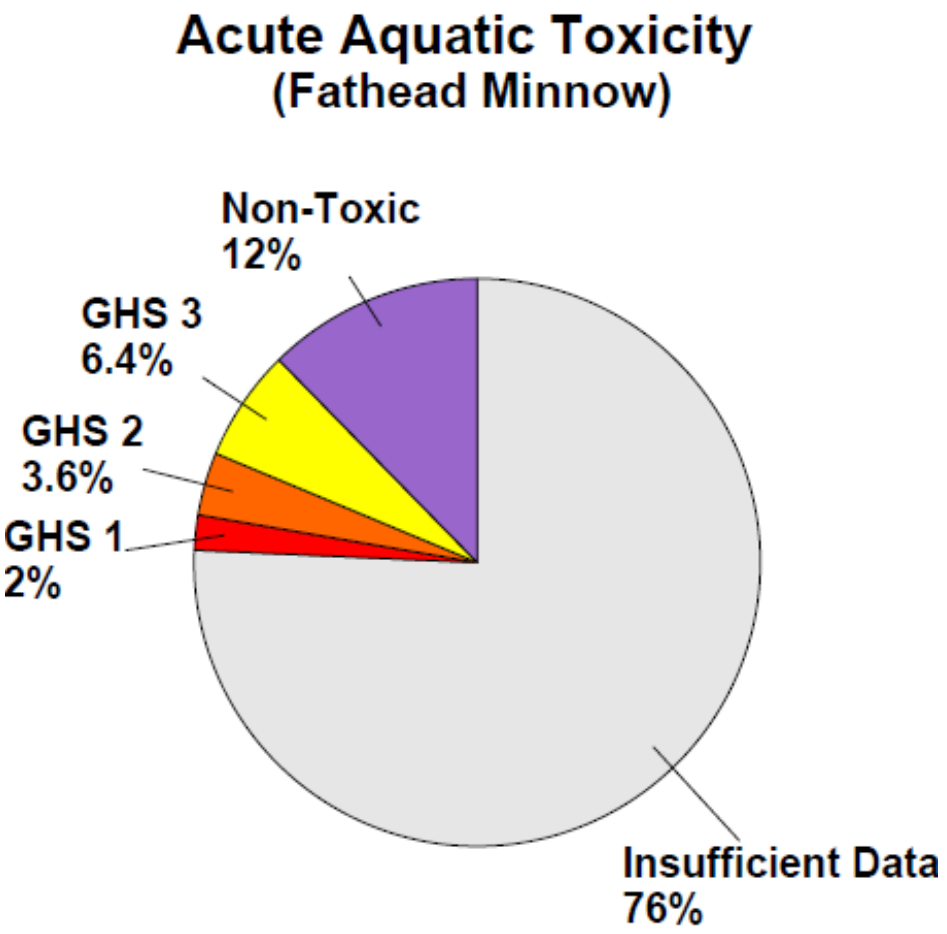
Table 6.3-1. Available and unavailable information for characterizing the hazard of stimulation chemicals used in hydraulic fracturing.

Number of chemicals	Proportion of all chemicals	Identified by unique CASRN	Impact or toxicity	Quantity of use or emissions
176	55%	Available	Available	Available
17	5%	Available	Available	Unavailable
6	2%	Available	Unavailable	Available
121	38%	Unavailable	Unavailable	Available

Shonkoff et al. (2015)

Critical Data Gap for chemicals used in HF: Basic Information on Toxicity Missing





Stringfellow et al. (2015)

PSE Bringing science to energy policy

Produced water used for food crop irrigation in the San Joaquin Valley

"BUT WE DON'T FRAC"
(so there's no chemical risk)

Lauren Sommer

PLOS ONE

RESEARCH ARTICLE

Comparison of chemical-use between hydraulic fracturing, acidizing, and routine oil and gas development

William T. Stringfellow[1,2], Mary Kay Camarillo[1,2], Jeremy K. Domen[1,2], Seth B. C. Shonkoff[3,4]*

1 Earth & Environmental Sciences Area, Lawrence Berkeley National Lab, Berkeley, CA, United States of America, **2** Ecological Engineering Research Program, School of Engineering & Computer Science, University of the Pacific, 3601 Pacific Avenue, Stockton, CA, United States of America, **3** PSE Healthy Energy, 1440 Broadway, Suite 205, Oakland CA, United States of America, **4** Department of Environmental Science, Policy and Management, University of California, Berkeley, Berkeley, CA, United States of America

* sshonkoff@psehealthyenergy.org

OPEN ACCESS

Citation: Stringfellow WT, Camarillo MK, Domen JK, Shonkoff SBC (2017) Comparison of chemical-use between hydraulic fracturing, acidizing, and routine oil and gas development. PLoS ONE 12(4): e0175344. https://doi.org/10.1371/journal.pone.0175344

Editor: John M. Senko, The University of Akron, UNITED STATES

Received: January 28, 2017

Accepted: March 26, 2017

Published: April 19, 2017

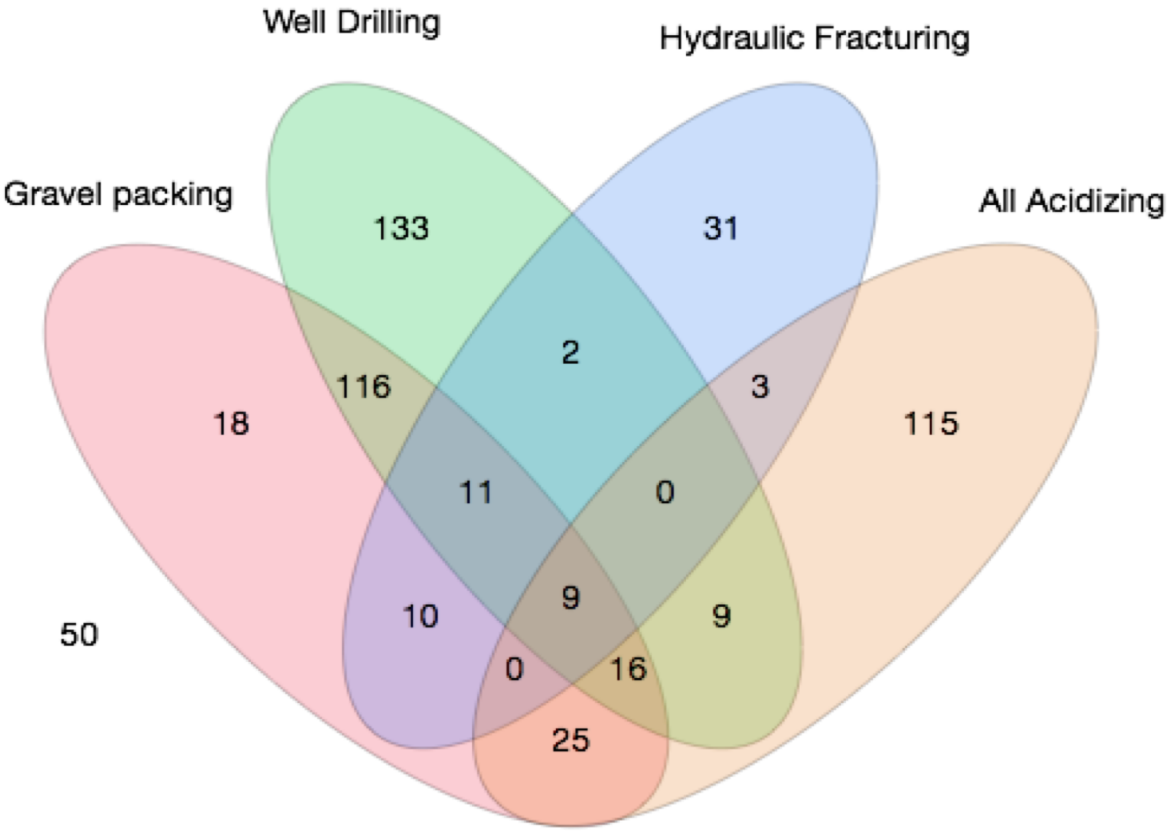
Data Availability Statement: Data are available from the South Coast Air Quality Monitoring District (http://www.aqmd.gov/). Additional data in Research Gate: DOI: 10.13140/RG.2.2.19128.55041.

Funding: This material is based upon work supported by the Department of Energy under Award Number DE-IA0000018. This study was supported in part by grants from The Broad Reach Fund and Laboratory Directed Research and Development (LDRD) funding from Berkeley Lab,

Abstract

The potential hazards and risks associated with well-stimulation in unconventional oil and gas development (hydraulic fracturing, acid fracturing, and matrix acidizing) have been investigated and evaluated and federal and state regulations requiring chemical disclosure for well-stimulation have been implemented as part of an overall risk management strategy for unconventional oil and gas development. Similar evaluations for chemicals used in other routine oil and gas development activities, such as maintenance acidizing, gravel packing, and well drilling, have not been previously conducted, in part due to a lack of reliable information concerning on-field chemical-use. In this study, we compare chemical-use between routine activities and the more closely regulated well-stimulation activities using data collected by the South Coast Air Quality Monitoring District (SCAQMD), which mandates the reporting of both unconventional and routine on-field chemical-use for parts of Southern California. Analysis of this data shows that there is significant overlap in chemical-use between so-called unconventional activities and routine activities conducted for well maintenance, well-completion, or rework. A comparison within the SCAQMD shows a significant overlap between both types and amounts of chemicals used for well-stimulation treatments included under State mandatory-disclosure regulations and routine treatments that are not included under State regulations. A comparison between SCAQMD chemical-use for routine treatments and state-wide chemical-use for hydraulic fracturing also showed close similarity in chemical-use between activities covered under chemical disclosure requirements (e.g. hydraulic fracturing) and many other oil and gas field activities. The results of this study indicate regulations and risk assessments focused exclusively on chemicals used in well-stimulation activities may underestimate potential hazard or risk from overall oil field chemical-use.

Overlap of all chemical usage according to activity (SCAQMD)



Note:
This figure only includes chemicals <u>WITHOUT</u> available CASRN data

Stringfellow, Shonkoff, et al. (2017)

PSE Bringing science to energy policy

Summary of available chemical data for non-hydraulic fracturing events (SCAQMD)

Number of chemicals	Proportion of all Chemicals	Identified by unique CASRN	Toxicity	Quantity of use
151	30%	Available	Available	Available
1	0%	Available	Available	Unavailable
97	18%	Available	Unavailable	Available
43	8%	Unavailable	Unavailable	Available
233	44%	Unavailable	Unavailable	Unavailable

Stringfellow, Shonkoff, et al. (2017)

Hazard Assessment of Chemical Additives Used in Oil Fields that Reuse Produced Water for Agricultural Irrigation, Livestock Watering, and Groundwater Recharge in The San Joaquin Valley of California: Preliminary Results

Authors:

Seth B.C. Shonkoff, PhD, MPH[1,2,3]

William T. Stringfellow, PhD[3,4]

Jeremy K. Domen, MS[3,4]

[1] PSE Healthy Energy, Inc., Oakland, CA

[2] Department of Environmental Science, Policy, and Management, University of California, Berkeley

[3] Earth & Environmental Sciences Area, Lawrence Berkeley National Laboratory

[4] Ecological Engineering Research Program, University of the Pacific

Technical Report

September 2016

Dataset Summary

- Data collected under authority of California Water Code section 13267
- Chemical additive data from 7 operators that provide produced water for reuse in California
  - Chevron, Valley Water Management Company, California Resources Production Corporations, Bellaire Oil Company, Hathaway, Modus, and Little Creek Properties/Daybreak Oil and Gas
- Period of January 2014 – June 2016
- Operations span 5 oil fields
  - Deer Creek, Mount Poso, Jasmine, Kern Front, and Kern River oil fields

Shonkoff, et al. (2016)

Methods

- **Chemical toxicity** was rated according to United Nations Globally Harmonized System (GHS) of Classification and Labelling of Chemicals

  - Lower numbers indicate higher toxicity

  - Designation of “1” is the most toxic

- **Carcinogenicity and other health hazards** were determined by if the chemical was on a regulatory/hazard list

- **Biodegradability** was categorized according to OECD criteria for biodegradability

- **Bioconcentration** was calculated using U.S. EPA EPISuite Software and categorized according to U.S. EPA criteria for bioaccumulation

Shonkoff, et al. (2016)

Chemical disclosures

Total Chemicals	Chemicals without CASRN	Chemicals with CASRN
173	66 (38%)	107 (62%)

Chemicals without Chemical Abstract Services Registry Numbers (CASRN) could not be definitively identified and no further chemical analysis could be done on these chemicals

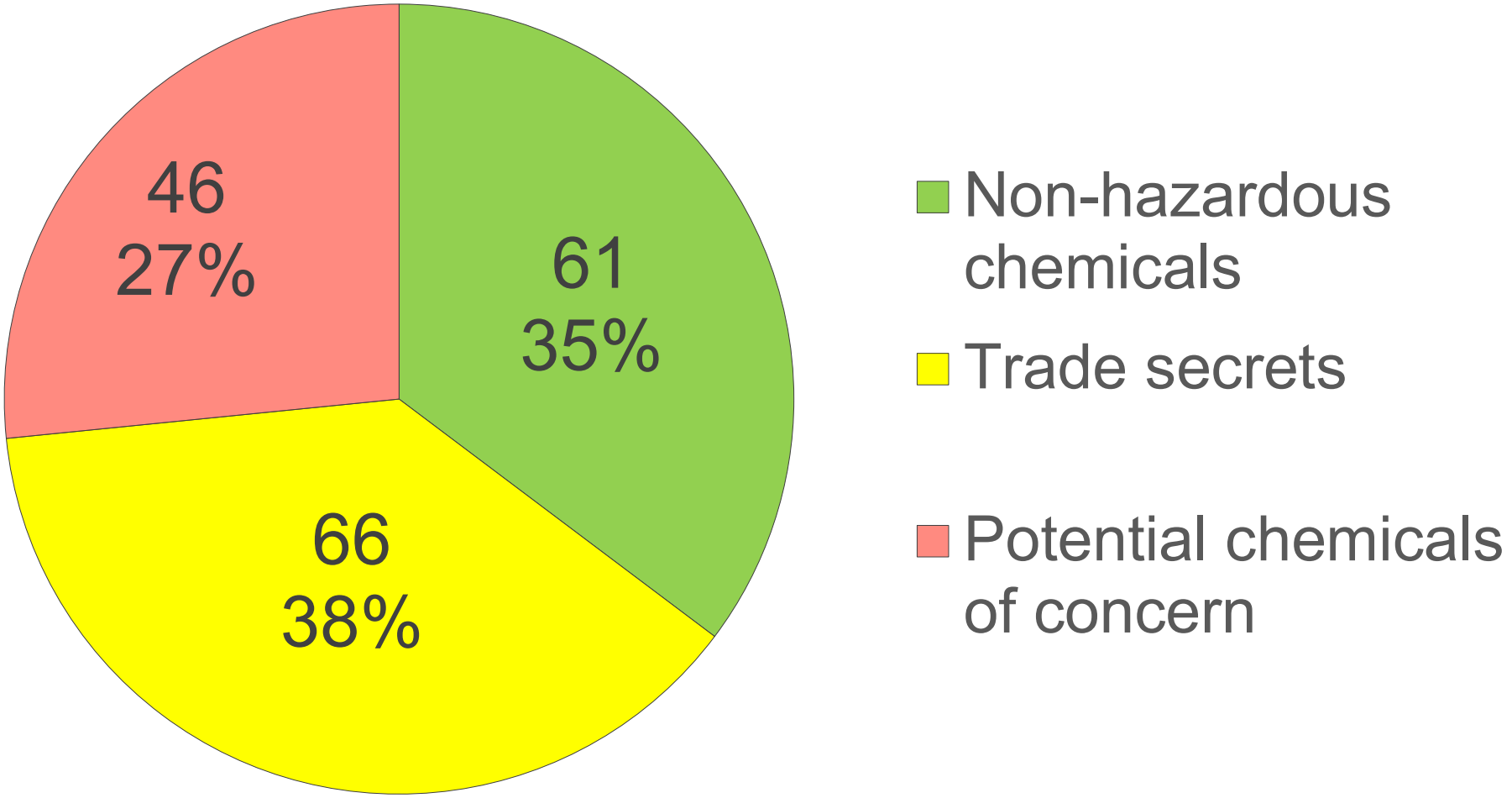
Shonkoff, et al. (2016)

Additional Considerations

# of Chemicals	Health and Environmental Hazards	Notes
8	California Prop 65	
8	USEPA National Primary Drinking Water Standard and Health Advisory Chemicals	
10	International Agency for Research on Cancer (IARC)	
1	Bioaccumulative	Only available for 86 chemicals
5	“Category 1 and 2” for Mammalian Toxicity	
39	“Category 1 and 2: for Ecotoxicity	

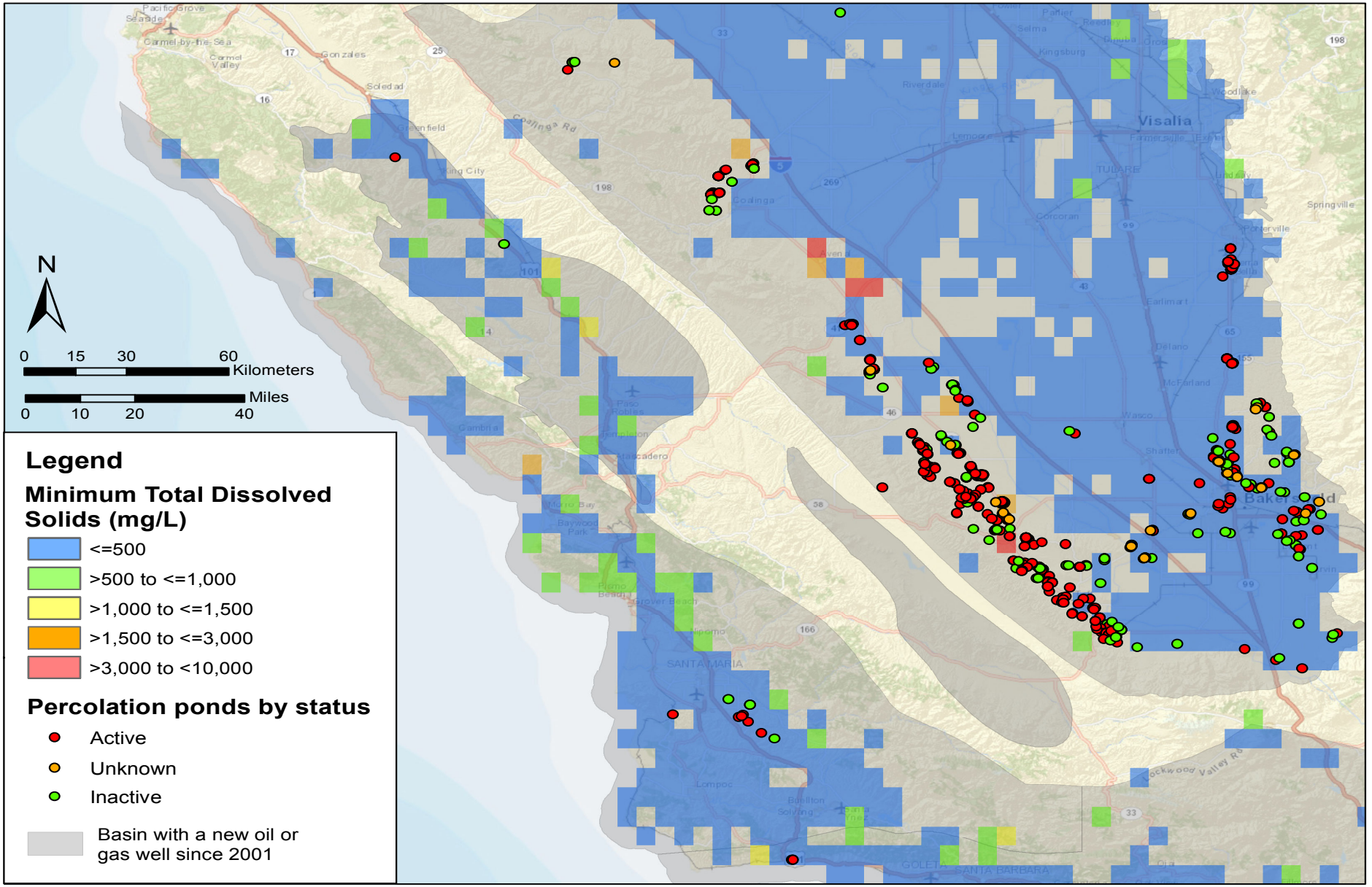
Shonkoff, et al. (2016)

Results summary



Shonkoff, et al. (2016)

Location of percolation pits used for produced water disposal and the location of groundwater of varying quality



CCST (2015)

Disposal of Produced Water in Percolation Pits (CCST Conclusion and Recommendation)

Conclusion: Produced water disposed in percolation pits likely contains hydraulic fracturing chemicals, associated breakdown products, and health-damaging naturally occurring constituents…and **"Unregulated percolation pits present an unjustified risk to water supply, wildlife, vegetation, and human health."**

CCST Recommendation: *"Ensure safe disposal of produced water in percolation pits with appropriate testing and treatment or phase out this practice."*

CCST (2015)

PSE Bringing science to energy policy


Clovis is conserving our water resources by irrigating with recycled water
RECYCLED WATER - DO NOT DRINK
AGUA DE DESPERDICIO RECLAMADA - NO TOME

Science and Policy Updates

- **AB 1328:** Enables the water boards to order O&G operators and their chemical suppliers to disclose chemical use in operations that discharge their produced water to land
- **Forthcoming Independent Scientific Study:** Evaluation of oilfield, water and other datasets to investigate key resource, health and environmental considerations for the reuse of produced water in California (CCST, PSE, LBNL)
- **Ongoing Food Safety Expert Panel**
- **Ongoing oil industry and water district crop testing**

Take home messages

- Chemical risks are not specific to hydraulic fracturing and unconventional OGD; chemical additives are used across all oil and gas development practices
- OPW can meet drinking water standards and MCLs and still pose health and environmental risks
- O&G fields are very dynamic systems; OPW is extremely variable between and within oilfields.
- Significant knowledge gaps persist including:
  - Chemical composition of OPW within and between O&G fields
  - Disclosure of chemical use in O&G development
  - Environmental, toxicological and health profiles of OPW
  - Appropriate monitoring approaches and associated limits of detection for OPW
  - Appropriate treatment approaches for OPW

Thank you

Seth B.C. Shonkoff, PhD, MPH

sshonkoff@psehealthyenergy.org
sshonkoff@berkeley.edu

www.psehealthyenergy.org
@PhySciEng

PSE
Bringing science
to energy policy

BERKELEY LAB

Sources Cited

- Central Valley Regional Water Quality Control Board Food Safety Expert Panel. https://www.waterboards.ca.gov/centralvalley/water_issues/oil_fields/food_safety/
- DiGiulio DC, Shonkoff SBC, Jackson RB. 2018. The Need to Protect Fresh and Brackish Groundwater Resources During Unconventional Oil and Gas Development. Current Opinion in Environmental Science & Health. 3:1-7. https://authors.elsevier.com/c/1Wf1I8nIePIe~Z
- DiGiulio D, Shonkoff SBC. 2017. Is Reuse of Produced Water Safe? First, Let's Find out What's in It. August 2017. EM Magazine, a copyrighted publication of the Air & Waste Management Association.
- Stringfellow WT, Camarillo MK, Domen JK, Shonkoff SBC. 2017. Comparison of Chemical-Use Between Hydraulic Fracturing, Acidizing, and Routine Oil and Gas Development. PLoS ONE. 12(4): e0175344. https://doi.org/10.1371/journal.pone.0175344
- Shonkoff SBC, Domen JK, Stringfellow WT. 2016. Hazard Assessment of Chemical Additives Used in Oil Fields that Reuse Produced Water for Agricultural Irrigation, Livestock Watering, and Groundwater Recharge in the San Joaquin Valley of California: Preliminary Results. PSE Healthy Energy. September 2016. https://www.psehealthyenergy.org/our-work/publications/archive/hazard-assessment-of-chemical-additives-used-in-oil-fields-that-reuse-produced-water-for-agricultural-irrigation-2/
- Shonkoff SBC, Maddalena RL, Hays J, Stringfellow W, Wettstein ZS, Harrison, R, Sandelin W, McKone, TE. 2015. Potential Impacts of Well Stimulation on Human Health in California. In: An Independent Scientific Assessment of Well Stimulation in California. California Council on Science and Technology, Sacramento, CA. http://ccst.us/publications/2015/vol-II-chapter-6.pdf

Produced Water Disposal: Fractured Wells

- Percolation pits
- Class II injection wells
- "Other" & "not reported"
  - Data gap